

# **INTERAGENCY WHITEBARK PINE MONITORING PROTOCOL FOR THE GREATER YELLOWSTONE ECOSYSTEM**

This version superseded by Version 1.1 - June, 2011

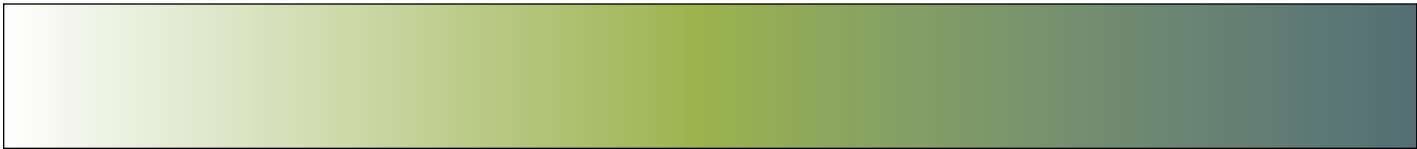
Greater Yellowstone Whitebark Pine Monitoring Working Group

Version 1.00

June 1, 2007

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# **INTERAGENCY WHITEBARK PINE MONITORING PLAN AND PROTOCOL FOR THE GREATER YELLOWSTONE ECOSYSTEM**

Greater Yellowstone Whitebark Pine Monitoring Working Group

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## REVISING THE PROTOCOL

### *Revision History Log*

All changes must be documented, and updated protocol versions must be recorded in the Revision History Log that accompanies the protocol. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02, etc.) for minor changes that do not require a change in analytical or procedural methods. A project leader must review minor modifications for clarity and technical soundness, incorporate, and communicate all changes to affected and prospective users of the protocol. Major revisions that involve a change in analytical or procedural methods are designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...). The Whitebark Pine Monitoring Working Group must review and approve major modifications.

The following table lists all edits and amendments to this document since the original publication date. Information entered in the log must be complete and concise. Users of this monitoring protocol will promptly notify the project leader and/or a member of the Whitebark Pine Monitoring Working Group about recommended and required changes. A project leader is responsible for completing the revision history log, changing the date and version number on the title page and in the footer of the document file(s), and managing web-based and other distribution of updated protocol materials.

### *Master Version Table*

| Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem |                                                        |                                                    |                                                                                                                |                                                                                                               |
|--------------------------------------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------|----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| Version 1.0, June 1, 2007                                                            |                                                        |                                                    |                                                                                                                |                                                                                                               |
| Date and number of Previous Version                                                  | Date of Revision                                       | Author(s) of Revision (with title and affiliation) | Location in Document and Concise Description of Revision                                                       | Reason for Change                                                                                             |
| EXAMPLE ENTRY:<br>May 1, 2007<br>Version 1.0                                         | EXAMPLE ENTRY:<br>Various – Fall and Winter, 2007/2008 | EXAMPLE ENTRY:<br>Rob Daley, GRYN Data Manager     | EXAMPLE ENTRY:<br>Chapter 4 – updated table 4-1<br><br>Appendix 2 – updated data field names and descriptions. | EXAMPLE ENTRY:<br>These changes were made based on lessons learned in 2007 and to update contact information. |
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# Chapter 1



## Introduction and Background

Whitebark pine (*Pinus albicaulis*) occurs in the subalpine zone of the Pacific Northwest and northern Rocky Mountains, where it is adapted to a harsh environment with poor soils, steep slopes, high winds and extreme cold temperatures. Although its inaccessibility and often gnarled growth forms render whitebark pine of low commercial value, it is high in ecological value and has been called a “keystone” species in the subalpine zone (Tomback et al. 2001).



*Photo courtesy of Katherine Kendall*

Whitebark pine can exist under conditions tolerated by few other trees, which may alter the microclimate and enable other species, such as subalpine fir (*Abies lasiocarpa*), to follow (Tomback et al. 1993). Its occurrence on wind-swept ridges plays an important role in snow accumulation. Perhaps its best-known role in these ecosystems is as a food source for a variety of wildlife species. Whitebark pine seeds are large and high in fat content, making them a valuable food source for numerous wildlife species (Kendall and Arno 1990), especially grizzly bears, which find them in red squirrel middens (Mattson et al. 1992). In fact, in the Greater Yellowstone

Ecosystem (GYE), annual whitebark pine cone production in the GYE is one of the major predictors of annual survival and reproduction of the bears (Mattson et al. 1992).

Whitebark pine stands have been decimated in areas of the Cascades and northern Rocky Mountains due to the introduction of the introduced pathogen white pine blister rust (*Cronartium ribicola*). In addition, whitebark pine is impacted by mountain pine beetles (*Dendroctonus ponderosae*) and competition with subalpine fir and Engelmann spruce (*Picea engelmannii*). In order to track the status of the whitebark pine population in the Greater Yellowstone Ecosystem, the National Park Service, US Forest Service and US Geological Survey have developed the following protocol to monitor the level of blister rust infection and other impacts on whitebark pine. This effort represents an expansion of the blister rust monitoring currently performed by the Interagency Grizzly Bear Study Team and will help to understand the status of this important species in the ecosystem.



## Introduction and Background

### Relevance to Parks

Due to the collaborative nature of whitebark pine monitoring in the Greater Yellowstone Ecosystem, the purpose of monitoring must be relevant to all agencies involved. Following are short descriptions of how whitebark pine monitoring fulfills the guiding principles and goals of the National Park Service (NPS), US Forest Service (USFS) and US Geological Survey (USGS).

### ***National Park Service I&M Program***

The mission of the National Park Service is “to conserve, unimpaired, the natural and cultural resources and values of the national park system for the enjoyment of this and future generations” (NPS 1999). To uphold this goal, the Director of NPS approved the Natural Resource Challenge in 2000 to encourage national parks to focus on the preservation of the nation’s natural heritage through science, natural resource inventories and expanded resource monitoring (NPS 1999).

The goal of monitoring is to detect change over time and to use this information to understand the state of the parks’ ecosystems. Monitoring in the NPS is intended to aid in the development of broadly based, scientifically sound information on the current status and long-term trends in the health, composition, structure and function of park ecosystems. While many Executive Orders and legislative acts direct the purpose of the I&M program, one legislative act of particular relevance is the 1993 Government Performance and Results Act (GPRA). GPRA sets goals to help federal agencies become more accountable to the public for the money they spend and the results that are achieved. GPRA is required as part of the National Park Omnibus Management Act, which calls for the creation of Strategic Plans and Annual Performance Plans. The National Park Service created a Strategic Plan for 2001-2005 (NPS 2001), with the ‘Category 1’ goal of “preserving park resources,” which includes goals that fit the mission of the I&M program, such as choosing vital signs for assessing the health of park ecosystems. In addition, each park also creates five-year strategic plans and annual performance plans that guide progress toward the Service-wide goals.

The National I&M Program has created five major long-term goals that I&M networks must strive to achieve (NPS 2003). These goals include:

1. *Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work*



*Photo courtesy of B. Riley McClelland*



*more effectively with other agencies and individuals for the benefit of park resources.*

2. *Provide early warning of “abnormal” conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management.*
3. *Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.*
4. *Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.*
5. *Provide a means of measuring progress toward performance goals.*

### ***Multi-agency guidance***

The Final Conservation Strategy for the Grizzly Bear in the Yellowstone Ecosystem (Interagency Conservation Strategy Team 2003) directs the NPS, USFS and USGS to monitor food sources of the grizzly bear, including ungulate carcasses, cutthroat trout, army cutworm moths and whitebark pine. Specifically mentioned in the conservation strategy is monitoring of select transects throughout the GYE for cone production and white pine blister rust occurrence. Cone transect monitoring has been led by the Interagency Grizzly Bear Study Team and consists of cone counts and some blister rust monitoring (Haroldson et al. 2004). Blister rust is an important factor in the survival and reproduction of whitebark pine stands throughout the Northwest, and it has been determined that current blister rust monitoring within the GYE is not sufficient to understand the impacts of this introduced pathogen on whitebark pine stands and cone production.

Thus, the National Park Service, US Forest Service and US Geological Survey have determined a need to expand blister rust monitoring, as well as monitoring the impacts of succession and mountain pine beetle, on whitebark pine. It is assumed that increased monitoring of whitebark pine will aid in decisions regarding management of the species in the GYE. For instance, monitoring may determine if the status of whitebark pine warrants active restoration of the species (i.e., planting) and the monitoring design can be adjusted to compare alternative restoration practices.

### **Threats and Concerns**

Several of the major threats and concerns regarding whitebark pine within the Greater Yellowstone Inventory and Monitoring Network (GRYN) have also been identified as vital signs chosen by the GRYN as indicators of ecosystem health. These include climate, forest insects and disease and fire. The relationships among whitebark pine and these other vital signs are described in the following paragraphs and in more detail in Appendix IA.



## Introduction and Background

### ***Forest insects and disease***

White pine blister rust, an exotic fungus first introduced into Vancouver, British Columbia, in 1910, enters the stomata of the whitebark pine needles and then erupts into cankers on the branches, leading to the cessation of cone production and in some cases, the eventual death of the tree (Tomback et al. 2001). Depending on the level of infection, a tree with white pine blister rust can live for decades; however, saplings that are infected generally die within three years (Koteen 2002). Infection by blister rust also weakens the tree and can lead to death by an accumulation of factors, including mountain pine beetle, other pathogens, root diseases and unfavorable climatic conditions (Koteen 2002). While white pine blister rust has devastated populations in areas with maritime climates (namely the Pacific Northwest and Glacier National Park) with infection rates of 82% in the north Cascades (Kendall and Keane 2001) and 90% in Glacier (Koteen 2002), some researchers have suggested that the drier climate of the GYE may be relatively inhospitable to the spread of blister rust (Koteen 2002). Results of recent surveys on blister rust infection rates in the GYE have shown average rates of <5% in Yellowstone and <15% in Grand Teton, and a highest single-site incidence of 40-44% in Grand Teton (Kendall and Keane 2001), an increase from the 1.1% average infection rate found in 1967 (with the highest single-site incidence of 2.3% [Koteen 2002]).

Another threat to whitebark pine populations in the GYE is the mountain pine beetle. The mountain pine beetle (*Dendroctonus ponderosae*) is a native insect that has coevolved with pine forests in the western U.S. (Logan and Powell 2001). Host tree species of mountain pine beetle include ponderosa pine, lodgepole pine, western white pine and whitebark pine (Kipfmüller and Swetnam 2002). Variations in climate are largely responsible for the success of mountain pine beetle outbreaks. Mild summers and winters tend to favor outbreaks, while cold winters and hot summers tend to decrease beetle activity and increase brood mortality (Kipfmüller and Swetnam 2002). Evidence has shown that mountain pine beetles tend to attack—and are more successful when attacking—trees that are already weakened by some other process, such as moisture stress, pathogens or mistletoe (Kipfmüller and Swetnam 2002). Because some evidence suggests that older trees that have been weakened due to other pathogens are more susceptible to mountain pine beetle infestations, it has been suggested that fire suppression can lead to an increase in the spread of infestations because it fosters mature, late-successional stands of trees (Perkins and Roberts 2003, Tomback et al. 2001).



*Photo courtesy of Katherine Kendall*



## Climate

Climate change is hypothesized to affect whitebark pine communities through three mechanisms: 1) causing a shift in pathogen ranges, which may lead to new regions of hospitable climate for white pine blister rust and, thus, increase the potential for infection; 2) increasing temperatures, which can lead to decreases in range availability for whitebark pine, due to competitive exclusion by more heat-tolerant species, such as lodgepole pine (Mattson et al. 2001); and 3) changes in the frequency of severe fires, which lead to overall decreases in whitebark pine numbers (while whitebark pine is adapted to small fires, large, stand-replacing fires may be detrimental to its overall distribution and abundance [Koteen 2002]). According to Koteen (2002), climate change can also affect the range of blister rust through the following processes: “1) altering the dispersal, reproductive or developmental processes of the pathogen directly; 2) increasing pathogen virulence or growth to host populations; or 3) increas[ing] pathogen predation of host species by mediating pathogen competition with symbiotic organisms, such as mycorrhizae, that protect plants against pathogens.”



Photo courtesy of B. Riley McClelland

In general, changes in climate can affect the resiliency of tree populations because seed production, germination and establishment are particularly sensitive to variations in the environment. While recruitment may decrease significantly due to climate change, persistence of adult trees (albeit without reproducing) can lead to a deceptively “healthy” looking forest (Brubaker 1986).



NPS Photo

## Fire

Fire is an integral part of the ecology of whitebark pine communities. Whitebark pine has adapted to a fire-prone ecosystem using two strategies: 1) large trees (i.e., trees with a diameter larger than a pole) can survive low- to moderate-severity fires; and 2) Clark’s nutcracker facilitates the establishment of whitebark pine in newly burned areas that are created by mixed severity and stand-replacement fires by caching whitebark pine seeds (USFS n/a). Larger, stand-replacing fires can, however, kill mature, seed-producing whitebark pine trees, and may increase in frequency with a warmer and drier climate (Koteen 2002). However, a lack of fire, in conjunction with an increase in temperature and decrease in precipitation, may allow later successional species, such as subalpine fir and Engelmann spruce, to outcompete whitebark pine (Tomback et al. 2001).



## Introduction and Background

### Other Monitoring Efforts: Past and Present

#### ***Within the Greater Yellowstone Ecosystem***

There have been several efforts in recent years to assess the status of whitebark pine and white pine blister rust. In 1995 Kate Kendall (USGS) initiated an effort to determine the status of whitebark pine in national parks of the Rocky Mountains, including the Greater Yellowstone Ecosystem (Kendall et al. 1996a). Dan Tyers (USFS) initiated a similar effort, primarily in the Gallatin National Forest (Kendall et al. 1996b), which is ongoing. More recently, Maria Newcomb completed a Master's thesis aimed at detecting and describing the spatial pattern of white pine blister rust, particularly in relation to its *Ribes* host species (Newcomb 2003). There have been additional smaller efforts, primarily by the USFS (e.g., Shoshone National Forest) to assess and/or monitor whitebark pine. Since 1980, the Interagency Grizzly Bear Study Team (USGS) has monitored cone production on 19 transects within the grizzly bear recovery zone of the GYE. This effort is used primarily as an indicator of activity and demography of bears, rather than an indicator of whitebark pine health or production.

Although there have been several efforts aimed at assessing whitebark pine in the GYE, contributing agencies share a concern that efforts have generally lacked consistency and cooperation and most efforts have not been explicitly designed to monitor whitebark pine on long time scales. Thus, the aim of our cooperative effort is to design a scientifically defensible and consistent monitoring program for whitebark pine throughout the entire GYE.

#### ***Outside the Greater Yellowstone Ecosystem***

There have been numerous monitoring efforts outside of the Greater Yellowstone Ecosystem. Probably the most prevalent has been the efforts of the Whitebark Pine Ecosystem Foundation (WPEF), a nonprofit group dedicated to counteracting the decline of whitebark pine and enhancing knowledge of its ecosystems. The WPEF has expended considerable effort in the development of monitoring protocols and training. We have drawn substantially from their effort, although we have also adjusted our protocol to better suit the objectives of our program.

### Measurable Long-term Objectives

When reviewing the literature on ecological monitoring, there is universal consensus that setting realistic, clear, specific and measurable monitoring objectives is a critical, but often difficult, first step. Olsen et al. (1999) summarizes well the need for clear and specific monitoring objectives in the following statement:

*“Although the need for a clear and concise statement of the monitoring objectives may be obvious, we feel that it is worth reemphasizing. Most of the thought that goes into a monitoring program should occur at this preliminary planning*



stage. As illustrated in Knopman and Voss (1989) and Gilbert (1987), different objectives require different monitoring designs. These objectives also guide, if not completely determine, the scope of inference of the study and the data collected, both of which are crucial for attaining the stated objectives. If the monitoring objectives are clearly stated, it will be easier to describe the statistical methods to be used to analyze the data. Although simple in concept, the presence of multiple and perhaps conflicting objectives and the reality that the objectives may change with time complicates monitoring program design. Consequently, an optimal design for any particular monitoring program may not exist, and the choice must be based on compromise (Stehman and Overton, 1994).



Photo courtesy of Dan Reinhart

Nevertheless, a clear and concise statement of monitoring objectives is essential to realize the necessary compromises, select appropriate locations for inclusion in the study, take relevant and meaningful measurements at these locations, and perform analyses that will provide a basis for the conclusions necessary for meeting the stated objectives. .... In all cases, a general statement of objectives is given that has the elements of 'describe the status and trends of...' This level of detail is not sufficient to guide the design of major monitoring."

**Olsen et al. 1999**

This step of defining and agreeing upon clear monitoring objectives will be a major thrust of our initial effort toward a long-term monitoring program. Long-term monitoring objectives are presented below.

### ***General Questions Being Asked***

Our specific monitoring objectives are intended to answer the following question(s): Is white pine blister rust increasing within the Greater Yellowstone Ecosystem, and is the resulting mortality of whitebark pine sufficient to warrant consideration of management intervention (e.g., active restoration)?

### ***Specific Long-term Monitoring Objectives***

**OBJECTIVE 1** - To estimate the proportion of whitebark pine trees (>1.4 m high) within the Greater Yellowstone Ecosystem (GRTE, YELL and six national forests) infected with white pine blister rust, and to estimate the rate at which infection of trees is changing over time.

*Justification/Rationale for this Objective:* White pine blister rust has devastated whitebark pine in other parts of the Northwest (Kendall and Keane 2001, Koteen



## Introduction and Background

2002), and anecdotal evidence suggests that infection rates may be escalating in the GYE (Koteen 2002, D. Tomback, pers. comm.). Whitebark pine is a keystone species of the upper subalpine ecosystem and its large seeds (largest of the conifers in that zone) represent an important food source for Clark's nutcrackers, red squirrels and grizzly bears (Tomback et al. 2001). The loss of seed-producing trees can affect not only grizzly bears and other wildlife, but also the persistence of this community type within the GYE.

**OBJECTIVE 2** - Within infected transects, to determine the relative severity of infection (i.e., stage and magnitude of infection and proportion of canopy kill) and to estimate the change in severity over time of white pine blister rust in whitebark pine trees > 1.4 m high within the Greater Yellowstone Ecosystem (GRTE, YELL and six national forests).

*Justification/Rationale for this Objective:* Determining the proportion of trees infected with white pine blister rust can be misleading without a further understanding of the magnitude of the infection. Given that within-tree spread of blister rust occurs primarily from new infections from the source, rather than spread from existing infections, trees that are infected at low levels may persist for considerable time in the absence of new infections (Koteen 2002). If the tree is infected near the crown, then the infection is most likely to cause cessation of cone production. It has been hypothesized that these types of infections occur more often than other types of infections in the GYE (Koteen 2002). The influence of the infection on tree mortality is highly dependent on the location of the infection, the age of the tree and other factors (such as mountain pine beetle infestations, root diseases, etc.); for instance, young trees that become infected almost always die relatively quickly, as do trees weakened by other causes (Koteen 2002).

**OBJECTIVE 3** – To estimate survival of individual whitebark pine trees > 1.4 m high in the Greater Yellowstone Ecosystem (GRTE, YELL and six national forests), explicitly taking into account the effect of the presence and severity of white pine blister rust infection, infestation by mountain pine beetle and dwarf mistletoe and fire.

*Justification/Rationale for this Objective.--* There has been some debate as to whether whitebark pine in the Greater Yellowstone Ecosystem is as vulnerable to the effects of white pine blister rust as it is in other regions (Carlson 1978, Arno 1986). Basidiospores of white pine blister rust are thought to be transported primarily during high-moisture events (e.g., during periods of rain and fog [Hirt 1942, Van Arsdel 1956]), and the Greater Yellowstone Ecosystem is generally drier than other regions where white pine blister rust has been devastating to whitebark pine. Further, within-tree spread of blister rust occurs primarily from new infections from the source, rather than spread from existing infections (Koteen 2002). Trees that are infected at low levels may persist for considerable time (i.e., decades) in the absence of new infections, depending on the location of the infection (Koteen 2002). Estimating survival will enable us to distinguish



the occurrence (and severity) of white pine blister rust from the ecological effect of infestation (i.e., loss of mature whitebark pine), which will allow for determination of the vulnerability of whitebark pine in the Greater Yellowstone Ecosystem directly, rather than relying on potentially controversial extrapolation from other regions.

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



*Photo courtesy of B. Riley McClelland*

## Future Considerations For Monitoring Whitebark Pine

### *Moving toward Model-based Inference*

The proposed objectives fall primarily under a “design-based” framework (e.g., Hansen et al. 1983), which uses probability sampling to derive inferences about the state variables and/or vital rates of interest. This approach has an advantage of minimizing the number of assumptions required to drawn inference, which makes it well suited for such things as litigation and controversial public policy decisions (Olsen et al. 1999). However, one disadvantage is that it is poorly suited for future predictions (Olsen et al. 1999). Predictions of future system states require a model-based approach, which comes at a cost of requiring a greater number of simplifying assumptions (Olsen et al. 1999). However, as



## Introduction and Background

our program advances to the point where it is reasonable to develop alternative hypotheses regarding system changes in response to environmental or management induced factors, a model-based approach will better enable us to move from a descriptive approach to a more scientific (e.g., quasi-experimental) approach that may have considerable advantage for understanding the system and for predicting the outcome of management decisions (see also Yoccoz et al. 2001).

### *Adaptive Management for Whitebark Pine Restoration*

If active restoration of whitebark pine is initiated via planting or other direct management intervention, a second phase of monitoring that would evaluate the relative effectiveness of alternative restoration strategies should be initiated Figure 1-1. This should be designed and implemented to inform decisions regarding the most effective strategy for achieving the management objectives of any restoration effort.

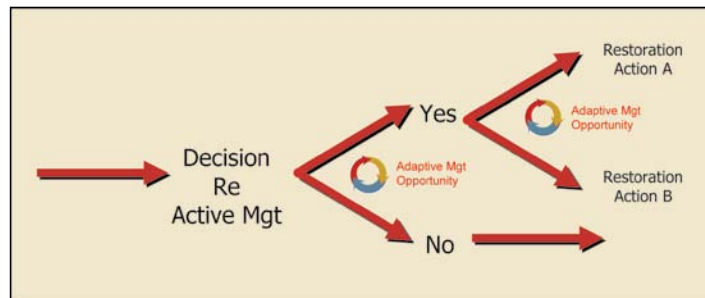


Figure 1-1. Conceptual diagram of potential decisions that could benefit from incorporating an adaptive management approach to the design.







## Sample Design

### Overall Design

The primary goal of the whitebark pine monitoring effort is to characterize the current status and change over time of blister rust in the GYE. Sampling will generally begin in June and end in October, with a team of two technicians and one crew leader. Our basic approach is a stratified 2-stage cluster survey design with stands (polygons) of whitebark pine being the primary units and 10x50 m transects being the secondary units.

### Target Population, Sample Frame And Sampling Units

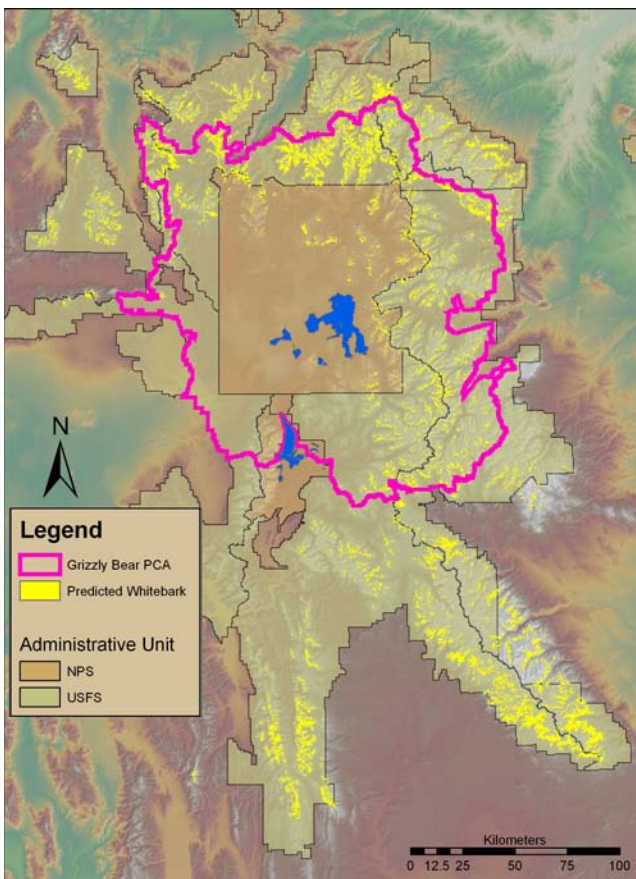


Figure 2-1. The study area showing administrative units (National Park Service and U.S. Forest Service) and the boundary of the grizzly bear Primary Conservation Area (PCA)

Our target population is all whitebark pine trees in the GYE. Ideally we would have identified the full target population and sampling frame a priori, especially as regards stratification variables. On one level the target population is easy to identify: all whitebark pine trees in the GYE. It is, however, not possible to identify and map all whitebark pine trees. This target population is also infeasible from a logistical standpoint. Accordingly we decided to define the target population in terms of identified whitebark pine stands or polygons in a GIS vegetative layer. A sample of stands would be chosen using a probability based sampling method followed by selection of transects within stands. Our initial sample frame, from which a sample was drawn in 2004, was from the vegetation layer of the cumulative effects model for grizzly bears derived from photo interpretation (Dixon 1997). From this frame, we identified whitebark pine stands of approximately 2.5 ha or greater within the grizzly bear Primary Conservation Area (PCA). In 2005, we extended our efforts outside the PCA using an expanded sample frame comprised of whitebark stands mapped by the USFS National Forests within the Greater Yellowstone Ecosystem. Areas that had burned since the 1988 fires were excluded from our samples, as they are too young, but these stands will likely be included in a later phase of this project focused on recruitment.

An effort is currently underway for a unified seamless sample frame derived from classified satellite imagery that is augmented with additional predictor variables.



## Sample Design

The initial results from this effort look very promising, although it may require some adjustment of our sample when it is completed in order to align our sample with the new sample frame. For example, if the new frame identifies stands of whitebark that were previously overlooked, we may need to augment our sample to include these stands.

### ***Stratification***

In 2004 we had not identified any stratification variables. At that time we were leaning toward stratifying on distance to road or some other variable that would account for the logistical difficulty of visiting some stands. We also knew that we had not accounted for all stands in the GYE due to gaps in our coverages and due to a lack of updates subsequent to fires (especially the 1988 fires). We also had questions about the validity of the data we did have, i.e. size of stand, etc. We attempted to correct for some of these deficiencies in 2005 and 2006. It became apparent, based on discussion with the field crews, that stratification of stands on the basis of the logistical difficulty of visiting them was not necessary. However, a natural stratification variable was identified; whether or not a stand was inside or outside the Grizzly Bear Primary Conservation Area (PCA). This stratification was instituted the second year of the initial survey (2005).

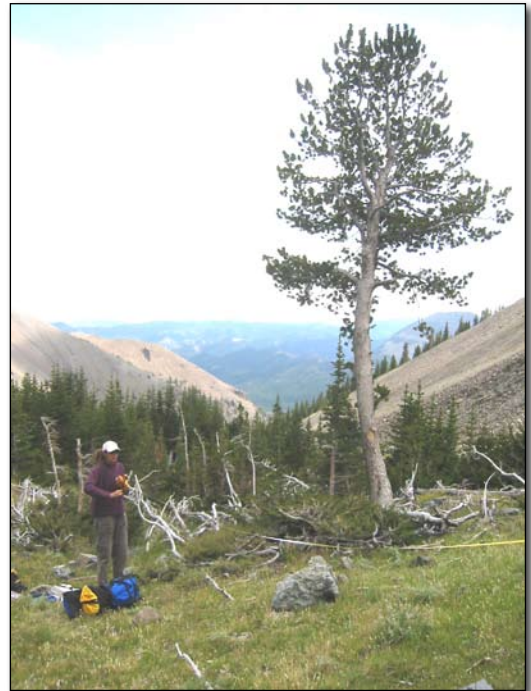


*Photo courtesy of Karla Sartor*

### ***Sampling Units***

Our primary sampling units are whitebark pine dominated stands of approximately 2.5 hectares or larger. Based on our initial sample frame, we had 2428 stands of whitebark within the PCA and 7,924 stands outside the PCA. Our secondary sampling units are 10 by 50 meter transects located within each stand (as recommended by the Whitebark Pine Ecosystem Foundation [WPEF] protocol).

Currently, we have identified 2362 whitebark pine stands inside the recovery zone and 8408 stands outside the recovery zone for a total of 10770 stands. These numbers have changed over the past 3 years for a number of reasons. There have been updates in the definition of a stand. There have been changes due to the incidence of fire. One problem we have faced is that the definition of a stand differs from one part of the GYE to another, i.e. the definition of a stand on the Gallatin National Forest was not the same as the definition of a stand on the Bridger-Teton National Forest. Thus a single stand in one administrative jurisdiction might have been denoted as 2 or more stands in another. One consequence of problems such as these is that there was a tendency to under or over sample parts of the GYE. Another implication of inadequate mapping is that some identified stands of whitebark were not whitebark pine, either due to misidentification or fire.



### ***Selection of Sampling Units***

We selected a simple random sample from our population of stands. However, the sample frame is subject to inaccuracies due to mapping errors and limitations of spatial extent of mapping. There was consequently the potential for the field crew to spend a great deal of time walking into an area only to find that a mapped polygon does not exist. Accordingly, if the initial polygon was not suitable then the crew choose the next nearest polygon. Our preliminary efforts indicate that this is an extremely rare event, which seems a minor constraint on the randomization procedure that is justified by the limited time during which the crew has to collect data.

In 2005, we discovered an additional source of inaccuracy of our initial sample frame. Different efforts contributing to the mapped distribution of whitebark pine used different criteria to define stands (polygons) of whitebark pine. This resulted in some administrative units having different probabilities of being sampled as an artifact of their delineation criteria. This was most apparent outside of the Grizzly Bear Conservation Area because similar criteria were used within that area as part of a cumulative effects model (Mattson et al. 2003). Most notably, this problem resulted in over sampling the Gallatin National Forest, and under sampling the Bridger-Teton National Forest. In 2006, we adjusted our sample to correct for this area such that our resulting sample was proportional to the actual area of whitebark pine based on a preliminary effort of consistently mapping whitebark pine using satellite imagery (Figure 2-2). Eventually, we anticipate that a fully consistent sample frame for the entire GYE will be available and we will need to evaluate the trade-offs at that time of switching to a new sample frame.

Within the selected primary unit, we had pre-selected a simple random sample of five points. The first of these was the targeted mid-point of our secondary unit. A random vector was used to lay out the 10 x 50 m transect. If no whitebark were included within this transect, the next closest alternate was used. In the event that alternative vectors from that location were unlikely to include whitebark, the next “alternative” starting point was used.

### **Temporal Revisit Design**

Infection by white pine blister rust is a slow process, such that detection of annual change would not be effective or practical. Consequently, we have based on our design on “rotating panel” approach of building a sample over a period of an approximately 5 year revisit frequency (Figure 2-3). This approach implies that we will build up a complete sample of the GYE over a 4-5 year period. A rotating panel design with a 5-year rotation implies that each panel (i.e., the transects sample within a given year) would be revisited every 5 years. Thus a panel that was sampled in 2004 would be sampled again in 2009, and so on. The exact frequency will be determined by our forthcoming assessment of whether our actual sample is consistent with our preliminary simulations. These simulations (below) indicated that the gain in precision for estimating the proportion of trees infected with blister rust between 50 and 100 transects is substantial, but the relative gain after about



## Sample Design

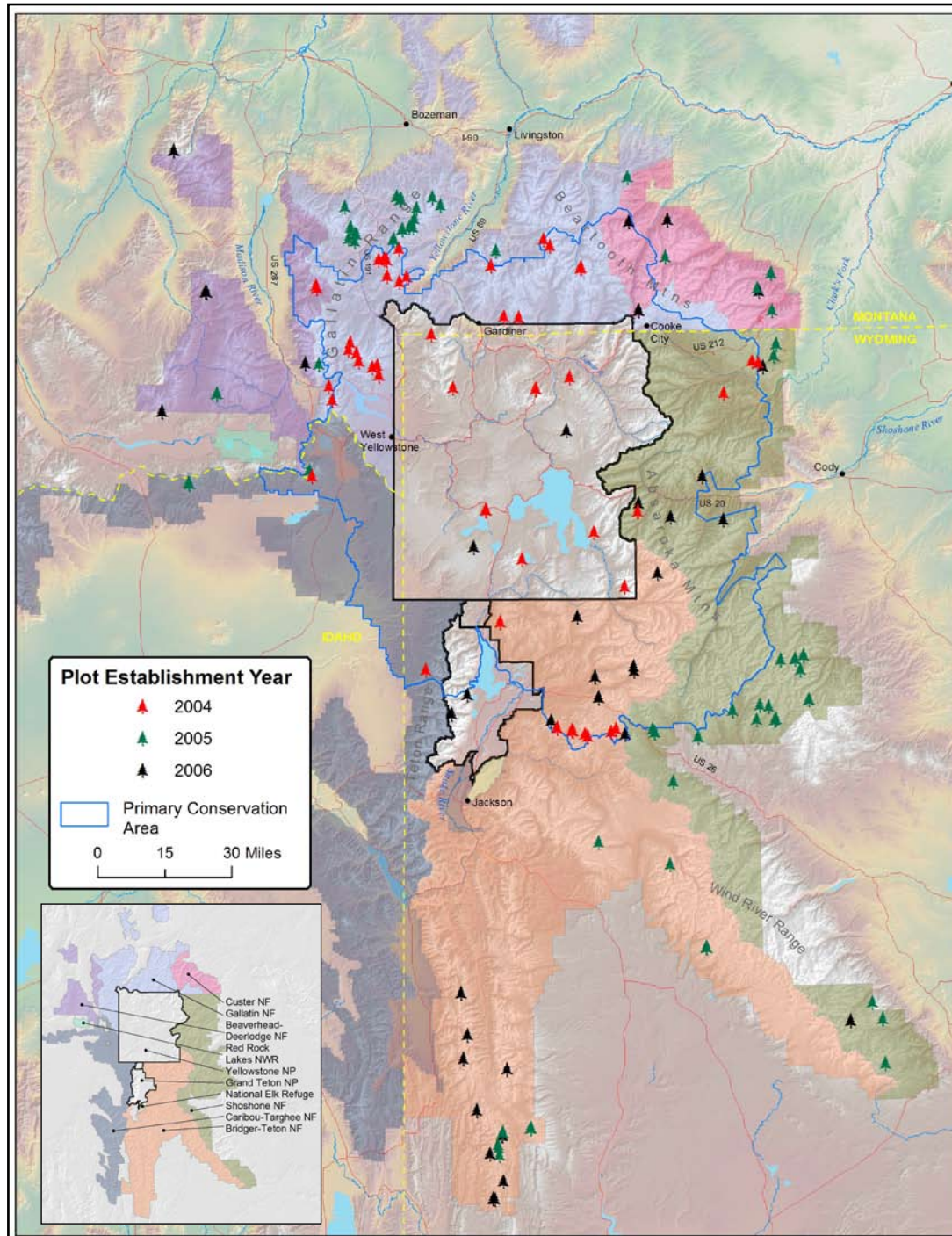


Figure 2-2. Study area showing the location of transects established and sampled from 2004-2006 on six national forests and two national parks.



| Panel | Year        |             |             |             |             |             |             |             |             |             |
|-------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|       | 1           | 2           | 3           | 4           | 5           | 6           | 7           | 8           | 9           | 10          |
| 1     | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled |
| 2     | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled |
| 3     | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled |
| 4     | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled |
| 5     | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled | Not Sampled |

Sampled

Not Sampled

Figure 2-3. A hypothetical rotating panel design based on a 5-year rotation.

150-200 transects may be insufficient to justify the additional cost and effort.

In contrast to blister rust infection, the effects of mountain pine beetle occur much more rapidly. However, our pilot efforts have indicated that mountain pine beetle is sampled more efficiently through aerial surveys because the indicators of an attack in a given tree may be easy to overlook until after the tree has been dead long enough for the needles to turn brown and the bark to begin falling off. Our approach of sampling every five years will certainly be sufficient to estimate mortality due to pine beetle upon each revisit, but we believe that initial detection of outbreaks is best accomplished through the complimentary efforts of aerial surveys by the USFS Forest Health Monitoring Program.

## Some Preliminary Assessments

The previous protocols have suggested using a variable length transect such that the length is extended from an initial value of 50 m if there are not at least 50 trees within the transect. However, a “variable-length” transect may result in biased estimates of the primary parameter of interest. The basis for this variable length is also a perception that a minimum of 50 trees is needed. However, the sampling unit is the plot, not the individual trees. Using individual trees as the sampling unit would be a form of pseudoreplication (Hurlbert 1984) that results in an inappropriate error term for subsequent statistical analyses. Simulations by Dr. Steve Cherry (Montana State University, Department of Statistics) have indicated the degree of bias from using variable length plots. Given the potential for biased estimates, the tradeoffs between number of transects vs number of trees per transect, and concerns about pseudoreplication, we will use fixed length plots.

### *Balancing the number of transects and the number of trees within each transect*

Recognition of the potential bias resulting from variable length transects still does not resolve our concern about how to balance the number of transects with the number of trees within each transect. Thus a second simulation was used to explore these tradeoffs.

For this simulation, the mean number of trees within transects varied from 10 to 50 in increments of 10. The number of transects varied from 50 to 150 in increments of 50. Thus, there were 15 combinations of transect/tree numbers. The number of trees in each transect was determined by drawing a random sample from a negative binomial distribution with the specified mean. The negative binomial was used because the number of trees was more variable than required for sampling from a Poisson distribution. Once the number of trees on a plot was determined, the number infected was determined by assuming each tree had a probability of 0.10 of being infected (based on infection rates observed



## Sample Design

during previous studies). The mean and standard error was computed for each trial and 1000 trials were run for each of the 15 transect/tree size combinations. The results indicated that the standard errors were fairly low in each case (Figure 2-4).

Another view of the tradeoffs between the number of transects and the number of trees within each transect is to examine the resulting confidence intervals (Figure 2-5). Obviously, sampling more transects and more trees within each transect will yield better results. But, realistically, it appears that 100 transects with somewhere around 15 to 20 larger trees per transect on average will be sufficient to produce reasonable estimates of status. It also appears that we gain relatively more efficiency by increasing the number of transects in our sample, as opposed to increasing the number of trees per transect. However, these results are based on an assumed simple random sampling plan with clusters

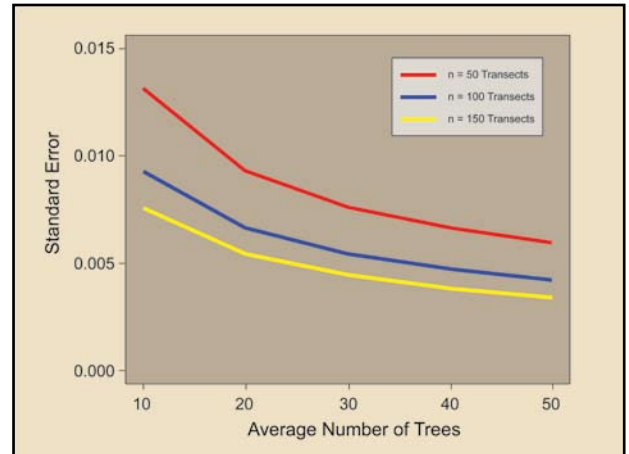


Figure 2-4. Results from simulation showing the mean standard error as a function of the average number of trees (ranging from 10-50), given 50, 100, or 150 transects.

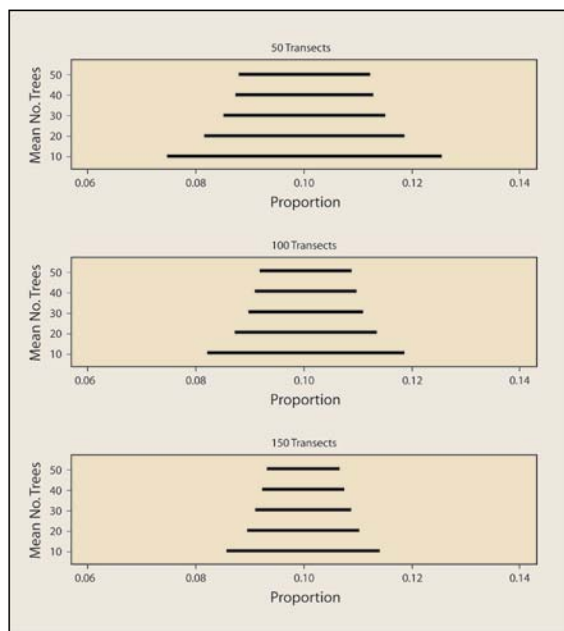


Figure 2-5. Results from simulation showing the empirical 95% confidence interval as a function of the mean number of trees and the number of transects, given a true value of 0.10 proportion of trees.

### A Preliminary Evaluation of Precision, Desired Level of Change Detection, and Sample Sizes

We have used previous data collected by Dan Tyers and Kate Kendall to investigate the precision of estimation of the proportion of infected trees assuming that the transects represented a simple random sample of transects across the ecosystem. The updated sampling plan and information of polygon size (in square meters) allows us to update this work. The constraints on randomization have the advantage of helping to insure that the transects are spatially distributed as needed. However, a disadvantage is that such constraints can increase variability in the estimates. This is particularly likely to occur when the units have unequal inclusion probabilities.

We investigated the precision via simulation. The simulations were done in the statistical computing lan-



guage R. We carried out two types of simulations. The first assumed 100 transects with varying proportions of infection from 0.1 to 0.3 in increments of 0.05. The second assumed an infection rate of 0.1 with 50, 100, 200 and 300 transects. The basic assumption is that a polygon is chosen randomly with a transect randomly chosen within each transect. We further varied the average number of trees in each transect from 5 to 35 in increments of 5. We assumed the number of trees followed a negative binomial distribution with the variance equal to about 10 times the mean. This was based on the results we observed in the transects read by Tyers and Kendall. The proportion of infected trees in the several hundred transects run by Tyers and Kendall was around 0.1 for pole size trees and larger. We assumed the infection rates in the transects followed a binomial distribution with the indicated means. In all cases the proposed method of sampling and analysis produced essentially unbiased estimates of the infection rates. The standard errors are standard deviations of the estimated rates of infection in 1000 simulations.

### ***Simulation 1***

As can be seen from Figure 2-6, the standard errors are fairly large. The second is that the average number of trees per polygon is important. The mean number of larger trees observed on the plots run by Tyers and Kendall was around 15 but the overall mean number of trees (including seedlings and saplings) was quite a bit higher. Also, note that the precision decreases dramatically as the proportion of infected trees increases. This obviously has implications for monitoring the change in infection rates over time. As more trees become infected it may be more difficult to detect meaningful changes. In other words, the number of plots needed to detect a meaningful change from 0.10 will be smaller than the number required to detect a meaningful change from 0.30.

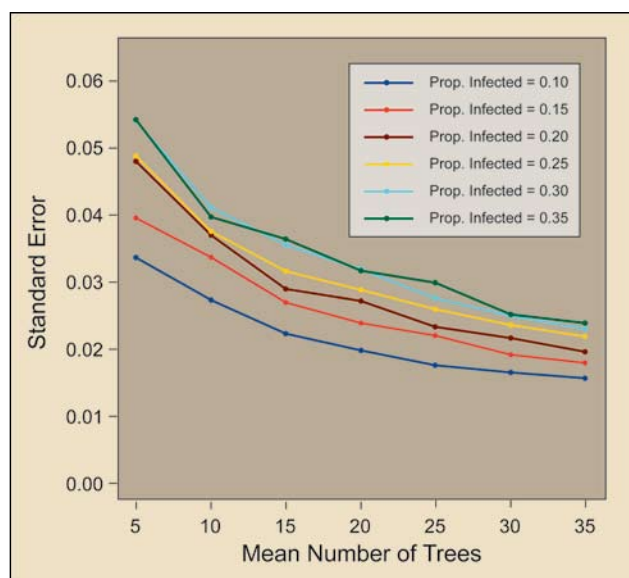


*Figure 2-6. The standard error as a function of the mean number of trees per transect and the proportion of trees infected.*



## Sample Design

### Simulation 2

Given a mean infection rate of 0.10 for this comparison, increasing the number of transects improves precision; but the relative advantage of adding more transects decreases as the mean number of trees increases until approximately an average of 20 trees per transect (Figure 2-7). Beyond this, the advantage of adding additional transects is diminished, especially when at least 100 transects have been established. Our sample through 2006 is 166 transects with an average of approximately 27 trees per transect.

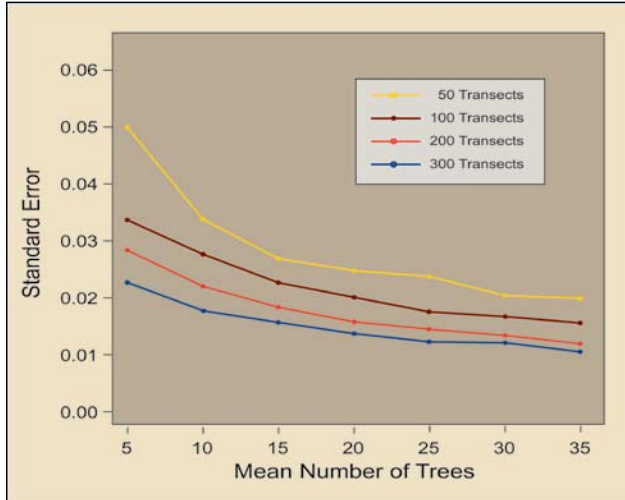


Figure 2-7. The standard error as a function of the mean number of trees per transect and the number of transects.

### Simulation 3

In simulation three, we also briefly investigated the improvement in precision attained by increasing the number of transects within the polygons. The mean infection rate was set at 0.10. Figure 2-8 shows the results for selecting 100 polygons with 1 transect per polygon, 200 polygons with 1 transect per polygon, and 100 polygons with 2 transects per polygon. It appears that there is some gain by increasing the number of transects within polygons. This gain in precision is not great but there is an increase and it would be attained with much less effort on the part of field crews. Further, have some level of replicate samples (transects) within polygons gives us a needed within-stand (polygon) variation component for our analysis.

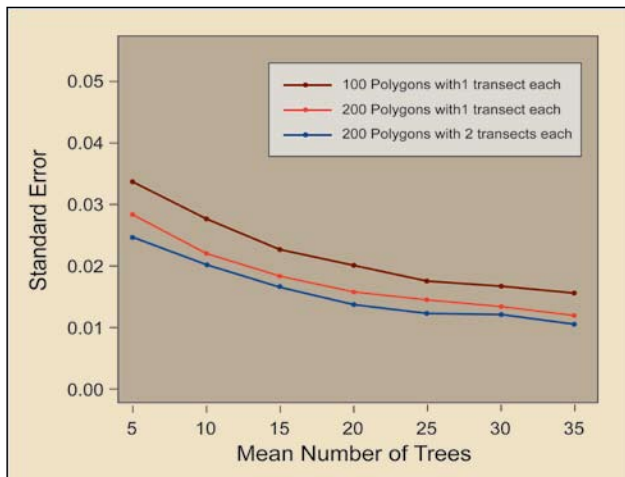


Figure 2-8. The standard error as a function of the mean number of trees per transect, the number of polygons (whitebark pine stands) and the number transects per polygon.



## A Revised Evaluation based on Preliminary Data

### *Within and Between Stand Variation*

Denoting transects as secondary sampling units (SSU) and stands as primary sampling units (PSU) we have a two-stage cluster sample. One problem immediately apparent is that with only one SSU per PSU there is no chance to quantify within stand sampling variability of infection rate. In an effort to at least evaluate the importance of within stand variability field crews were instructed to sample an additional transect when possible. Although the second transects were selected randomly from within a stand field crews chose second transects when they had time to complete them, i.e. either the first transect was quickly run due to there being few trees or it was close to a road. Thus, the use of second transects assumes that within stand variability is not related to either of those 2 variables.

The tables below summarize stand visitation by year and stratification variable.

| Table 2-1. Number of whitebark pine stands visited and transects run by year in the Greater Yellow-stone Ecosystem. There are a total of 10770 such stands currently mapped in the ecosystem. |               |                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|------------------|
| Year                                                                                                                                                                                          | Number Stands | Number Transects |
| 2004                                                                                                                                                                                          | 45            | 51               |
| 2005                                                                                                                                                                                          | 55            | 76               |
| 2006                                                                                                                                                                                          | 36            | 40               |

| Table 2-2. Number of whitebark pine stands visited and transects run by year inside the Grizzly Bear PCA. There are a total of 2362 such stands currently mapped in the ecosystem. |               |                  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|------------------|
| Year                                                                                                                                                                               | Number Stands | Number Transects |
| 2004                                                                                                                                                                               | 43            | 49               |
| 2005                                                                                                                                                                               | 0             | 0                |
| 2006                                                                                                                                                                               | 16            | 18               |

| Table 2-3. Number of whitebark pine stands visited and transects run by year outside the Grizzly Bear PCA. There are a total of 8408 such stands currently mapped in the ecosystem. |               |                  |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|------------------|
| Year                                                                                                                                                                                | Number Stands | Number Transects |
| 2004                                                                                                                                                                                | 43            | 49               |
| 2005                                                                                                                                                                                | 0             | 0                |
| 2006                                                                                                                                                                                | 16            | 18               |



## Sample Design

### Estimation

We assume we have the following sampling design. We have 2 strata. Within each strata we have a 2 stage cluster sample. It is apparent from above that an analysis based on this design requires assumptions that are going to be violated to some extent. These assumptions are based on modifications to our original sampling plan imposed by logistics, different definitions of a stand in 2 different administrative units, changes to the sampling frame of stands due to changes in definitions and mapping, and other reasons. Ideally we would use the first 3 years of data as a pilot study to aid in the design and implementation of a sampling plan whose validity would not depend on so many assumptions. Unfortunately, this is both logistically and politically undesirable. We present an initial analysis of the results based on both the above suggested sampling plans.

### Cluster Sampling

We randomly sampled 59 stands from the 2362 stands inside the recovery zone and 77 stands from the 8408 outside the recovery zone. Due to logistical constraints we were able to sample only one transect from most stands but, we did get 2 transects run on 8 stands inside the recovery zone and 23 stands outside the recovery zone. The area of each stand was determined (in meters squared) and this was used to determine the potential number of 500 square meter transects that could have been run. This is not strictly true because we did not grid each stand into separate transects but determined a transect location and orientation randomly. The total number of trees was recorded on each transect as well as the number that were believed to be infected with white pine blister rust. We estimated the proportion of trees infected with rust in each of the strata and in the ecosystem as a whole. We accomplished this as follows.

Let  $y_{ij}$  denote the number of trees recorded on the  $j$ th transect in stand  $i$ . Let  $\bar{y}_i$  be the mean number of trees per transect in stand  $i$ . Let  $M_i$  be the number of transects in stand  $i$ . The estimate of the total number of trees is given by equation 5.28 on page 148 in Lohr (1999):

$$\hat{\bar{y}} = \frac{\sum M_i \bar{y}_i}{\sum M_i}.$$

Let  $x_{ij}$  be the number of infected trees recorded on the  $j$ th transect. Let  $\bar{x}_i$  be the mean number of infected trees per transect in stand  $i$ . The estimate of the total number of infected trees is :

$$\hat{\bar{x}} = \frac{\sum M_i \bar{x}_i}{\sum M_i}.$$

The proportion of infected trees is then



$$\hat{p} = \frac{\hat{\bar{x}}}{\hat{\bar{y}}} = \frac{\sum M_i \bar{x}_i}{\sum M_i \bar{y}_i}.$$

Ignoring the within stand variability the variance is

$$\hat{V}(\hat{p}) = (1 - n/N) \left[ \frac{1}{n(n-1) (\overline{M_i \bar{y}_i})^2} \sum (M_i \bar{x}_i - \hat{p} M_i \bar{y}_i)^2 \right].$$

These calculations are carried out for each stratum separately then combined to produce an estimate for the ecosystem. The results are given below.

| Stratum Population | Stratum Sample Size | $\hat{p}$ | $\hat{V}(\hat{p})$ | SE      |
|--------------------|---------------------|-----------|--------------------|---------|
| 2362               | 59                  | 0.1383    | 0.0020219          | 0.04497 |
| 8408               | 77                  | 0.2957    | 0.0020247          | 0.04500 |

Let  $\hat{p}_o$  be the estimated proportion outside the recovery zone and  $\hat{p}_I$  be the estimated proportion inside the recovery zone. Similarly we use  $N_o$  and  $N_I$  to denote the number of stands outside and inside the recovery zone, respectively. The total number of stands is  $N = N_o + N_I$ . We can combine the stratum level estimates above into an ecosystem wide estimate as

$$\hat{p}_{str} = \frac{N_o}{N} \hat{p}_o + \frac{N_I}{N} \hat{p}_I$$

with estimated variance

$$\hat{V}(\hat{p}_{str}) = \left( \frac{N_o}{N} \right)^2 \hat{V}(\hat{p}_o) + \left( \frac{N_I}{N} \right)^2 \hat{V}(\hat{p}_I).$$

The estimate for the entire ecosystem is then

$$\hat{p}_{str} = \frac{2362}{10770} (0.1383) + \frac{8408}{10770} (0.2957) = 0.2612.$$

The estimated variance is

$$\hat{V}(\hat{p}_s) = \left( \frac{2362}{10770} \right)^2 (0.0020219) + \left( \frac{8408}{10770} \right)^2 (0.0020247) = 0.00133$$

yielding a standard error of 0.0365.



## Sample Design

The above calculations of variances and standard errors ignore the finite population correction factors (which are very close to 1). They also ignore the within stand variability. We feel this is justified based on analysis of multitransect stands. We evaluated this, for example, by analyzing the stands outside the recovery zone for which we had  $m_i = 2$  transects. We had  $i = 1; 2, \dots, 23$  such stands. We estimate the proportion of infected trees outside the recovery zone to be  $\hat{p} = 0.282$ . This is close to the estimate using all 77 stands. Define  $d_{ij} = y_{ij} - \hat{p}x_{ij}$  and

$$s_i^2 = \frac{\sum_{j=1}^{m_i} (d_{ij} - \bar{p}d)^2}{m_i - 1} = \sum_{j=1}^2 (d_{ij} - \bar{p}d)^2.$$

Ignoring the finite population correction factor, the estimate of the within stand variance is given by

$$\frac{1}{n^2 N} \left( \frac{n}{\sum_{i=1}^n M_i \bar{x}_i} \right)^2 \frac{\sum_{i=1}^n (M_i^2 s_i^2)}{m_i}$$

which is added to the between stand variance formula above. Ignoring the within stand variance we estimate the variance of the estimated proportion to be 0.007481 (se = 0.08649) and taking the within stand variability into account yields an estimated variance of 0.007494 (se = 0.08657). Thus, the within stand variability adds little for these 23 stands. If these stands are typical then we would appear to be justified in sampling only a single transect within each stand. However, we believe that it is worthwhile to continue to sample multiple transects per stand when feasible so that we may continue to evaluate this.

### Change Over Time

White pine blister rust has been in the GYE for decades. Aside from anecdotal accounts little has been done on quantifying its spread. USGS Research Biologist Kate Kendall led a study in the mid 1990's to examine the extent of rust in the GYE. The data have never been published, however Kendall has made the data available.

We were able to identify 113 transects in the GYE that contained enough information to carry out an initial analysis. These 113 plots all fell within the PCA. Plot layout and field crew training differed from our protocol. Plot locations were not randomly selected, or at least were not selected using a probability based sampling method. Trees were classified into age categories based on diameter at breast height (DBH). We did not consider seedlings (DBH < 1 inch) in the following analysis. Kendall also recognized that diagnosis of rust infection was often subjective. Her field crews used 3 different codes for rust infection, definitely infected, probably infected, and uninfected. Data were recorded at the tree level. For our analysis we pooled definitely infected and probably infected into a single category (infected).

We treated the 113 plots as a simple random sample of plots and estimated the proportion of infected trees using ratio estimation. This approach is equivalent to considering the sample to be a single stage cluster sample with plots as primary sample units and trees as



secondary sample units. We estimated the proportion of infected trees to be 0.086 with a standard error of 0.0162. Our estimate of infection inside the PCA was 0.138, an increase of 0.052 over an approximately 8 to 10 year period. We bootstrapped the standard error of the difference in infection rates (0.052). The 95% confidence interval, based on identification of the 2.5<sup>th</sup> and 97.5<sup>th</sup> percentiles of the bootstrap distribution of the difference in infection rates ranged from -0.023 to 0.175, i.e. the data are consistent with changes in infection rate ranging from a decrease of approximately 2.3% to an increase of 17.5%. We caution that formal statistical inference is valid only under an assumption that Kendall's data resulted from a simple random sample of plots selected from a larger population of plots. Our primary use of these data is to provide us with ball park estimates of the infection rate in the mid to late 90's and of changes since that time. We believe it is adequate for that. We have no previous data from outside the PCA where our estimated infection rates are considerably higher. One question of interest is how to estimate a change in the rate of infection. The comparison discussed above is not relevant as it was based on a comparison of 2 estimates from data collected using 2 different methods. The obvious estimator for our data is the difference between the estimated rates of infection in time period 2 and time period 1. However, this would not be a difference in proportions determined from 2 independent samples because the data are paired by transect. Let  $\hat{p}_j$  be the estimated rate of infection at time period  $j$ . Let

$$y_{\cdot j} = \sum_{i=1}^n M_i y_{ij}.$$

Then

$$\hat{p}_j = \frac{\sum_{i=1}^n M_i x_{ij}}{y_{\cdot j}}$$

and

$$\hat{p}_2 - \hat{p}_1 = \sum_{i=1}^n M_i \left[ \frac{x_{i2}}{y_{\cdot 2}} - \frac{x_{i1}}{y_{\cdot 1}} \right] = \sum_{i=1}^n d_i$$

The standard error of the estimated difference is just the standard deviation of the  $d_i$ 's. This standard error should be less than a standard error computed ignoring the paired nature of the data. Standard errors could also be estimated using bootstrapping, which might be advisable as it obviates the requirement of normality.

We do not have data currently available to assess how well such an approach might work. A simple example of the approach using fake data follows. The sample size is 67 stands with sizes equal to the sizes of the 67 stands we currently have inside the recovery zone. We created a new data set with counts adjusted to create an increase in infection rate of 0.071. The data are paired but manipulated so that total number of trees and number of infected trees varied. The mean of the bootstrap distribution (based on 1000 bootstrap iterations) was 0.076 implying a slight bias in the estimate. The bootstrapped standard error was 0.020, large enough to justify ignoring the bias but small enough to provide some confidence in the ability to detect changes of interest to managers.



# Sample Design

### Multiple observer plots

One source of error which has not been adequately addressed by existing protocols, but anecdotal evidence indicates may be extremely important, is observer differences. To better assess the extent of this potential source of error, we will use a double observer approach for a subset of the sample. For this effort a second (or third) observer should work one tree behind the initial observer, but remain sufficiently close so as not to impose a safety hazard. All observers will record the same information for each tree without any knowledge of what the other recorded. We emphasize that this is not a test of the accuracy of the individual observing. Observers should not compare notes, communicate about what they recorded or in any way alter their data in response to the other observer. Our intent is only to determine the extent of consistency among observers so that, if necessary, we might better take this into account in our final design.





# Chapter 3



## *Field Methods*

### Measurement Units

All measurements will be taken or converted to metric units. The International System of Units is a modernized version of the metric system established by international agreement that provides a logical and interconnected framework for all measurements in science, industry and commerce. As such, metric is the only acceptable standard for all scientific endeavors and will be the only acceptable units for this monitoring program.

### Field Season

#### ***Seasonal Timing of Whitebark Pine Blister Rust Surveys***

Surveying will start in June, depending on the hiring date of the field crews and on accessibility to whitebark pine (WbP) stands. Surveying should continue to late September/October, depending on funding and accessibility to stands.



### Field Sampling

#### ***Establishing Transects***

Within each stand 5 random points will be selected to serve as potential center points for each transect and a corresponding random number between 0 and 359 will be selected to define the vector for the transect. The random points will be listed in rank order of selection, such that the first point in the list is the intended starting location. If that location is unsuitable (i.e., misclassified as having WbP when it does not), the next closest point on the list becomes the starting point, and so on.

A handheld GPS will be used to locate the coordinates. If a site is suitable for sampling (i.e., has at least one live WbP tree >1.4 m hgt) a 10 x 50 m transect will be permanently established (Figure 3-1). From the center point (UTM coordinates provided), a random vector (0 to 359°) will be determined for the transect (a list will be provided). With a compass, walk the random vector out 25 meters using a metric forestry tape. Monument the 25 meter mark with a 12" steel nail and a large washer driven in at ground



## Field Methods

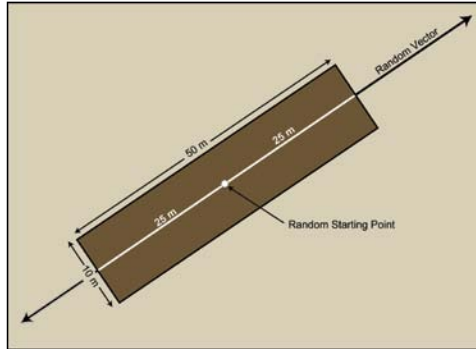


Figure 3-1. The layout of 10 x 50 m transects.

is a non-target habitat type (e.g., open meadow, body of water, rock outcropping cliff), shift the transect by adding the amount that falls into the mosaic, to the other portion of the transect (Figure 3-2).

After completion of monumenting, begin to delineate the boundaries of the 10 x 50 m rectangle. With a second metric tape, measure out 10 m using the centerline tape as a reference (5 m on both sides). At approximately 5 m intervals, place a removable surveyor's flag. These flags will provide a visual reference for the plot.

All WbP trees within the transect and > 1.4 m in height will be marked and included as secondary sampling units. All <1.4 m high WbP seedlings and saplings will be included in the regeneration count. A given tree or cluster of trees will be included within a plot if, and only if, the center of the trunk (or cluster of trunks) at ground level is within 5 m of the center of the transect line. Dead WbP trees > 1.4 m in height within the plot will not be marked but will be recorded as being present.

level. This will be considered the “end” point of the plot. Back at the center point, walk the “back” vector (azimuth) 25 meters. At this monument, attach a numbered tag to the nail and washer and again drive in to ground level. This is the “beginning” of the transect. Leave the tape stretched between the monuments until completion of the survey. At the center point and at both monuments record a UTM. Take a photo of the transect that captures the general nature of the stand.

If a transect has the minimum requirements for WbP but lies partly in an area that

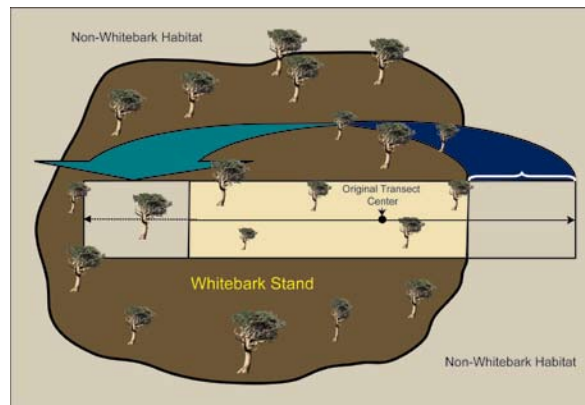


Figure 3-2. When a given transect extends beyond whitebark habitat (e.g., into alpine tundra), then a distance equal to that which is outside of whitebark habitat is added to the opposite end of the transect to compensate.



## Data Collection

### *Individual Transect Fields*

#### Transect Location and Layout

On the first visit to a given transect, detailed information regarding the location of the transect is recorded (Table 3-1). This will help ensure that data for a given administrative unit can be properly accessed, as well as aiding in relocating the transect for subsequent visits to determine trends. Additional data fields describe the layout of each transect (Table 3-2).



*Figure 3-3. Basal sprouts associated with a given tree are not considered as individual seedlings or saplings.*

tallies should include the hike into and out of the transect. Since black bears also sometimes excavate middens, these surveys are used by the IGBST as anecdotal evidence only and will be independently corroborated.

#### Survey of Trees < 1.4m DBH

Individual whitebark pine trees within the transect < 1.4 m DBH will not be marked, but they will be counted and assessed for white pine blister rust. When < 1.4 m DBH trees are found in direct association with a > 1.4 m DBH tree (e.g. appear to be growing from the base of the tree and thus are possibly branches), they are not considered for this survey as individual seedling/saplings (Figure 3-3). The data fields associated with this survey are summarized in Table 3-3.

#### Survey of Red Squirrel Middens

For the purpose of determining if grizzly bears are in the area, a survey is also conducted for red squirrel middens. However, an important distinction for this survey is that, unlike all other data fields, it is not restricted to the transect itself. As above, a tally (and total) of all red squirrel middens should be made for undisturbed middens (i.e., no evidence of having been excavated by bears) and excavated middens (i.e., evidence present of having been excavated by bears). These



*The excavation of red squirrel middens can be an indicator of grizzly bear use of the area.*



## Field Methods

| Table 3-1: Fields describing identity and location of a transect |                                                                                                                                    |                                                                                                                                                                                                                                                                                                           |
|------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Field Name                                                       | Description                                                                                                                        | Potential Values                                                                                                                                                                                                                                                                                          |
| Polygon ID                                                       | Unique identification for each WbP stand in CEM Model Vegetation Layer that will be provided.                                      | 1-xxxxx                                                                                                                                                                                                                                                                                                   |
| Transect ID                                                      | Number between 1-5 that will be provided by the mapping department denoting which of the 5 random sites was used for the transect. | 1-5                                                                                                                                                                                                                                                                                                       |
| Date                                                             | Date of transect survey                                                                                                            | MM/DD/YY                                                                                                                                                                                                                                                                                                  |
| Field Crew                                                       | Full Name of any person involved in surveying on a particular day.                                                                 | Full Name-<br>First Middle I. Last                                                                                                                                                                                                                                                                        |
| State                                                            | Two-letter State abbreviation for state in which transect survey occurred.                                                         | MT, WY, ID                                                                                                                                                                                                                                                                                                |
| County                                                           | County name in which transect survey occurred.                                                                                     | All counties in study area                                                                                                                                                                                                                                                                                |
| Ownership                                                        | Name/abbreviation of administering agency or owner                                                                                 | USFS, NPS, Other (specify)                                                                                                                                                                                                                                                                                |
| Forest/Park                                                      | Name of administering national forest or national park on which survey occurred.                                                   | YELL = Yellowstone National Park<br>GRTE = Grand Teton National Park<br>GNF = Gallatin National Forest<br>BTNF = Bridger Teton National Forest<br>SNF = Shoshone National Forest<br>CTNF = Caribou-Targhee National Forest<br>BDNF = Beaverhead-Deerlodge National Forest<br>CNF = Custer National Forest |
| District                                                         | Name of district within park or forest                                                                                             | All districts in study area                                                                                                                                                                                                                                                                               |
| Contact name                                                     | Name of best person to contact for assistance on forest/park where the transect survey occurred.                                   | Contact name                                                                                                                                                                                                                                                                                              |
| Location description                                             | Short, detailed description of where the polygon is located using landmark names                                                   | Text description                                                                                                                                                                                                                                                                                          |
| Topo Map ID [USGS 7.5' quad map name]                            | Name of USGS 7.5 minute quadrangle                                                                                                 | Quad name                                                                                                                                                                                                                                                                                                 |



| Table 3-2: Fields describing layout attributes of a given transect. |                                                                               |                                                                      |
|---------------------------------------------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Field Name                                                          | Description                                                                   | Potential Values                                                     |
| Transect Begin Point                                                | UTM Easting(NAD83) - coordinate at the beginning monument.                    | UTM Easting(NAD83)                                                   |
|                                                                     | UTM Northing(NAD83) - coordinate at the beginning monument.                   | UTM Northing(NAD83)                                                  |
|                                                                     | GPS unit error for UTM Easting at beginning monument.                         | 310,000-690,000                                                      |
|                                                                     | GPS unit error for UTM Northing at beginning monument.                        | 4,660,000-5,128,000                                                  |
| Transect Center Point                                               | UTM Easting(NAD83) - coordinate for the random center point of the transect.  | UTM Easting(NAD83)                                                   |
|                                                                     | UTM Northing(NAD83) - coordinate for the random center point of the transect. | UTM Northing(NAD83)                                                  |
| Transect End Point                                                  | UTM Easting(NAD83) - coordinate at the beginning monument.                    | UTM Easting(NAD83)                                                   |
|                                                                     | UTM Easting(NAD83) - coordinate at the beginning monument.                    | UTM Northing(NAD83)                                                  |
|                                                                     | GPS unit error for UTM Easting at beginning monument.                         | 310,000-690,000                                                      |
|                                                                     | GPS unit error for UTM Northing at beginning monument.                        | 4,660,000-5,128,000                                                  |
| Habitat Type                                                        | Climax community habitat type from Steele et al. guide.                       | Climax community habitat types from Steele et al. guide.             |
| Cover Type                                                          | Cover type from Despain descriptive guide, arboreal community type.           | Cover types from Despain descriptive guide, arboreal community type. |
| Transect Orientation                                                | Randomly selected vector                                                      | Degree 0° - 360°                                                     |

| Table 3-3: Fields describing counts of trees < 1.4 m DBH. |               |                                                                                                                                                                                                                                                     |
|-----------------------------------------------------------|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Field Name                                                | Sub-Field     | Description                                                                                                                                                                                                                                         |
| Blister Rust Present                                      | Tally         | A running tally of whitebark pine trees < 1.4 m DBH that are infected with white pine blister rust. (e.g.,  ). The tally is only used to derive the total count. |
|                                                           | Total         | The total count of whitebark pine trees < 1.4 m DBH that are infected with white pine blister rust.                                                                                                                                                 |
| Blister Rust Absent                                       | Same as above | Same as above for trees that are not infected with white pine blister rust.                                                                                                                                                                         |
| Blister Rust Uncertain                                    | Same as above | Same as above for trees in which the presence of white pine blister rust is uncertain.                                                                                                                                                              |



## Field Methods

### Multiple Observer Transects

The final data field recorded at the individual transect scale is whether or not the transect is a “multiple observer” transect. A multiple observer transect is a transect in which more than one observer is independently recording individual tree measurements, including the presence of white pine blister rust. Multiple observer transects are used to evaluate observer variation in individual tree attributes. **THIS IS NOT A TEST OF OBSERVER COMPETENCE!** A multitude of factors may influence an observer’s ability to detect blister rust and other attributes of individual trees, including observer experience, position on the ground, entanglement of branches, lighting, optics used, etc. Consequently, it is important to be able to account for observer variation in our analysis so that we can try to better understand what part of the variation is due to observer differences compared to actual changes in infection levels of blister rust. Thus, it is extremely important for multiple observers to not view this as a competition among observers or as any test of their abilities. Observers should always record the data exactly as they would if they were alone. Although consultation is a normal part of training and gaining experience, a given data field from a multiple observer plot should never be changed as a result of consultation with other observers. This defeats the purpose of the multiple observer plots, and reduces our ability to account for observer variation.

### Individual Tree Measurements

#### ***Dead Whitebark Pine Trees***

Dead WbP trees >1.4 m height within the plot will not be marked, but will be recorded as being present. DBH will be the only individual tree measurement taken. In contrast with the WPEF protocol (Tomback 2004), no determination of cause of death shall be recorded due to the unreliability of retrospective assignment of cause of death. Evidence of insect or disease agents should be noted in the comments.

#### ***Live Whitebark Pine Trees > 1.4 m DBH***

All live WbP trees >1.4 m in height within the transect will be individually marked with an aluminum tag at 1.4 m (BH) on the side of the tree facing, and perpendicular to, the transect centerline. Tags will be fixed to the tree by an aluminum nail (2 1/8” long). Hammered the nail into the trunk such that the point of the nail is at an angle above the head of the nail. This will ensure that the tag will hang off the end of the nail and not imbed in the tree. In federally designated Wilderness Areas, tags will be placed on the same side of the tree, but at the base of the tree, rather than BH. The data fields for the individual tree measurements are summarized below in Table 3-4 and additional details are provided below.



*Tree tags*



**Table 4: Fields describing individual tree measurements of whitebark pine trees > 1.4 m DBH.**

| Field Name                    | Description                                                                                                                                                                                                                                                                                         | Potential Values                                                                                                                   |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Tree ID (tag no.)             | Numeric value from metal tag fastened to tree                                                                                                                                                                                                                                                       | Within a range of zero to all positive integers                                                                                    |
| Observer                      | Initials of observer who performed the actual visual identification of cankers for that particular tree.                                                                                                                                                                                            | Initials                                                                                                                           |
| Clump Number                  | For each transect, start with # 1 and with each consecutive clump of WbP along the transect, increase the number by one.                                                                                                                                                                            | Integer from 1 to x.                                                                                                               |
| Clump Letter                  | Sequential letter assigned to each individual stem (tree) within a given clump.                                                                                                                                                                                                                     | Each member of a clump is assigned a letter- a,b,c,d,e,f, etc. Start back at "a" with a new clump (i.e. clump 1a,1b,1c, 2a,2b,2c). |
| DBH(cm)                       | Tree diameter at breast height (1.4 m, measured and recorded in centimeters                                                                                                                                                                                                                         | Within a range of positive numeric values to include one decimal place [specify a reasonable lower and upper limit?]               |
| Height Class                  | Tree height class code                                                                                                                                                                                                                                                                              | 1: <= 5m<br>2: > 5m <= 10m<br>3: >= 10m                                                                                            |
| Tree Status                   | Tree status code                                                                                                                                                                                                                                                                                    | L: Live (green needles present)<br>RD: Recently Dead (non-green needles present)<br>D: Dead (needles absent)                       |
| Health Index                  | To be designed                                                                                                                                                                                                                                                                                      |                                                                                                                                    |
| Branch Cankers - Upper Third  | A = The number of blister rust cankers observed on branches in the top one third of the tree that have aecia present.<br>I = The number of blister rust cankers observed on branches in the top one third of the tree that do not have aecia present, but were determined via secondary indicators. | Counts of cankers in each category (A & I).                                                                                        |
| Branch Cankers - Middle Third | Same as above, except on the middle one third of the tree                                                                                                                                                                                                                                           | Counts of cankers in each category (A & I).                                                                                        |
| Branch Cankers - Bottom Third | Same as above, except on the bottom one third of the tree                                                                                                                                                                                                                                           | Counts of cankers in each category (A & I).                                                                                        |



## Field Methods

| Table 4: Cont.                       |                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Field Name                           | Description                                                                                                                                                                                                                                                                                                                 | Potential Values                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Bole Cankers – Upper Third           | A = The number of blister rust cankers observed on the bole of the tree in the top one third of the tree that have aecia present.<br>I = The number of blister rust cankers observed on the bole of the tree in the top one third of the tree that do not have aecia present, but were determined via secondary indicators. | Counts of cankers in each category (A & I).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Bole Cankers – Middle Third          | Same as above, except on the middle one third of the tree                                                                                                                                                                                                                                                                   | Counts of cankers in each category (A & I).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Bole Cankers – Bottom Third          | Same as above, except on the bottom one third of the tree                                                                                                                                                                                                                                                                   | Counts of cankers in each category (A & I).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Rodent Chewing                       | Total number of cankers with rodent chewing                                                                                                                                                                                                                                                                                 | Counts of cankers with this indicator                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Flagging                             | Total number of cankers with dead branch flagging                                                                                                                                                                                                                                                                           | Counts of cankers with this indicator                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Swelling                             | Total number of cankers with swelling observed                                                                                                                                                                                                                                                                              | Counts of cankers with this indicator                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Oozing Sap                           | Total number of cankers with oozing sap observed                                                                                                                                                                                                                                                                            | Counts of cankers with this indicator                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Live Canopy Volume (%) – Upper Third | The percent of canopy in the upper one third of the foliage that is alive                                                                                                                                                                                                                                                   | 0-100                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Mountain Pine Beetle                 | Observable evidence (e.g., galleries) of mountain pine beetle on tree                                                                                                                                                                                                                                                       | 'yes' or 'no'                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| General Health Comments              | Observer description of tree condition                                                                                                                                                                                                                                                                                      | Bt = broken top<br>Db = dead branch (sometimes associated with positioning on the tree denoted as T = top, M = middle, B = bottom, and a number as to how many are present in that particular location i.e. Db2- 1 M, 1 B means two dead branches, one found in the middle 1/3 <sup>rd</sup> one found in the bottom 1/3 <sup>rd</sup> )<br>Ad = animal damage<br>Md = mechanical damage<br>Ns = needle shed<br>Us = understory (found in the understory, shaded by another tree or trees)<br>Dt = dead top<br>Tg = trunk girdling<br>Bg = branch girdling<br>F = flagging<br>H = healthy<br>Uh = unhealthy (for some unknown reason)<br>NFP = needle/foliage problems |



## Individual Tree Fields

### Clump Number and Letter

Tree clusters (clumps) may form when multiple seeds are cached at the same location by Clark's nutcrackers or squirrels. Although multiple trunks of an individual tree are certainly possible, it is more often the case that multiple trees can sprout from the same location. Thus, to ignore that these are individual trees can be problematic and under sample the density of trees at a given location. Further, a given tree within a cluster may suffer damage and/or mortality from blister rust, while an adjacent trunk with less or no infection may remain undamaged and survive. For our purposes, we have defined several criteria to determine if a particular growth form should be considered a lone tree, an individual bole that is part of a clump or simply a branch emerging from a bole. Any tree separated at ground level by  $>1'$  is considered a lone tree and is marked accordingly. Trees in proximity to each other with  $<1'$  of separation below DBH (1.4m) are considered members of a clump. Each tree clump (i.e., tree with  $>1$  main stem) will be assigned a consecutive number as they are encountered, such that the first clump encountered is clump # 1, the second is clump #2 and so on (Figure 3-4). Within each clump, the individual main stems (boles) are each assigned a consecutive letter, identifying them as a bole within a clump.

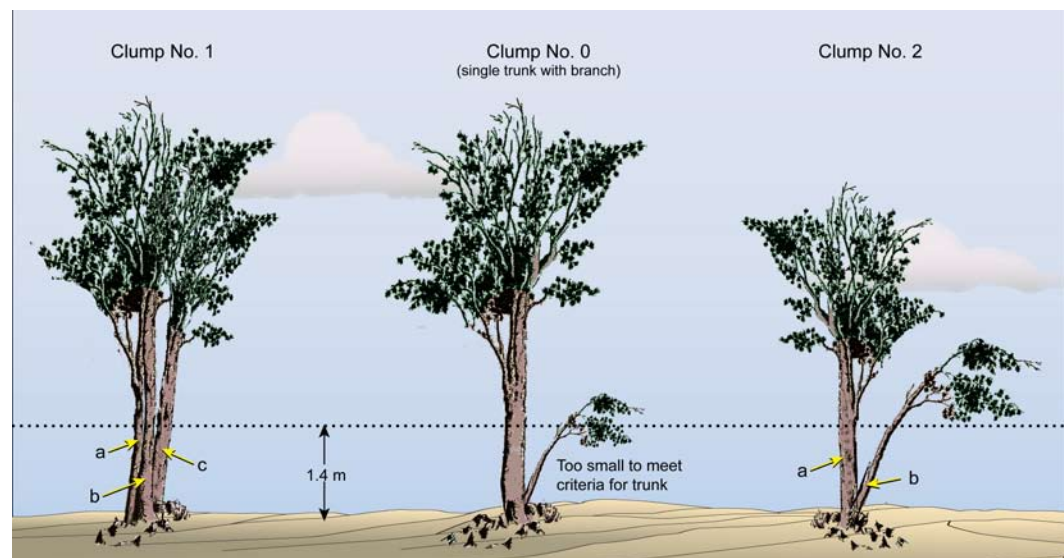


Figure 3-4. Tree cluster are assigned when individual stems cannot be distinguished as being an distinct individual tree. This often happens as a result of seeds being cached by Clark's Nutcrackers.

### Branch vs Bole

In order to discern between a branch and a bole, 3 of the 4 following criteria must be met for a given stem to be considered as a separate bole of a a given tree:



## Field Methods

1. There must be a discernible growth groove that separates that stem from other stems of the tree.
2. The diameter of a given stem must be  $> 25\%$  of the diameter of the largest stem.
3. The stem must be  $< 1'$  from the “mother” tree to which it is associated. Otherwise it is to be considered as a separate seedling, sapling, or tree.
4. The angle of the stem in question must at less than a  $< 45^\circ$  angle from the main stem.

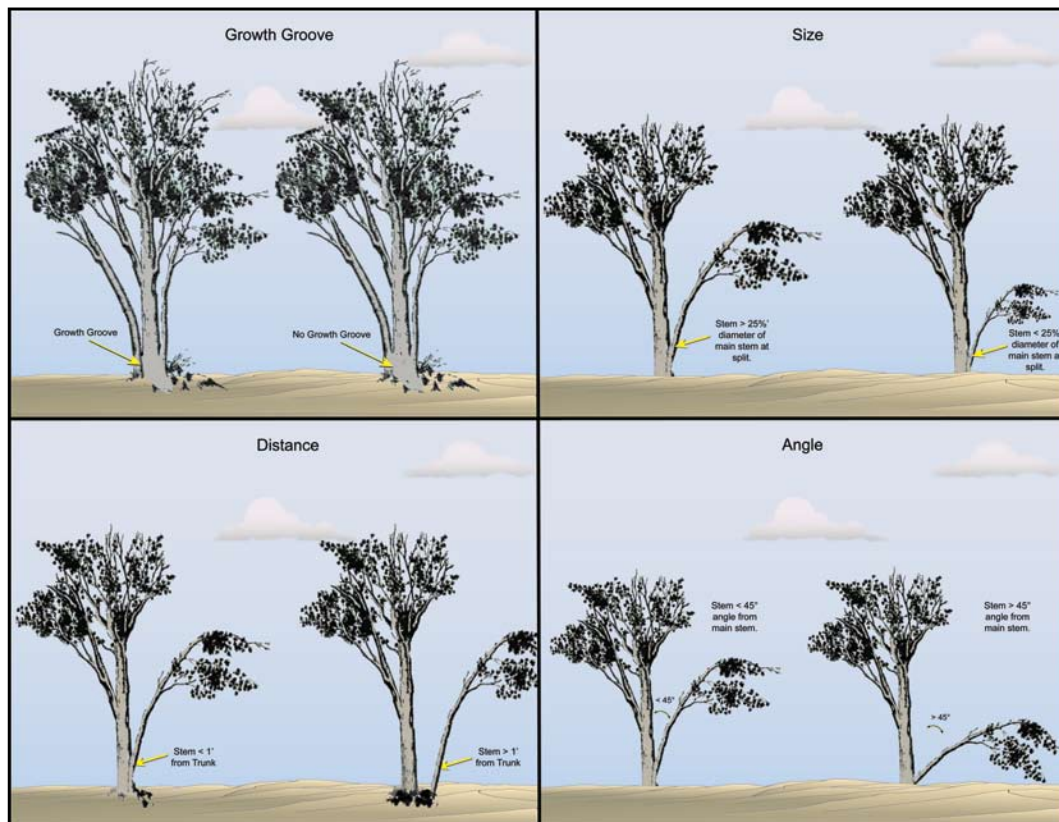


Figure 3-5. The criteria by which a branch is distinguished from a bole within a given tree.

### Number of Cankers

The number of cankers is recorded for each tree based on: (1) whether or not it occurs on a branch or a bole; (2) which third of the tree (bole) or foliage (branch) it occurs; and (3) whether or not it was determined to be a canker based on aecia being present or by at least 3 of 5 of the other indicators (below).



## Branch vs bole cankers

**Tree Thirds.**-- Both the severity of blister rust infection and the detectability of blister rust cankers are influenced by position on the tree. In addition to whether the infection is branches or the bole(s), these attributes are also influenced by how high they are in the tree. For example, a girdling canker near the top of a tree may result in top kill, whereas a girdling canker near the bottom could kill the tree. Similarly, cankers near the bottom of a tree are more likely to be detected than those obscured by branches near the top. To account for differences in severity and detectability, we have adopted the concept proposed by Six and Newcomb (in review) of dividing each tree and foliage into thirds for the purpose of recording blister rust infection.

The bole of the tree is divided into thirds for bole cankers. The bole is defined as the most vertically oriented portion of the tree that extends from the ground to a division point or split at which the observer can no longer discern by diameter any size difference in regards to a given stem (Figure 3-6). Cankers observed above this point are considered branch cankers. Should a bole canker in a given third of the bole extend beyond that third to the next, it is assigned to the lowest third (Figure 3-7).

The extent of live foliage is also divided into thirds for the purpose of counting branch cankers. In contrast to Six and Newcomb (in review), who propose a rating system based on percent of the area infected

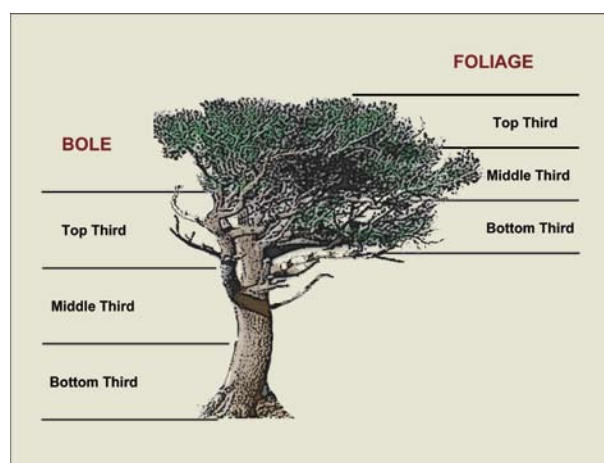


Figure 3-6. Bole and branch cankers are each assigned to their relative position (thirds) in the bole or foliage.

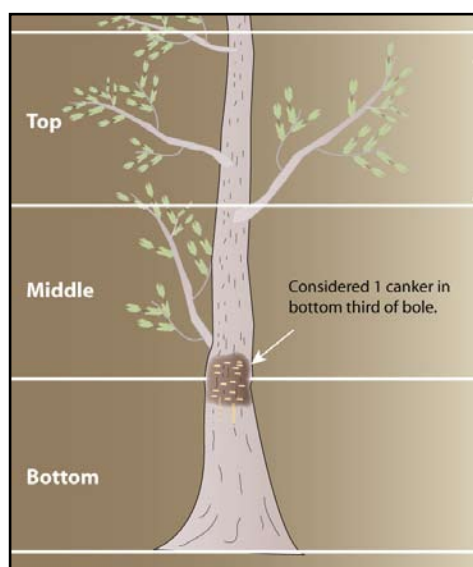


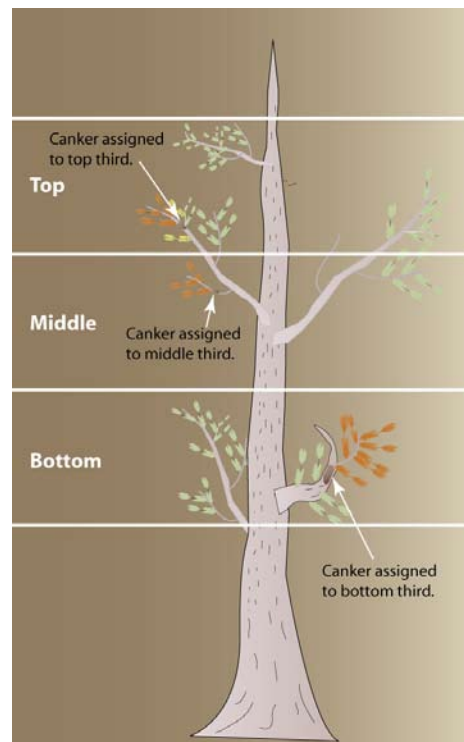
Figure 3-7. Bole cankers that cover more than one third are assigned to the lowest third in which they occur.

within each third, we are counting cankers. The reason for the approach taken by Six and Newcomb is to expedite the assessment, as well as the recognition that counts of cankers may be highly influenced by the circumstances under which they are counted. We recognize the weaknesses of counting cankers, but have adopted this approach as an initial approach to better enable us to refine an alternative. Additionally, Six and Newcomb (in review) found that the mean number of cankers from counts was highly correlated with their rating system. Branch cankers are assigned to the third in which the canker occurs, rather than by the origin of the branch on which they occur (Figure 3-8).



## Field Methods

Figure 3-8. Branch cankers are to the third in which they occur.



### Criteria for Inclusion of Cankers in the Count

Based on:

Hoff, R. J. 1992. *How to recognize blister rust infection on whitebark pine*. USDA Forest Service, Intermountain Research Station, Research Note INT-406, Ogden, Utah.

We had two criteria for determining the presence of a blister rust canker: (1) the presence of aecia; or (2) the presence of three of five secondary indicators. The number of cankers meeting each of those criteria is recorded. Those that have aecia present should be noted

in the “A” column under the corresponding location (upper 1/3rd, middle 1/3rd, etc.). The presence of aecia (left), is considered definitive and sufficient evidence, such that other indicators need not be present to assign it as a canker. It should be noted that “A” denotes the visible presence of aecia, and should not be confused with designation of “active” cankers used on efforts monitoring blister rust. Active cankers may, or may not,

Photo: USFS, Dorena G.R.C. (left), Erin Shamman (right).



Aecia, shown as sporulating (left) and empty (right) are considered as definitive evidence for the presence of a canker.



have visible aecia; thus, we do not attempt to distinguish active vs inactive cankers.

An alternative criteria for determining the occurrence of a blister rust canker is the presence of three of five secondary indicators. If three of five secondary indicators are present in the same spot on the tree, a canker will be counted. These cankers should be recorded under the “I” column. As above, “I” denotes the presence of secondary indicators and should not be confused with “inactive” cankers recorded on other studies. Cankers having visible aecia and other secondary indicators are not counted twice for each form of evidence. Thus if aecia are visible, secondary indicators need not be recorded.

Secondary indicators consist of:

**Flagging-** When cankers girdle a branch, the branch dies and becomes a “flag”.

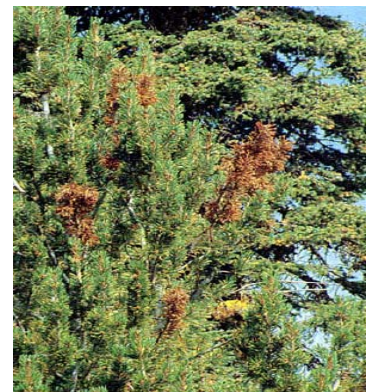


Photo Courtesy of USFS, Roy Hoff

*Flagging*



Photo Courtesy of USFS, Roy Hoff

*Swelling*

**Swelling-** The occurrence of a canker often causes swelling on the branch or trunk (which may be yellow-orange in color). This is amplified when scrubbed with water.

**Roughened Bark-** The occurrence of a canker often causes roughened bark.



Photo Courtesy of USFS, Roy Hoff

*Roughened Bark*



## Field Methods

Rodent chewing (stripped bark)- The high sugar content associated with cankers makes them attractive to rodents. Thus chewing of these sweet tissues is often an indicator of blister rust.



*Rodent Chewing*



*Oozing Sap*

Oozing Pitch- Pitch is often associated with the dead portion of a canker which may run down the branch or trunk. Pitch is often associated with the margin of a canker and may run down the branch or trunk.

In addition to these secondary indicators being used to verify the occurrence of a canker, the number of occurrences of each indicator itself is also recorded. This is intended to aid us in determining which indicators are best suited to identify the occurrence of blister rust.

### **Mountain Pine Beetle**

Note the presence or absence of mountain pine beetle in all WbP live, recently dead and dead. Also make note (comments) of the presence of mountain pine beetle in the stand and general area.

#### Identification of mountain pine beetle infestation

Mountain pine beetle infestation can be identified by small, popcorn-shaped masses called pitch tubes and presence of live mountain pine beetle and characteristic J-shaped galleries under the bark (Figure 3-9). Crew members should become familiar with these signs of infestation and be able to positively identify mountain pine beetle presence/absence on both live and dead trees within the plots. See the following website for help-



*Figure 3-9. Mountain pine beetle galleries.*



ful images: <http://www.ext.colostate.edu/pubs/insect/05528.html> (Leatherman DA. 2002. Mountain pine beetle fact sheet. Colorado State University Cooperative Extension. Publication number 5.528.

### ***Observer Health Comments***

This section is included to comment on any additional visual health observations for each tree. It is intended to augment the blister rust infection data by providing information on other types of damage or influences that may be effecting the health of the tree.

### ***Equipment***

The following materials should be taken in field each day that surveys are conducted. Make certain that you have sufficient amounts of the various articles on the list to get you through the survey and the rest of the day.

1. *Timepiece*
2. *Binoculars*
3. *1 metric forestry tape*
4. *DBH tape*
5. *2 Compasses*
6. *GPS unit*
7. *Extra batteries*
8. *Maps-topographic, aerial and photo quad*
9. *Data sheets, clipboard, pens and pencils*
10. *Digital camera*
11. *Tree tags, nails and wire-bring plenty*
12. *Hammer*
13. *Monumenting nails and washers*
14. *Flagging/Survey flags*
15. *Habitat and cover type forms*
16. *Bear spray*
17. *First aid kit*
18. *Radio and batteries or cell phone*
19. *PDA (including extra batteries, waterproof case, and extra memory card)*

### **Safety in the Field**

General safety in the field is discussed in detail in the safety standard operating procedure (SOP) found in the appendix; however, under all circumstances, safety comes first. If weather (e.g. lightning, cold, rain, snow) an animal (bear, moose) or road conditions are placing you at risk, STOP. Take cover, get warm, pull over or do whatever you need to do to get yourself to safety.

Should you encounter a bear or a bear closure, leave the area immediately!

Check in at regular intervals (daily if possible) with the crew leader.



# Chapter 4



## Data Management

### Data Model

The current data model in Microsoft Access format includes a table that stores location, site and other transect data and a separate table that stores data for individual trees within transects. Fields ‘Stand\_ID’ and ‘Transect\_ID’ are included in each table to support the relationship between parameter values for trees with those for transects and stands. Associated lookup tables contain known values that facilitate data entry by providing pick lists and promote high quality data by controlling the consistency of data entry for these parameters. Figure 4-1 shows some of the lookup tables and a partial list of parameters for trees and transects. Refer to the attached data dictionary for a complete list and description of data fields and value domains.

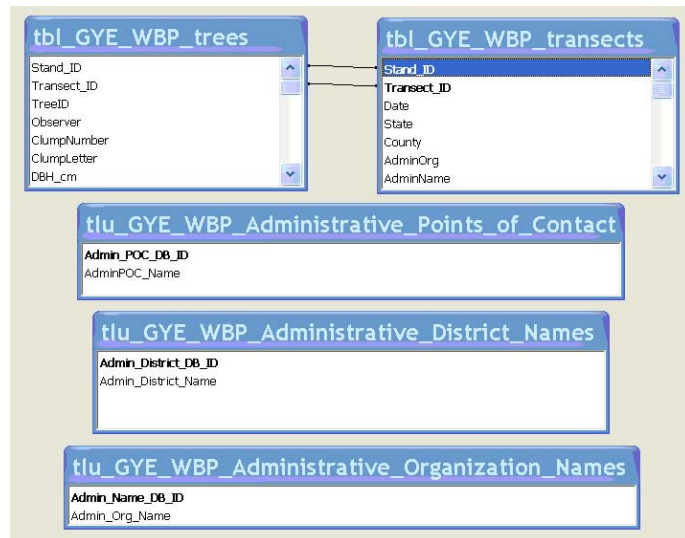


Figure 4-1. General data model for whitebark pine monitoring project.

### Data Stewardship Roles and Responsibilities

The stewardship of data and materials for the project is shared among staff of the USGS Interagency Grizzly Bear Study Team and the NPS Greater Yellowstone Monitoring Network, as listed in Table 4-1. To successfully catalog, organize, structure, archive and make available relevant whitebark pine monitoring data and results, project staff should expect to spend approximately one third of their time, overall, on activities related to the stewardship, analysis, and reporting of project data.



## Data Management

| Table 4-1: Data Stewardship Roles and Responsibilities                   |                          |              |                     |
|--------------------------------------------------------------------------|--------------------------|--------------|---------------------|
| Data Stewardship Responsibility:                                         | Name                     | Organization | Contact Information |
| Master copy of protocol                                                  | Ecologist/Project Leader | NPS-GRYN     | (406) 994-2281      |
| Master copy of database                                                  | Data/Office Manager      | USGS - IGBST | (406) 994-5041      |
| Master copy of database and protocol (backup person)                     | Data Manager             | NPS-GRYN     | (406) 994-4124      |
| USFS database Coordination                                               | Data Manager             | NPS-GRYN     | (406) 994-4124      |
| Security and backup plan for primary database                            | Data Manager             | NPS-GRYN     | (406) 994-4124      |
| Verification of data in primary database                                 | Project Leader           | NPS          | (406) 994-2281      |
| Validation of data in primary database                                   | Project Leader           | NPS          | (406) 994-2281      |
| Original data sheets/field forms                                         | Project Leader           | NPS          | (406) 994-2281      |
| Documentation for data structure and database application                | Data Manager             | NPS-GRYN     | (406) 994-4124      |
| Maintenance of documentation for data structure and database application | Data Manager             | NPS-GRYN     | (406) 994-4124      |
| Annual storage and long-term archiving of physical project materials     | Data/Office Manager      | USGS – IGBST | (406) 994-5041      |

## Data Entry and Quality Assurance

### Data Entry

#### Using Paper Field Forms

Data from field data sheets will be entered in the computerized database as soon as possible after each field hitch, once field crews return to a base location where a working copy of the GYE Whitebark Pine Database is available. The person responsible for the master database (see Table 4-1) will make a data entry form available on a portable laptop, in the USGS-IGBST office or in the NPS-GRYN office.

In most cases the field crew leader will perform the data entry. If necessary a qualified person appointed by the field crew leader and approved by the project leader will enter the data.



### Using Handheld Electronic Device

Using an electronic device in the field will preclude manual data entry on paper, except in cases where electronic units have failed. Spare data collection units and extra batteries will be supplied for use in the field. However, paper copies of data forms must always be carried as a backup to electronic equipment. For extended backcountry missions over multiple days, the investment in data collected is at risk from accidental loss. To minimize this risk, field crew members will back up field data at least once each day to a secondary device or memory card.

### Digital Images

Store digital images that represent the general nature of established transects in a folder called 'GYE\_WBP\_Images' within the parent folder in which the database is stored. File size for digital images stored with the project data should normally be between 300KB and 1MB. Project staff will resize original image files larger than 1MB. Project staff will select at least one image per visit (where available), and not more than five images per transect per visit. Project staff will name image files to include the stand ID, transect ID, and the date the image was acquired. Images of things other than surveyed transects will not be stored in the project's file structure.

### ***Data Verification***

Crew members are responsible for legible, accurate written entries on field forms and in log books. As a first step to verify data, crew members will visually check and double-check the recorded values on the day of data collection. On a daily or weekly basis, as allowed by the schedule and duration of field visits, the crew leader gathers the data collection forms and verifies the completeness, accuracy and legibility of each form prior to the initial data entry.

The critical parameters (i.e., those representing occurrence, distribution or severity of blister rust or pine beetle) for all data collected via paper field forms will be re-entered so that the values can be compared to the original data entry and differences corrected. This step can be automated using electronic handheld devices for data entry.

### Data Validation

After verifying that entered data were correctly transcribed from field forms, data must be validated for logical accuracy by the field crew leader or a qualified alternative designated by the field crew leader and approved by the project leader.

Data validation will include:

- *Assessment of data distribution and ranges for values out of range, or inconsistent with expected values for the field circumstances. Note: this step may be automated as part of the data entry phase using electronic handheld devices.*



## Data Management

- *Review of spatial data to ensure accuracy, e.g. that all transect points based on coordinates obtained during field work are located within the sample frame.*
- *Assessment of data structural integrity (e.g., data types, relationships, consistencies, etc).*

All errors identified during quality control procedures (e.g., data verification and validation) must be corrected on the original data forms (paper or electronic) with a complete log of all corrections kept on file with the master data base.

### Meta Data

Documenting the whitebark pine data set, the data source(s) and the methodology by which the data are acquired establishes the basis for interpreting and appropriately using data and results from the whitebark pine monitoring project. Metadata for the project is kept in several locations and formats, as listed in Table 4-1. The person listed in Table 4-1 (Data Stewardship Roles and Responsibilities) with responsibility for database documentation will annually review and update the content and structure of the metadata.

Metadata Sources for the Whitebark Pine Monitoring Project include:

- *Parameter descriptions in this monitoring protocol document*
- *Table descriptions in the GYE WBP database application*
- *Field descriptions for tables in the GYE WBP database application*
- *Excel Data Dictionary for the GYE WBP database application (Appendix 2)*

### Archiving

The GRYN data manager maintains an archive copy of the GYE Whitebark Pine Database on the GRYN server for access by network staff and as another backup for the database managed by IGBST staff. All data on the GRYN server receive daily differential and weekly full backups stored on-site and quarterly backups stored off-site. At the end of each field season all physical project materials, including field data collection forms, site sketches, and log books, are submitted by the project crew leader to staff at the USGS IGBST office in Bozeman, MT for storage and archival. The project crew leader also provides copies of these materials to the GRYN data manager.

### File naming structure

All files will be named according to the standards for the I&M program, as described in WASO (2004).







## Analysis & Reporting

### Analysis

Our data analysis is intended to provide estimates for the target population, rather than merely reporting the observed values from our sample.

#### Parameter Estimation

Let  $y_i$  be the observation for the  $i$ th transect,  $i=1, \dots, n$ . Let  $\psi_i$  be the probability that the  $i$ th transect is sampled. As indicated above this is the area of the transect (500 square meters) divided by the area of the polygon times  $1/N$ . Define a new variable  $v_i = y_i / \psi_i$ . This is actually an unbiased estimator of the population quantity of interest  $y$  but we have  $n$  observations to work with so a better estimator is

$$\hat{y} = (1/n) \sum_{i=1}^n v_i = (1/n) \sum_{i=1}^n (y_i / \psi_i).$$

The estimated variance is the sample variance divided by  $n$ ,

$$s_{\hat{y}}^2 = \frac{\sum_{i=1}^n (v_i - \hat{y})^2}{n(n-1)}.$$

One of the key parameters we want to estimate is the proportion of trees infected. There are at least two approaches one can take for this but we will use the technique known as ratio estimation. Let  $y_i$  be the total number of infected trees on the  $i$ th transect and let  $m_i$  be the total number of trees on the  $i$ th transect. The estimate of the population proportion is

$$\hat{p} = \frac{\sum_{i=1}^n \frac{y_i}{\psi_i}}{\sum_{i=1}^n \frac{m_i}{\psi_i}} = \frac{\sum_{i=1}^n v_i}{\sum_{i=1}^n u_i}.$$



# Analysis & Reporting

The estimated variance of  $\hat{p}$  is (ignoring the finite population correction factor)

$$s_{\hat{p}}^2 = \frac{\sum_{i=1}^n (v_i - \hat{p}u_i)^2}{n(n-1)\bar{u}^2}.$$

The ratio estimator is biased, but negligibly so, and will tend to be more precise than the other intuitively reasonable estimator: the mean of the sample proportions from each transect. We would use the same approach to estimate the mean severity index.



## ***Reporting***

Our approach to reporting is hierarchical and intended for multiple audiences and media. The primary delivery system will be the internet via the Greater Yellowstone Science Learning Center (GYSLC), currently located at: <http://www.greateryellowstonescience.org/index1.html>. However, the individual products available on the web site are also in a format (pdf) that will facilitate easy printing or enable us to deliver a printed version to appropriate audiences.

The GYSLC is a partnership between Grand Teton, Yellowstone, and Bighorn Canyon national parks, the Greater Yellowstone I&M Network, and the Rocky Mountains Cooperative Ecosystem Studies Unit. Its purpose is to build stronger relationships with scientists and better communicate science results to interested park audiences.

The hub of the Learning Center is a web page that gathers information about a number of resource topics in one place. The web-enabled Learning Center concept is founded in the belief that all internet-using members of the public, from university researchers to primary school students, should be able to access the vast amounts of scientific information that exist about YELL, GRTE, and BICA's natural and cultural resources, appropriate to their level of technical sophistication. As technology advances and our ideas evolve, we fully expect changes in our reporting system, but currently the GYSLC is designed to be resource centric rather than institutionally driven. It is our belief that most users scientific information will find it easier to navigate when all of the information about a given resource are located together, rather than having to find each source of information within the institutional unit where it originated. The latter is still easily accessed via the project level of the web site.

Our information is organized hierarchically within two major levels, the resource level and the project level. The resource level reports on the condition of the resource, regardless of the source of information. This is the level that best synthesizes the available information regarding the status and trends of the resource. In contrast the project level reports the available information from a given project, whether it be monitoring, research, etc. Thus, I & M monitoring data will contribute to, and sometimes be the only source of information for the resource level. In addition, the results from the monitoring itself will be reported at the project level. Thus, someone looking for the most comprehensive information about status and trend of a resource would find it at the resource level, and someone looking for the specific results from a given project would find it at the project level.

### **Resource Level**

The home page for a given resource (Figure 5-1) will provide background information for that resource, as well as a series of products at the resource level. At this level a projects page will provide additional links to all of the projects related to that resource. The resource-level products for whitebark pine will include an: (1) overview, (2) almanac, (3) references and links, and (4) scientists, each of which are explained below:



## Analysis & Reporting

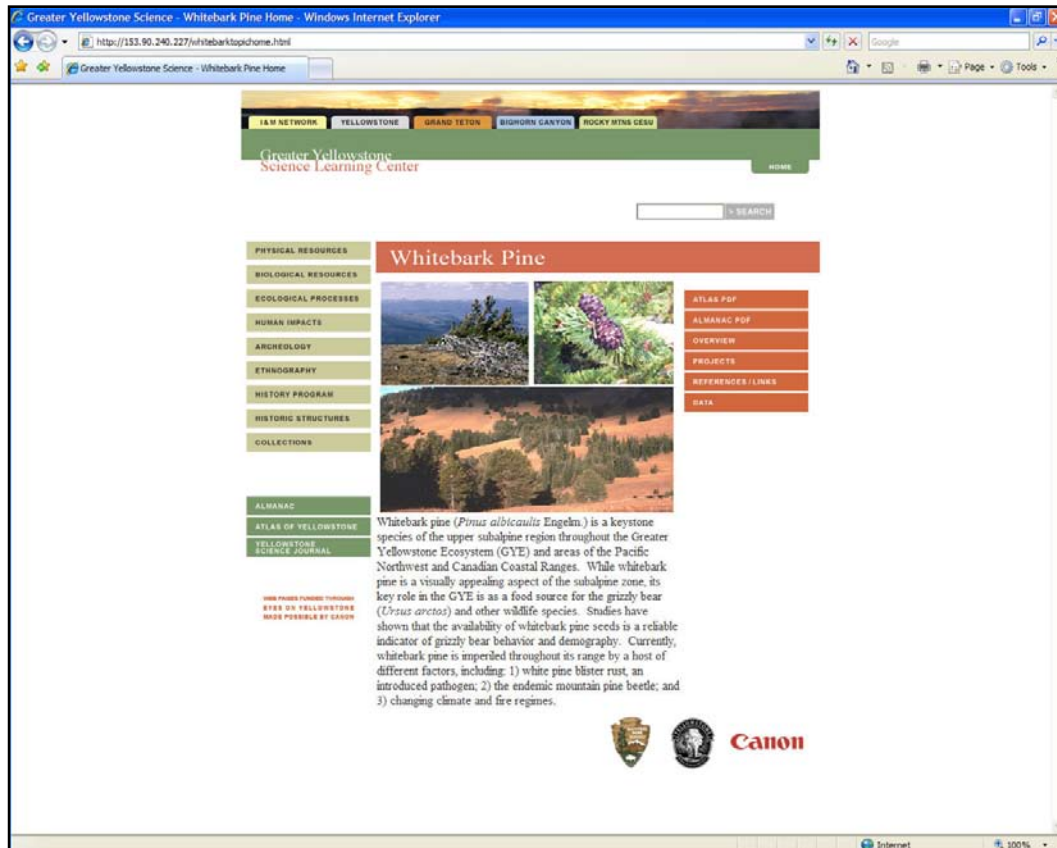


Figure 5-1. The home page for a given resource will provide access to a several products, including a link to the individual projects related to that resource.

### Overview

The Overview provides the background on a given resource. It is a description of the natural history and ecological function of the resource, as well as how it is managed and monitored, including relevant citations. The overview includes the following sections:

- *Overview. This covers basic taxonomic information and the species' scientific name, and explains how the species in Greater Yellowstone is similar to or different from species that are known by similar names elsewhere in the world.*
- *Distribution. This describes where the species is currently present in its entire native range and in Greater Yellowstone in particular. This section may also include information about the historic and prehistoric range of the species. This section should also include information about the population size or relative abundance of the species across its range and in Greater Yellowstone in particular.*



- *Physical description.* This describes how the individual species are visually identified and what physical characteristics distinguish them from other species.
- *Ecology.* This includes topics such as habitat (a description of what the species needs in its environment to survive and how it affects its environment; what it eats and what eats it) and life cycle (how the species reproduces, life stages, life span, what causes or contributes to its death). Other topics may be more specific to a particular species.
- *Status in the Greater Yellowstone Area.* If applicable, this includes an explanation of the species' legal status, i.e., whether the species has ever been or is now listed or being considered for listing as a threatened or endangered species, and what, if any, special protections apply. Regardless of the species' legal status, describe what, if any, threats exist to its presence as a viable population in Greater Yellowstone.
- *Management activities in YELL, GRTE or BICA).* This may include information on historical or past management policies and practices if they are significantly different from those currently in effect. In any case, some indication should be given as to how long the current management policies and practices have been in place.

### ***Almanac or Resource Brief***

The Almanac: or Resource Brief (the name is still being considered) is a one-page synopsis that explains the importance of the resource, its status and trends, and a discussion of the drivers and stressors (at least for species) contributing to the status and trends (Figure 5-2). Thus, the text consists of three parts:

- *Importance.* This is a one-paragraph explanation of why the resource matters. This could refer to its ecological role or historical significance specifically as it pertains to Greater Yellowstone.
- *Status and Trend.* This is a one-paragraph summary of the current population and how the resource has changed over a specified period of time.
- *Discussion.* This is a one-paragraph discussion of the key reason(s) for any changes that have occurred (e.g., the key drivers and stressors). If this is unknown or not applicable, describe the issues faced in managing this resource and recent progress or accomplishments.

The text should be accompanied by minimal relevant graphics: photos, maps, and/or graphs. For natural resource topics for which data are available, include graphs to show the most important trends over a relevant period of time. Such graphs may not be possible or the best use of space for all cultural resource topics.



## Analysis & Reporting

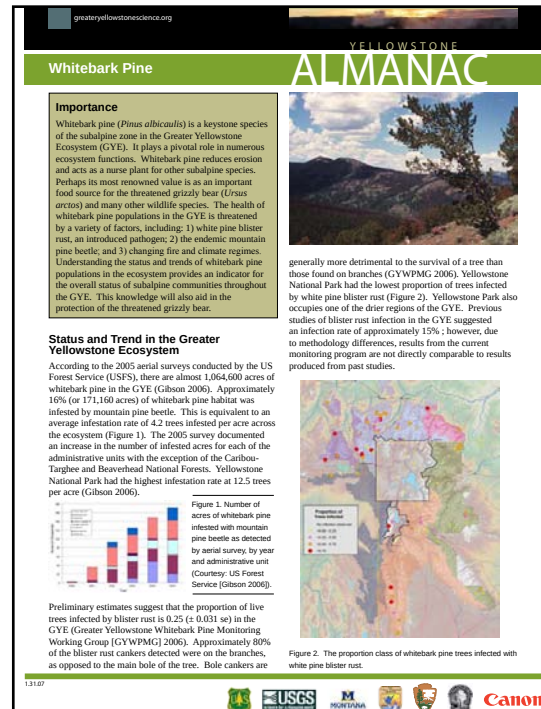


Figure 5-2. The Almanac: or Resource Brief (the name is still being considered) is a one-page resource brief that explains the importance of the resource, its status and trends, and a discussion of the drivers and stressors contributing to the status and trends.

### References and Links

This section would include PDFs or links to agency or other documents like the relevant Management EISs, monitoring plans, MOUs, briefing statements—any document that influences how we manage or partner on a resource. We would also include key references for that topic. Internet links to the agencies or groups most commonly associated with that topic would also be provided.

### Scientists

Here we envision linking to web pages and other information from the most important scientists working in the Greater Yellowstone Network on this topic.

### Projects

One navigation pathway from the resource home page is to the individual projects related to that resource, of which our monitoring programs are such projects. This would lead to an additional set of products and resources which are described within the project-level discussion below.



## Annual Report to the Superintendent

The annual report to the superintendent is a printable document that extracts the most relevant information for each resource from the individual almanacs into a single collection (Figure 5-3). This is preceded by an executive summary that further extracts the information highlights for that year. The resources are group into five classes that are relevant to their management implications: (1) Ecosystem Drivers, (2) Stressors, (3) Landscape-scale Indicators, (4) Rare and Sensitive Species, and (5) Species of Management Concern.

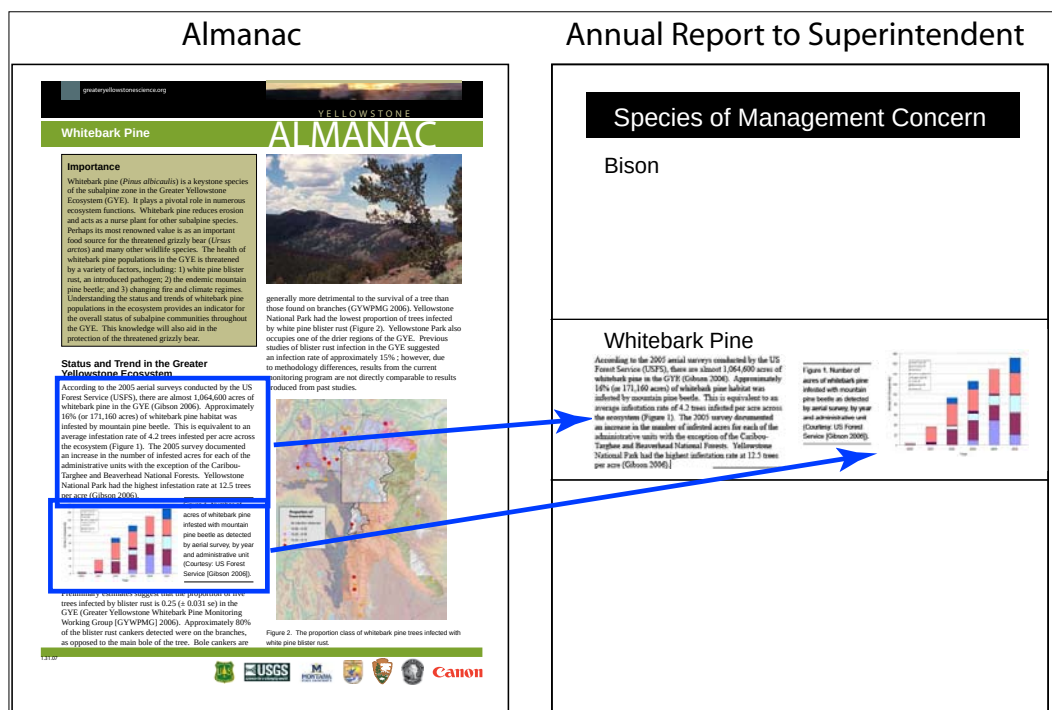


Figure 5-3. The annual report to the superintendent extracts the most relevant information from the individual resource almanacs into a single collection.

## Periodic Synthesis Report

From the outset, the I & M program, in partnership with the parks were expected to synthesize the vital signs (reportable resources) in some form that would help us to better understand the state of the parks. Although the Annual Report to the Superintendents provides an excellent means of reporting the status and trend of individual resources, it does not address the sum of the parts. Thus, there remains a need for some mechanism to merge the results of all efforts into a meaningful synthesis (Figure 5-4).



## Analysis & Reporting

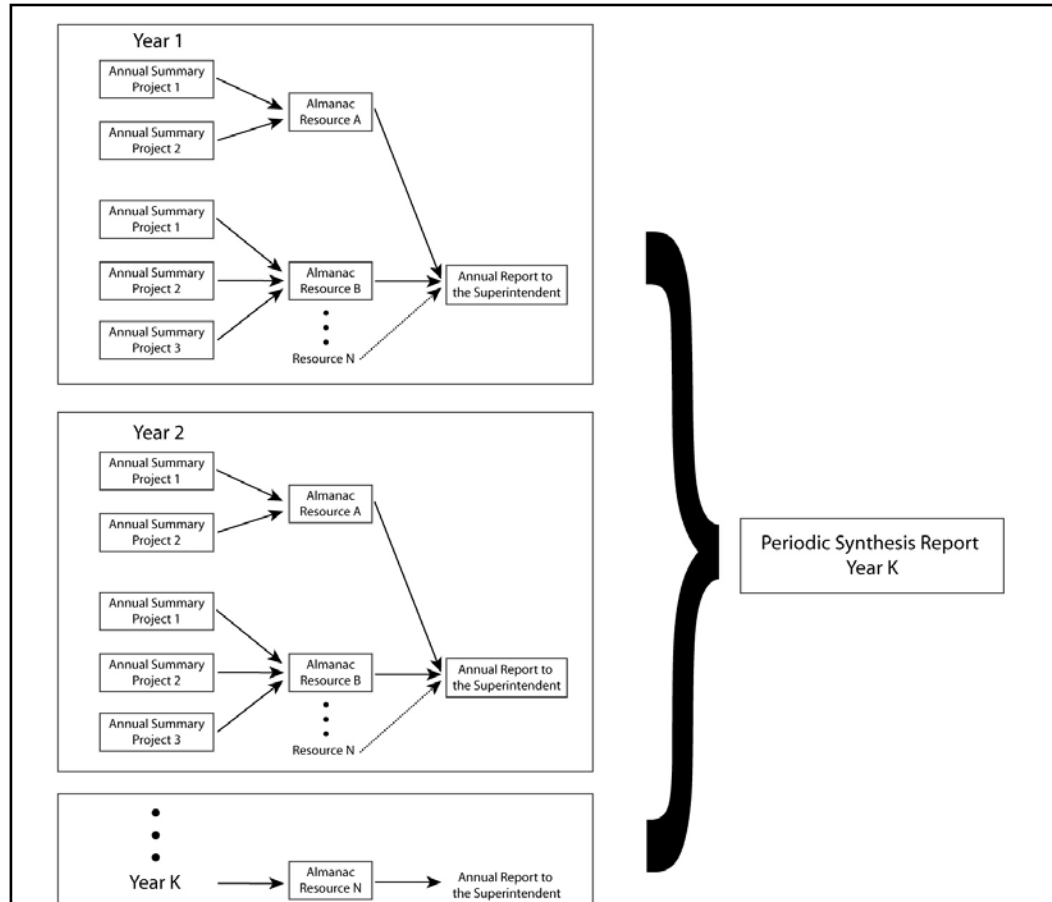


Figure 5-4. A periodic report will synthesize all of the data collected for the period, and will include estimates of any trends, estimates and effects of any covariates measured, include a regional context. The report will also include an assessment of any threats that have been hypothesized or observed, and how the vital sign influences or is influenced by other vital signs being monitored.

For this synthesis, we use the same grouping structure as the Report to the Superintendents. This would be a familiar structure, and would lend itself well to a synthesis. For each category, the synthesis would consider the following elements:

- The synthesis would be conducted every 5-10 years (the exact interval needs to be determined).
- The synthesis of each element should directly address the major concerns or considerations that contributed to why this vital sign was selected in the first place (i.e., its importance).
- The synthesis for each element is not restricted to the vital sign (reportable resource) itself; rather it includes additional relationships, associations, and interactions that are related to that vital sign (e.g., as an indicator, or as a



*stressor/driver or recipient of a stressor/driver).*

- *Although it is probably unrealistic to think that this synthesis would be a sufficient means of parameterizing complex ecosystem models, the synthesis report should draw upon and feed back to the conceptual models to the extent practical.*
- *The models presented in this synthesis should concentrate on a few of the most important components. More detailed models can be presented on other forms better suited to their appropriate audience.*
- *The syntheses should include important issues and concerns even if we have no data. This will facilitate understanding our information needs and should help direct future monitoring and research.*
- *Similarly, the syntheses report should constitute a time to take a step back and see what we have learned. This can simultaneously serve to facilitate a program review, and to allow us to look at where we want to go with a better understanding of where we have been.*
- *Like the Almanac, the syntheses report is not limited to I&M or park projects. Rather, it is a comprehensive assessment of what we have learned about the system. As such, it draws upon all of the resources that contribute to our understanding. This does not imply that all outside scientists need to write parts (although in some cases that may be warranted); rather, it implies that we synthesize all of the evidence.*



## Analysis & Reporting

### Project Level

The projects level entry page provides an initial portal to the individual projects related to the resource, in this case whitebark pine (Figure 5-5). From this page, one can navigate to any project associated with that resource.

The screenshot shows the 'Greater Yellowstone Science Learning Center' website. The main heading is 'Whitebark Pine'. Below this, there is a 'Project List' table. To the left of the table, there are two images: one of whitebark pine cones and another of a whitebark pine tree in a landscape.

| Project                                                | Status   | Project Type | Organization                        |
|--------------------------------------------------------|----------|--------------|-------------------------------------|
| Greater Yellowstone Whitebark Pine Monitoring          | Ongoing  | Monitoring   | Interagency Working Group           |
| Treeline dynamics in the Greater Yellowstone ecosystem | Complete | Thesis       | MSU / I&M Network                   |
| Whitebark Pine Cone Surveys                            | Ongoing  | Monitoring   | Interagency Grizzly Bear Study Team |
| Aerial Detection Surveys                               | Ongoing  | Detection    | USFS, Forest Health Monitoring      |
| Whitebark and Limber Pine Information system           | Ongoing  | Database     | USFS                                |

Figure 5-5. The project level entry page of the Greater Yellowstone Science Learning Center provides a list of the projects on a given topic, and serves as a portal to one or more project level pages.

### Project Summary

The project summary (Figure 5-6) is a two page synthesis of the current status and results of ongoing, planned, or completed projects. Thus, it serves as an intermediate between the resource-centric Almanac and the more detailed annual or synthesis project reports. It is intended to provide the reader with an up to date summary of a specific project and would generally include the following sections:



- Introduction and Background
- Methods
- Preliminary Results
- Discussion
- Project Contacts

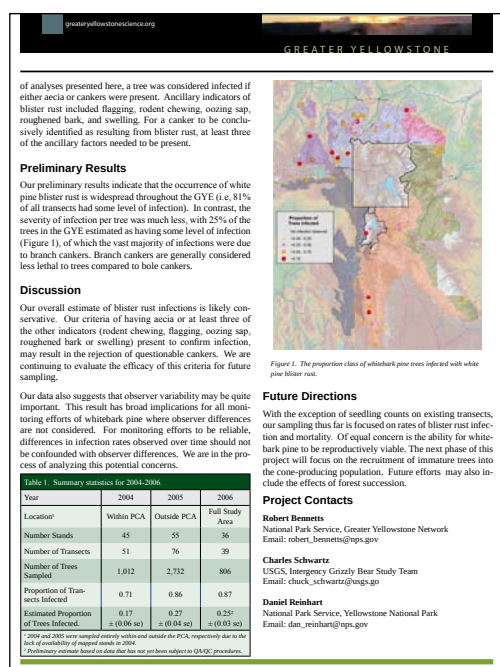


Figure 5-6. The project summary is a two page synthesis of the current status and results of ongoing, planned, or completed projects.

## Annual Project Reports

Annual project reports (Figure 5-7) will synthesize the accomplishments and results of a given year's effort for that project. The provide additional detail not included within the project summary, and contribute to the information that will be compiled in a periodic synthesis report. These annual reports will include at a minimum the following sections:

- **Introduction** - Explaining the purpose and background of the project.
- **Methods** - A brief synopsis of the methods with reference to the full monitoring protocol.
- **Results** – The results of the current year's efforts, including estimates of



# Analysis & Reporting

*blister rust infection.*

- **Discussion** – A short narrative describing the current years results in the context of previous years, observed trends or patterns, and implications to management.

GREATER YELLOWSTONE

## 2006 Annual Report

Greater Yellowstone Whitebark Pine  
Monitoring Working Group

## Monitoring Whitebark Pine in the Greater Yellowstone Ecosystem

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



Photo courtesy B.R. McCaffland

working together to ensure the viability and function of WbP throughout the region. As a result of this effort, an additional working group was formed for the purpose of integrating the common interests, goals and resources into one unified monitoring program for the Greater Yellowstone area. The Greater Yellowstone Whitebark Pine Monitoring Working Group consists of representatives from the U.S. Forest Service (USFS), National Park Service (NPS), U.S. Geological Survey (USGS), and Montana State University (MSU). This report is a summary of the data collected from the third field season of this long-term monitoring project.

**A Unified Effort**

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



Photo courtesy Lisa Lundblinger

**Background of the Program**

Forest monitoring has shown a rapid and precipitous decline of WbP in varying degrees throughout its range due to non-native white pine blister rust (Kendall and Keane 2001) and native mountain pine beetle (Gibson 2006). Given the ecological importance of WbP in the Greater Yellowstone Ecosystem (GYE) and that 98% of WbP occurs on public lands, the conservation of this species depends heavily on the collaboration of all public land management units in the GYE. Established in 1998, the Greater Yellowstone Whitebark Pine Committee, comprised of resource managers from eight federal land management units, has been

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Figure 5-7. Annual project reports will synthesize the accomplishments and results of a given year’s effort for that project.





# Chapter 6



## *Personnel Requirements & Training*

### Personnel Requirements

To complete the monitoring of whitebark pine, the following positions will be required: 1) project manager; 2) crew leader; 3) crew members. The roles, responsibilities and minimum qualifications for the positions are described in Table 6-1.

### Training

This section explains training required to: 1) positively identify white pine blister rust infection and/or signs of possible infection; 2) positively identify mountain pine beetle infestation; 3) take standard forest measurements helpful in monitoring whitebark pine and mark trees; and 4) identify plant species, including tree species of interest and those plants that will help to determine cover and habitat types.



### *Identification of white pine blister rust infection*

White pine blister rust infection can be identified in one of two ways: the observer may see sporulating cankers, which constitutes a positive identification, or the observer may identify other signs of possible infection. Signs of possible infection include: rodent chewing (including bark stripping); flagging (branches with dead needles); swelled cankers (cankers present, but no aecia); roughened bark (which may be identified with rubbed water); and/or oozing sap. Crew members should be able to identify these signs of infection on both short saplings and tall, large, adult trees through the use of binoculars. Because detection of infection is quite difficult on large trees, it is essential that the crews become extremely competent with canker identification and expert with the use of binoculars, moving around a tree to get clear views of potential infections. The following papers should be of great use to field crews:

*Hoff RJ. 1992. How to recognize blister rust infection on whitebark pine. USDA Forest Service, Intermountain Research Station, INT-406.*

*Hunt RS and Meagher MD. 1992. How to recognize white pine blister rust cankers. Forestry Canada, Pacific Forestry Centre.*



## Personnel Requirements & Training

**Table 6: Roles, responsibilities and minimum qualifications for each position.**

| Position        | Roles                                                                                                                                                                                                                                            | Responsibilities                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Minimum Qualifications                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Project Manager | -Serves as a liaison among project cooperators (cooperating agencies), other related projects (i.e., monitoring by other groups or in neighboring locales), and between other staff (crew leader and members) and the GRYN (and its cooperators) | <ul style="list-style-type: none"> <li>-To hire other staff members (crew leader and members)</li> <li>-To coordinate field schedules and availability of supplies with the crew leader</li> <li>-To participate in the creation of (and possibly lead) training for crew leader and members</li> <li>-To inform GRYN staff and cooperators of the progress of monitoring and any areas where adjustments may be needed</li> <li>-To act as a direct channel of communication between this project and others of this nature, thus building relationships and cooperation among this project and other similar projects</li> <li>-To be the party responsible for providing data from fieldwork to GRYN staff for analysis in a quality checked format, along with copies of all original data, and to be available for any questions pertaining to the data</li> </ul> | <ul style="list-style-type: none"> <li>-Excellence in identifying (and explaining the identification of) whitebark pine, white pine blister rust, mountain pine beetle, dwarf mistletoe parasitism, other tree and herbaceous species of interest to the project</li> <li>-Experience hiring personnel</li> <li>-Experience managing projects and communicating results in a clear and concise manner to all interested parties through a variety of media</li> <li>-Experience collecting and quality checking reliable data</li> <li>-Experience training crews and performing field work</li> </ul>                                                                                                                                                     |
| Crew Leader     | -Serves as the leader of the field crew members and is the primarily liaison between the project manager and the crew members                                                                                                                    | <ul style="list-style-type: none"> <li>-To participate in field training</li> <li>-To act as the primary coordinator with respect to field schedules and supplies</li> <li>-To serve as the party who is primarily responsible for the safety of crew members and to conduct safety training for crew members</li> <li>-To accompany crew members in the field until they demonstrate the ability to be self-sufficient</li> <li>-To act as a direct liaison between the project manager and the crew members</li> <li>-To enter and quality check all data before submitting for analysis</li> </ul>                                                                                                                                                                                                                                                                   | <ul style="list-style-type: none"> <li>-Experience performing field work</li> <li>-Experience training, leading and coordinating crews</li> <li>-Experience with data collection, entry and quality assurance</li> <li>-Experience communicating with a variety of audiences</li> <li>-Experience with teaching outdoor safety and route finding</li> <li>-Excellence in identifying (and explaining the identification of) whitebark pine, white pine blister rust, mountain pine beetle, dwarf mistletoe parasitism, other tree and herbaceous species of interest to the project</li> <li>-Experience using a GPS unit</li> <li>-Must be able to hike long distances to high elevation sites in difficult weather and carry a heavy backpack</li> </ul> |



**Table 6-1. Cont.**

| Position     | Roles                                                                                                         | Responsibilities                                                                                                                                                                                                                                                                                                                                                                                                | Minimum Qualifications                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|--------------|---------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Crew Members | -Serve as the back bone of the field operation by performing all field work related to the monitoring project | <ul style="list-style-type: none"> <li>-To participate in field training</li> <li>-To alert crew leader of any scheduling conflicts or needed supplies</li> <li>-To account for safety of yourself and others at all times</li> <li>-To be responsible for all loaned equipment and use it properly</li> <li>-To collect reliable, accurate data and submit it to the crew leader in a timely manner</li> </ul> | <ul style="list-style-type: none"> <li>-Capability to learn to identify tree and herbaceous species, white pine blister rust infection, mountain pine beetle infestations and dwarf mistletoe parasitism</li> <li>-Capability to learn backcountry safety and route finding</li> <li>-Capability to learn the use of a GPS unit and undergo training if necessary</li> <li>-Experience communicating and working with a variety of personalities in close settings under arduous conditions</li> <li>-Must be able to hike long distances to high elevation sites in difficult weather and carry a heavy backpack</li> <li>-Preferably have experience performing field work in forest measurements, have experience working with dichotomous keys and identifying species, and have extensive hiking/backpacking experience</li> </ul> |

## Taking Standard Forest Measurements and Marking Trees

Monitoring whitebark pine requires understanding how to measure the diameter at breast height (DBH) of trees. DBH should be practiced by all field crew members prior to starting the field season. It is important to attempt to measure all trees at approximately the same height from the ground. This can be accomplished by measuring out 1.4 m (4.5 ft) on each person to give them an idea of where DBH measurements should be taken, as this measurement will vary depending on each crew member's height. In addition, it is important to try to measure around the tree as straight as possible, as altering the diameter line will cause the measurement to be inaccurate. Diagram A explains how to measure trees under various circumstances (taken from Jenkins M. Great Smoky Mountains National Park: vegetation monitoring protocols. National Park Service—Great Smoky Mountains National Park. 40 pp.).

Marking trees is also an important aspect of establishing long-term plots for monitoring whitebark pine. Crew members should use small, round, numbered metal tags in sequential order from the beginning of the transect to the end. It is essential to use aluminum nails that are of the correct diameter (2 1/8 " long wood siding type) to allow the metal tags to hang to the end of the nail instead of being pressed against the bark of the tree. Hammering tags into the bark of the tree can result in the loss of tags due to the bark growing over the tag between site visits.



## Personnel Requirements & Training

### Identifying Plant Species, Cover Types and Habitat Types

Crew members should become familiar with using dichotomous keys during training. Additionally, identifying characteristics of the species should be clarified in the field and with pictures. Cover typing requires the ability to estimate relative abundance of different tree species and age classes, while habitat typing also requires identification of herbaceous vegetation within the plot. Crew members should be familiar with all possible habitat types—either by picture or through field visits—prior to the field season. Crew members should also be familiar with the scientific names for all commonly encountered plants and be confident of the tree species they will be identifying. Field crews should be comfortable with the identification of cover (according to Despain’s cover types) and habitat types (according to Steele’s cover types) using the (dichotomous-key based) identification sheets provided to them.

### Identifying Whitebark versus Limber Pine

The easiest, most obvious and accurate way to tell the difference between whitebark and limber pine is by their cones. If a tree is producing cones, they can be seen in the top canopy. Typically, old and occasionally cut, fresh cones can be found scattered on the forest floor close to the trunk. Whitebark cones are deep purple in color, squat, thick and sappy. They are extremely tight and more difficult to open when they are fresh. Due to the fact that they are highly sought after by wildlife, intact, fresh whitebark cones rarely remain in the canopy once they have matured. Often, the remains or skeleton of the outer shell of a cone can be seen in the canopy after birds have eaten the fleshy seeds from the inside. In contrast, limber pine cones are green in color and are significantly longer and thinner than whitebark. Because they are less sought after by wildlife, they tend to remain in the canopy, gradually turn brown, open their bracts and eventually fall to the ground. It is more typical to find limber pine cones on the forest floor at the base of the tree than whitebark cones.

If cones are not visible, there is a period of time (early spring through late July-mid August) that the young male and female “catkin-like” cones can be found on the terminal ends of the branches of both species. The young whitebark cones are all bright red to deep purple, whereas the limber pine young cones are generally green-yellow (note: the exception to this is that for a very short time in early spring, the male immature cones of limber pine can also appear red). Later in the season (mid August-September), the whitebark “catkin-like” bodies will begin to turn dark brown as they age. The limber pine “catkin-like” bodies begin to turn a more tan color as they age.

The elevation (is it above 7500 ft?) at and substrate (is the geology of a limestone nature?) on which a given tree is found can also provide clues to aid in the identification process, but neither should be used solely as identifiers.



Whitebark Pine Cones

Photo courtesy of Lisa Landenburger



Limber Pine Cones

Photo courtesy of Lisa Landenburger



Photo courtesy of Karla Sartor

Early season “catkin-like” cones of whitebark pine.

In a situation where a mixed stand is encountered, use cone identification as the main tool to identify between the two species. Next, look at the immature female/male cones on the end of the branches (Keep in mind the “note” mentioned above: If you encounter a tree that has just a few red “catkin” and green-yellow “catkins”, it is most likely limber pine. Make sure you survey the tree entirely before you draw any conclusions as to which species the tree belongs). If it is still unclear as to which species of conifers you are encountering on a transect and you cannot, with 100% confidence, verify which trees on the plot are whitebark, select an alternate plot from the list provided to sample. (It is fine to monument a mixed plot as long as you can clearly eliminate any limber pine from the sample and are completely confident that you have done so).







## Continual Improvement

Quality assurance extends beyond data management and must be an integral component of all aspects of the GRYN program. The USFS Forest Inventory and Analysis Program (FIA) identified three aspects of quality assurance (prevention, assessment and correction), which are referred to as the QA triangle (Figure 7-1). In the context of the overall GRYN program, prevention is addressed through sound development of sampling design, data management and analysis. Although prevention is extremely important, it is not sufficient by itself, due to changing programs, funding, environments, technologies, etc. Thus, this protocol includes the following section for assessment (i.e., the review process) and correction.

### Review Process

Reviews may be periodic (planned at a predefined interval) or episodic (resulting from changing mandates, funding, priorities, etc). The review process should permeate through all phases of our monitoring. It also should permeate through all of our thematic elements (i.e., applicability, reliability and feasibility), although it may not be the same review process for each element. Rather, the details of a given review should reflect which element(s) is being targeted. For example, a review intended to assess the scientific reliability is likely to be conducted by qualified scientists. In contrast, a scientific review panel may have little insight if a review is intended to assess whether or not the monitoring meets the needs of managers. Consequently, the review strategy should also clearly specify the purpose of the review and, at least in general terms, who should conduct the review.

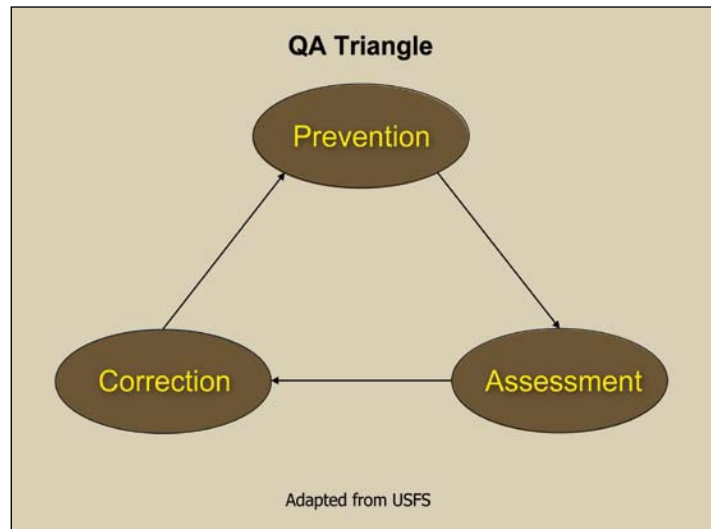


Figure 7-1. The quality assurance triangle. Adapted from the USFS.



## Continual Improvement

### 2008 Program Review

A special case of the general review process for each protocol is that an overall program review is planned for 2008. This review would explicitly examine the suite of protocols using criteria discussed below for whether or not the individual protocols are meeting park information needs and I&M standards for scientific defensibility. More importantly, all of our initial twelve protocols should be completed by this time, and this review would be an opportunity to examine whether we have the best compliment of vital signs and/or have made the best compromises during implementation between the expected costs and benefits.

### Process for Change

Determining the status and trends of selected indicators of the condition of park ecosystems is an essential and critical goal of the I&M Program. Understanding the spatial and temporal scales over which change occurs is paramount to achieving this goal. We have considered the spatial and temporal scale in several elements of this report, including sampling design and implementation. However, many ecosystem attributes of interest operate at such long time scales that implementing a temporal sampling design requires a long-term commitment that enables teasing apart true change from environmental noise (i.e., variation). Thus, one of the key values of the I&M program is its long-term prospect. Frequent changes in monitoring protocols in the attributes being monitored and how they are being monitored would likely lead to an ever-weakening ability to meet the program goals, leading to erosion of support, further weakening the program, etc. Thus, at the outset the GRYN needs to be vigilant about disruptive change in our monitoring, while at the same time recognizing that changing resources and management regimes may require some degree of flexibility. The difficulty lies in finding the right balance between maintaining the necessary consistency to meet our program goals with enough flexibility to meet the challenges of changing natural and political environments. Thus, when making changes in protocols, the following questions should be addressed:

1. *What are the criteria for determining whether or not a change is warranted?*  
*These should reflect the general themes identified above:*
  - *Reliability - The data are not reliable in their present form*
  - *Applicability- The data are not applicable to managers, the public, etc. in their present form*
  - *Feasibility- The data are not feasible to obtain in their present form (e.g., funding, logistics, priorities, etc).*
2. *If it is determined that a change is required, what programmatic element needs to be changed?*
  - *Objectives?*



- *Design?*
- *Field Methods?*
- *Data Management?*
- *Analysis?*
- *Reporting?*

*Note: Changing a vital sign or an objective is far more drastic than changing a reporting method. Thus the criteria for making changes to different elements may reflect their relative degree of severity.*

3. *What is the procedure for making the change?*
4. *What precautions will be taken to ensure that the revised protocol will be acceptable?*
  - *Pre-change reviews (based on planned changes)?*
  - *Post-change reviews (based on results from implemented changes)?*
  - *Testing concurrent with existing protocol?*
  - *Post-change analyses*
5. *How will the transition to the revised protocol be accomplished?*
  - *Will there be a period of overlap; if so, how?*







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# *Appendix 1*



## *Field Forms*

## Field Forms

## Field Forms

[illegible]



# *Appendix 2*



## *Data Dictionary*



## Data Dictionary

| Field Name (label) on hardcopy data collection form | Database Field Name                                | Field Caption | Field Description                                                                                                                                                | Valid Field Values                                                | Entry Required During Survey | Entry Required in Database | Database Quality Control Procedure | Database Design Notes                                    |
|-----------------------------------------------------|----------------------------------------------------|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|------------------------------|----------------------------|------------------------------------|----------------------------------------------------------|
| <b>Table: tbl_GYE_WBP_transects</b>                 |                                                    |               |                                                                                                                                                                  |                                                                   |                              |                            |                                    |                                                          |
| <b>Transect Location Attributes</b>                 |                                                    |               |                                                                                                                                                                  |                                                                   |                              |                            |                                    |                                                          |
| Polygon ID                                          | Stand_ID                                           | Stand         | User-generated identifier from timber stand selection process. One stand can contain multiple transects.                                                         | <positive integer value>                                          | required                     | required                   | Double data entry and cross check  |                                                          |
| Transect ID                                         | Transect_ID                                        | Trans         | User-generated identifier from transect selection and identification process                                                                                     | 1, 2, 3, 4, or 5                                                  | required                     | required                   |                                    |                                                          |
| Date                                                | Date                                               | Date          | Date of transect survey event                                                                                                                                    | <valid date>                                                      | required                     | required                   |                                    |                                                          |
| Observer                                            | <i>dropped this field from database after 2005</i> |               | Full Name of person identifying blister rust infection(s). To avoid confusion with tree-level observer names (initials), this field was discontinued after 2005. |                                                                   |                              |                            |                                    |                                                          |
| State                                               | State                                              | State         | 2 character abbreviation of the state in which the survey occurred                                                                                               | not applicable                                                    | not applicable               | not applicable             |                                    |                                                          |
| County                                              | County                                             | Co            | Name of county in which the survey occurred                                                                                                                      | MT, WY, ID                                                        | optional                     | required                   |                                    |                                                          |
| Ownership                                           | AdminOrg                                           | Own           | Abbreviated name of administering organization (i.e. 'USFS', 'NPS', etc)                                                                                         | From lookup table: 'tbl_GYE_WBP_County_Names'                     | optional                     | required                   |                                    |                                                          |
| Forest/Park                                         | AdminName                                          | Admin         | Name of administering unit (e.g. <National Forest name> or <National Park name>)                                                                                 | USFS, NPS, Other (specify)                                        | optional                     | required                   |                                    |                                                          |
| District                                            | AdminDist                                          | Dist          | Name of USFS District or NPS Subdistrict                                                                                                                         | From lookup table: 'tbl_GYE_WBP_Administrative_Unit_Names'        | optional                     | required                   |                                    |                                                          |
| Contact name                                        | AdminPOC                                           | Contact       | Name of person serving as point of contact (POC) for the project activities occurring on the admin unit.                                                         | From lookup table: 'tbl_GYE_WBP_Administrative_District_Names'    | optional                     | required                   |                                    |                                                          |
| Contact phone                                       | <i>field not in database as of 12/2005</i>         |               |                                                                                                                                                                  | From lookup table: 'tbl_GYE_WBP_Administrative_Points_of_Contact' | optional                     | required                   |                                    |                                                          |
| Location Description                                | LocDesor                                           | Loc           | Phone number of individual agency contact                                                                                                                        | [Should be able to list all contact numbers]                      | optional                     | required                   |                                    |                                                          |
| Topo Map ID                                         | TopoMapName                                        | Topo          | Narrative description of transect location                                                                                                                       | From a range of alphanumeric characters                           | required                     | required                   |                                    | Create a lookup table containing official quad map names |
| <b>Transect Layout Attributes</b>                   |                                                    |               |                                                                                                                                                                  |                                                                   |                              |                            |                                    |                                                          |
| Transect Begin UTM Easting (NAD83)                  | BegUTME_12_83                                      | B_UTME        | Eastings Coordinate at beginning point of transect. UTM zone 12, NAD83                                                                                           | Between 310000 - 690000                                           | required                     | required                   |                                    |                                                          |
| Transect Begin UTM Northing (NAD83)                 | BegUTMN_12_83                                      | B_UTMN        | Northing Coordinate at beginning point of transect. UTM zone 12, NAD83                                                                                           | Between 4860000 - 5128000                                         | required                     | required                   |                                    |                                                          |



| Field Name (label) on hardcopy data collection form | Database Field Name | Database Field Caption | Field Description                                                                                                                                                                                                                                                                                                     | Valid Field Values                                    | Entry Required During Field Survey | Entry Required in Database | Database Quality Control Procedure | Database Design Notes                                                                                                             |
|-----------------------------------------------------|---------------------|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|------------------------------------|----------------------------|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| Transect Begin Location Error                       | BegErrMeters        | B_err                  | Estimated transect beginning point position error in meters - normally recorded from recreation-grade GPS. If possible less than <??> meters. Narrative of pertinent information about the position of the point at the beginning of the transect.                                                                    | <positive integer value> less than <??> when possible | required                           | required                   |                                    | Determine maximum acceptable value, or specify requirement to minimize estimated error value prior to recording coordinate values |
| while space below Transect Begin                    | BegComment          | B_comm                 |                                                                                                                                                                                                                                                                                                                       | From a range of alphanumeric characters               | optional                           | optional                   |                                    |                                                                                                                                   |
| Transect Random Point UTM Easting (NAD83)           | CHUTME_12_83        | C_UTMe                 | Easting Coordinate at center point of transect, UTM zone 12, NAD83. For 2006 this value was recorded in the field using recreation-grade GPS. Transect center coordinates were not recorded in 2004 (field value = 0)                                                                                                 | Between 310000 - 690000                               | required                           | required                   |                                    |                                                                                                                                   |
| Transect Random Point UTM Northing (NAD83)          | CHUTMN_12_83        | C_UTMn                 | Northing Coordinate at center point of transect, UTM zone 12, NAD83. For 2006 this value was recorded in the field using recreation-grade GPS. Transect center coordinates were not recorded in 2004 (field value = 0)                                                                                                | Between 4860000 - 5126000                             | required                           | required                   |                                    | Determine maximum acceptable value, or specify requirement to minimize estimated error value prior to recording coordinate values |
| Transect Random Point Location Error                | ChErrMeters         | C_err                  | Estimated transect center point position error in meters - normally recorded from recreation-grade GPS. If possible less than <??> meters. coordinate value generated in the office using GIS, UTM zone 12, NAD83, as the initial easting coordinate of the target point location for crews to establish the transect | <positive integer value> less than <??> when possible | required                           | required                   |                                    |                                                                                                                                   |
| Transect Random Point UTM Easting (NAD83)           | RdmUTME_12_83       | R_UTMe                 | coordinate value generated in the office using GIS, UTM zone 12, NAD83, as the initial northing coordinate of the target point location for crews to establish the transect                                                                                                                                           | Between 310000 - 690000                               | required                           | required                   |                                    |                                                                                                                                   |
| Transect Random Point UTM Northing (NAD83)          | RdmUTMN_12_83       | R_UTMn                 | Easting Coordinate at end point of transect, UTM zone 12, NAD83                                                                                                                                                                                                                                                       | Between 4860000 - 5126000                             | required                           | required                   |                                    |                                                                                                                                   |
| Transect End UTM Easting (NAD83)                    | EndUTME_12_83       | E_UTMe                 | Northing Coordinate at end point of transect, UTM zone 12, NAD83                                                                                                                                                                                                                                                      | Between 310000 - 690000                               | required                           | required                   |                                    |                                                                                                                                   |
| Transect End UTM Northing (NAD83)                   | EndUTMN_12_83       | E_UTMn                 |                                                                                                                                                                                                                                                                                                                       | Between 4860000 - 5126000                             | required                           | required                   |                                    | Determine maximum acceptable value, or specify requirement to minimize estimated error value prior to recording coordinate values |
| Transect End Location Error                         | EndErrMeters        | E_err                  | Estimated transect end point position error in meters - normally recorded from recreation-grade GPS. If possible less than <??> meters.                                                                                                                                                                               | <positive integer value> less than <??> when possible | required                           | required                   |                                    |                                                                                                                                   |



## Data Dictionary

| Field Name (label) on hardcopy data collection form | Database Field Name | Database Field Caption | Field Description                                                                                                                                                           | Valid Field Values                              | Entry Required During Survey | Entry Required in Database | Database Quality Control Procedure | Database Design Notes                                        |
|-----------------------------------------------------|---------------------|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|------------------------------|----------------------------|------------------------------------|--------------------------------------------------------------|
| white space below Transect End                      | EndComment          | E_comm                 | Narrative of pertinent information about the position of the point at the end of the transect                                                                               | From a range of alphanumeric characters         | optional                     | optional                   |                                    |                                                              |
| <b>Transect General Attributes</b>                  |                     |                        |                                                                                                                                                                             |                                                 |                              |                            |                                    |                                                              |
| Habitat Type                                        | HabitatType         | Hab                    | Climax community habitat type from Steele et al. guide.                                                                                                                     | [to be developed]                               | required                     | required                   |                                    | Create a lookup table containing official habitat type codes |
| Cover Type                                          | CoverType           | CovT                   | Cover type from Despain descriptive guide, arboreal community type.                                                                                                         | [to be developed]                               | required                     | required                   |                                    | Create a lookup table containing official cover type codes   |
| Blister Rust Present Tally                          | not applicable      | not applicable         | Tally is not stored in database. It is on the field data collection sheet to help keep track of count for which total is entered in field 'BRPresTotal'                     | not applicable                                  | required                     | not applicable             |                                    |                                                              |
| Blister Rust Present Total                          | BRPht140cmTotal     | BRP14                  | The total plot-wide count of whitebark pine trees less than 1.4 meters in height in which white pine blister rust infection is observed.                                    | Within a range of zero to all positive integers | required                     | required                   |                                    |                                                              |
| Blister Rust Absent Tally                           | not applicable      | not applicable         | Tally is not stored in database. It is on the field data collection sheet to help keep track of count for which total is entered in field 'BRABstTotal'                     | not applicable                                  | required                     | not applicable             |                                    |                                                              |
| Blister Rust Absent Total                           | BRABst140cmTotal    | BRAB14                 | The total plot-wide count of whitebark pine trees less than 1.4 meters in height in which white pine blister rust infection is not observed                                 | Within a range of zero to all positive integers | required                     | required                   |                                    |                                                              |
| Blister Rust Uncertain Tally                        | not applicable      | not applicable         | Tally is not stored in database. It is on the field data collection sheet to help keep track of count for which total is entered in field 'BRUncTotal'                      | not applicable                                  | required                     | not applicable             |                                    |                                                              |
| Blister Rust Uncertain Total                        | BRUht140cmTotal     | BRU14                  | The total plot-wide count of whitebark pine trees less than 1.4 meters in height in which the observer is uncertain about the presence of white pine blister rust infection | Within a range of zero to all positive integers | required                     | required                   |                                    |                                                              |
| Squirrel Middens Undisturbed Tally                  | not applicable      | not applicable         | Tally is not stored in database. It is on the field data collection sheet to help keep track of count for which total is entered in field 'SMU_ Total'                      | not applicable                                  | required                     | not applicable             |                                    |                                                              |
| Squirrel Middens Undisturbed Total                  | SMU_ Total          | SMU                    | The total plot-wide count of undisturbed squirrel middens observed                                                                                                          | Within a range of zero to all positive integers | required                     | not applicable             |                                    |                                                              |
| Squirrel Middens Excavated Tally                    | not applicable      | not applicable         | Tally is not stored in database. It is on the field data collection sheet to help keep track of count for which total is entered in field 'SME_ Total'                      | not applicable                                  | required                     | not applicable             |                                    |                                                              |
| Squirrel Middens Excavated Total                    | SME_ Total          | SME                    | The total plot-wide count of excavated squirrel middens observed                                                                                                            | Within a range of zero to all positive integers | required                     | not applicable             |                                    |                                                              |



| Field Name (label) on hardcopy data collection form | Database Field Name | Database Field Caption | Field Description                                                                                                                                                                                                                               | Valid Field Values       | Entry Required During Field Survey | Entry Required in Database | Database Quality Control Procedure | Database Design Notes |
|-----------------------------------------------------|---------------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------------------------------------|----------------------------|------------------------------------|-----------------------|
| Branch Cankers - Upper Third - Indicators           | UBrC_I              | UBrC_I                 | For 2005 this is the count of blister rust cankers observed on branches in the top one third of the tree that do not have aecia present, but were determined via secondary indicators. For 2004 the value is blank - not collected/recorded.    | <positive integer value> | required                           | required                   |                                    |                       |
| <not on data collection form>                       | UBrC_Total          | UBrC_T                 | For 2005 this value is the sum of values in fields 'UBrC_A' and 'UBrC_I'. For 2004 this value is from 2004 data field 'UpperBranchCankers'                                                                                                      | <positive integer value> | not applicable                     | required                   |                                    |                       |
| Branch Cankers - Middle Third - Aecia               | MBrC_A              | MBrC_A                 | For 2005 this is the count of blister rust cankers observed on branches in the middle one third of the tree that have aecia present. For 2004 the value is blank - not collected/recorded.                                                      | <positive integer value> | required                           | required                   |                                    |                       |
| Branch Cankers - Middle Third - Indicators          | MBrC_I              | MBrC_I                 | For 2005 this is the count of blister rust cankers observed on branches in the middle one third of the tree that do not have aecia present, but were determined via secondary indicators. For 2004 the value is blank - not collected/recorded. | <positive integer value> | required                           | required                   |                                    |                       |
| <not on data collection form>                       | MBrC_Total          | MBrC_T                 | For 2005 this value is the sum of values in fields 'MBrC_A' and 'MBrC_I'. For 2004 this value is from 2004 data field 'MiddleBranchCankers'                                                                                                     | <positive integer value> | not applicable                     | required                   |                                    |                       |
| Branch Cankers - Bottom Third - Aecia               | BBrC_A              | BBrC_A                 | For 2005 this is the count of blister rust cankers observed on branches in the bottom one third of the tree that have aecia present. For 2004 the value is blank - not collected/recorded.                                                      | <positive integer value> | required                           | required                   |                                    |                       |
| Branch Cankers - Bottom Third - Indicators          | BBrC_I              | BBrC_I                 | For 2005 this is the count of blister rust cankers observed on branches in the bottom one third of the tree that do not have aecia present, but were determined via secondary indicators. For 2004 the value is blank - not collected/recorded. | <positive integer value> | required                           | required                   |                                    |                       |
| <not on data collection form>                       | BBrC_Total          | BBrC_T                 | For 2005 this value is the sum of values in fields 'BBrC_A' and 'BBrC_I'. For 2004 this value is from 2004 data field 'BottomBranchCankers'                                                                                                     | <positive integer value> | not applicable                     | required                   |                                    |                       |
| Bole Cankers - Upper Third - Aecia                  | UBoC_A              | UBoC_A                 | For 2005 this is the count of blister rust cankers observed on the bole of the tree in the top one third of the tree that have aecia present. For 2004 the value is blank - not collected/recorded.                                             | <positive integer value> | required                           | required                   |                                    |                       |



# Data Dictionary

| Field Name (label) on hardcopy data collection form | Database Field Name           | Database Field Caption | Field Description                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Valid Field Values                                                                                                                                                                                     | Entry Required During Survey | Entry Required in Database | Database Quality Control Procedure | Database Design Notes |
|-----------------------------------------------------|-------------------------------|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|----------------------------|------------------------------------|-----------------------|
| <not on data collection form>                       | PrimaryObserver               | PriObs                 | This is a post-hoc assignment made by the project leader to facilitate statistical analysis for multi-observer transects.<br>For multi-observer transects, if PrimaryObserver = 1, then the person indicated in field 'Observer' is treated as the primary observer. If PrimaryObserver = 0, then the person(s) indicated in field 'Observer' are treated as secondary/tertiary/etc. observers.<br>For single observer transects PrimaryObserver is assigned a value of '1'. | 1 = the primary observer for multi-observer transects<br>0 = other than primary observer for multi-observer transects                                                                                  |                              |                            |                                    |                       |
| Clump Number                                        | ClumpNumber                   | ClumN                  | Sequential number for clumps within a transect. The same number is assigned to each member of the same clump—these include live and dead trees. Each clump as a whole receives a different number.                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                        |                              |                            |                                    |                       |
| Clump Letter                                        | ClumpLetter                   | ClumL                  | Sequential letter assigned to each individual stem (tree) within a given clump.                                                                                                                                                                                                                                                                                                                                                                                              | <positive integer value>                                                                                                                                                                               | required if applicable       | required                   |                                    |                       |
| DBH(cm)                                             | DBH_cm                        | DBHcm                  | Tree diameter in centimeters measured at breast height. Blank spaces denote multi-observer trees for which DBH was not re-recorded following the first observer.                                                                                                                                                                                                                                                                                                             | <single alphabetic character>                                                                                                                                                                          | required                     | required                   |                                    |                       |
| Height Class                                        | HeightClass                   | HGT                    | Tree height class code. A blank space denotes multi-observer trees for which height class was not re-recorded following the first observer.                                                                                                                                                                                                                                                                                                                                  | Within a range of positive numeric values to include one decimal place, normally between (Specify a reasonable lower and upper limit)<br>code 1 = (1.4>=5 m)<br>code 2 = (5>=10 m)<br>code 3 = (>10 m) | required                     | required                   |                                    |                       |
| Tree Status                                         | TreeStatus                    | Status                 | tree health status code                                                                                                                                                                                                                                                                                                                                                                                                                                                      | L: Live (green needles present)<br>RD: Recently Dead (non-green needles present)<br>D: Dead (needles absent)                                                                                           | required                     | required                   |                                    |                       |
| Crown Ratio (%)                                     | dropped this field after 2005 | not applicable         | estimate of the portion of the tree bole supporting live, healthy foliage. Expressed as a percent of the actual tree height                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                        | required                     | required                   |                                    |                       |
| Health Index (2004 only)                            | HealthIndexOld                | HI_Old                 | Experimental attribute. Not on 2005 Data Collection form. Retained in database for 2004 data.                                                                                                                                                                                                                                                                                                                                                                                | 0 - 100<br>n=no infection, 1=, m=, s=, name were not applying this at the time of the data collection or it is a dead tree                                                                             | required                     | required                   |                                    |                       |
| Branch Cankers - Upper Third - Ascia                | UBrC_A                        | UBrC_A                 | For 2005 this is the count of blister rust cankers observed on branches in the top one third of the tree that have ascia present. For 2004 the value is blank - not collected/recorded.                                                                                                                                                                                                                                                                                      | <positive integer value>                                                                                                                                                                               | required                     | required                   |                                    |                       |



| Field Name (label) on hardcopy data collection form | Database Field Name | Database Field Caption | Field Description                                                                                                                                                                                                                               | Valid Field Values       | Entry Required During Field Survey | Entry Required in Database | Database Quality Control Procedure | Database Design Notes |
|-----------------------------------------------------|---------------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------------------------------------|----------------------------|------------------------------------|-----------------------|
| Branch Cankers - Upper Third - Indicators           | UBrC_I              | UBrC_I                 | For 2005 this is the count of blister rust cankers observed on branches in the top one third of the tree that do not have aecia present, but were determined via secondary indicators. For 2004 the value is blank - not collected/recorded.    | <positive integer value> | required                           | required                   |                                    |                       |
| <not on data collection form>                       | UBrC_Total          | UBrC_T                 | For 2005 this value is the sum of values in fields 'UBrC_A' and 'UBrC_I'. For 2004 this value is from 2004 data field 'UpperBranchCankers'                                                                                                      | <positive integer value> | not applicable                     | required                   |                                    |                       |
| Branch Cankers - Middle Third - Aecia               | MBrC_A              | MBrC_A                 | For 2005 this is the count of blister rust cankers observed on branches in the middle one third of the tree that have aecia present. For 2004 the value is blank - not collected/recorded.                                                      | <positive integer value> | required                           | required                   |                                    |                       |
| Branch Cankers - Middle Third - Indicators          | MBrC_I              | MBrC_I                 | For 2005 this is the count of blister rust cankers observed on branches in the middle one third of the tree that do not have aecia present, but were determined via secondary indicators. For 2004 the value is blank - not collected/recorded. | <positive integer value> | required                           | required                   |                                    |                       |
| <not on data collection form>                       | MBrC_Total          | MBrC_T                 | For 2005 this value is the sum of values in fields 'MBrC_A' and 'MBrC_I'. For 2004 this value is from 2004 data field 'MiddleBranchCankers'                                                                                                     | <positive integer value> | not applicable                     | required                   |                                    |                       |
| Branch Cankers - Bottom Third - Aecia               | BBrC_A              | BBrC_A                 | For 2005 this is the count of blister rust cankers observed on branches in the bottom one third of the tree that have aecia present. For 2004 the value is blank - not collected/recorded.                                                      | <positive integer value> | required                           | required                   |                                    |                       |
| Branch Cankers - Bottom Third - Indicators          | BBrC_I              | BBrC_I                 | For 2005 this is the count of blister rust cankers observed on branches in the bottom one third of the tree that do not have aecia present, but were determined via secondary indicators. For 2004 the value is blank - not collected/recorded. | <positive integer value> | required                           | required                   |                                    |                       |
| <not on data collection form>                       | BBrC_Total          | BBrC_T                 | For 2005 this value is the sum of values in fields 'BBrC_A' and 'BBrC_I'. For 2004 this value is from 2004 data field 'BottomBranchCankers'                                                                                                     | <positive integer value> | not applicable                     | required                   |                                    |                       |
| Bole Cankers - Upper Third - Aecia                  | UBoC_A              | UBoC_A                 | For 2005 this is the count of blister rust cankers observed on the bole of the tree in the top one third of the tree that have aecia present. For 2004 the value is blank - not collected/recorded.                                             | <positive integer value> | required                           | required                   |                                    |                       |



# Data Dictionary

| Field Name (label) on hardcopy data collection form | Database Field Name | Database Field Caption | Field Description                                                                                                                                                                                                                                           | Valid Field Values       | Entry Required During Survey | Entry Required in Database | Database Quality Control Procedure | Database Design Notes |
|-----------------------------------------------------|---------------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------------------------------|----------------------------|------------------------------------|-----------------------|
| Bole Cankers - Upper Third - Indicators             | UBoleC_I            | UBoC_I                 | For 2005 this is the count of blister rust cankers observed on the bole of the tree in the top one third of the tree that do not have aecia present, but were determined via secondary indicators. For 2004 the value is blank - not collected/recorded.    | <positive integer value> | required                     | required                   |                                    |                       |
| <not on data collection form>                       | UBoleC_Total        | UBoC_T                 | For 2005 this value is the sum of values in fields 'UBoleC_A' and 'UBoleC_I' For 2004 this value is from 2004 data field 'UpperBoleCankers'                                                                                                                 | <positive integer value> | not applicable               | required                   |                                    |                       |
| Bole Cankers - Middle Third - Aecia                 | MBoleC_A            | MBoC_A                 | For 2005 this is the count of blister rust cankers observed on the bole of the tree in the middle one third of the tree that have aecia present. For 2004 the value is blank - not collected/recorded.                                                      | <positive integer value> | required                     | required                   |                                    |                       |
| Bole Cankers - Middle Third - Indicators            | MBoleC_I            | MBoC_I                 | For 2005 this is the count of blister rust cankers observed on the bole of the tree in the middle one third of the tree that do not have aecia present, but were determined via secondary indicators. For 2004 the value is blank - not collected/recorded. | <positive integer value> | required                     | required                   |                                    |                       |
| <not on data collection form>                       | MBoleC_Total        | MBoC_T                 | For 2005 this value is the sum of values in fields 'MBoleC_A' and 'MBoleC_I' For 2004 this value is from 2004 data field 'MiddleBoleCankers'                                                                                                                | <positive integer value> | not applicable               | required                   |                                    |                       |
| Bole Cankers - Bottom Third - Aecia                 | BBoleC_A            | BBoC_A                 | For 2005 this is the count of blister rust cankers observed on the bole of the tree in the bottom one third of the tree that have aecia present. For 2004 the value is blank - not collected/recorded.                                                      | <positive integer value> | required                     | required                   |                                    |                       |
| Bole Cankers - Bottom Third - Indicators            | BBoleC_I            | BBoC_I                 | For 2005 this is the count of blister rust cankers observed on the bole of the tree in the bottom one third of the tree that do not have aecia present, but were determined via secondary indicators. For 2004 the value is blank - not collected/recorded. | <positive integer value> | required                     | required                   |                                    |                       |
| <not on data collection form>                       | BBoleC_Total        | BBoC_T                 | For 2005 this value is the sum of values in fields 'BBoleC_A' and 'BBoleC_I' For 2004 this value is from 2004 data field 'BottomBoleCankers'                                                                                                                | <positive integer value> | not applicable               | required                   |                                    |                       |



| Field Name (label) on hardcopy data collection form | Database Field Name                 | Database Field Caption | Field Description                                                                                                                                                                                                                                                                                                                                                                                                                       | Valid Field Values       | Entry Required During Survey | Entry Required in Database | Database Quality Control Procedure | Database Design Notes |
|-----------------------------------------------------|-------------------------------------|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------------------------------|----------------------------|------------------------------------|-----------------------|
| <not on data collection form>                       | AeciaPresent                        | Aec_P                  | Run query 'qry_upd_AeciaPresent' to update values in this field.<br>1=aecia present; 0=aecia not present. For 2005 this value is generated by an update query based on the contents of tree branch and tree bole 'aecia' fields. For 2004, the value is from field 'AeciaPresent'.                                                                                                                                                      | 0 or 1                   | not applicable               | required                   |                                    |                       |
| <not on data collection form>                       | InfectionPresent                    | Inf_P                  | Run query 'qry_upd_InfectionPresent' to update values in this field AFTER values in field 'AeciaPresent' are updated.<br>1=white pine blister rust present in tree based on observed presence of aecia AND/OR observed presence of at least three of the five other indicators of infection (rodent chewing, flagging, swelling, roughened bark, oozing sap).<br>0=infection or sufficient indicators of infection not observed on tree | 0 or 1                   | not applicable               | required                   |                                    |                       |
| Rodent Chewing                                      | RodentChewing                       | RodCh                  | The observed count of separate chewed areas observed on the entire tree. -999=not on data sheet at the time these plots were visited                                                                                                                                                                                                                                                                                                    | <positive integer value> | required                     | required                   |                                    |                       |
| Flagging                                            | Flagging                            | Flag                   | The observed count of separate flagging areas observed on the entire tree. -999=not on data sheet at the time these plots were visited                                                                                                                                                                                                                                                                                                  | <positive integer value> | required                     | required                   |                                    |                       |
| Swelling                                            | Swelling                            | Swell                  | The observed count of separate swelling areas observed on the entire tree. -999=not on data sheet at the time these plots were visited                                                                                                                                                                                                                                                                                                  | <positive integer value> | required                     | required                   |                                    |                       |
| Roughened Bark                                      | RoughBark                           | RoughB                 | The observed count of separate roughened bark areas observed on the entire tree. -999=not on data sheet at the time these plots were visited                                                                                                                                                                                                                                                                                            | <positive integer value> | required                     | required                   |                                    |                       |
| Oozing Sap                                          | OozingSap                           | OozS                   | The observed count of separate oozing sap areas observed on the entire tree. -999=not on data sheet at the time these plots were visited                                                                                                                                                                                                                                                                                                | <positive integer value> | required                     | required                   |                                    |                       |
| Live Canopy Volume (%) - Upper Third                | UpdLiveCroyVol                      | ULCV                   | The percent of canopy in the upper one third of the foliage that is alive.                                                                                                                                                                                                                                                                                                                                                              | 0 - 100                  | required                     | required                   |                                    |                       |
| Live Canopy Volume (%) - Middle Third               | field not in database as of 12/2005 | not applicable         |                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0 - 100                  | required                     | required                   |                                    |                       |
| Live Canopy Volume (%) - Bottom Third               | field not in database as of 12/2005 | not applicable         |                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0 - 100                  | required                     | required                   |                                    |                       |



# Data Dictionary

| Field Name (label) on hardcopy data collection form | Database Field Name | Database Field Caption | Field Description                                                                                                                                                | Valid Field Values                      | Entry Required During Field Survey | Entry Required in Database | Database Quality Control Procedure | Database Design Notes |
|-----------------------------------------------------|---------------------|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|------------------------------------|----------------------------|------------------------------------|-----------------------|
| Mountain Pine Beetle                                | MtnPineBeetle       | MPB                    | y=observed presence of Mountain Pine Beetle on tree, n=absence of Mountain Pine Beetle not observed on tree                                                      | 'y' or 'n'                              | required                           | required                   |                                    |                       |
| Comments                                            | TreesHlthComment    | Health                 | popular health of tree f=flagging, dt=dead top, db=dead branches, ns=needle shed, us=understory, md=mischemical damage of some sort, ad=animal damage ie elk rub |                                         |                                    |                            |                                    |                       |
| Not on 2004 or 2005 field data collection sheet     | DataCollMethod      | Method                 | Data Collection Method - title, version, and date of protocol by which data were collected                                                                       | From a range of alphanumeric characters | not applicable                     | required                   |                                    |                       |

