



Protocol Implementation Plan for Monitoring White Pine in Great Basin National Park

Standard Operating Procedures, version 1.0

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Contents

	Page
Figures.....	v
Tables.....	vi
Appendices.....	viii
Background.....	1
Standard Operating Procedure (SOP) 1: Preparation for the Field Season.....	2
Annual Review	2
Hiring Qualified Field Technicians.....	2
Arranging Overnight Facilities and Research Permits	3
Review the List of Spatially-Balanced Sampling Locations	3
Scheduling and Organizing Field Work	5
Equipment Preparation	6
Measuring Equipment	6
Plot Marking and Tree Tagging Equipment.....	6
Navigation and Recording Equipment	7
Communication and Safety	7
Miscellaneous Field Equipment	7
Preparation of Navigation and Field Data Management Equipment:.....	7
Preparation for Backcountry Travel	8
Miscellaneous Preparatory Notes:.....	8
Preparation of Navigation and Field Data Management Equipment.....	8
Season Closeout.....	9
Standard Operating Procedure (SOP) 2: Training Observers	10
Roles and Responsibilities.....	10
Training Location	10
Training Outline	11
Goals for Crewmembers.....	11

Training Agenda	12
Definitions	12
Procedures	13
Crew Organization.....	13
Equipment Operation.....	14
Field Operations	14
Plant Identification	15
Tree Pest Identification.....	16
Miscellaneous Training Topics	16
Standard Operating Procedure (SOP) 3: Establishing Plots	18
Driving Directions	18
Great Basin National Park.....	18
Establishing Permanent Macroplots	18
Locating Plots.....	18
Accepting or Rejecting a Macroplot Location	18
How to Lay Out a Macroplot.....	19
Subplot Boundary Layout.....	20
Plot Offsetting and Replacement.....	20
Regeneration Plots.....	21
Tagging Trees.....	21
Krummholz.....	24
Standard Operating Procedure (SOP) 4: Measuring Response Variables	26
Before Going into the Field.....	26
Measuring Response Variables	26
Tree-level Data	28
Regeneration Data	29
Standard Operating Procedure (SOP) 5: Data Management.....	31
Data Collection.....	31

Collecting and managing data	31
Importing and managing photographs	32
Project File Storage Conventions	33
Database Design	34
Data Dictionary	36
Standard Operating Procedure (SOP) 6: Data Summary, Analysis, and Reporting	46
Data Analysis for Status Estimation.....	46
Trend Analysis.....	47
Pilot Data.....	49
Reporting.....	54
Literature Cited	55

Figures

	Page
Figure 1.1. Top 10 GRTS sites in each stratum in GRBA.....	4
Figure 2.1. Compass displaying components used to find a bearing.....	14
Figure 3.1. Plot design for macroplot.....	19
Figure 3.2. Figure showing growth groove distinction, size requirement, and angle requirement for differentiating between individual trees and clumps.	23
Figure 3.3. Photograph showing fallen limber pine within a monitoring plot in Craters of the Moon National Monument and Preserve	24
Figure 3.4. Photograph showing whitebark pine tree growing in krummholz growth form.....	25
Figure 4.1. Plot design for macroplot.....	27
Figure 5.1. The white pine monitoring protocol database model.....	35
Figure 6.1. Site-level means of DBH by year for sites within each of three “Parks.”	51
Figure 6.2. Residual diagnostics for the DBH measurements for the reduced model for regional inference.....	52

Tables

	Page
Table 2.1 Training agenda and schedule for field crewmembers.....	12
Table 2.2 Important field definitions for monitoring white pine plots in the Pacific West Region.	13
Table 3.1. Plot rejection criteria. Use the codes in italics to note the criteria used to drop a plot.....	19
Table 5.1. Handwriting best practices.	32
Table 5.2. Data dictionary for tbl_Sites. A Site can be a Park, a Park Sub-Unit, or a Sampling Frame within a Park or Park Sub-Unit. All sampling plots fall within a Site.	36
Table 5.3. Data dictionary for tbl_Locations. A Location is a Plot to be sampled. UTM Coordinates are associated with the SW corner of the Plot.	37
Table 5.4. Data dictionary for tbl_LocData_PlotInfo. UTM Coordinates and Azimuths of Corner Points of the Location (plot). Coordinates are collected with GPS unit, and Azimuths are collected with compass.	38
Table 5.5. Data dictionary for tbl_Events. An Event is a sampling occurrence at a Plot. Observers (from tluContacts) are recorded in xref_Event_Contacts table.	39
Table 5.6. Data dictionary for tbl_EvData_PlotPhotos. This table holds information about Plot Photos taken during a sampling Event.....	40
Table 5.7. Data dictionary for tbl_EvData_SeedlingCounts. This table holds all of the Seedling Counts associated with a sampling Event.	41
Table 5.8. Data dictionary for tbl_EvData_TreeData. This table holds all of the Tree Data associated with a sampling Event.	41
Table 5.9. Data dictionary for tbl_EvData_WildlifeObs. This table holds the Wildlife Observation data associated with a sampling Event.	44
Table 5.10. Data dictionary for tlu_TreeStatus_Codes. Lookup table of TreeStatus Codes for Tree Data.	44
Table 5.11. Data dictionary for tluContacts. Lookup table of Contacts associated with protocol data collection and entry. Contacts linked to Events in xref_Event_Contacts table.....	44
Table 5.12. Data dictionary for tlu_Species_Parks. Lookup table of Species_Codes, Park, and Species Names. Allows park-specific species lists for Seedling Counts and Tree Data.	45

Table 5.13. Data dictionary for tlu_HeightClass_Seedlings. Lookup table of HeightClass Codes for Seedling Counts.....	45
Table 5.14. Data dictionary for tlu_Indicators_Rust. Lookup table of blister rust Indicators for Tree Data.	45

Appendices

	Page
Appendix A: First 10 Points of each Stratum in GRTS Draw	58
Appendix B: Field Data Collection Sheet.....	59
Appendix C: Site Information Sheet Example.....	61

Background

This document provides detailed information on how to monitor two species of white pine (*Pinus longaeva* and *P. flexilis*) in Great Basin National Park in the Mojave Desert Network (MOJN) Inventory & Monitoring Program. This Protocol Implementation Plan adapts objectives, sampling design, and SOPs from the multi-network White Pine Monitoring Protocol Narrative and SOPs (McKinney et al. 2013), currently implemented in Klamath, Sierra Nevada, and Upper Columbia Basin Networks, to MOJN parks. The standard operating procedures presented here and the methods described in the associated protocol narrative will be used to monitor white pine stands.

Standard Operating Procedure (SOP) 1: Preparation for the Field Season

Version 1.0

Revision History

Version #	Date of Revision	Revised By	Changes

This SOP describes the step-by-step procedures to prepare for field work and to prepare and organize field equipment prior to the personnel training and entry into the field. Adequate preparation of equipment for the field and is crucial to a successful monitoring program.

Annual Review

Prior to the field season each year, beginning in December and January, the Project Lead should review the entire protocol, including SOPs, and plan the field season. The season close-out notes from the previous year should also be reviewed for any outstanding tasks that need to be completed.

Annual planning includes:

- Hiring qualified field technicians
- Arranging overnight facilities and research permits
- Reviewing list of sampling locations
- Scheduling sampling
- Preparing field equipment (e.g., GPS, cameras)
- Preparing for any required backcountry travel

Hiring Qualified Field Technicians

Begin the process of hiring of field technicians no later than December of the preceding year. A minimum of two dedicated field technicians are required each season to complete sampling. A 3- or 4-person crew is highly desirable (required for implementation years), though a 2- person crew is adequate to accomplish plot revisits in the subsequent years following the first three years of initial implementation. Past descriptions and announcement documentation will be stored in MOJN white pine project directories for personnel information. Sharing of field technicians among other networks also implementing this protocol, Upper Columbia Basin Network (UCBN), Sierra Nevada Network (SIEN), and Klamath Network (KLMN), is strongly recommended; because of the wide phenological window within which sampling can be accomplished each season.

Positions need to be advertised by March of each year and filled by April or at the latest May. Sharing of technicians and joint training among KLMN, SIEN, and UCBN should be pursued each year. Review of technician training including plant identification is particularly important.

Seek field technicians who can quickly learn or already know common plants found in white pine stands in Great Basin National Park (GRBA), and who have experience working independently outdoors all day in remote and sometimes arduous conditions. Make potential field technicians aware of the steep and rugged terrain where white pine monitoring often takes place and ensure they are prepared to carry field equipment and personal gear long distances while travelling on foot. The field technician must have a mind for safety and exercise safe behavior while working in the field.

The Project Lead should seek individuals with the following capabilities:

- College-level training in plant taxonomy or systematic botany and forest inventory methods (e.g., use of clinometers).
- Previous experience working at least seasonally under rugged field conditions and in group living situations.
- Evidence of personal initiative and an independent, self-starter work ethic.
- Meticulous attention to details and demonstrated interest in natural resource conservation.

Additional details of required and desired qualifications are available from past job announcements and descriptions in Network white pine project personnel directories.

Arranging Overnight Facilities and Research Permits

Implementing this protocol will require camping in front-country and backcountry locations. Camping sites for field crews need to be reserved with GRBA as early as possible before the field season. Campsite or other overnight facilities should be optimized in terms of convenience ahead of time based on the field schedule for plot sampling.

Check to make sure research permits are up to date, and to inform the Park point-of-contact (usually a resource chief or surrogate) for the protocol of the plans for the year's sampling by March. The Park contact should be consulted at this time about any potential impediments to plans due to trail, road, or campsite closures, or other planned inconveniences. Research permits can be requested through the NPS research permit and reporting system (<https://irma.nps.gov/rprs/>). Requests are coordinated through the MOJN Program Manager.

Review the List of Spatially-Balanced Sampling Locations

Important Note: White pine sampling locations have been randomly selected using the Generalized Random Tessellation Stratified (GRTS) spatially-balanced sampling algorithm (see Table 1.1; Stevens and Olsen 2004, Theobald et al. 2007, Kincaid 2011). To maintain the spatial balance of the sample, the suite of sites included in the sample *must* follow the GRTS ordered list numerically (sites can be moved slightly to avoid rejecting them, referred to as “offsetting”, see SOP 3 —Plot Offsetting and Replacement for further details). Each panel (yearly collection of sample locations to be visited) will be an ordered subset of the GRTS list, and panel membership is noted for each

sample location (Appendix A). These lists will be consulted before going into the field in subsequent years. Once all permanent plots have been established, tables of sites should be created and included in a revised version of this SOP for future reference. To view the maps and coordinates of sampling locations, stored as shapefiles, access the Network white pine project GIS. The survey package (Kincaid et al. 2011, available on-line from the [EPA website](#)) in the R statistical software and environment (version 2.11.0, 2010; R Development Core Team, Vienna, Austria, available online at from the [R project website](#)) was used to generate GRTS sampling locations. The R code that was used for GRTS draw is available in the MOJN white pine project directory in the Sampling Design subdirectory (see SOP 5).

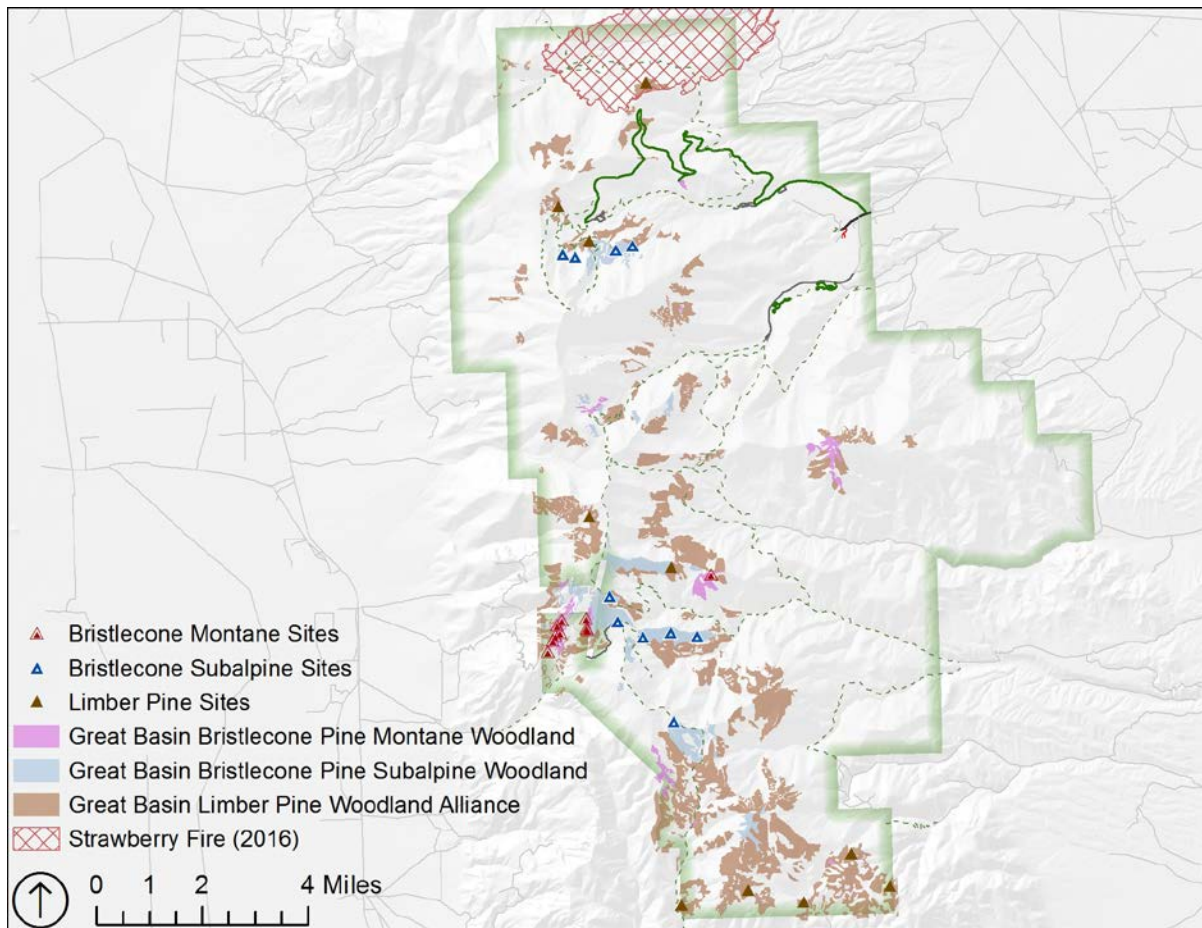


Figure 1.1. Top 10 GRTS sites in each stratum in GRBA.

Review each site within the target panel (e.g., panel 2 for start-up year 2, or for subsequent years in which panel 2 is scheduled for sampling) ahead of field work to determine a priori if sites need to be replaced. Criteria for dropping sites are listed in SOP 3. Use the project GIS with high resolution imagery (e.g., NAIP imagery) to determine if any target species trees appear to be within the plot area, or to identify other potential problems. ArcMap extensions, such as Hawth's Analysis Tools (H. Beyer, 2006, [available on-line](#)) can be used to draw plots to assist in this office review. The supply of replacement sites will be drawn, in GRTS list order, from the list of oversamples provided. Track the

evaluation status of each site so that inclusion probabilities can be recalculated to support the use of design-based status estimators and properly weighted trend analyses (Table A.1; Kincaid 2011). Note, however, that these are equal probability surveys, and GRTS weights are not used in the estimation procedures described in SOP 6.

Survey planning for years subsequent to start-up should also carefully review fixed sampling locations; MOJN staff will retire sites that can no longer be sampled and replace them as necessary. Plan visits to sampling locations by grouping visits into “hitches” of 4-10 days long. Hitches refer to time spent in the field collecting data at multiple sampling locations and usually include several overnights. Load waypoints for the final evaluated list of target panel and oversample locations into project GPS units following instructions in MOJN general SOP *Using Garmin 76CSx GPS Devices* (Lehman 2017).

Scheduling and Organizing Field Work

Field work should be scheduled in early spring, and scheduling efforts should begin no later than the previous January/February. The Project Lead will coordinate this planning with the GRBA natural resource staff. A crew of 2-3 people working for two weeks each sampling season must be available in order to complete the field data collection.

Prior to the field season, the entire schedule of locations that will be sampled should be organized to avoid unnecessary travel time. During the 3-year start-up period, new sample sites for each year (panel) will be visited following the ordered GRTS lists.

Review this list carefully and prepare hitches that enable proximal sites to be visited as efficiently as possible. Spatially proximal sites are not necessarily in GRTS order. Therefore, ensure that the complete suite of sites within each panel can be accomplished during the season; otherwise, a spatially unbalanced “hole” in the sample will result. If it is unclear whether the full panel can be visited, then a smaller subset of panel sites, following GRTS order, should be targeted first, thereby ensuring spatial balance. In subsequent years, field routes for hitches will be established based on past experience traversing Park terrain and the particular arrangement of sample locations to minimize total travel time.

Field work plans must include a flexible window of dates to accommodate unusual weather events, fire activity, snowmelt, and other complications such as trail and Park road maintenance. Access roads and other important location information may need to be loaded into GPS units to aid in efficient navigation to sample sites. Camping sites should be planned and reserved to avoid unnecessary and unproductive travel to and from areas to be sampled. Anticipate that some sites will be dropped, particularly during the first few years of implementation when possible sampling frame errors have not yet been resolved. Allow time at the end of each sampling session to add replacements for rejected sites. Because of the GRTS spatially-balanced design, replacement points will not necessarily be near dropped sites (but see Odion et al. [2011] for an alternative approach used in KLMN vegetation monitoring), underscoring the importance of thorough office evaluation before going into the field. SOP 3 describes procedures for replacing sites during field work.

Field crews will assemble “site information packets” for their trips into the field before the season begins. Though time consuming to create, these packets guide the entire week in the field and should be created carefully. Site information packets include a backcountry travel plan (see *Mojave Desert Network Inventory & Monitoring Field Safety Plan* [Tallent et al. 2017]) for each day of the trip; driving and hiking route maps; a Site Information Sheet for each plot (which summarizes how to get to the plot and each stand being visited; see Appendix C for an example); list of UTM coordinates for transect start locations, plots, and permanent photo points; field data collection sheets (see Appendix B); emergency contact information; and the locations and phone numbers of local services, such as hospitals. The crew will also need to load GPS units and/or Tablets with plot and photo point coordinates.

Target sample sizes are 10 plots per panel, where a panel refers to a collection of plots measured in a given year. Sampling during plot establishment, when plot marking and tree tagging is most time consuming, will take longer. Pilot work conducted in McKinney et al. (2013) indicates that one plot can be completed per day, although remote plots that require extensive travel should be allocated extra travel time.

Equipment Preparation

The following equipment should be assembled each spring, and sufficient time must be allotted to order replacement equipment. The amounts of individual items required are listed since they change according to the number of field participants and crews available.

Measuring Equipment

- Four 50-m reel tapes
- Wire pin flags for temporary plot boundary markers (approx. 30)
- 2 small tape measures for assessing seedling/sapling height classes
- Surveyor’s pins for temporarily anchoring corners
- Compass with inclinometer for estimating slopes
- Laser rangefinder with capacity for measuring tree height
- Diameter tape
- Small hatchet
- Yellow crayon for temporarily marking seedlings during counts
- Plant ID references (e.g., regional floras and photographic tree guides)
- 10x binoculars for looking into tall trees for rust, cone production, etc.
- Handheld tally devices for regeneration plot seedling count tallies (at least 3)

Plot Marking and Tree Tagging Equipment

- Short (e.g., 8-10 inches) ½ in rebar
- Aluminum rebar caps ½ in dia. with —NPS engraved
- 1 ¼ round aluminum or brass tree tags consecutively numbered in sets of 500
- Wood siding sinker head style galvanized aluminum nails, 2 ¼ in length
- Steel wire for securing tags to small trees where nails won’t work
- Pliers with wire cutter

- Small mallet suitable for driving rebar and tag nails

Navigation and Recording Equipment

- GPS unit with pre-loaded sampling location waypoints (MOJN supplied, or comparable unit)
- Tablet with field data sheets (if used by this crew) + AC/DC converter for charging batteries.
- Weatherized field data entry forms (Appendix B)
- Backup copies of data entry forms
- Mechanical pencils and clip boards
- Field reference maps identifying clusters of proximal sample points, access locations, and other key travel information

Communication and Safety

- Cell phone
- InReach satellite locator device (pre-programmed)
- Park 2-way radios
- Emergency contact information
- Fire extinguisher, shovel, and other park-specific vehicle safety equipment required
- Sunscreen
- Water cube (don't forget to fill)
- First Aid kit

Miscellaneous Field Equipment

- Digital camera
- Spare batteries for GPS, Tablet, camera, laser range finder
- Field-relevant SOPs (SOP 1–5)
- Plastic file box for storage of data sheets (in vehicle) with folders and extra forms, mechanical pencils, and Rite-in-the-Rain note paper
- Wire brush for cleaning tires, boots, and trousers of weed seeds, and for exposing discolored bark on trees infected with rust
- Small spray bottle for wetting tree bark to help identify rust symptoms
- Solvent for cleaning pitch off of tapes and other equipment
- Daypack and overnight backpack

Preparation of Navigation and Field Data Management Equipment:

1. The sampling point locations must be uploaded to each GPS unit following procedures outlined in MOJN general SOP *Using Garmin 76CSx GPS Devices* (Lehman 2017). GPS preplanning also includes review of satellite availability for the duration of the scheduled sampling window. Park sites may be in dense forest with closed canopy, compromising the performance of GPS units. Some sites near cliffs can have poor satellite coverage as well. Make necessary schedule changes if an unusually poor arrangement of satellites is scheduled during the sampling window. Digital data entry tools (tablet device) should be checked and preloaded with software and files. At least one back-up GPS unit should also be available and have all necessary files pre-loaded.

2. Access roads and other important location information need to be loaded into GPS units to aid in efficient orientation to sample sites.
3. Completely charge all GPS units, data entry units, radios, digital cameras, and backup batteries prior to departure for the field. Provide back-up batteries to each field crew!
4. Paper field data forms should be prepared and at least 25% of them printed to Rite-in-the-Rain paper for each field crew. Field reference maps of park sampling areas and plot locations must be prepared in advance of field work with sample points organized and color coded by proximity in order to guide efficient field travel. Reference maps should be printed on Rite-in-the-Rain paper. Note that paper field data forms are only for back-up in case of tablet failure.

Preparation for Backcountry Travel

1. The Project Lead and Field Lead should be familiar with rules and regulations pertaining to working and camping in the backcountry. If field sampling is expected to occur in the backcountry, it is the Project Lead's responsibility to make certain all crewmembers are aware of the park-specific backcountry rules and regulations.
2. Ensure all backcountry communication devices (refer to the MOJN Safety Plan for an updated list; Tallent et al. 2017) are charged.

Miscellaneous Preparatory Notes:

1. Analysis and reporting of previous year's data is necessary before starting a new field effort. This is covered in SOP 5, Data Management, and SOP 6, Data Summary, Analysis, and Reporting. It is particularly important that adequacy of population boundaries and sampling efforts has been considered, and any changes to sampling design have been made before new points are generated.
2. Prepare a realistic schedule of events in advance of group arrival, and circulate to crew leaders and organizers ahead of time to manage expectations and ensure timely arrival.
3. Apply for a research permit (<https://irma.nps.gov/rprs/>) well ahead of the field season, as early as February/March. Arrange with the staff at GRBA for your arrival and stay during field season.
4. The *Mojave Desert Network Inventory & Monitoring Field Safety Plan* (Tallent et al. 2017) should be reviewed before the field crew heads into the Park. Make sure all crew leaders know where vehicle keys are to be stored during field operations, the location of the nearest pay phone and/or cellular phone coverage opportunity, and emergency contact and operation procedures for GRBA staff.

Preparation of Navigation and Field Data Management Equipment

Development of randomly generated sampling points must be conducted following the procedures described at the beginning of this SOP, and a digital text file (.txt or .dbf) created with the Stand ID, Transect ID, Plot IDs, transect azimuths, and UTM coordinates (UTM zone 11, NAD83 for GRBA). Because only permanent transects are used the coordinates will not change from year to year unless there are adjustments in the protocol. This coordinate list will be uploaded to each GPS unit

following procedures outlined in MOJN general SOP *Using Garmin 76CSx GPS Devices* (Lehman 2017). The coordinates will also be uploaded to the tablet, if a tablet is used by the field crew. Data entry forms should be revised and printed, with extra copies available for each crew. Back-up GPS units should be available and have all necessary files pre-loaded. The azimuths of each transect will be included in the list of plot ID's and coordinates.

Season Closeout

After the field season, clean and organize all non-electronic equipment and store in well labeled plastic bins in MOJN Ready-Room. Tablets are stored by MOJN under the direction of the Data Manager. Each compass must be adjusted to account for magnetic declination, or magnetic variation, by adding approximately 12°E in GRBA to the direction of “true” or grid north. Orienteering-grade compass housings can be adjusted, usually by turning a small set screw, so that the fixed north arrow, usually inscribed on the bottom of the plastic housing points to 12° rather than 0°. This will ensure that when this fixed north arrow is aligned with the red end of the magnetic arrow, the compass directional arrow will actually point in the correct direction according to “true” or grid north.

Standard Operating Procedure (SOP) 2: Training Observers

Version 1.0

Revision History

Version #	Date of Revision	Revised By	Changes

Procedures for plot set-up and measurements are detailed in SOPs 3 and 4. Procedures for data management are in SOP 5. These SOPs should be used as training manuals and hard copies provided to each technician for reference throughout the field season. Note that field SOPs are not meant to be stand-alone training manuals or replace the thorough documentation available for GPS and field botany techniques. Training personnel should refer to these SOPs as a guide and seek out additional information in the suggested reading and through hands-on training courses provided by NPS and outside sources. Up-to-date and certified park species lists are available through the Integrated Resource Management Applications (IRMA) [NPSpecies module](#).

Roles and Responsibilities

Identify one Lead Trainer, typically the Project Lead or the Field Lead. This person should be well versed in the protocol and SOPs, and have considerable experience both conducting field work as well as training and directing technicians. The Lead Trainer must have either previously worked in the field implementing this protocol, or have had direct experience working in white pine ecosystems infected with blister rust. The Lead Trainer should provide field technicians with a copy of the narrative and SOPs prior to technicians arriving on site for training. At the start of field training, technicians should be familiar with program objectives, ecological context, and field methods.

Training Location

Indoor lab environments with sufficient space to set up laptops and to project presentations are helpful for presenting much of the training material to crewmembers. Teach field procedures outside at a white pine site or another analogous woodland location. The group should complete data collection as a training exercise for one or more of the actual plots in that year's panel to simultaneously deliver hands-on experience and to carry out necessary fieldwork. Ideally, the group can visit a site where a range of blister rust infection symptoms can be seen. Currently this may be difficult at GRBA due to rarity of infections. Sites with signs of mountain pine beetle and other wood-boring beetles should be located ahead of training if possible and these locations visited during training. Also, practice sample points located in an anticipated training area can be included in the waypoint list, enabling participants to practice GPS navigation and plot set-up without trampling vegetation in an actual plot. Instruct the crew on how to relocate plot markers.

Training Outline

Goals for Crewmembers

- Understand and demonstrate a sincere understanding and appreciation for, and commitment to follow, safety procedures, including regular communication with Park points of contact and plant identification terminology.
- Review use of plant identification manuals, keys, and photos.
- Acquire proficiency in identification of common native and invasive herbs, shrubs, and trees found in white pine stands.
- Acquire confidence and consistency in measuring tree diameters at 1.37 m above ground.
- Demonstrate an ability to distinguish trees, stems, and clumps and assign identification codes to them. Discuss the relative difficulty of this determination in high subalpine sites such as those where stem/clump distinction becomes challenging.
- Accurately measure tree heights with both a clinometer and a laser rangefinder (in case the rangefinder is not available).
- Acquire confidence in recognizing the signs of blister rust, mistletoe infection, and mountain pine beetle.
- Acquire confidence and consistency in visually estimating the amount of live and dead canopy, and the amount of canopy and bole infected with blister rust (hypothetically, at least, during training).
- Acquire proficiency in use of GPS equipment, compass orienteering, and navigation to sampling points.
- Acquire proficiency in use of tablet PCs (if applicable) and accompanying data entry software, including troubleshooting and procedures for backing up data.
- Demonstrate competence in all field skills, including meticulous data entry, compass reading, and attention to detail in the field environment.
- Understand procedures for plot boundary decisions, sampling frame errors, and dropping and adding sites.
- Understand and demonstrate a sincere appreciation for, and commitment to follow, procedures for the prevention of non-native species spread during fieldwork.
- Demonstrate an understanding of overall program monitoring goals.

Training Agenda

Table 2.1 Training agenda and schedule for field crewmembers.

Training Day	Time	Activities
Day 1	Morning	Arrival and orientation Get acquainted, backgrounds of participants, team building Individual protocol study
	Afternoon	Group program orientation and protocol discussion Data management and QA/QC Introductory review of safety procedures and contact information Additional network- or park-specific safety training will be done on-site in the parks where monitoring is conducted. Review of procedures for preventing the spread of non-native species
Day 2	Morning	Field demonstration of all field methods, including use of tablet PCs and GPS practice Review of plot boundary decisions, add/drop criteria, procedures, and documentation
	Afternoon	Plant identification Blister rust, mistletoe, and pine beetle identification Methods practice and calibration among observers (i.e., repeatability among observers for measuring DBH, tree height)
Day 3	Morning	Practice navigating to plots and plot set up Field walk identifying plants and general travel and hazard issues, and procedures to prevent non-native species spread
	Afternoon	Group field methods practice and calibration
Day 4	Morning	Group practice – set-up of 1 real plot
	Afternoon	Group practice – completion of 1 real plot
Day 5	Morning	Group practice, troubleshooting, GRTS and field decisions
	Afternoon	Review, scheduling, planning Outstanding issues

Definitions

Definitions for key field terms that crews are required to know are presented in Table 2.2 and should be reviewed during training.

Table 2.2 Important field definitions for monitoring white pine plots in the Pacific West Region.

Term	Definition
Aecia	Cup-like reproductive structures of white pine blister rust that produce aeciospores. These bright yellow/orange blisters on active cankers on the bark of white pine trees.
Azimuth	Azimuth is the horizontal component of a compass direction. It is usually expressed in degrees.
Bole	Stem of tree
DBH	Diameter at Breast Height = Diameter of the tree bole at 1.37 m above ground.
Dead Pine	The dead stem must be standing or leaning and will not be counted if lying on the ground.
Krummholz	A tree growth form often seen at or above timberline and/or in open sites exposed to high winds and cold temperatures. Tree boles and branches are often twisted and the growth forms a stunted prostrate mat with many stems. Bristlecone pine, mountain hemlock, and subalpine fir commonly grow as krummholz.
“In” (for Pine or conifer stem)	The plant originates from the ground (is rooted or partially rooted) within the inside edge of the plot; a plant is either “in” or “out,” never halfway.
Panel	A panel of sampling locations or plots consists of a subset of the total sample size that is visited within a given year or season. For example, for 90 sample points, 3 panels of 30 points each are visited once each year for 3 years, and then this rotation is repeated.
Pine Sucker	A pine stem shorter than 46 cm (1.5 ft) tall
Plot	The defined unit of measurement (e.g., 50 x 50 m), with boundaries framed permanently by rebar corner and center pins, and temporarily during sampling along sides and center by 50-m reel tapes. The plot is anchored by a corner pin in the lower right corner at the GRTS sample point UTM coordinates.
Target Population	The predetermined collection of plant communities for which statistical inference is desired; in GRBA, this is limber pine and bristlecone pine.
Sampling Frame	The physical representation of the target population. This is always imperfect and sampling frame errors and procedures for addressing them must be covered in training.

Procedures

Crew Organization

Field crews need a minimum of two observers, three is ideal, and four is acceptable. Larger crew sizes are inefficient. Provide each crew with a complete set of measuring equipment. Also provide each crew with a hard copy of each of the relevant field SOPs for reference during training and field operations. Provide each crew with a hard copy map of the park site as well as with a larger scale map indicating the crew’s individual sampling points and their IDs. These hard copy maps are crucial for field efficiency and to minimize errors associated with misidentified points. Once the crew is established, it should be maintained throughout the duration of training and sampling in order to maintain consistency.

Equipment Operation

1. Navigating to waypoints using Garmin 76CSx GPS units is described in detail in MOJN general SOP *Using Garmin GPS Devices* (Lehman 2017). This document should be made available to crews and discussed as part field crew training. Sample location waypoints should be uploaded to the GPS units at the beginning of the field season. This procedure is also described in the MOJN general SOP. It is not necessary to delete waypoints that are stored on the GPS unit at the end of the field season because all transect and plot locations are permanent and will be revisited during the next sampling season.
2. Teach crewmembers how to use a compass outside and away from magnetic interference. Compasses should be held flat, on an open palm, in front of and close to the user's body. To move the compass around for alignment of arrows and determination of a bearing, or azimuth, the user should move with the whole body rather than just the arm or hand. A simple mnemonic for using orienteering compasses is to "put red in the shed," where "red" is the magnetic arrow that always points to magnetic north, and the "shed" is the fixed north arrow inscribed on the bottom of the moveable housing (See Figure 2.1).



Figure 2.1. Compass displaying components used to find a bearing

Once the "shed" is set to accommodate the magnetic declination and the "red" is in the "shed," the compass directional arrow that is inscribed on the outside of the compass housing along the end of the base plate will always point to a true bearing or azimuth. You should site the line on an object ahead of you and walk towards the object. Transects should be oriented along the pre-assigned azimuth by turning the compass housing to the desired number, and then turning the body until "red is in the shed."

Field Operations

Before fieldwork begins, designate at least one full day of training, and a few days after that for very slow data collection days. Prioritize with crews the importance of consistency and ensure all

crewmembers collect each piece of data in the same way. The first day of training, and the slow-paced data collection days thereafter, follow the steps below.

1. Designate a lead trainer. This will typically be the Protocol Lead, if present, or the designated Field Lead. This person should be available to troubleshoot and reassign new equipment as needed.
2. Ensure all data collection techniques are taught to all crewmembers for consistency, even if crewmembers have done the same measurement before.
3. Ensure all personnel display competence using GPS navigation. If needed, teach GPS training in the field.
4. Review basic plant identification for local flora. All crewmembers must be very comfortable identifying the species of interest for this protocol, aspen and all conifer species (only some conifer species are included in this monitoring, yet crews must be able to tell those species from other conifers in the area). This training should include familiarizing crews with adult and juvenile individuals.
5. Practice locating transect start locations with GPS, maps, and compass.
6. Practice taking measurements and performing data entry (have extra field data entry sheets for this exercise).
 - a. The field crew will be trained in recording slope using a clinometer and laser range finder
7. Teach all field measurement operations outside. Every piece of data collected should be
 - b. All crewmembers must be very comfortable determining aspect and angle bearings in the field since these are crucial skills for establishing and relocating plots. Practice relocating plots using a bearing.
8. **Emphasize clear communication practices between crewmembers during data entry.** All data recorders must repeat back to the observers each piece of data that is recorded to ensure there were no discrepancies.
9. Once crews are comfortable with basic operations, have them switch roles to re-measure the plots and compare results.

Plant Identification

All crewmembers should review common plants found in GRBA in the MOJN plant guide *Common Herbaceous Plants of Great Basin National Park* (Mills 2017). For GRBA, *Flora of the North and South Snake Ranges* (Clifton 2012) is a very useful key to assist plant identification. In addition to these two informal guides, plant naming should follow the 2012 updated version of *The Jepson Manual* (Hickman 1993).

Additional Plant ID Resources

- Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Chapter 8 in *Measuring and monitoring plant populations*. US Department of Interior, Bureau of Land Management, Denver, Colorado.
- *Flora of the Pacific Northwest*. CD-ROM Version 1.0. University of Washington Press, Seattle, Washington.
- Harrington, H. D., and L. W. Durrell. 1957. *How to identify plants*. Ohio University Press, Athens, Ohio.

- Harris, J. G., and M. W. Harris. 2001. Plant identification terminology, an illustrated glossary. 2nd edition. Spring Lake Publishing, Spring Lake, Utah.
- U.S. Department of Agriculture Natural Resources Conservation Service (USDA, NRCS). 2006. The PLANTS Database. National Plant Data Center, Baton Rouge, Louisiana. [Available online.](#)

Tree Pest Identification

Crews must have formal training for how to identify health-related variables, including white pine blister rust symptoms, pine beetle occurrence, and dwarf mistletoe infection. If there is not a staff member qualified to train crews on how to identify insects and disease, the MOJN Project Lead needs to seek out training opportunities from a local forest pathologist (e.g., US Forest Service or state forestry department) for themselves and/or the crew. The seminal document for identifying white pine blister rust in the field is Hoff (1992). Each network has an electronic and reference copy of this paper. Copies are provided to monitoring crews prior to each field season and used during training. It is imperative to understand that extensive training is required to identify cankers and other symptoms of blister rust infection.

Miscellaneous Training Topics

1. Give adequate time must be to properly set up plots and for decision-making associated with plot boundaries and dropping plots. While effort has been made to minimize these decisions (e.g., through office evaluation with a GIS), problems will inevitably be encountered. Each technician should understand that in order for the GRTS sample to remain valid, a plot location must be selected in the immediate vicinity of the GRTS point. A rejected plot location may be replaced by using an offset procedure described in SOP 3 or via sequential selection of new sites from the GRTS sample.
2. Objective positioning of the plot is essential for unbiased parameter estimates. Placement of the plot is described in SOP 3 but needs to be demonstrated for circumstances that may not be straightforward in training.
3. Placing the diameter tape consistently at 1.37 m (just above the nail) is important to characterize rate of tree growth accurately, for example, between consecutive sampling events. Practice diameter at breast height (DBH) measurements on challenging trees (e.g., where slopes are steep) with multiple observers to calibrate. Refer to page 3 of the Forest Service Tree Measurements document ([available online](#)) for instructions on using the clinometers to measure tree height. Print hard copies of the diagrams included in the document for field reference.
4. Plant identification should be practiced throughout the training week in both a lab and field setting, and must include inspection of tree trunks and conifer needles. Emphasize the importance of plant recognition despite the emphasis on tree measurements. Recognizing other plants helps prevent misidentification of target species and will aid in documenting ancillary observations, such as an unusually dense understory of *Ribes*, an alternate host of blister rust. Crews can contribute to Park management and conservation by identifying a previously unknown infestation of a noxious weed and promptly reporting its location to Park staff for immediate treatment.
5. MOJN takes safety seriously. All crewmembers must be very familiar with the *Mojave Desert Network Inventory & Monitoring Field Safety Plan* (Tallent et al. 2017) and feel

confident in their Operational Leadership training. Reinforce the MOJN safety culture with all crewmembers.

6. Weed spread prevention is a critical issue in all NPS field activities. Teach crews to scrub boots, spray vehicles, and remove plant material from backpacks and gear.

Standard Operating Procedure (SOP) 3: Establishing Plots

Version 1.0

Revision History

Version #	Date of Revision	Revised By	Changes
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This SOP provides detailed directions for how to navigate to GRBA and the stands within the Park.

Driving Directions

Great Basin National Park

From the MOJN Office in Boulder City, NV, follow US-93 N for 280 miles. Turn right onto US-50E/US-6 E toward Baker, NV. Follow this for 30 miles. Turn right onto Lehman Caves Road in Baker, NV. There will be a sign indicating the Park entrance. This trip usually takes about 5 hours.

Establishing Permanent Macroplots

Locating Plots

Use the GPS to navigate to the specified plot location by following instructions in MOJN general SOP *Using Garmin 76CSx GPS Devices* (Lehman 2017).

Accepting or Rejecting a Macroplot Location

Upon arrival at the selected point (SW corner of the plot; Figure 3.1), verify that the location is suitable for plot establishment. A plot is 'rejected' following criteria listed in Table 3.1. If any part of the plot falls outside of the park boundary it must be rejected. If the slope is steeper than 30 degrees, the plot must also be rejected since it is too steep to safely and efficiently work at the plot. Further, if the plot is not steeper than 35 degrees, but has other unsafe features, the crew always has the ability to reject the plot due to unsafe terrain (crewmembers must always display operational leadership, even in plot establishment). If a road or trail goes through the plot, follow the offset procedures. Plots can only be accepted if they have at least one living target species white pine tree (≥ 1.37 m) must be rooted within the plot boundaries. If a target species tree is found within plot boundaries, it must be the correct species for the current sample frame in order for the plot to be established. For instance, a plot containing one bristlecone pine would fail to meet the plot establishment criterion if working in the limber pine sampling frame. If no target species trees are located within the plot, then refer to the Plot Offsetting and Replacement section of this SOP.

Table 3.1. Plot rejection criteria. Use the codes in italics to note the criteria used to drop a plot.

Rejection Criteria	Code
Outside park boundary	bndry
Dangerous/prohibitively difficult to work on (e.g., slope >35°, talus or rimrock)	unsafe
Road or improved trail	road or trail
No live white pine trees	trees
Other circumstances – detail this in the notes	other

How to Lay Out a Macroplot

Plots are oriented in the cardinal directions such that two parallel sides of the plot run west to east and the opposite parallel sides of the plot run south to north (Figure 3.1). The point that the crew hiked to becomes the plot anchor point, which is the SW corner of the plot (corner #1, Figure 3.1). Follow the steps below to lay out the macroplot.

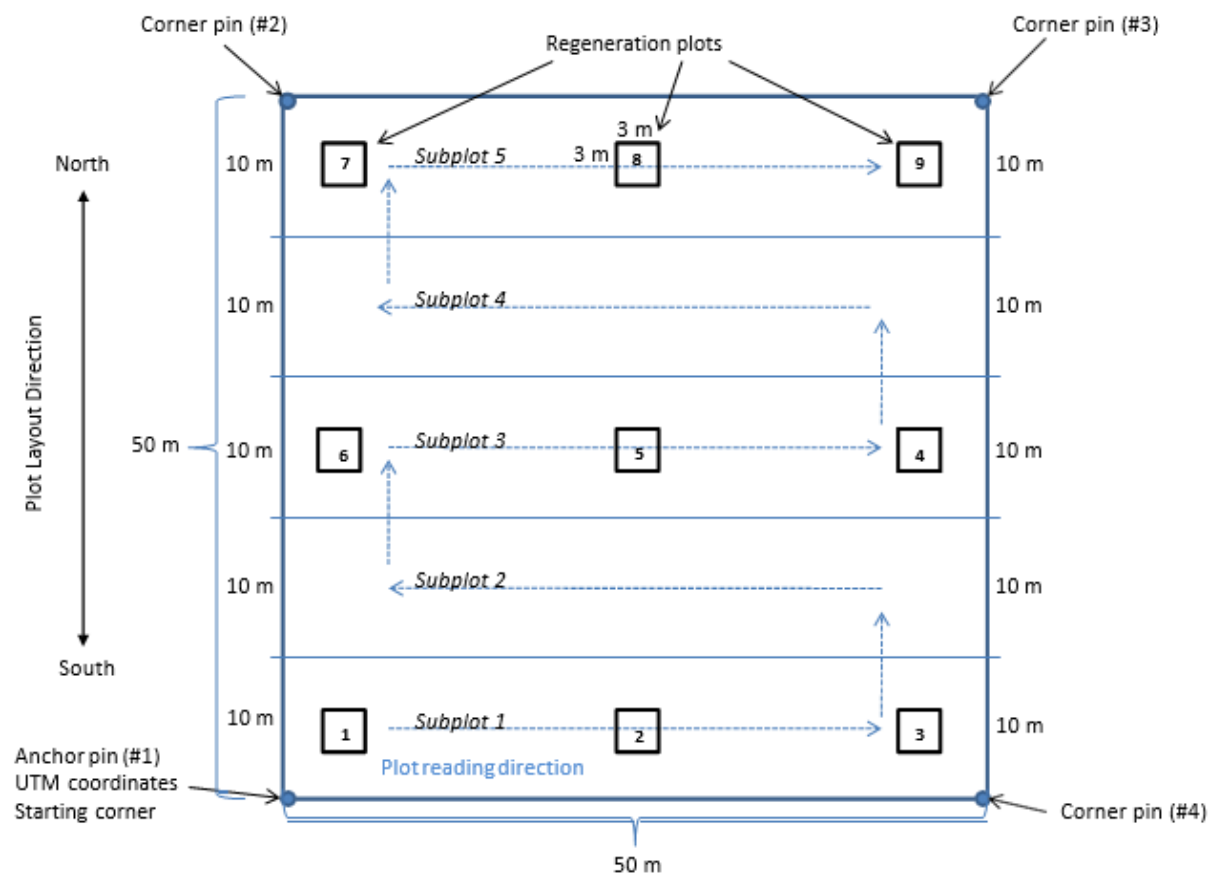


Figure 3.1. Plot design for macroplot. Macroplot is 50 m x 50 m and consists of five, 10 m x 50 m subplots to facilitate plot reading and quantitative comparisons with other monitoring projects. Within each macroplot are nine, 3 m x 3 m regeneration plots.

1. Place a surveyor's pin at the location between the boots of the GPS operator to temporarily mark corner #1.
2. Two or three crewmembers then use their compasses to find the north azimuth and run the meter tape out 50 m to establish the NW corner.
3. Once at the NW corner, the crewmembers turn 90 degrees east and go 50 m to establish the NE corner.
4. From the NW corner, turn 90 degrees south and go 50 m to establish the SE corner.
5. Finally from the NE corner, turn 90 degrees west to meet back at the SW corner (corner #1).
6. Once the crew has laid out the meter tapes and pin flags, and is certain that the plot can be accepted at the location, install the rebar markers. Drive 0.5 in diameter rebar into the ground at each corner point, leaving 5 cm sticking up above the ground. Place an aluminum rebar cap on each rebar.

Maintain straight lines along plot boundaries, even if vegetation is in the way. When trees are encountered along the plot boundaries, use temporary survey markers to start and stop reel tape lines on either side of a tree, maintaining a straight layout. Two people should perform this task with one person holding one end of the meter tape and a second person measuring out the 50 m distances and placing the flags in the ground at the corners. Both people should check that the correct azimuth is being followed. It is critical to take care at this step to ensure the plot is correctly laid out since this will be the permanent plot for the life of the project. If a mistake is made, go back and correct it, not matter how far back in the process the mistake occurred.

Subplot Boundary Layout

The following procedures are to facilitate plot reading and are not part of the permanent marking procedure. Therefore, these procedures are conducted each time a plot is visited and measurements taken. After the permanent markers at the four macroplot corners are located, place temporary pin flag markers at 10 m intervals starting at the anchor pin (i.e., corner #1) and moving north along the plot west edge to corner #2 (Figure 3.1). Repeat this procedure on the opposite side of the macroplot, moving south from corner #3 along the plot east edge to corner #4. Moving from east to west or vice versa, use as many pin flags as necessary to mark the four boundary lines between subplots. Pay special attention to clearly mark which subplot a tree belongs in if it falls near the line.

Take three photos once the macroplot and subplot boundaries are delineated. Take one photo from corner point #1 toward the plot center and another photo from corner point #3 toward the plot center. Record the photo file names, their locations, and azimuth. Take a third photo from a landmark feature (e.g., large boulder) where the general nature of the stand that the macroplot sits in is apparent. Record the photo file name, distance, and azimuth from the landmark to corner point #1, and take descriptive notes of the landmark feature. Detailed notes should also be made describing the plot setting and landscape configuration that will aid plot revisits (e.g., very few trees situated on a saddle, or dense stand lying in a gully) and note any unique aspects about the area.

Plot Offsetting and Replacement

If a plot meets any of the rejection criteria listed in Table 3.1, initiate offsetting procedures to see if a suitable plot can be located. To do this, draw a random azimuth between 0° and 359° and a random distance between 5 m and 120 m, and move to that location and review the rejection criteria again.

Accept this point as the new permanent plot location if none of the rejection criteria is met. A list of random numbers for distance (between 5 m and 120 m) and azimuth (between 0° and 359°) will be provided to crews before each hitch. Random numbers will be automatically generated in the field computer, if used. If using a paper random number table, use the list in sequential order such that the first site where the initial point is unsuitable uses the first set of numbers from the random numbers list, etc. Permanently establish the plot following the above procedures. Note Offset in the notes field of the data sheet and note the direction and distance used.

If the new offset point is also unsuitable, the site is dropped and replaced with the first (or next to be used) GRTS point on the oversample list (Appendix A). Navigate to the next point (plot location) on the original trip (hitch) list. Note that the replacement point will likely not be near the dropped site and may not be visited until another hitch to another part of the Park. The Project Lead or Field Lead will coordinate the inclusion of new oversample sites into hitch planning. Note that this issue will be rarely encountered once all three panels have been visited and sites established. However, there may be occasions when plots need to be retired and replaced over time.

If a plot fails to meet the rejection criteria and at least one live white pine tree is in the plot, but a portion of the plot lies in an inaccessible area, then the plot is shifted away from the area and into accessible terrain. For example, if a 50 x 50 m plot has 10 m at one of its edges land against a cliff face, the plot is shifted away from the cliff by 10 m. This is only done for inaccessible areas and not for non-target vegetation or land cover. Examples of inaccessible areas include bodies of water, slopes >35°, and glaciers. An example of non-target vegetation or land cover includes a dense stand of Douglas-fir in GRBA. If there is a single live white pine tree near the beginning of the plot, and the plot then runs into a pure Douglas-fir stand, for example, the plot is still established in its intended direction. Non-target forest and land cover types are included as long as the minimum requirements of plot establishment are met. If the plot is shifted, notes are made recording the direction, distance, and reason for the shift. A new macroplot anchor point (i.e., corner point #1) will result in these cases and must be documented. However, if a plot intersects a permanently altered and non-natural land cover type, such as a parking lot or paved road where there is no possibility of white pine tree establishment and growth, the plot should be offset or replaced.

Regeneration Plots

There are nine regeneration plots in each macroplot; three sets of three running through subplots 1, 3, and 5 (Figure 3.1). These plots are 3 x 3 m and are not permanently marked, but they are numbered consecutively beginning at corner #1 and zigzag through the subplots of the macroplot; crewmembers measure then regeneration plots by moving east through subplot 1, 3, and 5, and west through subplots 2 and 4 (Figure 3.1). These plots should be marked as the regeneration plot data is collected, therefore it is described in detail in SOP 4- Measuring Response Variables.

Tagging Trees

All trees taller than breast height (1.37 m) will be tagged at breast height. The exception is that dead, non-target species trees <5 cm DBH will not be tagged or measured. A tree, or cluster of trees, is included if at least half of the bole lies within the plot boundary. For trees <5 cm DBH, tags will be loosely wired near breast height. For trees ≥5 cm DBH, tags will be nailed to the tree at breast height

with the nail head pointing slightly downward so that moisture runs away from the bole and driven in only deep enough to secure the tags. It is essential that the tags be nailed at breast height so that future diameter re-measurements are taken at precisely the same location and thus allows tree diameter growth to be accurately calculated for long-term trend analyses. Measuring trees with wired-on tags should be done carefully because the tag may be resting higher or lower than 1.37 m. The sequentially-numbered tags are made of stainless steel or aluminum. The tags are about 2.5 cm in diameter and are generally inconspicuous. Tree tags are placed on the same side of the bole throughout the macroplot. The direction of tag placement is determined by considering the relative position of the macroplot to features that may bring Park visitors near the plot. For example, if there is a trail east of the macroplot, tree tags should be placed on the west side of trees – away from visitor sight. If there is a hiking trail or road near the plot, place the tree tags on the opposing side of the tree for the entire plot. If there are no roads or trails, then the north side of the trees should be tagged (i.e., the default). The location of tag placement (side of tree) is recorded on the data sheet if it has been changed from the default north side.

Limber pine often grow in “tree clumps”. Tree clumps are groups of stems that may be branches of the same individual (i.e., same genotype) or multi-genic clusters of individual trees (i.e., multiple genotypes in the same clump). This characteristic growth form is usually the result of the caching behavior of Clark’s nutcracker (Linhart and Tomback 1985). Nutcrackers place multiple seeds in a cache and these seeds are often gathered from more than one parent tree. The distinction between multi-genic tree clusters and multiple stems of the same individual is impossible to make in the field. However, given the monitoring objectives, it is important to accurately quantify tree clump structure so that estimates of plot structure and composition are reasonably accurate. The section below outlines how to distinguish individual trees, stems that are part of a clump, and branches of a stem, and describes how to treat each condition as it relates to tagging and recording trees. This procedure is similar to that used in the Whitebark Pine Ecosystem Foundation methods (Tomback et al. 2005) and by the Greater Yellowstone Network (Greater Yellowstone Whitebark Pine Monitoring Working Group 2007).

- 1) Individual tree: If a stem is growing in a tree clump and can be traced separately to ground level (i.e., not connected to another stem), then it is considered a separate tree and not a member of the tree clump. It receives a tree tag with a unique number and no letter designation (see below).
- 2) Stem part of a tree clump: If a stem is growing in a tree clump and is attached to another stem above ground level but below 1.37 m (DBH), then it is considered to be a member of the tree clump (i.e., not an individual tree). It receives a tree tag with a unique number and a letter designation. (Stems attached to other stems but that split apart above 1.37 m are treated as the same tree because they would only have one DBH.) Each stem in a tree clump receives a tree tag with a unique tag number and letter on the data sheet or database; letters are assigned in consecutive order. See example below.
- 3) Branches: Branches do not receive tree tags. Figure 3.2 details these conditions. A stem is considered a branch of another stem if any of the following three conditions are met.

- o If there is not a discernible growth groove that separates the stem from another stem, then it is a branch.
- o If the diameter of the stem is $<25\%$ of the diameter of the main bole, then it is a branch.
- o If the angle where the stem in question splits from the main stem is at an angle $>45^\circ$ from the main stem, then it is a branch.

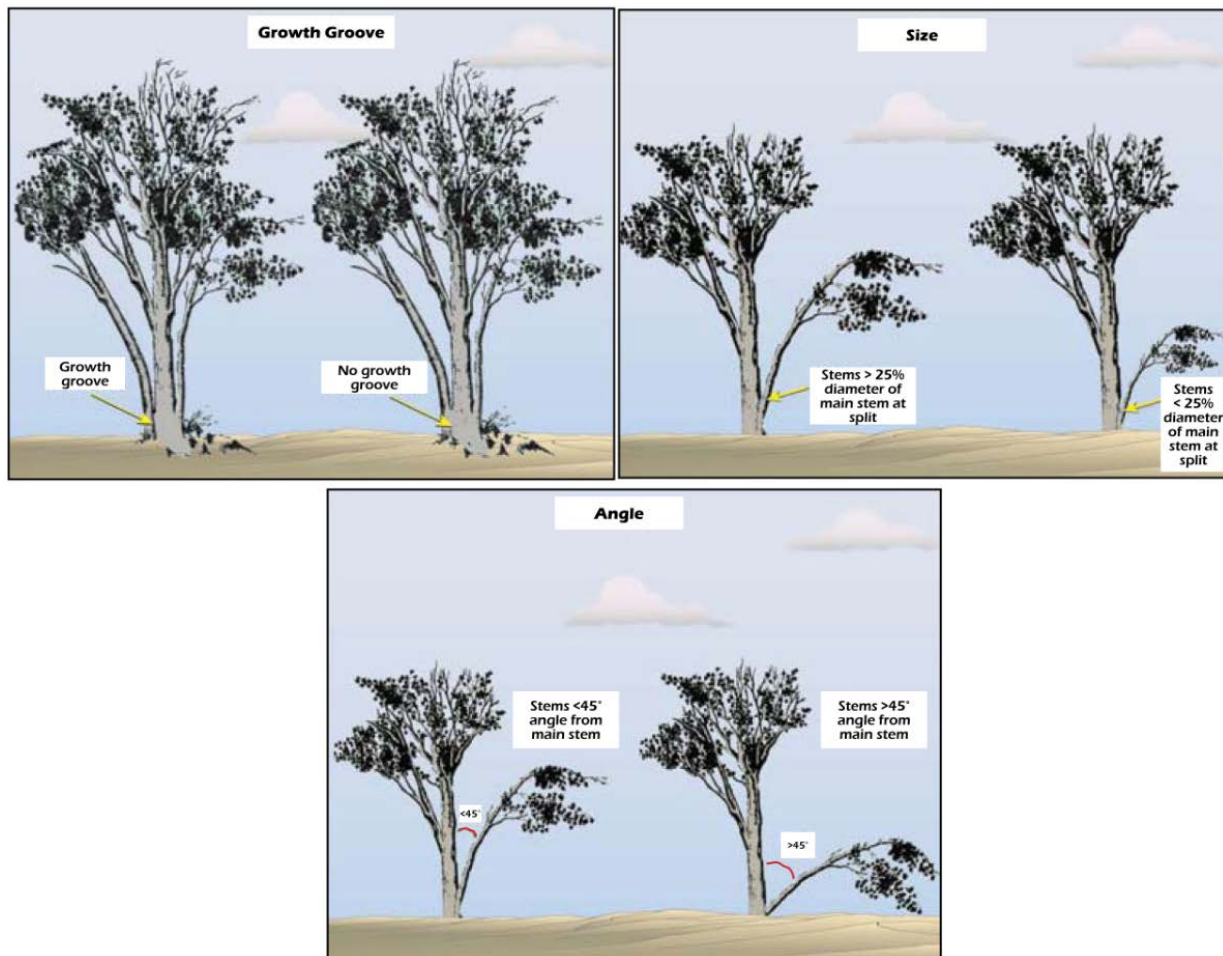


Figure 3.2. Figure showing growth groove distinction, size requirement, and angle requirement for differentiating between individual trees and clumps. Figure modified from the Greater Yellowstone White Pine Monitoring Program.

For example, consider approaching a cluster of trees. The first stem is growing in association with the cluster, but its stem extends to the ground uninterrupted by another stem. It is considered a tree and receives a tree tag with a unique number (e.g., #100) and does not have a clump letter assigned to it. The second tree has four stems that are joined above ground level, but below 1.37 m. Each stem has a growth groove, is $>25\%$ the diameter of the largest stem, and is growing at an angle $<45^\circ$ from the main stem. These four stems would be counted as part of a

tree clump and would be assigned the following tree tags with clump letter designation: 101a, 102b, 103c, and 104d. The unique tag numbers tell us that these stems are individual stems, and not branches, and therefore are included in calculations for basal area and composition, for example. The letter designation tells us that they are located within a tree clump.

Lastly, each tree clump is given a number in the data sheet that is assigned in a consecutive order. For the example given above, if this was the fourth tree clump found in the plot, the data sheet would indicate tree clump 4 for each tagged tree (101a, 102b, 103c, and 104d).

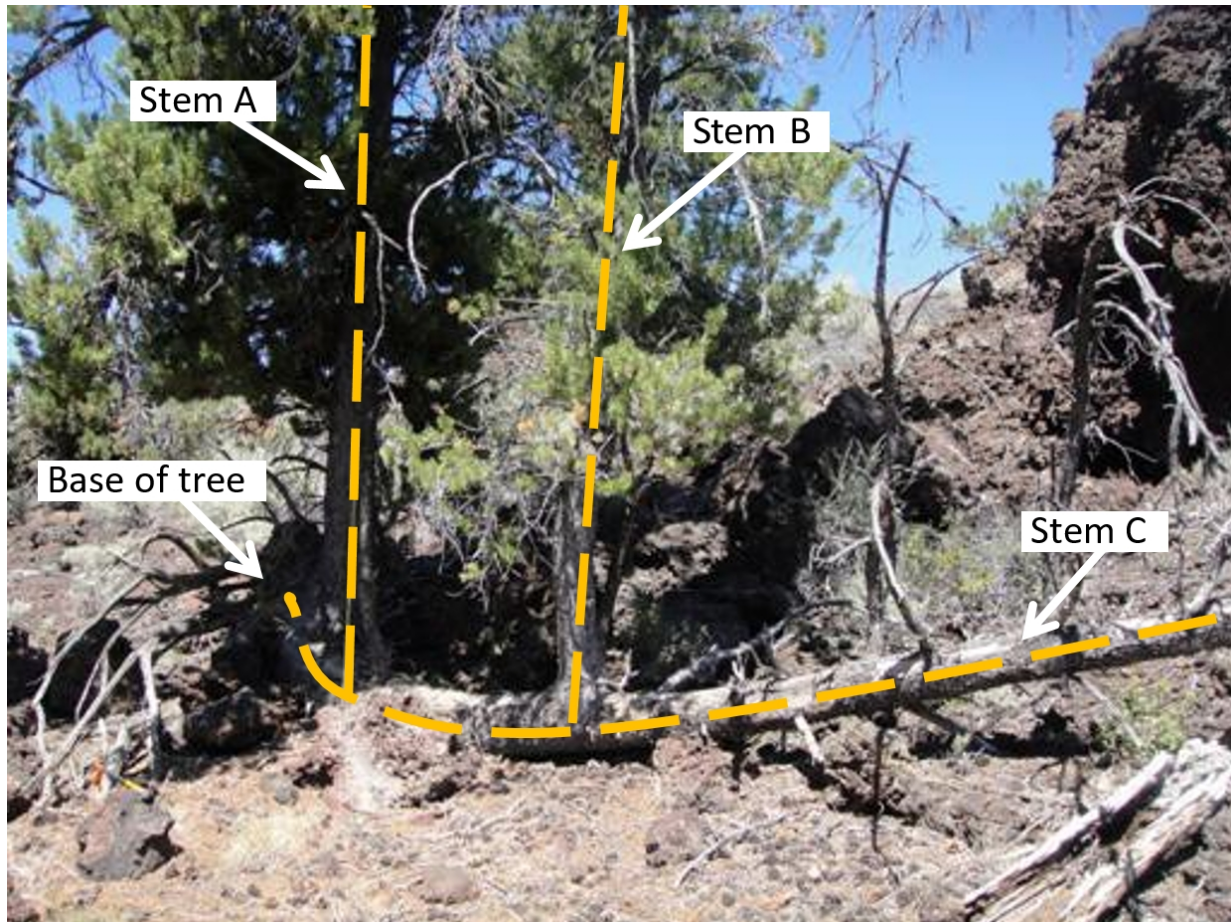


Figure 3.3. Photograph showing fallen limber pine within a monitoring plot in Craters of the Moon National Monument and Preserve. Stem C was the original leader and is now laying horizontal and completely dead. Stems A and B were originally branches and are now growing as leaders. Stem A was tagged and recorded because it had the largest DBH. Stem B had a similar DBH as stem A (over 25%) and the angle $<45^\circ$ from stem A. Stem B was not recorded, however, because there was no obvious growth groove separating stem A and stem B.

Krummholz

Trees growing at high elevations and in cold and windy exposed areas may grow in a stunted or twisted form called krummholz (German word meaning crooked, bent, or twisted wood). Harsh growing conditions can cause these trees to grow prostrate and resemble a shrub with many

branches. It is often difficult to distinguish a main stem from a branch in a krummholz because of the low growth form. Each krummholz must be dealt with on a case by case basis with observers carefully searching for growth grooves that could differentiate a single krummholz tree from a clump. Only trees reaching 1.37 m height should be tagged and measured. Figure 3.4 shows an example photo of a krummholz whitebark pine tree.



Figure 3.4. Photograph showing whitebark pine tree growing in krummholz growth form. Tree is growing in an exposed, high elevation area in Sequoia and Kings Canyon National Parks and exhibits the stunted and bushy form typical of krummholz. Photo taken by Robert Kenan, NPS.

Version 1.0

Version #	Date of Revision	Revised By	Changes

Before Going into the Field

Measuring Response Variables

Repeat this procedure until all five subplots have been read.

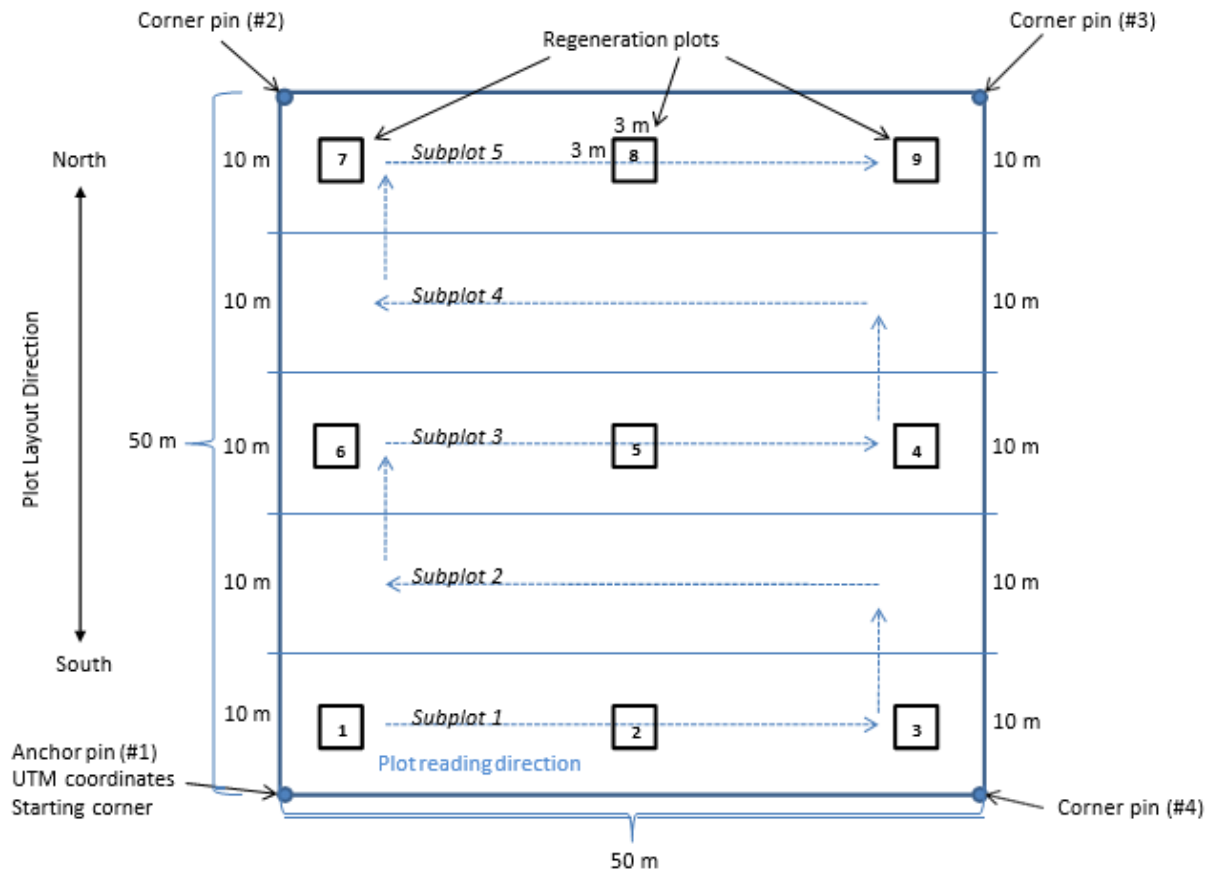


Figure 4.1. Plot design for macroplot. Macroplot is 50 m x 50 m and consists of five, 10 m x 50 m subplots to facilitate plot reading and quantitative comparisons with other monitoring projects. Within each macroplot are nine, 3 m x 3 m regeneration plots.

During plot revisits, the plot recorder has information about which subplot each tagged tree is located in (SOP 3) and should communicate with the plot reader about this. In plot revisits, it is critical that the reader carefully search for trees that were missed during plot establishment and does not get complacent when all of the tagged trees have been found. In addition, seedlings (defined as an individual <1.37 m height) will recruit into the tree class (i.e., ≥ 1.37 m height) over time, and therefore, new untagged trees will be encountered. What to do with untagged trees is discussed below.

All information is called out by the plot reader and verbally repeated by the plot recorder. It is the reader's responsibility to correct the recorder if they made a mistake in repeating the information. If the recorder does not hear a correction, then they enter the information on paper data sheet or tablet (depending on the network).

Note the location, species, and if possible, an approximate count of the number of plants within any patches of noxious weeds that are encountered while working in parks. For abundant species like cheatgrass, this is not necessary. However, for rare and incipient infestations, white pine crews may

provide invaluable early detection of invasive species. Provide this information in plot notes in the data entry form (field computer) or data field sheet, and alert Park staff as soon as possible.

Tree-level Data

For all trees (except dead, non-target species with a DBH <5 cm), measure and record the following: subplot number, tag number, tree clump number and clump letter if applicable (see SOP 3), species, status (live, dead, recently dead, live krummholz, etc.), DBH (± 0.1 cm, the location where the nail is in the tree), and height (± 0.1 m). Status of trees in a krummholz growth form will be labeled as live krummholz, dead krummholz, or recently dead krummholz (SOP 3). For dead trees, determine which category the tree belongs to: recently dead (no green needles present) or dead (no needles on the tree). If a tagged tree is dead during a revisit, record dead or recently dead, and attempt to determine its proximal cause of death by the categories: fire, beetle, rust, mistletoe, mechanical, or unknown. Measurements and assessments are not made in subsequent revisits once a tree is determined to be dead.

For living trees that are white pine species (i.e., limber and bristlecone pine), visually divide the bole and the branches each into thirds (thus six areas). Use binoculars to carefully and systematically search the bole and branches of the tree for signs of blister rust infection, looking on as many sides of the tree as is possible. Record an “A” for an active canker (i.e., a canker with visible aecia, or fruiting bodies containing spores) or an “I” if at least three of the following six *indicators* are present in the same location on the tree (e.g., upper third branches): rodent chewing, flagging, swelling, roughened bark, old aecia, and oozing sap. Photos and descriptions of each of these indicators are presented in Hoff (1992). Mark the indicators used to determine an “I” designation on the data sheet.

For this protocol, a “bole” is defined as the vertically oriented part of the tree extending from the ground to a division point or split where the observer can no longer discern the bole from a branch based on diameter. A bole ends at the last vertical section of the main stem. If a bole canker extends across two different thirds of the bole, its location is assigned to the lower third. Branches are defined as all the main branches that begin as bifurcations off the bole, encompassing all foliage, and supporting twigs and side branches. We use the term branches by convention and for consistency with established monitoring projects; note that this definition is the same as that for canopy.

The percentage of the total tree canopy that has been killed by blister rust is estimated by visually dividing the tree’s crown into thirds and estimating the percentage crown kill for each third (McKinney and Tomback 2007). Therefore, a crown kill (%) value is recorded for each third of the crown of an infected tree. All dead branches are considered, whether caused by blister rust, bark stripping, or mechanical damage. The three different crown kill values are averaged for each tree infected with blister rust during data analysis so that each infected tree has one crown kill value.

For living trees, look for signs of mountain pine beetle current or past infestation and record presence/absence of: pitch tubes, J-shaped galleries, and frass. It is important to note that J-shaped galleries (or crooks at the lower end of the gallery) are only searched for on dead or recently dead pine trees because bark has to be peeled away to determine if this condition is present. Therefore, living pine trees can only receive a positive indication of beetle infestation by the external signs of

pitch tubes and/or frass. For dead pine trees, use a hatchet to peel away bark and look for the characteristic J-shaped gallery in the tree's cambium. Also search for indications of dwarf mistletoe infection and record yes or no for mistletoe infection.

Search each live white pine tree with binoculars for the presence of ovulate (female) cones and record whether cones are present or absent. Ovulate cones are quite small in early summer and put on most of their growth throughout the summer. It is therefore important to take care when surveying trees for cones during this time-period (June to early July). Use multiple vantage points and look within needle bundles for signs of emerging cones.

During plot revisits, locate the corner of each subplot where initial tree tagging occurred. The data recorder should look at the data record and tell the field reader what the first tag number is. The crew should move throughout the sub-plot, beginning with the first tree previously tagged. All trees should be systematically searched for a tag. Trees previously tagged are re-measured and recorded. All new trees (i.e., untagged trees) are tagged. Record the tag number, subplot number, and in the notes indicate the tag number, distance, and direction of its closest neighbors. Make and record all necessary measurements. Record on the data sheet the total number of "new" trees that were tagged during the sampling event. If a previously recorded tree is not found during a plot revisit, look at the data sheet to determine which subplot the tree was in, and which trees were its closest neighbors. Systematically search the ground area where the tree is believed to have been and record the outcome in the notes section of the data sheet or tablet. For example, record whether the tag was found on the ground, or not found at all.

Regeneration Data

Seedling densities are estimated in the nine 3 m x 3 m regeneration plots situated within each macroplot (Figure 4.1). Follow these steps to locate where the regeneration plots must be measured within the macroplot.

1. From each corner point of the macroplot, measure 3 m in either direction of the macroplot boundary, and then measure 3 m into the macroplot. Mark this point with a pin flag; this point represents the outer corner of each of the four corner regeneration plots – numbers 1, 3, 7, and 9 (Figure 3.1). Establish the other three corners for each of these regeneration plots by measuring 3 m in the appropriate direction and marking the corners with a pin flag (Figure 3.1).
2. The five remaining regeneration plots (numbers 2, 4, 5, 6, and 8) are located near the 25-m midpoints of each macroplot side, with regeneration plot 5 situated over plot center of the macroplot (Figure 3.1).
3. Move directly east from corner #1 towards corner #4 for 23.5 m using the reel tape. Turn 90° from this point into the plot (north) and follow for 3 m. Mark this point with a pin flag. This is the SW corner of regeneration plot 2.
4. Follow the same procedures to mark the other three corners as given above for regeneration plots 1, 3, 7, and 9. After completing subplots 1, 2, and 3, move to corner #4 and follow the plot boundary north for 23.5 m using the reel tape. Turn 90° from this point into the plot (west) and follow for 3 m. Mark this point with a pin flag. This is the SE corner of regeneration plot 4.

5. Follow the same procedures to mark the other three corners as given above for regeneration plots 1, 3, 7, and 9. Move west along boundary line between subplots 2 and 3 for 23.5 m using the reel tape. Turn 90° from this point into subplot 3 (north) and follow for 3.5 m. Mark this point with a pin flag. This is the SE corner of regeneration plot 5.
6. Follow the same procedures to mark the other three corners as given above for regeneration plots 1, 3, 7, and 9. Move to west side of macroplot until reaching 23.5 m point on macroplot boundary line between corner #1 and corner #2. Turn 90° from this point into subplot 3 (east) and follow for 3 m. Mark this point with a pin flag. This is the SW corner of regeneration plot 6.
7. Follow the same procedures to mark the other three corners as given above for regeneration plots 1, 3, 7, and 9. Following establishment of regeneration plot 7, move east from corner #2 to corner #3 for 23.5 m using the reel tape. Turn 90° from this point into the plot (south) and follow for 3 m. Mark this point with a pin flag. This is the NW corner of regeneration plot #8.
8. Follow the same procedures to mark the other three corners as given above for regeneration plots 1, 3, 7, and 9. Establish regeneration plot 9 following the same procedures as given above for 1, 3, and 7.

Regeneration subplots are numbered, and data are recorded by regeneration plot number. Beginning at regeneration plot #1 (lower left corner of the macroplot, corner #1). Within each regeneration plot, tally all conifer seedlings and record them by species and height class as follows: class 1 = 20 to <50 cm; class 2 = 50 to <100 cm; class 3 = 100 to <137 cm).

Multiple handheld tally devices should be used to keep track of seedling counts for dense regeneration plots. Begin with a single species (e.g., bristlecone pine). Use one tally device to record the number of bristlecone pine seedlings in height class one, a second tally device for class two, and a third for class three. Be sure to keep track of which height class is being recorded.

Seedlings can be marked with a temporary tree marking crayon to eliminate confusion surrounding which seedlings have been counted and which seedlings have not. Once you have finished with all the bristlecone pine seedlings in a given regeneration plot, repeat the procedure for the next species until all species have been recorded.

Standard Operating Procedure (SOP) 5: Data Management

Version 1.0

Revision History

Version #	Date of Revision	Revised By	Changes

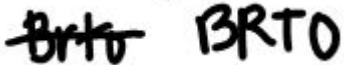
This SOP describes the data management procedures used for the data collected during white pine monitoring. The database model is described in detail, including definitions of all input and computed data fields. Procedures for data certification, data archiving, quality assurance/quality control (QA/QC), and handling of sensitive information are provided. A list of the yearly white pine monitoring data management tasks is presented, including timing for execution of various data management steps.

Data Collection

Collecting and managing data

Data collected in the field will be recorded on paper data sheets until an electronic data collection system is deemed practical. To minimize potential ambiguity of field data sheets, MOJN has established handwriting best practices, which are summarized in Table 5.1.

Table 5.1. Handwriting best practices.

Description	Correct Method
Use a line through the 7	
Use a line through the 0 (zero)	
Single line through mistakes Never erase Never scribble out	
Never use "ditto" marks	Line with arrow through the column or row where data is repeated
Clear distinction between P and D	
Date format	mm/dd/yyyy
Time format	24 hour, hh:mm (e.g. 13:00)
Fill in every field	use a line through it or N/A (not applicable)
Decimal points	Points should be distinct and unmistakable for commas or dashes
Park or Park Code is always four alpha characters	DEVA, GRBA, JOTR, LAKE, MANZ, MOJA, PARA

Before leaving a stand, the crew leader is responsible for ensuring that all forms have been filled out completely and that the information on each form is logical and legible. Upon returning from each field trip, data sheets will be filed in the incoming data file cabinet. After data have been entered into the database, the field data sheets will be scanned to 300 dpi or greater PDF files. When retroactive changes are made to paper data sheets, they must be re-scanned. The Protocol Lead is responsible for safekeeping and organization of the data sheets until data entry and verification procedures have been completed, at which point the data sheets are stored, and eventually archived, by the network Data Manager.

Importing and managing photographs

To import photographs from a MOJN camera memory card, insert the card into a USB card reader and plug the reader into a computer that has access to the MOJN shared drive (M:\). Open Windows Explorer and navigate to the memory card. Run the script titled TransferPhotos.bat and follow the prompts. For devices without a memory card (e.g. phone camera) or memory cards without the TransferPhotos.bat script, consult the Data Management team.

All incoming photos can be found in M:\MONITORING_FieldPhotoOriginals_DoNotModify. The photos in this folder are organized by memory card ID and date and should never be renamed or edited. White pine monitoring photos should be copied into M:\MONITORING\Pine\Data\Images and organized by park, at which point they may be renamed according to the following convention:

PlotID_YYYYMMDD_description

PlotID is the unique plot ID code. This code includes the four-letter park code, a letter indicating the protocol (“N” for Pine), and a 3-digit number indicating the GRTS number of the plot.

The *description* should adhere to the following standard, where ##### is a four digit number corresponding to the last four digits of the original photo filename, C1 and C3 stand for plot corners #1 and #3, respectively, and L stands for the landmark from which the third plot photograph is taken. If the plot is rejected, overview photos of the plot must also be taken:

Repeat Photos

C1_####

C3_####

L_####

Plot Rejection Photos

REJECT_####

Project File Storage Conventions

All of the files associated with the development and implementation of this protocol will be stored on the MOJN server under the folder \Monitoring\Pine.

The Pine folder will contain at a minimum the following folders:

- **Analyses** (Contains R scripts and results)
- **Data**
 - o **Database** (Contains the database front-end, current backend, and backups of previous database versions)
 - o **FieldData** (Contains a scan of all field data sheets grouped in folders by park and field season.)
 - o **Images** (Contains all photographs taken at a site grouped in folders by park and field season.)
- **Implementation**
 - o **FieldDataForms** (Contains blank field data sheets and lookup code “cheat sheets”)
 - o **GIS_Basedata** (Contains spatial data for navigation and simple map making)
 - o **SitePackets** (Contains a Word file for each spring including navigation waypoints and a map with the suggested access route)
- **ProjectFiles**
 - o **Permits** (Contains copies of permits for conducting field work)
 - o **Protocol** (Contains folders for the published protocol narrative and SOPs, draft revisions of the narrative and SOPs, and files documenting the protocol development process)

- o **SampleDesign** (Contains files specific to the GRTS draw)
- **Reports** (Contains data and trends reports)

Other parts of this SOP will provide additional information on required file naming procedures that are specific to this protocol. Where file naming procedures are not defined, it should be assumed the MOJN general SOP *MOJN File Naming Conventions* is applicable.

Database Design

The MOJN white pine data will be stored in a MOJN-hosted copy of the Microsoft Access database that is used by UCBN, SIEN, and KLMN to store their white pine data. The database structure conforms to the standards of version 3.2 of the Natural Resource Database Template (NRDT), and consists of a user interface front-end (holding user forms for data entry, review, and export) that is linked to a back-end database file (holding the core pine data tables). Network-specific components of the database such as equipment lookup tables will be populated with information relevant to MOJN. The database will track the quality control and quality assurance process (data processing level) that has been applied to each site visit. A data model for the white pine monitoring database shows the relationships among the core data tables, lookup tables, and cross reference tables (Figure 5.1).



Data Dictionary

This data dictionary provides a description for every table in the database back-end file, and for each table, lists the field names and their associated field type, size, and description.

Table 5.2. Data dictionary for tbl_Sites. A Site can be a Park, a Park Sub-Unit, or a Sampling Frame within a Park or Park Sub-Unit. All sampling plots fall within a Site.

Field Name	Type	Format	Description
Site_ID	GUID	alphanumeric	Primary key, uniquely identifying each tbl_Sites record
GIS_Location_ID	GUID	alphanumeric	Link to GIS feature, if applicable
Network_Code	text	4-letter code	Network code
Unit_Code	text	4-letter code	Park unit code
SubUnit_Code	text	4- to 8-letter code	Park sub-unit code, if applicable
Sample_Frame	text	4- to 8-letter code	Sampling frame (if applicable) in which Plots are located
Site_Name	text	(e.g., Unit_SubUnit_SampleFrame)	Unique name for a site (includes UnitCode and/or SubUnitCode)
Site_Description	text	up to 255 characters	Description for a site, if applicable
Site_Notes	text	up to 255 characters	General notes on the site, if applicable

Table 5.3. Data dictionary for tbl_Locations. A Location is a Plot to be sampled. UTM Coordinates are associated with the SW corner of the Plot.

Field Name	Type	Format	Description
Location_ID	GUID	alphanumeric	Primary key, uniquely identifying each tbl_Locations record
Site_ID_F	GUID	alphanumeric	Link to tbl_Sites (foreign key)
GIS_Location_ID	GUID	alphanumeric	Link to GIS feature, if applicable
Meta_MID	GUID	alphanumeric	Link to Metadata record (e.g., NPS Data Store recordID)
PlotID_Number	Integer	numeric	Location (PlotID) number
Loc_Name	text	up to 100 characters	Name of the location (constructed from SiteName [tbl_Sites] and PlotID_Number)
Panel_ID	text	Up to 15 characters	Panel associated with Location (Plot). (E.g., 1, 2, 3, OS, where OS stands for Over-Sample)
Panel_YrEst	Integer	numeric	Year that Panel plot locations were established
PlotCorner_Primary_Ref	text	up to 10 characters	Plot Corner used as primary XY Coordinates for Plot (Default is SW)
PlotCorner_X_Coord	Double	decimal	X coordinate of Plot Corner Primary Reference
PlotCorner_Y_Coord	Double	decimal	Y coordinate of Plot Corner Primary Reference
PCornerPrim_to_PC2_Azi m	Integer	numeric	Azimuth (degrees) from Primary Plot Corner to Plot Corner 2 (Default is 0)
Coord_Units	text	(e.g., meters)	Coordinate distance units (meters)
Coord_System	text	(e.g., UTM)	Coordinate system
UTM_Zone	text	(e.g., 11N)	UTM Zone
Datum	text	(e.g., NAD83)	Datum of mapping ellipsoid
Est_H_Error_m	Double	decimal	Estimated horizontal accuracy in meters
Accuracy_Notes	text	up to 255 characters	Positional accuracy notes, if applicable
GPS_Unit	text	up to 100 characters	GPS unit used to collect Location coordinates, if applicable
Updated_Date	Date	mm/dd/yyyy	Date of entry or last change
Loc_Notes	text	up to 255 characters	General notes on the location, if applicable
Plot_X_Orig_IfChg	Double	decimal	Original X Coordinate (stored if Coordinate changed via frontend DB form)
Plot_Y_Orig_IfChg	Double	decimal	Original Y Coordinate (stored if Coordinate changed via frontend DB form)

Table 5.4. Data dictionary for tbl_LocData_PlotInfo. UTM Coordinates and Azimuths of Corner Points of the Location (plot). Coordinates are collected with GPS unit, and Azimuths are collected with compass.

Field Name	Type	Format	Description
PlotCorner_ID	GUID	alphanumeric	Primary key, uniquely identifying each tbl_LocData_CornerPoints record
Location_ID	GUID	alphanumeric	Link to tbl_Locations (foreign key)
PlotCorner2_Ref	text	up to 10 characters	Plot Corner 2 name (Default is NW)
PC2_X_Coord	Double	decimal	X coordinate of Plot Corner 2
PC2_Y_Coord	Double	decimal	Y coordinate of Plot Corner 2
PC2_to_PC3_Azim	Integer	numeric	Azimuth (degrees) from Plot Corner 2 to Plot Corner 3 (Default is 90)
PlotCorner3_Ref	text	up to 10 characters	Plot Corner 3 name (Default is NE)
PC3_X_Coord	Double	decimal	X coordinate of Plot Corner 3
PC3_Y_Coord	Double	decimal	Y coordinate of Plot Corner 3
PC3_to_PC4_Azim	Integer	numeric	Azimuth (degrees) from Plot Corner 3 to Plot Corner 4 (Default is 180)
PlotCorner4_Ref	text	up to 10 characters	Plot Corner 4 name (Default is SE)
PC4_X_Coord	Double	decimal	X coordinate of Plot Corner 4
PC4_Y_Coord	Double	decimal	Y coordinate of Plot Corner 4
PC4_to_PC1_Azim	Integer	numeric	Azimuth (degrees) from Plot Corner 4 to Plot Corner 1 (Default is 270)
Coord_Units	text	(e.g., meters)	Coordinate distance units (meters)
Coord_System	text	(e.g., UTM)	Coordinate system
UTM_Zone	text	(e.g., 11N)	UTM Zone
Datum	text	(e.g., NAD83)	Datum of mapping ellipsoid
GPS_Unit	text	up to 100 characters	GPS unit used to collect Plot Corner coordinates
LocData_Date	Date	mm/dd/yyyy	Date on which Plot Corner data collected
Plot_Aspect_deg	Integer	numeric	Orientation of Plot (degrees, 0-359)
Plot_Aspect_Notes	text	up to 255 characters	Notes regarding plot aspect measurement
Plot_Elevation_m	Integer	numeric	Elevation (meters) above sea level of Plot
Plot_Elev_Notes	text	up to 255 characters	Notes regarding plot elevation measurement
Plot_Slope_deg	Integer	numeric	Slope of Plot (degrees)
Plot_Slope_Notes	text	up to 255 characters	Notes regarding plot slope measurement

Table 5.5. Data dictionary for tbl_Events. An Event is a sampling occurrence at a Plot. Observers (from tluContacts) are recorded in xref_Event_Contacts table.

Field Name	Type	Format	Description
Event_ID	GUID	alphanumeric	Primary key, uniquely identifying each tbl_Events record
Location_ID	GUID	alphanumeric	Link to tbl_Locations (foreign key)
ProtoVersion_ID	text	alphanumeric	Link to tlu_Protocol_Ver (indicates the Protocol version in use at time of Event)
Start_Date	Date	mm/dd/yyyy	Starting date for the event
Start_Time	DateTime	24 HR time	Starting time for the event
End_Date	Date	mm/dd/yyyy	Ending date for the event
End_Time	DateTime	24 HR time	Ending time for the event
SeedlingCnt_PlotSize	Integer	numeric	Size (length of single side, in meters) of Seedling Count plots (default is 3)
NoSeedlingsInPlot_YN	text	Yes/No	Yes/No field for indicating whether or not any seedlings were found in plot
Event_Notes	text	up to 255 characters	Notes regarding the sampling Event, if applicable
Plot_Notes	text	up to 255 characters	Notes regarding conditions/observations at the Plot at time of sampling, if applicable
WildObs_Notes	text	up to 255 characters	Notes regarding wildlife observations at the Plot at time of sampling, if applicable
SqMidden_Count	Integer	numeric	Count of Pine Squirrel middens within the Plot
Sq_FreshCones_YN	text	Yes/No	Presence (Yes/No) of fresh sign of cone consumption by Pine Squirrels in Plot
Repeat_Sample_YN	text	Yes/No	Yes/No field for indicating whether Event represents a repeat sample, within a given year, of the Location (Plot). Any repeat samples are rarely used, and are excluded from data summaries.

Table 5.6. Data dictionary for tbl_EvData_PlotPhotos. This table holds information about Plot Photos taken during a sampling Event.

Field Name	Type	Format	Description
PlotPhoto_ID	GUID	alphanumeric	Unique identifier for each tbl_EvData_PlotPhotos record
Event_ID	GUID	alphanumeric	Co-Primary key. Link to tbl_Events (foreign key)
PlotPhoto_Number	Integer	numeric	Co-Primary key. Plot Photo number (sequential for photos taken at a given Plot)
PlotPhoto_File_Name	text	up to 255 characters	Name of Plot Photo file. SiteName_PlotNumber_Date (where Date in yyyyymmdd format)
PlotPhoto_File_Path	text	up to 255 characters	File Path (directory folder location) of Plot Photo file
PlotPhoto_Loc_Ref	text	up to 25 characters	Location Reference for Plot Photo (Corner 1, Corner 3, or See_Notes)
PlotPhoto_Bear_deg	Integer	numeric	Bearing (in degrees) on which Stand Photo taken, if applicable
Camera_ImageID	text	up to 55 characters	Image ID from the field camera
PlotPhoto_Notes	text	up to 255 characters	Notes regarding Plot Photo, if applicable
PlotPhoto_Date	Date	mm/dd/yyyy	Date on which Plot Photo taken

Table 5.7. Data dictionary for tbl_EvData_SeedlingCounts. This table holds all of the Seedling Counts associated with a sampling Event.

Field Name	Type	Format	Description
SeedlingCount_ID	GUID	alphanumeric	Unique identifier for each tbl_EvData_SeedlingCounts record
Event_ID	GUID	alphanumeric	Co-Primary key. Link to tbl_Events (foreign key)
Seedling_SubPlot_ID	Integer	numeric	Co-Primary key. SubPlot number associated with seedling count record
Species_Code	text	6 characters	Co-Primary key. Species code (from tlu_Species_Parks); includes Dead
HghtClass_Descrip1	text	up to 55 characters	Height Class Description 1 (from tlu_HeightClass_Seedlings)
Height_D1_Count	Integer	numeric	Count of Height Class Description 1 seedlings for the given species
HghtClass_Descrip2	text	up to 55 characters	Height Class Description 2 (from tlu_HeightClass_Seedlings)
Height_D2_Count	Integer	numeric	Count of Height Class Description 2 seedlings for the given species
HghtClass_Descrip3	text	up to 55 characters	Height Class Description 3 (from tlu_HeightClass_Seedlings)
Height_D3_Count	Integer	numeric	Count of Height Class Description 3 seedlings for the given species
Seedling_SubPlot_Notes	text	up to 255 characters	Notes regarding SubPlot seedling count, if applicable

Table 5.8. Data dictionary for tbl_EvData_TreeData. This table holds all of the Tree Data associated with a sampling Event.

Field Name	Type	Format	Description
TreeData_ID	GUID	alphanumeric	Unique identifier for each tbl_EvData_TreeData record
Event_ID	GUID	alphanumeric	Co-Primary key. Link to tbl_Events (foreign key)
TreeData_SubPlot_StripID	Integer	numeric	Identification (numeric) of sub plot strip (1-5) in which tree data collected
TreeData_SubPlot_StripNotes	text	up to 255 characters	Notes regarding the sub plot strip
TreeID_Number	Integer	numeric	Co-Primary key. Tree tag number
Species_Code	text	alphanumeric	Species code (from tlu_Species_Parks)
Clump_Number	Integer	numeric	Clump number, if applicable
Stem_Letter	text	1-2 characters	Stem letter identifier, if applicable

Field Name	Type	Format	Description
TreeHeight_m	Double	decimal	Tree height (m) measured with range finder
TreeDBH_cm	Double	decimal	Tree diameter-at-breast-height (cm)
Krumholtz_YN	text	Yes/No	Yes/No field for indicating whether the tree is a krummholz tree
Tree_Status	text	up to 25 characters	Status of tree (from tlu_TreeStatus_Codes)
StatusDead_Cause	text	up to 255 characters	If Status = Dead, then note probable cause of death (from tlu_DeathCause_Codes)
CrownKill_Upper_perc	Integer	numeric	Ocular estimate of kill (%) in upper third of canopy
CrownKill_Mid_perc	Integer	numeric	Ocular estimate of kill (%) in middle third of canopy
CrownKill_Lower_perc	Integer	numeric	Ocular estimate of kill (%) in lower third of canopy
BranchCanks_A_Upper_YN	text	Yes/No	Presence (Yes/No) of branch cankers with aecia in upper third of canopy
BranchCanks_A_Mid_YN	text	Yes/No	Presence (Yes/No) of branch cankers with aecia in middle third of canopy
BranchCanks_A_Lower_YN	text	Yes/No	Presence (Yes/No) of branch cankers with aecia in lower third of canopy
BranchCanks_I_Upper_YN	text	Yes/No	Presence (Yes/No) of branch cankers without aecia in upper third of canopy. Requires at least 3 indicators in upper canopy.
BranchCanks_I_Mid_YN	text	Yes/No	Presence (Yes/No) of branch cankers without aecia in middle third of canopy. Requires at least 3 indicators in middle canopy.
BranchCanks_I_Lower_YN	text	Yes/No	Presence (Yes/No) of branch cankers without aecia in lower third of canopy. Requires at least 3 indicators in lower canopy.
BoleCankers_A_Upper_YN	text	Yes/No	Presence (Yes/No) of bole cankers with aecia in upper third of canopy
BoleCankers_A_Mid_YN	text	Yes/No	Presence (Yes/No) of bole cankers with aecia in middle third of canopy
BoleCankers_A_Lower_YN	text	Yes/No	Presence (Yes/No) of bole cankers with aecia in lower third of canopy
BoleCankers_I_Upper_YN	text	Yes/No	Presence (Yes/No) of bole cankers without aecia in upper third of canopy. Requires at least 3 indicators in upper canopy.

Field Name	Type	Format	Description
BoleCankers_I_Mid_YN	text	Yes/No	Presence (Yes/No) of bole cankers without aecia in middle third of canopy. Requires at least 3 indicators in middle canopy.
BoleCankers_I_Lower_YN	text	Yes/No	Presence (Yes/No) of bole cankers without aecia in lower third of canopy. Requires at least 3 indicators in lower canopy.
BranchCanks_ITypes_Upper	text	up to 25 characters	Indicator Types observed (from tlu_Indicators_Rust). Required if BranchCanks_I_Upper is Yes.
BranchCanks_ITypes_Mid	text	up to 25 characters	Indicator Types observed (from tlu_Indicators_Rust). Required if BranchCanks_I_Mid is Yes.
BranchCanks_ITypes_Lower	text	up to 25 characters	Indicator Types observed (from tlu_Indicators_Rust). Required if BranchCanks_I_Lower is Yes.
BoleCankers_ITypes_Upper	text	up to 25 characters	Indicator Types observed (from tlu_Indicators_Rust). Required if BoleCankers_I_Upper is Yes.
BoleCankers_ITypes_Mid	text	up to 25 characters	Indicator Types observed (from tlu_Indicators_Rust). Required if BoleCankers_I_Mid is Yes.
BoleCankers_ITypes_Lower	text	up to 25 characters	Indicator Types observed (from tlu_Indicators_Rust). Required if BoleCankers_I_Lower is Yes.
PineBeetle_JGalleries_YN	text	Yes/No	Presence (Yes/No) of pine beetle J-shaped galleries (only recorded for Dead or Recently Dead trees)
PineBeetle_PitchTube_YN	text	Yes/No	Presence (Yes/No) of pitch tubes
PineBeetle_Frass_YN	text	Yes/No	Presence (Yes/No) of frass
Mistletoe_YN	text	Yes/No	Presence (Yes/No) of mistletoe on tree.
FemaleCones_YN	text	Yes/No	Presence (Yes/No) of female cones on tree.
TreeData_Notes	text	up to 255 characters	Notes regarding tbl_EvData_TreeData record, if applicable

Table 5.9. Data dictionary for tbl_EvData_WildlifeObs. This table holds the Wildlife Observation data associated with a sampling Event.

Field Name	Type	Format	Description
WildlifeObs_ID	GUID	alphanumeric	Primary key, uniquely identifying each tbl_EvData_WildlifeObs record
Event_ID	GUID	alphanumeric	Co-Primary key. Link to tbl_Events (foreign key)
Hour_ofCount	Integer	numeric	Co-Primary key. Hour of Count of wildlife sign (Clark's nutcrackers and pine squirrel). Sequential, whole number value (e.g., 1, 2, 3).
Nutcracker_Sighting	Integer	numeric	Count of Clark's nutcracker sightings
Nutcracker_Calling	Integer	numeric	Count of Clark's nutcrackers calling
Squirrel_Pres_YN	text	Yes/No	Presence (Yes/No) of pine squirrels
StartTime_ofCount	DateTime	24-HR time	Start Time of the Hour Count
EndTime_ofCount	DateTime	24-HR time	End Time of the Hour Count

Table 5.10. Data dictionary for tlu_TreeStatus_Codes. Lookup table of TreeStatus Codes for Tree Data.

Field Name	Type	Format	Description
TreeStatus_Code	text	1–2 characters	Primary key. Unique tree status code
TreeStatus_Description	text	up to 255 characters	Description of tree status

Table 5.11. Data dictionary for tluContacts. Lookup table of Contacts associated with protocol data collection and entry. Contacts linked to Events in xref_Event_Contacts table.

Field Name	Type	Format	Description
Contact_Name	text	up to 100 characters	Primary key uniquely identifying each tluContacts record associated with this protocol
First_Name	text	up to 50 characters	First name of contact person
Last_Name	text	up to 150 characters	Last name of contact person
Organization	text	up to 255 characters	Organization with which contact person is affiliated

Table 5.12. Data dictionary for tlu_Species_Parks. Lookup table of Species_Codes, Park, and Species Names. Allows park-specific species lists for Seedling Counts and Tree Data.

Field Name	Type	Format	Description
SpCode	text	6 characters	Co-Primary key. Unique species code (3 letters from Genus plus 3 letters from Species).
Park	text	4-letter code	Co-Primary key. Park Code (4 letter) for the Park in which protocol data will be collected for this species.
SpeciesName	text	up to 150 characters	Full species name (Genus and Species).
FiveNeedleSp_YN	text	Yes/No	Is species a 5-Needle pine? (Yes/No). Used to refine data fields for Tree data entry.
SeedlingCount_YN	text	Yes/No	Include species in seedling counts? (Yes/No). Used to refine species lists for Seedling counts.
Park_SpCode	text	10 characters	ParkCode_SpeciesCode. Unique field tag comprised of the Park Code and the Species Code.

Table 5.13. Data dictionary for tlu_HeightClass_Seedlings. Lookup table of HeightClass Codes for Seedling Counts.

Field Name	Type	Format	Description
HeightClass_ID	GUID	alphanumeric	Primary key. Unique height class code
HeightClass_Description	text	up to 255 characters	Description of height class for seedlings

Table 5.14. Data dictionary for tlu_Indicators_Rust. Lookup table of blister rust Indicators for Tree Data.

Field Name	Type	Format	Description
IndicatorType	text	Up to 5 characters	Primary key. Unique one-letter Indicator code
IndicatorType_Description	text	up to 255 characters	Description of blister rust Indicator for tree data

Refer to the associated white pine monitoring protocol narrative (Hupp et al. 2018) for full descriptions of data entry, verification, and validation.

Standard Operating Procedure (SOP) 6: Data Summary, Analysis, and Reporting

Version 1.0

Revision History

Version #	Date of Revision	Revised By	Changes

The data summary, analysis, and reporting methods described here use the program R, an open-source statistical program (available free from the [R project](http://www.R-project.org/)). R is a platform for statistical computations and graphics, which runs on Windows, Unix, and Mac computers. R is a combination of a statistics package and a programming language. The R Wiki (<http://wiki.rproject.org/rwiki/doku.php>) provides an online forum and documentation. This SOP includes computational code for procedures written for R statistical language and environment. Direct references to R commands in the text are distinguished by **Courier New Font** rather than Times New Roman, with arguments for the commands noted by closed parentheses ().

Since this monitoring protocol focuses on monitoring in GRBA, inference on status and trends for white pine communities is directly considered at one scale: within-park. However, since MOJN anticipates implementing this protocol in additional parks in the future (such as Death Valley National Park and Mojave National Preserve), we have included additional instruction on how to analyze data across-parks, or within-network level. Further, since this protocol is a direct imitation of McKinney et al. (2013) which is carried out in multiple networks, we also describe how to analyze data across-networks, or the regional-level. We decided to include these additional methods because they are quite straightforward; park and network level inference can be treated as strata in the sampling design. Regional level inference will span the four networks and four pine species (whitebark pine, foxtail pine, bristlecone pine and limber pine). Status and trend estimation approaches are discussed first, and then issues involving regional trend inference are addressed.

Data Analysis for Status Estimation

Status analyses will provide a static view of target parameters (e.g. infection, mortality rates) at a given point in time for each scale of analysis. The goal of status analyses will be to provide visualization and parameter estimates for a given sampling frame (GRBA) or aggregations of sampling frames (network, region). Visualizations may be as simple as bubble maps that show the infected site with bubble icons scaled by parameter estimates. In this protocol, we selected samples using a tool that implements an equal-probability sampling design, the generalized random tessellation stratified (GRTS) algorithm (Stevens and Olsen 2004; refer to narrative, Hupp et al. 2018, for full description of GRTS draw).

The estimates for each parameter will be summarized within sites, and across the sample frame. Here we estimate variance by standard approaches, and by customized approaches that accommodate spatial

patterns in variance more closely. The neighborhood variance estimator, for instance, used with GRTS designs for status estimates, provides variance estimates that are 22% to 58% smaller than variance estimates computed assuming a simple random sample (Stevens and Olsen 2003).

We will use the *spsurvey* package in R (Kincaid et al. 2011) for our status analyses. The *spsurvey* package in R contains functions used to draw GRTS samples from sampling frames summarized in shapefiles. GRTS sample output files contain x- and y-coordinates and inclusion probabilities for each selected site. The *spsurvey* package also provides useful analysis tools for GRTS samples. The `total.est()` function in this package estimates means and totals as well as standard errors computed using the local neighborhood-weighted GRTS variance estimator. Inclusion probabilities from the GRTS sample are applied in these functions for unbiased estimation, and the neighborhood variance estimator capitalizes on the spatially-balanced sample for precise estimation. Stratification by networks and parks may be incorporated into these functions to obtain region, network, and park-level status estimation.

For any given year, it is possible that modeling analyses will also be augmented by modeling efforts to more effectively display the spatial patterns in the parameter of interest across park landscapes, either through purely spatial modeling approaches (kriging) or through more analytical models that incorporate environmental variables (logistic regression co-kriging). These supplemental analyses will depend upon the funding and staffing resources available in that year.

Trend Analysis

Accurate trend analyses are a crucial element of this protocol because they describe the presence and spread of an invasive pathogen in national park landscapes. We will analyze the trends of several indicators such as mean DBH, site basal area, and blister rust infection rates. An outline for the analysis of trends in white pine DBH is provided as an example. Pilot data from a similar survey in the Rocky Mountains are used to demonstrate a trend analysis with a linear mixed model. Linear mixed models are not the only way to analyze these data, but they present a feasible approach that can accommodate fixed and random effects on the parameters of interest.

Linear mixed model approach: Unlike a traditional linear model which can contain either fixed or random effects, the linear mixed model provides a flexible approach for trend analysis by combining terms for both *fixed* linear trend with *random* effects to account for year-to-year variation, site-to-site variation, and variation among site-level trends (Piepho and Ogutu 2002, VanLeeuwen et al. 1996). This model-based approach does not incorporate aspects of the survey design. However, given that an equal-probability sample is used, the spatial balance is not expected to adversely affect estimates of trend.

For inference at the park-level, the following mixed model for the white pine protocol was derived from the approach proposed by Piepho and Ogutu (2002):

$$y_{ijk} = \mu + w_j \beta_i + a_{k(i)} + b_{j(ik)} + \gamma_i + w_j t_{k(i)} + e_{j(ik)}$$

where:

$i = 1, \dots, 1$ indexes the 1 park (this is included for future use when additional parks may be included in this protocol)

$k = 1, \dots, k_i$ indexes the k^{th} site within the i^{th} park

$j = 1, \dots, j_{k(i)}$ indexes the j^{th} survey year of the k^{th} site in the i^{th} park

μ = fixed intercept of the linear time trend

w_j = is a constant representing the j^{th} year (covariate) which is centered such that the year of least variation occurs at $w_j = 0$

β_i = fixed linear slope of the i^{th} park

$a_{k(i)}$ = the random intercept of the k^{th} site in the i^{th} park, assumed independent and identically distributed as $N(0, \sigma_{a(i)}^2)$

$b_{j(i)}$ = random effect of the j^{th} year in the i^{th} park, assumed independent and identically distributed as $N(0, \sigma_{b(i)}^2)$

γ_i = fixed effect of the i^{th} park

$t_{k(i)}$ = random slope of the k^{th} site in the i^{th} park in the i^{th} network, assumed independent and identically distributed as $N(0, \sigma_{t(ik)}^2)$

$e_{j(ik)}$ = unexplained error, assumed independent and identically distributed as $N(0, \sigma_{e(ij)}^2)$

For regional inference, a single overall fixed slope is estimated across all parks using the following model:

$$y_{ijk} = \mu + w_j \beta + a_{k(i)} + b_{j(i)} + \gamma_i + w_j t_{k(i)} + e_{j(ik)}$$

Note that, in the regional model, β is no longer indexed by i and represents the overall trend for the region represented by the five parks.

Several terms are not estimable in the proposed linear mixed model due to the lack of balance among several factors. First, because MOJN monitors a single park, there is insufficient within-network replication to model specific network effects. Network-level inference is obtained by generalizing across parks similarly to the approach for regional inference. Second, sites are not visited more than once each year, so site-by-year interactions are inestimable. Site-by-year variation is included in the residual error term. Finally, effects of each white pine species are not incorporated in the model because the design does not allow for separation of species-park-network combinations of grouping factors. For example, bristlecone pine is only monitored at GRBA within the four networks.

Given appropriate replication of parks over time, R code is written to analyze the site-level means of DBH outcomes with the linear mixed model given above using the *lme4* R package. Data analysis will require a dataset (“DBHmean” in this example) formatted with columns for Year, WYear (w_j), Site, Park, Species, and the site-level means, Y . Note that the Site variable must be unique across all parks and that Site, Year, and Park must be defined as factors.

Estimate trend within each park:

```
trendfit.ByPark<-lmer(Y ~ WYear * Park + (-1+Park + Park:WYear|Site)
+ (-1+ Park|Year), data= DBHmean)
summary(trendfit.ByPark)
```

Estimate trend across parks:

```
trendfit.Regional <-lmer(Y ~ WYear + Park + (-1+Park +
Park:WYear|Site) + (-1+ Park|Year), data= DBHmean)
summary(trendfit.Regional)
```

The first model provides R code to estimate trends in time within GRBA as well as to measure components of variation such as site-to-site variation, year-to-year variation, and variation among site-level trends. Output from the second model will provide an estimate of the regional trend across all parks.

Pilot Data

Pilot data from a survey of whitebark pine forests in the northern Rocky Mountains (McKinney et al. 2009, McKinney and Fiedler 2010) are used to demonstrate the use of the linear mixed model for trend analysis. The data come from three ecosystems which fall within the boundaries of two national parks and five national forests. We treat the three ecosystems as analogous to national parks since they were summarized at this level. Surveys were conducted for three years spanning from 2004 to 2006.

While the pilot data represent whitebark pine populations from a similar system, some differences are discussed. First, this protocol focuses on limber pine and Great Basin bristlecone pine, and not whitebark pine. Second, the sites were not randomly selected but were selected to fall along a gradient of forest conditions including varying levels of mortality and blister rust infection rates and a range of ecosystems (McKinney et al. 2013). Third, 10 x 50 m belt transects are used, which are smaller than those used in the MOJN protocol. Finally, transects were located with additional hierarchical structure not present in the MOJN sampling design. In the pilot study, a site was defined as a contiguous set of two to four 100 x 100 m squares containing two transects each. This provided some spatial control over the allocation of transects. In this protocol, a single transect is located per site. The additional structure will be ignored in the data analysis example, so results from this example should not be used for inference.

An initial plot of the data reveals lack of balance in plots over time relative to the three parks (Figure 6.1). Park 3 only contains two sites (15 and 16) collected in a single year, 2006. Since this level of replication in time and space is inadequate for trend analysis, Park 3 is removed from the pilot dataset.

Almost all of the sites that were surveyed in both 2005 and 2006 exhibit an increasing trend between the two years.

Preliminary data analysis included both the untransformed site-level mean DBH and the natural logarithmic transformation of the site-level mean DBH. In all cases, the untransformed data satisfied model assumptions nearly as well as the logarithmically-transformed site-level means. The transformed outcomes allow a convenient interpretation of multiplicative change over time, so the logarithmic transformation is used for site-level means.

For DBH, the model for park-level inference generated estimates of year-to-year variation near zero, so those effects were removed from the random effects portion of the model. This reduced model yielded non-zero variance components but a convergence error occurred. The model was further reduced by omitting the fixed park slope effect (t -statistic = -0.6376, p = 0.7208) so that a common trend was assumed for both parks. This model, which is analogous to the regional analysis with equal slopes among parks yielded valid variance component estimates without convergence issues. Residual diagnostics suggested that these data meet the assumptions of equal variance (homoscedasticity) and normally-distributed errors for this model (Figure 6.2).

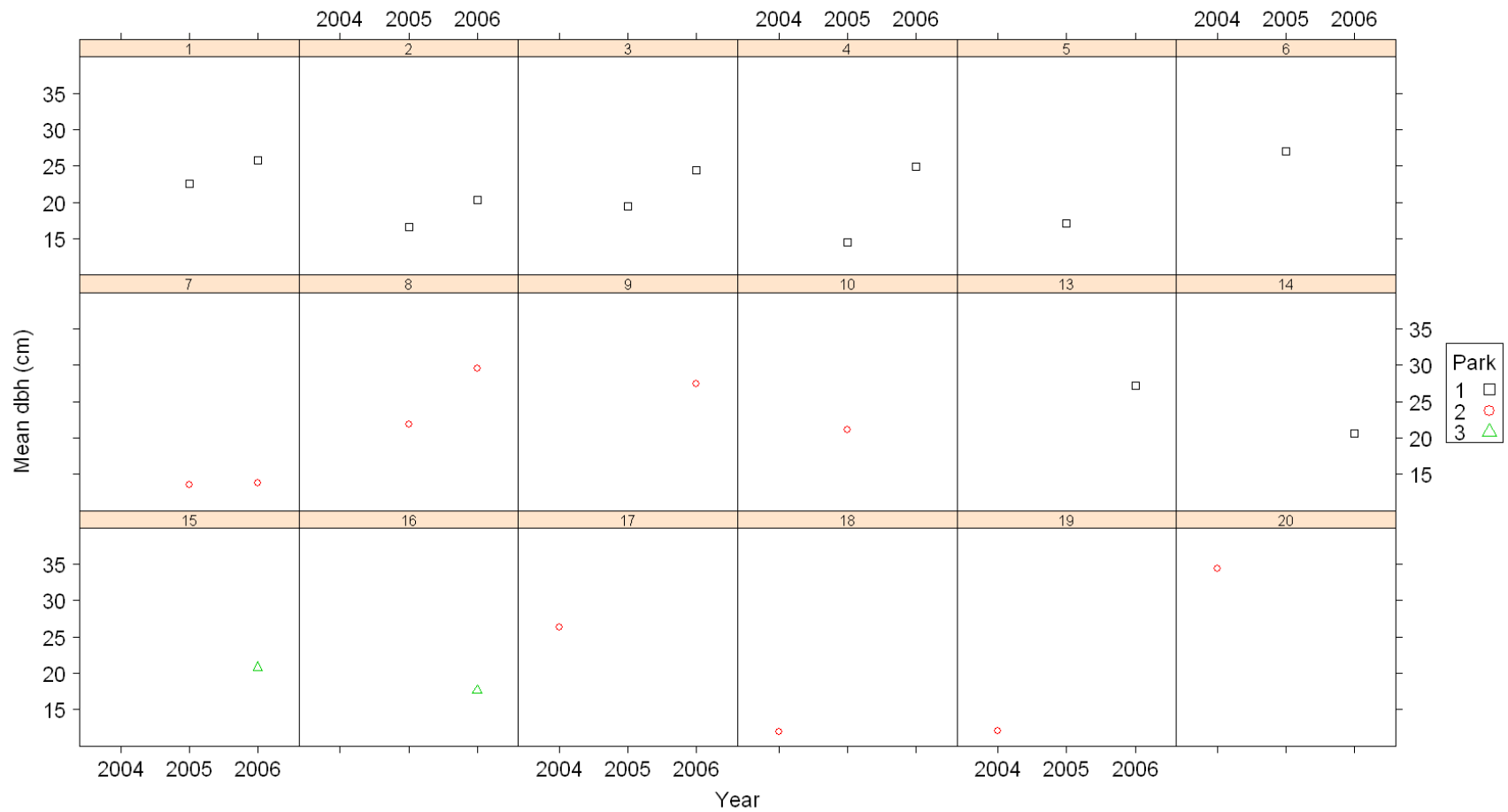


Figure 6.1. Site-level means of DBH by year for sites within each of three "Parks."

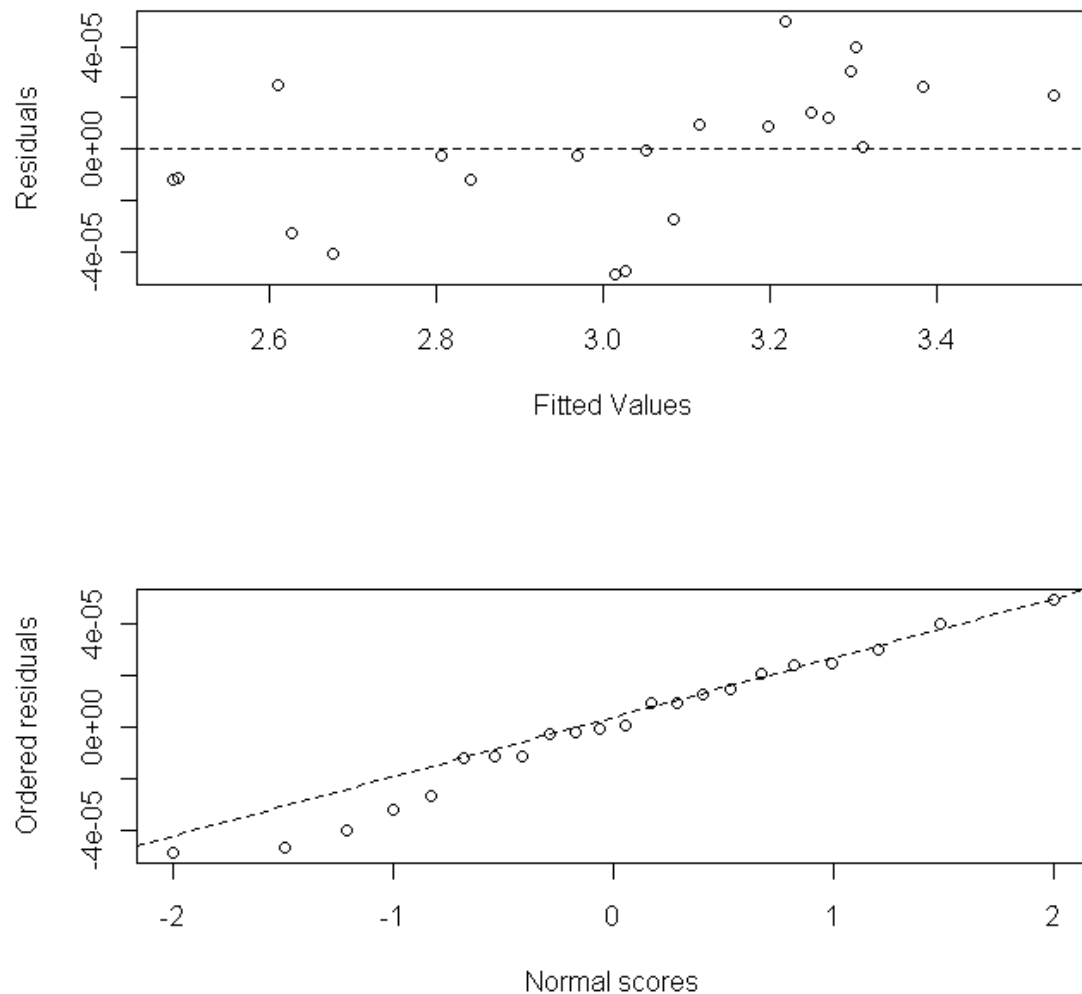


Figure 6.2. Residual diagnostics for the DBH measurements for the reduced model for regional inference.

The reduced linear mixed model for trend is applied to the pilot data using the following code in R:

```
trendfit.ByPark3<-lamer(log(MeanDBH) ~ WYear + Park + (-1+Park
+ Park:WYear|Site), data= DBHmean)
summary(trendfit.ByPark3)
```

Using the plot data, we ran the above code in R. The script produced the following output:

```
Linear mixed model fit by REML
Formula: log(MeanDBH) ~ WYear + Park + (-1 + Park + Park:WYear |
  Site) Data: DBHmean
```

```

AIC  BIC  logLik  deviance
REMLdev 30.92 46.19 -1.458 -
7.334 2.917
Random effects:
Groups Name      Variance Std.Dev.
Corr Site      Park1      1.6224e-01
0.4027876
      Park2      1.5104e-01 0.3886346 0.408
      Park1:WYear 3.8329e-02 0.1957768 -0.954 -0.360
      Park2:WYear 2.1066e-02 0.1451407 0.134 0.052 -0.128
Residual      4.6199e-06 0.0021494
Number of obs: 22, groups: Site, 16

Fixed effects:
      Estimate Std. Error t value
(Intercept) 2.76626 0.12773
21.657
WYear      0.20478 0.06286 3.258
Park2      0.09681 0.18218 0.531

Correlation of Fixed
Effects: (Intr) WYear
WYear -0.929
Park2 -0.624 0.568

```

The coefficient of WYear (w_j), $\beta_1 = 0.20478$, is the estimate of the slope for the log-transformed outcome for Park 1. Therefore, the multiplicative annual trend on the original scale is $e^{\beta_1} - 1 = 0.2273$. This implies that the population median is increasing by 22.73% each year. An annual change in median DBH of 22.73% should not be assumed to be representative of expected annual growth as the raw data used in this analysis were for illustrative purposes only. The 90% confidence interval is computed based on Satterthwaite degrees of freedom of 5.0033 calculated with the Giesbrecht and Burns (1985) approach and is obtained as follows:

$$\begin{aligned}
& \left(\exp\left(\beta_1 - t_{(1-\alpha/2, df)} SE(\beta_1)\right) - 1, \exp\left(\beta_1 + t_{(1-\alpha/2, df)} SE(\beta_1)\right) - 1 \right) \\
& = \left(\exp(0.20478 - 2.0148 \cdot 0.06286) - 1, \exp(0.20478 + 2.0148 \cdot 0.06286) - 1 \right) \\
& = (0.0813, 0.3929)
\end{aligned}$$

Therefore, the 90% confidence interval for the annual multiplicative change is 8.13% to 39.29%. Note that, because the park-level analysis was reduced to have a common slope, this estimate of trend and its 90% confidence interval also represent the regional analysis across parks.

Inference on regional trends across networks is of great interest to managers at KLMN, SIEN, UCBN, and MOJN. Stressors that affect all white pine species may induce similar changes in the

three white pine populations. Large-scale changes to white pine populations would be important to detect as early as possible. Analyses of measures that are summed at the site-level, such as basal area, should be standardized across networks. Furthermore, differences in the sampled populations must be assumed negligible.

Reporting

A summary report will be produced after each year of data collection by each Network, with a more detailed trend report produced in collaboration among the four Networks every 3 years, following the completion of the rotating panel cycle. The annual report will:

- Provide a summary history of the samples taken during each year of the study, tabulating numbers of samples for each sampling frame and showing these locations on maps of the parks.
- Provide summary status statistics, maps, and interpretation of the results relative to management goals.
- Provide a summary table of key resource condition indicators for use in park reporting and resource stewardship strategies.
- Evaluate data quality and identify any data quality concerns and/or deviations from protocols that affect data quality and interpretation.
- Evaluate and identify suggested or required changes to the protocol.

A 1-2 page resource brief will also be prepared as needed, or when there is an interesting story to tell, that will be provided to superintendents, park interpretive staff, and resource managers. Information from the annual summary report will also be provided to park managers in a timely fashion for informing and evaluating park resource stewardship strategies. Finally, invasive weed locations should be reported to the park resource managers immediately following completion of field activities. Reported information should include GPS locations and maps of locations with weeds encountered (if any) both within plots and as noted during travel between sampling locations.

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Appendix A: First 10 Points of each Stratum in GRTS Draw

Table A.1 Summary of GRTS draw by stratum.

GRTS #	Plot Code	Stratum	UTM 11N X (m)	UTM 11N Y (m)
1	GRBAN001	BRIMON	732198	732198
2	GRBAN002	BRIMON	732198	732198
3	GRBAN003	BRIMON	732198	732198
4	GRBAN004	BRIMON	732198	732198
5	GRBAN005	BRIMON	732198	732198
6	GRBAN006	BRIMON	732198	732198
7	GRBAN007	BRIMON	732198	732198
8	GRBAN008	BRIMON	732198	732198
9	GRBAN009	BRIMON	732198	732198
10	GRBAN010	BRIMON	732198	732198
201	GRBAN201	BRISUB	732198	732198
202	GRBAN202	BRISUB	732198	732198
203	GRBAN203	BRISUB	732198	732198
204	GRBAN204	BRISUB	732198	732198
205	GRBAN205	BRISUB	732198	732198
206	GRBAN206	BRISUB	732198	732198
207	GRBAN207	BRISUB	732198	732198
208	GRBAN208	BRISUB	732198	732198
209	GRBAN209	BRISUB	732198	732198
210	GRBAN210	BRISUB	732198	732198
401	GRBAN401	LIMWOO	732198	732198
402	GRBAN402	LIMWOO	732198	732198
403	GRBAN403	LIMWOO	732198	732198
404	GRBAN404	LIMWOO	732198	732198
405	GRBAN405	LIMWOO	732198	732198
406	GRBAN406	LIMWOO	732198	732198
407	GRBAN407	LIMWOO	732198	732198
408	GRBAN408	LIMWOO	732198	732198
409	GRBAN409	LIMWOO	732198	732198
410	GRBAN410	LIMWOO	732198	732198

Appendix B: Field Data Collection Sheet

Plot Field ID	Lower Left Corner (1) X	Lower Left Corner (1) Y	Date
Corner 1 to 2 azimuth (deg.)	Lower Right Corner (4) X	Lower Right Corner(4) Y	Observer
Corner 2 to 3 azimuth	Upper Left Corner (2) X	Upper Left Corner (2) Y	Plot Photo File 1
Corner 3 to 4 azimuth	Upper Right Corner (3) X	Upper Right Corner (3) Y	Plot Photo File 2
Slope (deg.)	Aspect (deg.)	Elevation (m)	Plot Photo File 3
Regeneration Plot 1 Count	20-50 cm	51-100 cm	101-137 cm
Regeneration Plot 2 Count	20-50 cm	51-100 cm	101-137 cm
Regeneration Plot 3 Count	20-50 cm	51-100 cm	101-137 cm
Regeneration Plot 4 Count	20-50 cm	51-100 cm	101-137 cm
Regeneration Plot 5 Count	20-50 cm	51-100 cm	101-137 cm
Regeneration Plot 6 Count	20-50 cm	51-100 cm	101-137 cm
Regeneration Plot 7 Count	20-50 cm	51-100 cm	101-137 cm
Regeneration Plot 8 Count	20-50 cm	51-100 cm	101-137 cm
Regeneration Plot 9 Count	20-50 cm	51-100 cm	101-137 cm
Notes			

Appendix C: Site Information Sheet Example

GRBA 204

Site Location Coordinates: 11S

Easting	733842	Northing	4309963
Latitude	38°54'26.80"N	Longitude	114°18'11.54"W
Map Name	Mt. Washington Area D / GRBA 204		

Directions:

1) From Mt. Washington A Parking, follow the road/ trail north for 0.48 miles, then turn east and travel for 0.81 miles until you reach Intersection 1.			
Intersection 1	Easting	733291	Northing 4308960
2) From Intersection 1, travel north for 0.71 miles until you reach Intersection 2.			
Intersection 2	Easting	733383	Northing 4310006
3) From Intersection 2, travel east for 0.14 miles until you reach Mt. Washington D2 Trailhead 204.			
Mt. Washington D2 Trailhead 204	Easting	733582	Northing 4309990
4) From Mt. Washington D2 Trailhead 204, travel east 0.17 miles (downhill) to GRBA 204.			
GRBA 204	Easting	733842	Northing 4309963

Estimated Walking Distance: **0.27 km / 0.17 mi** Gain: 50 ft.

Point Name	Type	EASTING	NORTHING
Mt. Washington A Parking	Start Point/ Parking Area	732158	4308622
Intersection 1	Intersection	733291	4308960
Intersection 2	Intersection	733383	4310006
Mt. Washington D2 Trailhead 204	Trailhead	733582	4309990
GRBA 204	Site Location	733842	4309963

Trail Topography: From Mt. Washington C3 Trailhead to GRBA 204.



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Mojave Desert Network
