



# Monitoring Vegetation Composition, Structure, and Function in the Parks of the Klamath Network

Natural Resource Report NPS/KLMN/NRR—2011/401



**ON THE COVER**

Douglas-fir (*Pseudotsuga menziesii*) at Oregon Caves National Monument.  
Photograph by: Daniel Sarr

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# **Monitoring Vegetation Composition, Structure and Function in the Parks of the Klamath Network**

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## Revision History Log

Details on the procedure for protocol revisions are described in SOP #16: Revising the Protocol.

| Prev.<br>Version # | Revision<br>Date | Author | Changes Made | Reason for Change | New<br>Version # |
|--------------------|------------------|--------|--------------|-------------------|------------------|
|                    |                  |        |              |                   |                  |
|                    |                  |        |              |                   |                  |
|                    |                  |        |              |                   |                  |
|                    |                  |        |              |                   |                  |
|                    |                  |        |              |                   |                  |

## 1.0 Background and Objective

### 1.1 Rationale for Monitoring Vegetation Composition and Structure

The development of the Klamath Network vital signs monitoring has emphasized the importance of documenting status and trends in the composition, structure, and function of ecosystems. Vegetation is a foundation for terrestrial ecosystem composition, structure, and function. Vegetation also ranked among the highest potential vital signs for monitoring in the Network's vital signs selection process. The reasons are simply that vegetation dominates biomass and energy pathways and defines the habitat for most other forms of life. Changes in vegetation composition, structure, and function will therefore have a profound effect on ecosystems. Monitoring vegetation change is thus imperative to detecting and understanding status and trends in park ecosystem vital signs, the overriding goal of NPS Inventory and Monitoring.

The vegetation of the Klamath parks contributes to the unique and renowned biodiversity of the region (for park descriptions of biodiversity and summaries of vegetative resources, see: [http://science.nature.nps.gov/im/units/klmn/Monitoring/Documents/PhaseII/Appendix\\_A\\_Park\\_Profiles.pdf](http://science.nature.nps.gov/im/units/klmn/Monitoring/Documents/PhaseII/Appendix_A_Park_Profiles.pdf)). The importance of the Klamath Region as a floristic center of diversity for western North America has been recognized in classic papers by Whittaker (1960, 1961) and Stebbins and Major (1965). This diversity is paralleled in other life forms, leading to the area being highlighted for its global biodiversity significance (DellaSala et al. 1999). The biological wealth of the region is generally attributed to the remarkable array of geologic parent materials and climates present (Wallace 1983) and the role the region played as a refugium during glacial maxima (Whittaker 1960, 1961). Disturbances such as fire have also been instrumental in producing spatial and temporal heterogeneity that promotes diversity (Taylor and Skinner 1998, Odion et al. 2004). Taylor and Skinner point out that, "Few forested regions have experienced fires as frequently and with such high variability in fire severity as those in the Klamath Mountains."

Natural processes that have shaped vegetation inside and outside parks have been directly affected by a variety of land use activities, fire suppression/management, plus climate/atmospheric changes and many other anthropogenic factors (see conceptual models in section 1.4). Vegetation sampling can help document changes in species composition, structure, and function that occur as a result of these processes.

The vegetation monitoring will also complement monitoring of another driver of change: non-native species invasion. The Network has another vital sign specific to invasive species in areas predicted to be most susceptible to invasion: road, and trail corridors. However, there remains a need to sample parks more broadly for invasive species, and to determine trends in well established invasive species. In some park settings, invasives are causing significant impacts to vegetation composition, structure, and function. Therefore, the vegetation protocol is needed to support both invasive species and general vegetation monitoring goals.

Some aspects of vegetation change will be monitored by other protocols and thus do not need to be part of the vegetation protocol. For instance, the land cover protocol should provide extensive, but spatially less detailed information about vegetation structure. It will quantify the extent of vegetation formations and their patch size, configuration, and connectivity. It will also provide information about spatial patterns of disturbance. The whitebark pine protocol will monitor

disturbances by diseases and insects in high elevation forests at plots that are co-located with vegetation plots. But the specific disease and insect sampling protocols are additions to the vegetation sampling under this protocol. The cave protocol will monitor the unique vegetation (non-vascular) at cave entrances, which are numerous at Lava Beds, but which will not be targeted with the probabilistic vegetation sampling design here. The intertidal protocol will monitor algae vegetation, which is abundant and diverse along the rocky coastline of Redwood National and State Parks. Finally, the aquatic protocols for streams and lakes will monitor aquatic macrophytes and periphyton (algae mixed with bacteria and other microorganisms). Also, many vegetation monitoring plots are co-located with landbird monitoring sites, which can help to identify habitat changes associated with trends in bird populations. Thus, the vegetation monitoring protocol plays a central role in the overall vital signs monitoring strategy of the Klamath Network.

## **1.2 Link to National Strategy**

Many parks and networks are working on vegetation protocols collaboratively and individually. The objectives differ from network to network, but there are commonalities. In developing this protocol, we have adopted many field procedures used to monitor vegetation at Great Smoky Mountains National Park since 1978. The Smokies, like the Klamath Region, are a mountainous landscape of notable biodiversity, owing to their functioning as a glacial refugium. Biogeographically, the Klamath and Smokies are western and eastern North American counterparts (Whittaker 1961). Coincidentally, the existing Smokies vegetation protocol addresses many of the Klamath Network's fundamental goals and perspectives for vegetation monitoring. We complemented the Smokies protocols with several additional monitoring procedures to meet the specific goals of the Klamath Network parks and to crosswalk with the other major vegetation monitoring programs on public land (the US Forest Service Forest Inventory and Analysis [FIA] monitoring and the NPS fire monitoring). Therefore, our vegetation protocol is consistent with a proven, national approach to vital signs monitoring in a biologically diverse region but is further refined to address the specific needs of the Klamath parks and to crosswalk with other monitoring.

## **1.3 Monitoring History**

Several vegetation monitoring programs have been conducted in the parks of the Klamath Network in the past, ranging from broad, systematic monitoring of forest resources to fire-effects monitoring. The US Forest Service maintains FIA plots in the parks. The FIA program uses a systematic design to detect change in forest ecosystems and has been in place for decades. This work has been conducted by Forest Service field crews and has not involved park staff. Comprehensive reports for entire western states have recently been released for California and Oregon (Christensen et al. 2009a, 2009b). These present, “basic resource information such as forest area, land use change, ownership, volume, biomass, and carbon sequestration; structure and function topics such as biodiversity, older forests, dead wood, and riparian forests; disturbance topics such as insects and diseases, fire, invasive plants, and air pollution; and information about the forest products industry, including data on tree growth and mortality, removals for timber products, and nontimber forest products.” No park-specific information or analyses are part of these reports. The number of FIA plots that exist in the parks is modest (Table 1). In addition, only a portion of FIA plots have sampling that includes understory vegetation. These are sites sampled under the Forest Health and Monitoring Program that nest

within the broader FIA framework. Thus, FIA monitoring will provide complementary, but much less detailed information at the scale of parks than this vegetation monitoring protocol.

**Table 1.** US Forest Service Inventory and Analysis plots in the park units of the Klamath Network.

| Park Unit | Crater Lake | Lassen Volcanic | Lava Beds | Oregon Caves | Redwood | Whiskeytown |
|-----------|-------------|-----------------|-----------|--------------|---------|-------------|
| FIA Plots | 28          | 13+             | 6-8       | 0            | 15-17   | 8-10        |

There are numerous plots in the Network parks that have been sampled as part of the NPS Fire Monitoring program in the parks. The methods are laid out in the NPS Fire Monitoring Handbook (FMH). These plots are sampled both before and after prescribed burns, wildfires (when unburned plots happen to burn in unplanned fires), and in vegetation treatments aimed at fire mitigation. This monitoring provides useful information about effects of prescribed fires, wildfires, and vegetation treatments, but there are important limitations. There are generally very few plots per burn or treatment unit and these are limited to select, homogeneous areas. There are typically no plots outside of burns or treatment units to serve as long-term controls and information on species diversity and species lists obtained from plots may be incomplete or unverified. Accordingly, the FMH monitoring will primarily complement the Network's monitoring by providing compatible information on parameters related to structure (including down wood and litter) and invasive species from the same sized plots in areas that are treated or that burn in wildfires. These areas are likely to be significantly undersampled by this protocol. The Klamath Network vegetation monitoring has the potential to complement FMH monitoring by sampling areas largely unaffected by prescribed fires or burned in wildfires, which can act as controls.

Although the monitoring we developed is not exactly the same as FMH or especially FIA monitoring, the existence of these two monitoring programs had an important influence on specific measures we chose. In order to complement and crosswalk our data to FIA and FMH monitoring, it was necessary for the Klamath Network vegetation monitoring to use, where possible, the same tree and fuel size classes and other categories (e.g., decay classes, terrain position classes, canopy height, etc.). In addition, the FIA and FMH monitoring protocols are described in detail and field tested, so we relied on the sampling manuals from the two programs to describe many general activities related to vegetation monitoring. A good example is our adoption of the FIA procedure for determining canopy base height. We present a table comparing FIA, FMH, and Klamath Network vegetation monitoring methods for easy, direct comparison (Appendix E).

There has also been a wide variety of park-specific vegetation sampling done in recent decades. Numerous agency and university researchers have worked on individual vegetation projects in all the parks using a variety of methods. Some of this work has been published, for example, the classic work of Robert Whittaker in the Siskiyou (Whittaker 1960), which sampled the Oregon Caves area (including the proposed monument expansion area) and the analysis of forest vegetation and environmental relationships in Lassen Volcanic by Albert Parker (1991). Relocating previous sampling locations or designing the Network's vegetation monitoring to complement past vegetation sampling by individual researchers does not appear possible. However, we will be able to compare our findings in meta-analyses.

### 1.4 Network Vegetation Monitoring Conceptual Modeling

The Network developed its monitoring plan with the use of conceptual models (Sarr et al. 2007, [http://science.nature.nps.gov/im/units/klmn/Monitoring/MON\\_Phase\\_III.cfm](http://science.nature.nps.gov/im/units/klmn/Monitoring/MON_Phase_III.cfm)) that provide the foundation for the Network's approach to monitoring the composition, structure, and function of ecosystems (Figure 1). Composition is the array of ecosystem components (genes, species, populations, special habitats, etc.). Structure refers to the spatial arrangement of physical components, such as canopy structure or corridors for species movement. Ecosystem function refers to the many processes that ecosystems require and provide through time, such as nutrient cycling, carbon cycling, hydrologic cycling, etc, which interact with disturbance processes, biological interactions (e.g., interspecific competition) and demographic and reproductive processes (Figure 1).

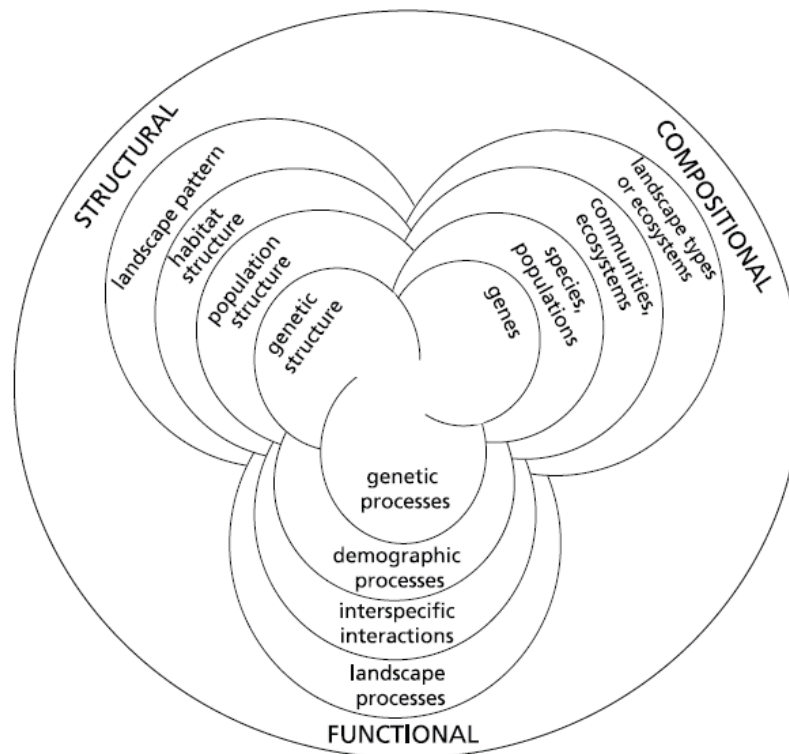


**Figure 1.** Conceptual model of the composition, structure, and function across levels of scale and biological organization (from Noss 1990).

Our holistic conceptual model (Figure 2) was developed through discussions with Network and park-based science staff and summarizes our view of the major influences on park ecosystems. These influences are abiotic, biotic, dynamic, and human environments that shape the composition, structure, and function of park ecosystems, with humans as a major influence in these ecosystems. A core concept of the Klamath Network monitoring program is that ecosystem composition, structure, and function can be used to assess the ecological integrity of park ecosystems as affected by humans (Figure 3). For terrestrial ecosystems, vegetation is a key determinant of these core ecosystem attributes at the landscape scale.

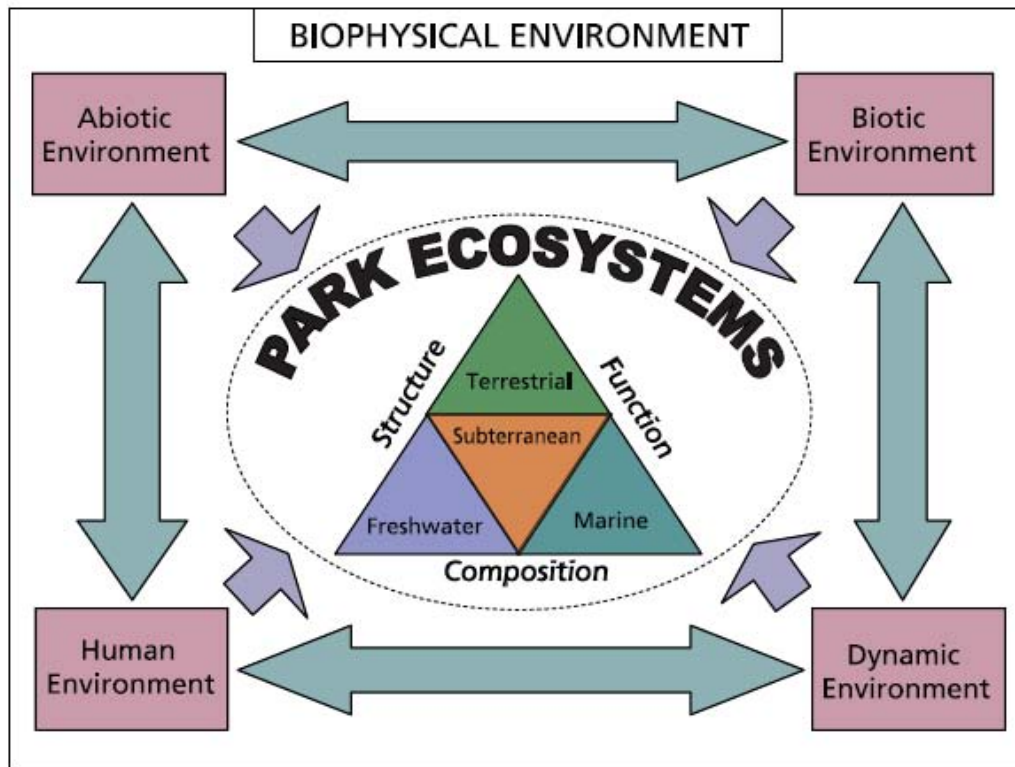


**Figure 2.** A holistic conceptual model of influences on Klamath park ecosystems.

A central goal of the long-term monitoring program is to detect changes that we suspect are caused by detrimental human actions. Potential sources of harm can come from near-field activities (e.g., campgrounds, local management actions, such as those related to fire, and point-source pollution) or from far-field effects (e.g., off-site pollution, climate change, and invasive species). Together, these stressors can affect the composition, structure, and function of park ecosystems, endangering their diversity and integrity (Figure 3).

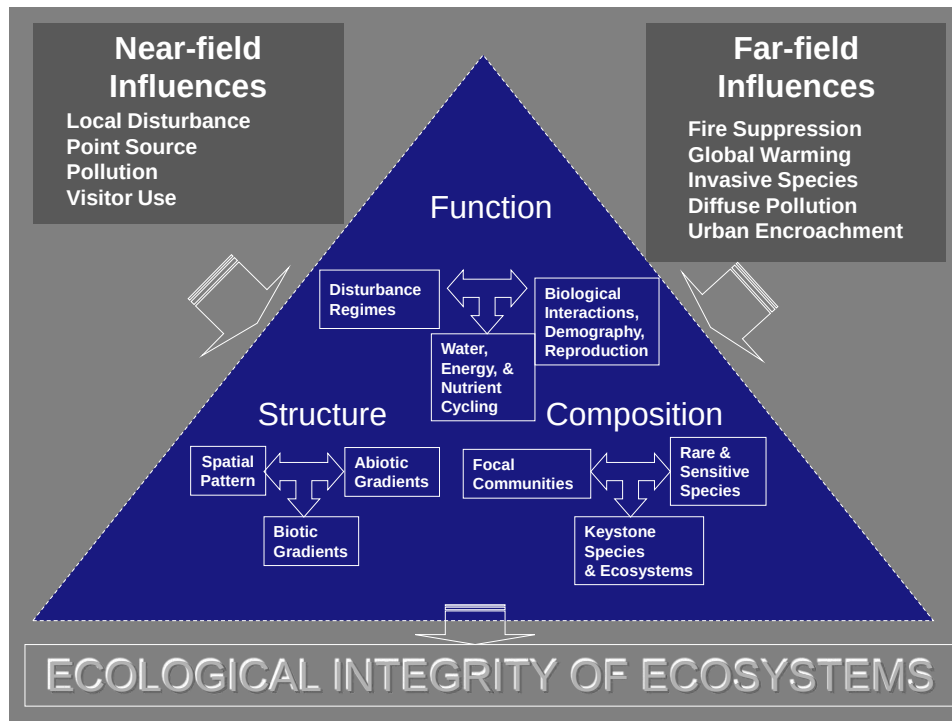


**Figure 3.** Human Influences on the structure, function, and composition of ecosystems.

Threats to terrestrial ecosystems range from local visitor use effects on individual species and ecosystems (e.g., trail development and stock use), to more widespread and diffuse effects, such as non-native plant and animal species introductions, and fire management or suppression treatments (Figure 4). These influences affect the structure of the habitat template, particularly the environmental gradients, disturbance regimes, and landscape patterns that create habitat for ecosystems, communities, and species of interest.

Approaches that monitor the status and trends in composition, structure, and function of ecosystems place greater emphasis on the types and degrees of relationships among different organisms in a community than more taxon-specific approaches. Traditional descriptive sampling of these relationships is often based on changes that occur along environmental gradients. Gradient relationships often emerge from multispecies sampling data, such as vegetation cover data for individual species. Multivariate approaches for analyzing these types of data may cause gradient relationships to emerge from the data at each time of sampling and allow determination of how these relationships change over time. Multivariate analysis of species composition data are therefore a key component of our data analysis (SOP #12: Reporting and Analysis of Data). How these gradient relationships among species change over time is likely to provide fundamental information about ecological integrity and can be a powerful way to initially detect change. For example, Manley et al. (2004) argue that a diversified, multispecies approach is the most comprehensive way to ensure that important trends are detected. In particular, we recognize conceptually that monitoring multiple species or attributes together may track changes in ecosystem composition, structure, and function better than taxonomic or functional groups (e.g., better than graminoids or hardwoods would detect change).

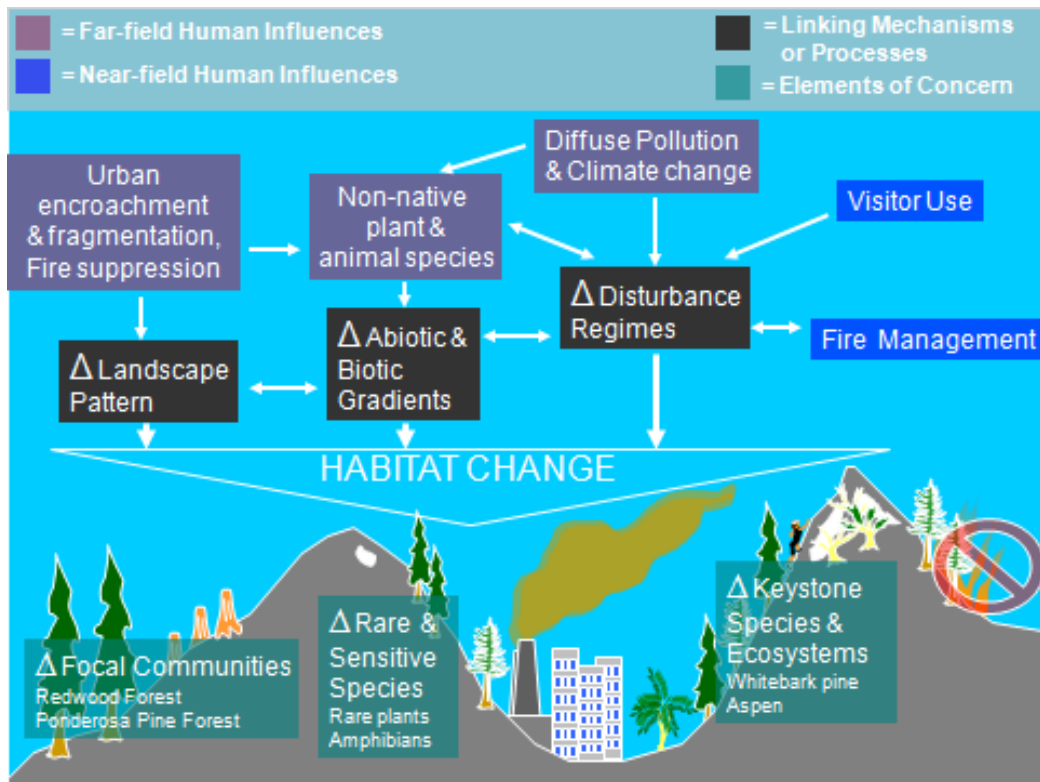


**Figure 4.** A conceptual model illustrating some key human influences on terrestrial ecosystems.

## 1.5 Vital Sign Objectives

The monitoring and sampling objectives for this protocol were largely determined at the two initial scoping meetings with Network plant ecologists and park vegetation and resource experts. Further refinement was done by the authors during the writing of this protocol based on additional study and assessment of other vital signs monitoring by the Klamath Network. Review of other networks' vegetation monitoring protocols, FIA and FMH approaches, and the results of the pilot study (Appendix A) also led to refinements of this protocol.

### 1.5.1 Monitoring Objectives

1. Describe the composition, structure, and function of vegetation communities in Klamath Network parks by installing and sampling a network of permanent plots established with a probabilistic sample design in safe, relatively accessible areas.
2. Quantify temporal and spatial change in these factors through the re-measurement of permanent plots.
3. Sample communities of special concern (alpine and riparian) at greater intensities to allow improved statistical sensitivity to ecological change and better identification of emerging threats.
4. Co-locate some vegetation plots with bird and stream sampling locations to provide more comprehensive status and trend data and evaluate interrelationships among biota.



## 2.0 Sampling Design and Rationale

The spatial sampling design was created to ensure that field data are statistically robust and could be collected by seasonal field crews safely and feasibly. The sampling focuses more intensively on special interest vegetation.

### 2.1 Special Interest Vegetation

Special interest vegetation types delineated under this protocol included riparian and wetland vegetation throughout the Network (except Lava Beds, where absent), and sensitive high elevation sites at Crater Lake, Lassen Volcanic, and the top of Shasta Bally, the highest peak in Whiskeytown. Additional special interest vegetation that will be monitored under different protocols, or by individual parks, is described in Table 2.

**Table 2.** Special interest vegetation in the Klamath Network that will be monitored under different protocols, by individual parks, or that may not be formally monitored.

| Special interest vegetation                                                    | Protocol monitored under                     |
|--------------------------------------------------------------------------------|----------------------------------------------|
| Cave entrance community                                                        | Cave entrance community, I&M Protocol        |
| Whitebark pine                                                                 | Whitebark pine I&M Protocol (co-implemented) |
| Chaparral (Crater Lake)                                                        | Land cover I&M Protocol                      |
| Montane meadows                                                                | Land cover I&M Protocol                      |
| Coastal vegetation, bald hills                                                 | Will be monitored by Redwood                 |
| <i>Puccinellia</i> meadow and old growth at Whiskeytown, serpentine at Redwood | None (may get monitored by park)             |

### 2.2 Location of Plots

We used the Generalized Random Tessellation Stratified (GRTS) method (Stevens and Olsen 2003, 2004) for plot location within the three sample frames (matrix, riparian/wetland, and sensitive high elevation). GRTS produces a spatially balanced design if points are used in the order in which they are chosen by GRTS. This makes it easy to discard sampling locations if found unsuitable and have a ready set of additional points from which to draw a new sample. This is valuable because any plot found to be too steep, dangerous, or barren (e.g., talus) upon arrival in the field will be considered unsuitable and not be included in long-term monitoring. Plots will also be discarded if travel times prove to be excessive on the first visit.

### 2.3 Sampling Frames

#### 2.3.1 All Vegetation

Due to budget constraints and safety considerations, it was necessary to limit sampling by accessibility. We therefore excluded areas more than 1 km from a road or trail. We chose to avoid steep slopes ( $>30^\circ$ ) and areas too dangerous to sample for reasons other than slope (e.g., barren lava flows, talus, scree slopes). We also did not want to sample roadside or trailside environments, which are being sampled by the Invasive Species Early Detection Protocol (Odion et al. 2010). Areas that are excluded from our spatial sampling frame are listed in Table 3. By using road coverages and excluding areas within 100 m of a road, all paved and administrative areas were dropped from the sampling frames via GIS. Coverages of the lava flows at Lava Beds were acquired from the park. The inner caldera of Crater Lake was all eliminated due to its steepness and instability. Lakes were not eliminated, but no points landed within them. Some

plot locations will be rejected after inspection in the field due to factors that could not be screened out by the GIS analyses.

**Table 3.** Areas that will not be sampled as part of the vegetation monitoring protocol.

| Park Unit                      | Area excluded                                                                                                                                                                                 | Reason                                                                                                                                                                                                             |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| All                            | Slopes greater than 30 degrees, locations less than 100 m from a road or trail, or farther than 1 km from a road or trail. Areas that meet the sampling criteria that are smaller than 2.5 ha | Too dangerous or inaccessible. Sampling plots on steep slopes causes significant soil and vegetation trampling disturbance.                                                                                        |
| Crater Lake National Park      | Inner rim of caldera                                                                                                                                                                          | Most of the area located within the caldera is highly unstable, surrounded by cliffs, or is part of Crater Lake itself, making access dangerous and/or difficult, or a time-consuming boat ride would be required. |
| Lassen Volcanic National Park  | Talus slopes                                                                                                                                                                                  | Little or no vegetation, very slow travel time, dangerous.                                                                                                                                                         |
| Lava Beds National Monument    | Callahan and Devil's Homestead flows, scree slopes on cinder cones; Riparian and high elevation areas                                                                                         | Little or no vegetation on lava flows. Safety concerns on lava flows which are composed of very sharp rock. Riparian and high elevation areas are lacking in the park.                                             |
| Oregon Caves National Monument | High elevation areas                                                                                                                                                                          | Limited to a very small area. Sample size would be too small.                                                                                                                                                      |
| Redwood National Park          | High elevations                                                                                                                                                                               | High elevation areas are lacking.                                                                                                                                                                                  |

We used GIS to develop shapefiles of the acceptable sampling domains for matrix, riparian, and high elevation areas of all parks, with areas shown in Table 3 excluded. Then, all parcels that were acceptable based on these criteria that were 2.5 ha or less in size were also excluded. This systematically eliminated polygons whose dimensions made it difficult or impossible to encompass a plot. The sampling frames are shown in Figure 5. We used GRTS to create a list of sampling locations, including an oversample. Sampling locations are shown, in Figure 6 in relation to topography. The file names and their locations are found in Appendix D.

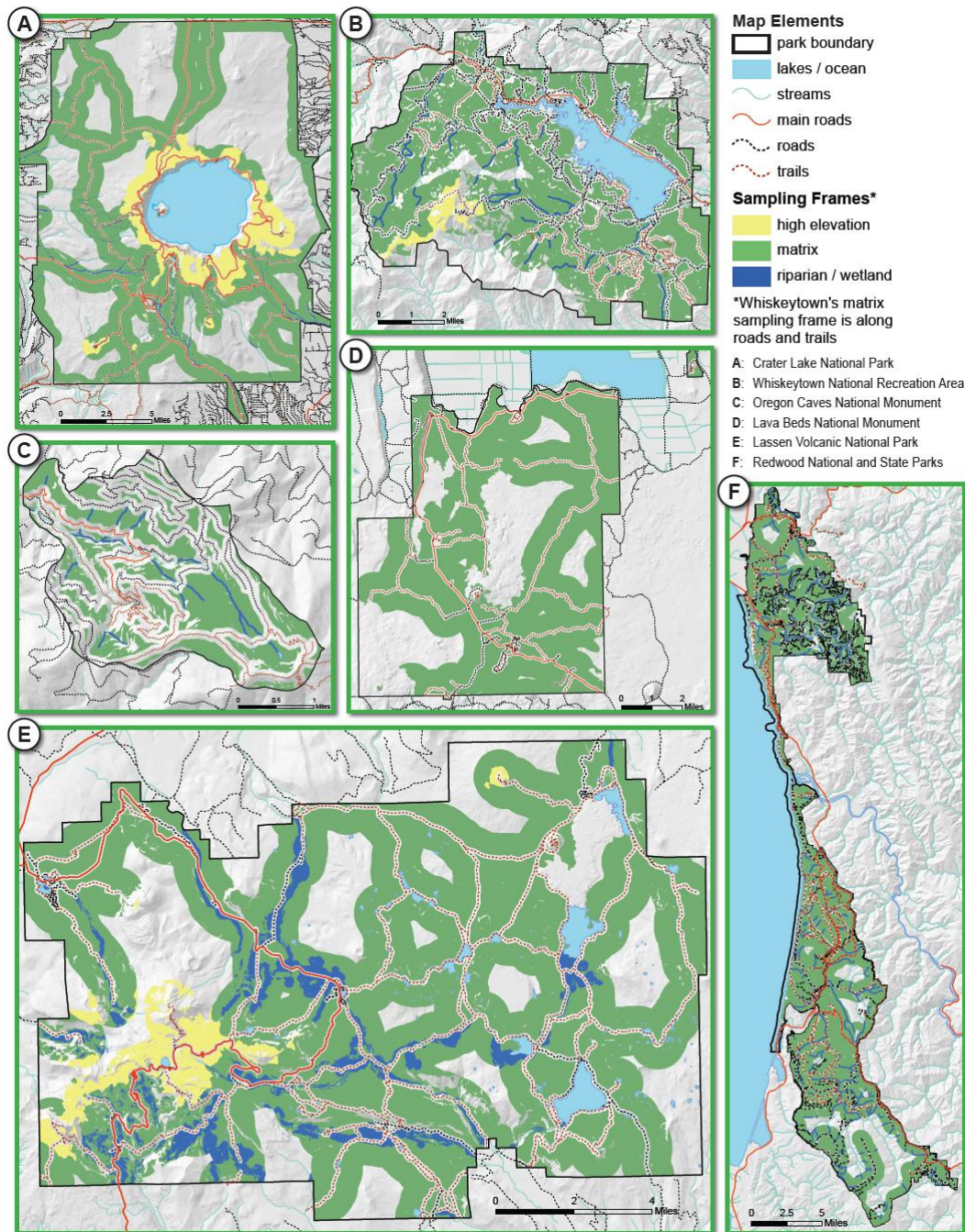


**Figure 5.** High elevation, matrix, and riparian/wetland sampling frames for all six parks. A = Crater Lake, B = Whiskeytown, C = Oregon Caves, D = Lava Beds, E = Lassen Volcanic, F = Redwood.

### 2.3.2 Comparison of Sampling Frames to Park-wide Environments

Table 4 compares the elevations sampled by the sampling frames with park-wide elevation parameters. Although their areas are smaller, the sampling frames at each park encompass most of the elevations that exist throughout the parks. Because rainfall variation within parks is largely a function of elevation, spatial variation in rainfall levels within each park should be captured by the sampling frames.

**Table 4.** Area (km<sup>2</sup>) and elevation (m) in each park as well as the composite of all sampling frames for each park.

|                 |                | Elevation (m)              |         |         |       |      |     |
|-----------------|----------------|----------------------------|---------|---------|-------|------|-----|
|                 |                | Area<br>(km <sup>2</sup> ) | Minimum | Maximum | Range | Mean | SD  |
| Crater Lake     | Entire park    | 737.81                     | 1222    | 2713    | 1491  | 1841 | 178 |
|                 | Sampling frame | 330.42                     | 1328    | 2679    | 1351  | 1838 | 194 |
| Lava Beds       | Entire park    | 189.02                     | 1228    | 1729    | 501   | 1361 | 110 |
|                 | Sampling frame | 111.36                     | 1231    | 1684    | 453   | 1347 | 102 |
| Lassen Volcanic | Entire park    | 433.8                      | 1594    | 3186    | 1592  | 2092 | 204 |
|                 | Sampling frame | 256.52                     | 1594    | 3149    | 1555  | 2076 | 189 |
| Whiskeytown     | Entire park    | 170.31                     | 258     | 1894    | 1636  | 728  | 369 |
|                 | Sampling frame | 84.27                      | 258     | 1885    | 1627  | 754  | 340 |
| Oregon Caves    | Entire park    | 18.22                      | 805     | 2028    | 1223  | 1385 | 270 |
|                 | Sampling frame | 7.1                        | 805     | 2028    | 1223  | 1417 | 272 |
| Redwood         | Entire park    | 572.18                     | 0       | 981     | 981   | 290  | 201 |
|                 | Sampling frame | 330.55                     | 1       | 981     | 980   | 313  | 194 |

The general topographic positions sampled by the plots are shown in Table 5. The software package Topographic Position Index (<http://www.jennessent.com>) was used to classify each park landscape into five topographic categories: valley, lower slope, middle slope, upper slope, and ridge. The software user specifies thresholds defining the topographic categories using histograms of the proportion of the landscape that falls into each category. We chose a default approach and applied it consistently to both the sampling frames and park landscapes as a whole for direct comparison. Maps illustrating the classified landscapes are shown in Figure 6. Detailed methods are available from Lorin Groshong, Klamath Network GIS specialist.

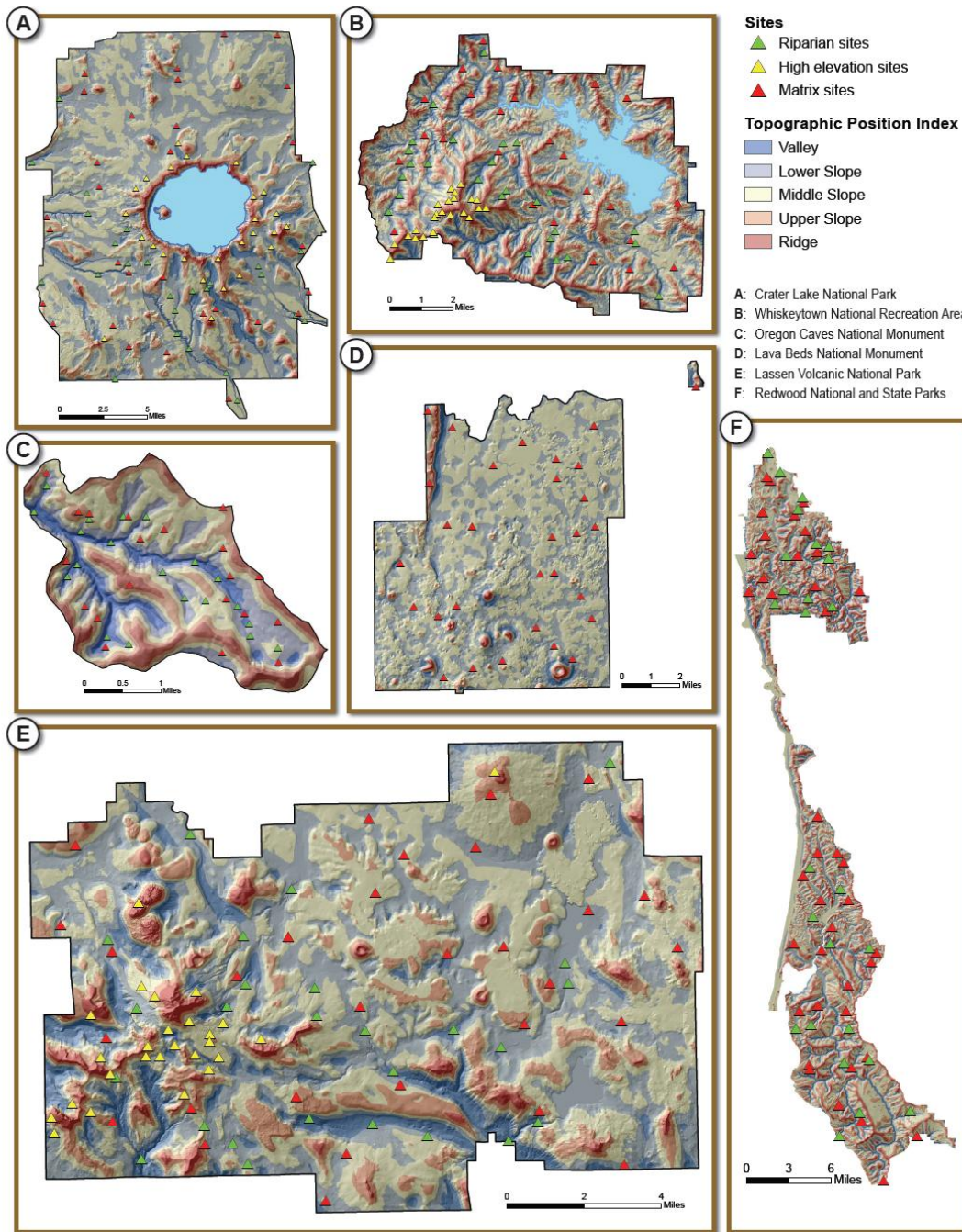


**Figure 6.** Sample locations for high elevation, matrix, and riparian/wetland sampling frames, shown in relation to topographic classes in the landscape (see text for methods).

As illustrated in Figure 6, at Crater Lake, Lassen Volcanic, and Whiskeytown there are more plots in valley locations and ridges, and generally fewer in mid-slope positions compared to the proportions of these categories park-wide. Similar patterns were found at Oregon Caves and Redwood, except that there were not more ridge plots in these parks. Lava Beds differed in having fewer plots in valley and ridge positions compared to the landscape as a whole. In general

these differences, caused by the non-random location of roads and trails, are fairly minor in magnitude. The exception is Oregon Caves, where valleys are sampled in much greater proportion compared to their presence in the landscape. This is due to the location of 20 riparian plots within the small confines of this park. We considered 20 plots to be a minimal sample size for any one sampling frame, and thus placed 20 plots in the riparian zones at Oregon Caves even though they account for a small area.

**Table 5.** Topographic positions sampled by plots located in each park compared with the percentage of each park in a particular topographic position class.

| Park         | Topographic position | Sq. km | % Park area | # Plots | % of plots |
|--------------|----------------------|--------|-------------|---------|------------|
| Crater Lake  | Valley               | 55.7   | 8           | 12      | 15         |
|              | Lower slope          | 305.4  | 41          | 32      | 39         |
|              | Middle slope         | 286.8  | 39          | 22      | 27         |
|              | Upper slope          | 72.3   | 10          | 10      | 12         |
|              | Ridge                | 17.5   | 2           | 6       | 7          |
| Redwood      | Valley               | 44.9   | 8           | 15      | 23         |
|              | Lower slope          | 113.9  | 20          | 13      | 20         |
|              | Middle slope         | 191.8  | 34          | 16      | 24         |
|              | Upper slope          | 154.2  | 27          | 14      | 21         |
|              | Ridge                | 67.3   | 12          | 8       | 12         |
| Lava Beds    | Valley               | 5.7    | 3           | 0       | 0          |
|              | Lower slope          | 70.6   | 37          | 9       | 30         |
|              | Middle slope         | 106.1  | 56          | 19      | 63         |
|              | Upper slope          | 5.1    | 3           | 2       | 7          |
|              | Ridge                | 1.6    | 1           | 0       | 0          |
| Lassen       | Valley               | 34.4   | 8           | 9       | 11         |
|              | Lower slope          | 152.4  | 35          | 28      | 34         |
|              | Middle slope         | 170.9  | 39          | 29      | 35         |
|              | Upper slope          | 62.1   | 14          | 13      | 16         |
|              | Ridge                | 14     | 3           | 3       | 4          |
| Oregon Caves | Valley               | 2.1    | 11          | 12      | 30         |
|              | Lower slope          | 4.7    | 26          | 11      | 28         |
|              | Middle slope         | 5.6    | 31          | 10      | 25         |
|              | Upper slope          | 3.7    | 20          | 4       | 10         |
|              | Ridge                | 2.2    | 12          | 3       | 8          |
| Whiskeytown  | Valley               | 16.5   | 10          | 19      | 25         |
|              | Lower slope          | 45.7   | 27          | 15      | 20         |
|              | Middle slope         | 59.2   | 35          | 19      | 25         |
|              | Upper slope          | 33.9   | 20          | 13      | 17         |
|              | Ridge                | 15     | 9           | 9       | 12         |

### **2.3.3 Riparian and Wetland Vegetation**

Separate riparian sampling frames were developed for Crater Lake, Whiskeytown, Redwood, and Oregon Caves. No riparian or wetland habitat exists at Lava Beds. Perennial stream coverages were derived from USGS National Hydrography Dataset (NHD) and confirmed by park resource staff. Perennial streams were buffered by 20 m to delineate the riparian sampling frames in each park. At Lassen Volcanic, wet meadow habitat is also extensive and co-located with riparian habitat. To include these wetlands, we created a combined riparian and wetland habitat sampling frame using the National Wetlands Inventory coverage to identify the extra riparian wetland habitat. Wetlands were chosen from this coverage after open water areas were first excluded.

Once suitable riparian and wetland habitat was delineated, we applied our selection criteria to exclude areas that were either within 100 m or more than a kilometer from a road or trail, and any areas where the slope exceeded 30 degrees. GRTS was used to locate plots within the suitable sampling areas. At Lassen Volcanic, plot location was done separately for riparian and wetland areas and wetland plots that fell within 500 m of riparian plots were excluded. The number of plots located in riparian habitats or a combination of riparian and wetland habitat (Lassen Volcanic only) was 30 percent of the total plots for a given park (except at Lava Beds, which had no riparian habitat). At Lassen Volcanic, plots were split evenly between riparian and wetland areas, which had similar total area in each sampling frame. Plot allocation is described in greater detail later in section 2.7 (Table 9). Riparian sampling frames for the parks are shown in Figure 6.

### **2.3.4 Sensitive High Elevation Vegetation**

Sensitive high elevation habitat was not precisely defined in scoping meetings for the vegetation protocol, so we define it here. Subalpine and alpine habitat occurs in both Crater Lake and Lassen Volcanic, but the elevational boundaries of the zones are poorly defined on the skeletal volcanic soils of the parks. The lower elevational boundaries of subalpine habitats have been defined as 1818 m (6000 ft) in Crater Lake and about 2121 m (7000 ft) in Lassen Volcanic. The subalpine areas above these contours constitute ~35% and 53% of the two park areas, respectively. Alpine zones above about 2424 m (8000 ft) in Crater Lake 2727 m and (9000 ft) in Lassen Volcanic, comprise less than 5% of each park, respectively. Thus, including all subalpine area in the definition of sensitive high elevation habitat would create an extensive area for locating targeted samples, and they would not be more intensively sampled by locating 30 percent of plots within this area. Conversely, including just alpine areas would be too limited. To balance these considerations and focus the samples in the most sensitive areas, we chose to select just the upper subalpine areas, along with alpine areas, as sensitive high elevation vegetation. Elevation thresholds of 2057 m (6750 ft) and 2424 m (8000 ft) were used at Crater Lake and Lassen Volcanic. The area above these contours represents 10.8% and 6.6% of each park, respectively.

Sensitive high elevation habitat on Shasta Bally, the highest peak at Whiskeytown, was also identified as a priority, although it does not reach upper subalpine elevations. The area is distinctive and characterized by extremes in weather and unique vegetation. We considered sensitive high elevation habitat on Shasta Bally to be all area above 1524 m (5000 ft), where unusual, isolated vegetation of red fir forest and upper montane chaparral occur along with rare plants and granitic outcrops. This area constitutes 3.4% of the park. Climate change may be a threat to this mountain-top-limited vegetation.

As with the other sampling frames, areas within 100 m or more than a kilometer from a road or trail, and any areas where the slope exceeded 30 degrees, were excluded. Polygons smaller than 2.5 ha were also excluded since plots may not fit within them. Figure 6 shows sampling locations for sensitive high elevation sampling frames for the parks.

## **2.4 Plot Layout and Design**

Our plot design is adapted from methodologies of the Carolina Vegetation Survey (Peet et al. 1998), which have been tested and are being used in Great Smoky Mountains National Park for vital signs monitoring (Jenkins 2006). According to Peet et al. (1998), this system is appropriate for diverse applications, incorporates multiple scales, yields data compatible with those from other common methods, and may be applied across a broad range of vegetation types. The Great Smoky Mountains National Park plot design is slightly reduced in intensity from the methods in Peet et al. (1998), making it more cost-effective and feasible. For application in the Klamath Network, we made additional changes to definitions of overstory tree diameter, snag classes, woody debris decay classes, and methods for sampling woody debris to aid in data compatibility with NPS Fire monitoring and FIA monitoring programs (Appendix E contains a comparison of these protocols). This will enable us to potentially do efficient meta-analyses with data from different programs. For example, we could analyze changes in the number of trees in forests that are less than or greater than 15 cm DBH because this is a common threshold. Had we chosen different tree size classes, such a meta-analysis would not be possible.

The standard unit of observation in the plot layout is a 10 x 10 m module (Figure 7). This modular design allows flexibility in sampling intensity, time commitment, and plot layout. A standard 2 x 5 arrangement of modules results in 20 x 50 m plot with a total area of 0.1 ha. This is consistent with the FMH standard plot size. In riparian zones, a linear series of modules is used to sample a comparable area but stay within the target habitat. Plots will be placed along contours perpendicular to the slope or lengthwise on ridges or along drainages (SOP #4: Site Set-up, Monumentation, and Description).

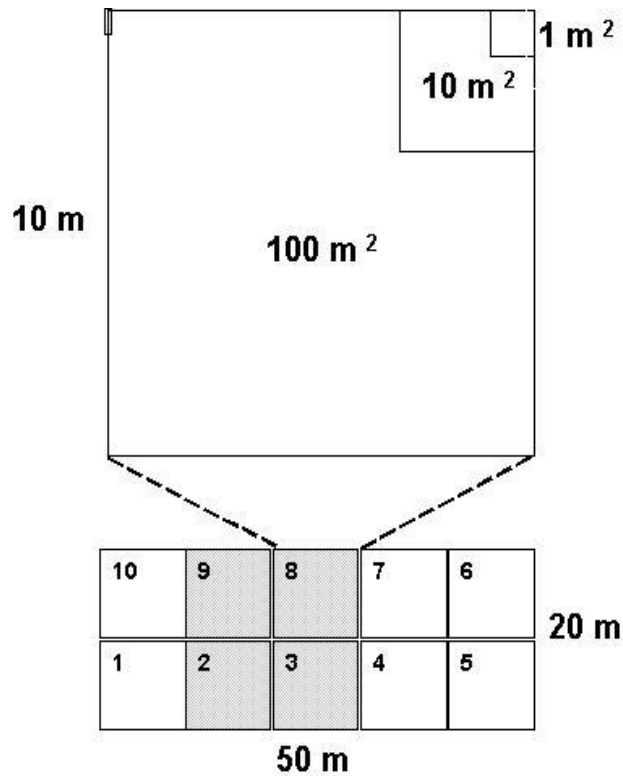


**Figure 7.** Layout of an intensive module (top) and a set of 10 modules as a 0.1 ha plot (bottom). Modules are numbered (1-10) and intensive modules (2, 3, 8, and 9) are shaded.

## 2.5 Parameters to be Monitored

A wide range of data is collected from each plot. On each forested plot, vegetation is assessed in four strata, from tree canopy to ground layers (SOP #6: Subplot Sampling [Species Cover, Tree Seedlings, and Saplings {<15 cm DBH}], SOP #7: Live and Dead Tree Sampling, and SOP #14: Collecting and Identifying Unknown Plants). Nested plots allow for the examination of relationships between area and species accumulation. Other components of vegetation to be examined include down wood, litter, and duff (SOP #8: Litter, Duff, and Downed Wood Sampling). The full list of parameters that will be measured under this protocol is provided in Table 6. The objective associated with each parameter is also listed in Table 4 along with the SOP describing the measurement methods for the parameters.

**Table 6.** Parameters that will be sampled under this protocol and the Compositional (C), Structural (S) and Functional (F) objective with which they are most associated. The SOP that describes how to sample each parameter, and a brief description of sampling specifics is also provided.

| Parameter                                                   | Objective | SOP | Sampling                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------|-----------|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Environmental variables:                                    | F         | 4   |                                                                                                                                                                                                                                                          |
| Slope                                                       |           |     | 1. Slope-measured at three locations.                                                                                                                                                                                                                    |
| Aspect                                                      |           |     | 2. Aspect-measured at three locations.                                                                                                                                                                                                                   |
| Elevation                                                   |           |     | 3. Elevation (from GPS)                                                                                                                                                                                                                                  |
| Microtopography                                             |           |     | 4. Microtopography:<br>Convex<br>Concave<br>Straight<br>Undulating                                                                                                                                                                                       |
| Macrotopography                                             |           |     | 5. Macrotopography:<br>apex, hill, or ridge top.<br>upper 1/3 of a hillslope.<br>middle 1/3 of a hillslope.<br>lower 1/3 of a hillslope.<br>bottom of a hillslope adjoining a valley bottom, usually with a shallower slope than the adjacent hillslope. |
| Disturbance                                                 |           |     | 6. Evidence of disturbance (from checklist).                                                                                                                                                                                                             |
| Plant cover types                                           | C         | 6   | Ocular estimate recorded for all species in nested subplots within each of 4 intensive modules. Cover is estimated for individuals belonging to four height strata:<br>S1 = (<0.75 m height),<br>S2 = (0.75-2.5 m),<br>S3 = 2.6-5 m),<br>S4 = >5.        |
| Vascular plant species                                      |           |     |                                                                                                                                                                                                                                                          |
| Rock, soil, fine and coarse wood and bryophyte (water/snow) |           |     |                                                                                                                                                                                                                                                          |
| Species presence                                            | C         | 6   | Percent cover of rock (>15 cm diameter), bare soil, water, bryophytes, fine wood (snow/water) and litter, and coarse woody debris are also recorded for the 100 m <sup>2</sup> plot.                                                                     |
| Photographs from photo points                               | S         | 5   | Presence of additional species only found outside intensive modules recorded as occurring elsewhere in the 20 x 50 plot.                                                                                                                                 |
| Shrub height                                                | S         | 6   | Each 20 x 50 plot will be photographed 6 times, once from each end of the long axis (2) and once in each of the intensive plot (4). Photographs will be taken at eye level, approximately 5-5.5 feet from the ground.                                    |
| Tree seedlings <15cm tall                                   | F         | 6   | The average height of shrub cover is measured for each intensive module. The height is the average for the 4 quadrants of each intensive module.                                                                                                         |
| Trees seedlings from 15cm to 2.54 cm DBH                    | F         | 6   | Density in the four 10 m <sup>2</sup> (3.16m x 3.16m) subplots located in the corner of the 4 intensive modules.                                                                                                                                         |
|                                                             |           |     | Density in the four 10 m <sup>2</sup> (3.16m x 3.16m) subplots located in the corner of the 4 intensive modules.                                                                                                                                         |

**Table 6.** Parameters that will be sampled under this protocol and the Compositional (C), Structural (S) and Functional (F) objective with which they are most associated. The SOP that describes how to sample each parameter, and a brief description of sampling specifics is also provided. (continued).

| Parameter                                   | Objective | SOP | Sampling                                                                                                                                                                                                                                                                 |
|---------------------------------------------|-----------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Tree saplings <1.4 m tall and DBH < 2.54 cm | F         | 6   | Density in the 4 intensive 100 m <sup>2</sup> (10 m x 10 m) modules                                                                                                                                                                                                      |
| Tree saplings from 2.54 - 5 cm DBH          | F         | 6   | Density in the 4 intensive 100 m <sup>2</sup> (10 m x 10 m) modules.                                                                                                                                                                                                     |
| Trees from 5-10cm DBH                       | F         | 6   | Density in the 4 intensive 100 m <sup>2</sup> (10 m x 10 m) modules.                                                                                                                                                                                                     |
| Trees from 10-15cm DBH                      | F         | 6   | Density in the 4 intensive 100 m <sup>2</sup> (10 m x 10 m) modules.                                                                                                                                                                                                     |
| Trees with DBH ≥ 15 cm                      | F         | 7   | Measured or estimated in all modules:<br>DBH to the nearest cm.<br>Canopy position: dominant, codominant, intermediate, suppressed, open grown<br>Canopy base height<br>Tree condition: No dieback; 1-25% dieback; 26-50% dieback; 51-75%, = > 75 % dieback; broken top. |
| Live canopy cover                           | S         | 7   | Average of 4 densiometer readings, one in each cardinal direction in each module.                                                                                                                                                                                        |
| Dead trees with DBH ≥ 15 cm                 | F         | 7   | DBH to nearest 1 cm in all modules.<br>Decay class<br>Cause of death (checklist)                                                                                                                                                                                         |
| Down wood 0-.62 cm in diameter              | S         | 8   | Tallied on the following meter segments of a 50 m centerline transect: 0-1, 5--6, 10-11, 15-16, 20-21, 25-26, 30-31, 35-36, 40-41, 45-47 meters.                                                                                                                         |
| Down wood 0.63-2.54 cm in diameter          | S         | 8   | Tallied on the following meter segments of a 50 m centerline transect: 0-2, 5-7, 10-12, 15-17, 20-22, 25-27, 30-32, 35-37, 40-42, 45-47 meters.                                                                                                                          |
| Down wood 2.5-7.6 cm in diameter            | S         | 8   | Tallied on the following meter segments of a 50 m centerline transect: 0-2, 5-7, 10-12, 15-17, 20-22, 25-27, 30-32, 35-37, 40-42, 45-47 meters.                                                                                                                          |
| Down wood greater than 7.6 cm in diameter   | S         | 8   | Tallied along the entire 50 m transect, and their width (in cm) and length (in m) measured.                                                                                                                                                                              |
| Litter and Duff                             | S         | 8   | Take depth/thickness measurements for litter and duff at 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 m along the 50 m transect.                                                                                                                                         |

One important environmental parameter that strongly affects vegetation is soil. Soil analyses would have to be conducted by outside laboratories. Though desirable, the Network does not have adequate funding to add soil analyses without subtracting something else from the vital signs monitoring program. Therefore, the Network will explore the possibility of obtaining additional funding in an effort to pay for collection and analysis of soils from each plot in each park during the second round of sampling (years 4-6 of the monitoring). This would provide baseline soil information from which future samples could be compared.

## **2.6 Rationale for Selection of Response Design**

The objectives of this protocol, available financial resources, and practical concerns were carefully considered when developing the spatial sampling design. We have incorporated many aspects of FMH and FIA. We are using the same plot size and most of the methods of FMH, but we cut out some of the time consuming aspects of this protocol, such as tree mapping, point intercept sampling. This was because FMH takes too long to sample one plot, often a whole day. We need to be able to sample plots and have sufficient travel time to and from plots in one day. We did not use the point intercept sampling because of how time consuming it is, and because it misses too many uncommon species. The main difference between our approach and FIA is the plot shape. Our module design allows much greater flexibility in linear habitats, such as riparian forests, than FIA circular plots. Other aspects of FIA are based on goals of the forest resource inventory, such as documenting tree volume and growth. We did not include these time-consuming forest mensuration methods. Nor did we wish to slope correct plots, which allows extrapolation of scale invariant parameters like stand volume across a unit area but is not appropriate for extrapolating nonlinear unit/area relationships, like floristic diversity across park landscapes.

A compositional goal of ours was to be able to document species richness at different scales, which is not possible with FMH or FIA. Our plot design is derived from the Whittaker plot, designed to explicitly evaluate species diversity. Our response design is also consistent with our multivariate data analysis approaches emphasizing relationships among all species, as described in SOP #12: Reporting and Analysis of Data.

The selected design offers a balance between statistical rigor and real-world applicability. For tracking changes in vegetation community composition, structure, and function through time, the plot and survey design offers several important advantages:

- *Plot design is appropriate for a variety of vegetation types and structures.*

The plot design may be readily modified to fit various vegetation types, topographic conditions, or study designs. The arrangement of 10 x 10 m modules can be modified to tailor the sampling design to a given area, as we have done for riparian sampling.

- *Plot design addresses community and species dynamics related to sampling scale.*

Since the protocol is based upon a modular design with nested subplots, the sample units may be added together to examine relationships at a variety of spatial scales. Since the modules are adjoining, analyses of scale-dependent relationships are possible. Many other plot designs contain more spatially distributed, but non-adjoining subplots. These other designs encompass a greater amount of spatial variability, which may be desirable for examining gross species richness. However, the distance between the plots is arbitrary and not related to the spatial

variability unique to each of the vegetation communities sampled. Therefore, greater variability accounted for by these plots may be an artifact of the sampling design and not a product of natural variation within the plant community.

- *Compatibility with other active sampling designs and studies.*

The design has been used to sample over 3000 plots in North Carolina, Tennessee, South Carolina, and Georgia. A similar design is used to monitor vegetation in the Prairie Cluster parks. The design also overlaps with the FMH plot design. The plot design used by NatureServe in its classification of vegetation in the Southeast also uses a 20 x 50 m layout and records species cover by strata.

- *The sampling is not too time-consuming.*

The average sampling time during the pilot study (Appendix A), was 4-5 hours. Although some plots, particularly in species-rich riparian vegetation, can take longer, the average sampling rate should be 1-2 plots per day, which allows for adequate sample sizes. Although the sampling frame includes plots that require hiking up to several kilometers on trails, it places nearly all plots in areas where travel to and from the site and sampling can be accomplished in a day. Although restricting the sampling frame by accessibility greatly increases the number of plots that can be sampled as part of the long-term monitoring program by decreasing travel times to plots, it does not create sampling frames that are unrepresentative of parks (Figures 5, 6).

## 2.6 Frequency and Timing of Sampling

The Network will have a 3 year, always revisit schedule in which two parks are paired together for sampling each year, as shown in Table 7. Careful consideration was given to pairing of parks in order to allow for a long field season by having one park that can be sampled early in the season and one late. We also strove to make the workload as even as possible among years by not combining large parks. In order to have a field season from May through September, the Network must combine field work in parks that are suited to sampling early and late in the field season. Fortunately, parks can be paired to accomplish this as follows: Lava Beds/Redwood, Whiskeytown/Lassen Volcanic, and Crater Lake/Oregon Caves. With six parks forming three pairs, and sampling every year, the Network can accommodate the 3 year revisit schedule for each park.

**Table 7.** Revisit design for the vegetation monitoring protocol.

|                               | Sampling Year |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|-------------------------------|---------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                               | 2011          | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
| Lava Beds & Redwood           | x             |      |      | x    |      |      | x    |      |      | x    |      |      | x    |      |      |
| Lassen Volcanic & Whiskeytown |               | x    |      |      | x    |      |      | x    |      |      | x    |      |      | x    |      |
| Crater Lake & Oregon Caves    |               |      | x    |      |      | x    |      |      | x    |      |      | x    |      |      | x    |

It is critical that plots be sampled during each revisit at the same general stage of vegetation phenology to the extent possible given unpredictability of climate. For example, low elevation vegetation at Whiskeytown contains many annual and ephemeral perennial species that may be present at maximum cover for a short period of time in spring. These species could be missed if

sampling is undertaken too late. Therefore, sampling in each park will correspond to the peak time for floral diversity and ease of identification. The seasons in which sampling shall take place in different areas of the Network are shown in Figure 8.

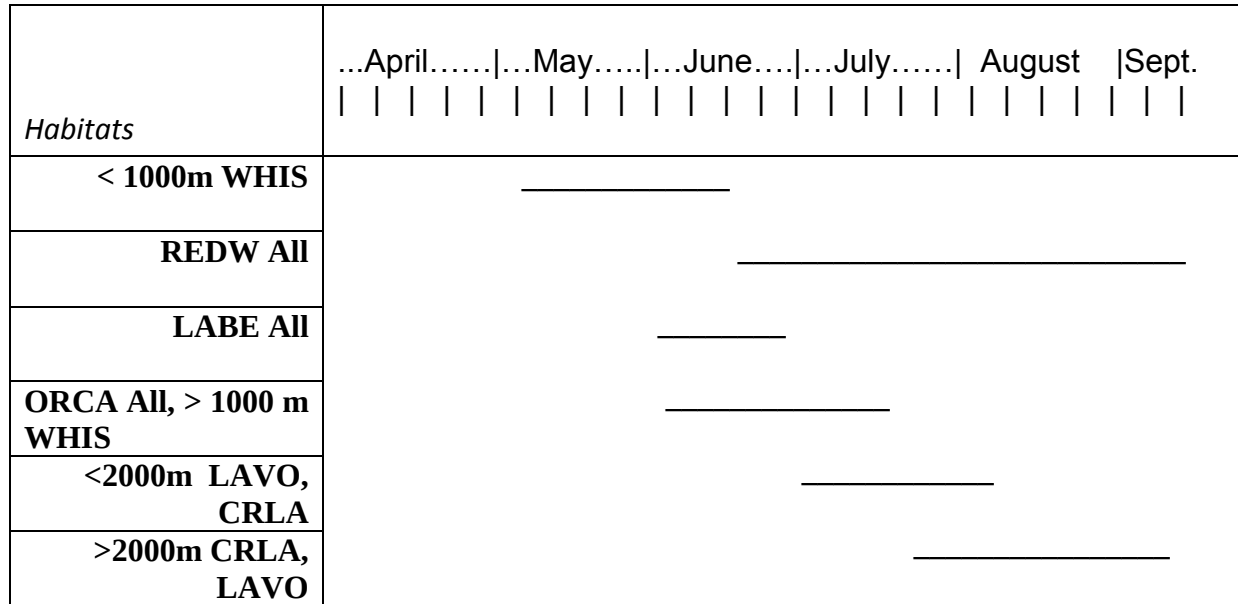


**Figure 8.** Bars denote seasonal windows for vegetation sampling in different elevation zones in different parks of the Klamath Network. WHIS = Whiskeytown, REDW = Redwood, LABE = Lava Beds, ORCA = Oregon Caves, LAVO = Lassen Volcanic, and CRLA = Crater Lake.

## 2.7 Sampling Effort in Parks

In evaluating the total Klamath I&M monitoring budget, it was determined that from \$129,000 to \$157,000 would be available for vegetation monitoring. The pilot study confirmed that, on average, five plots could be sampled per week by each two person crew. Thus, we are assuming that, given person days and staffing discussed below, we can average about 120 plots per year. The exact number each year will vary due to the pairing of parks (Table 7) and diversity of vegetation in the parks.

We allocated the number of plots to be sampled in each park based generally on the number of vegetation types present in each park (Table 8). This classification was presented and refined by experts from the parks at the vegetation protocol development meetings.

**Table 8.** Parameters used in defining sampling effort in each park. Park area and broadly defined vegetation types in the Klamath Network and their importance in each park. A= abundant, C = common, U = uncommon.

|                                 | <i>Park Unit</i> |                 |           |              |           |              |
|---------------------------------|------------------|-----------------|-----------|--------------|-----------|--------------|
|                                 | Crater Lake      | Lassen Volcanic | Lava Beds | Oregon Caves | Redwood   | Whiskeytown  |
| Area (sq km)                    | 738              | 430             | 188       | 18           | 550       | 176          |
| Percent of Network area         | 35.4             | 20.6            | 9.0       | 0.9          | 26.4      | 8.4          |
| <b>Vegetation</b>               |                  |                 |           |              |           |              |
| Coastal Environments            |                  |                 |           |              |           |              |
| Salt Marsh                      | -                | -               | -         | -            | U         | -            |
| Coastal strand, dune, scrub     | -                | -               | -         | -            | C         | -            |
| Coastal Prairie                 | -                | -               | -         | -            | U         | -            |
| Coastal Sitka Spruce Forest     | -                | -               | -         | -            | C         | -            |
| Low Elevation Environments      |                  |                 |           |              |           |              |
| Redwood Forest                  | -                | -               | -         | -            | A         | -            |
| Mixed Evergreen Forest          | -                | -               | -         | C            | C         | C            |
| Oak/Pine Woodlands*             | -                | U               | -         | U            | C         | A            |
| Serpentine vegetation           | -                | -               | -         | U            | U         | -            |
| Annual Grassland                | -                | -               | U         | -            | -         | U            |
| Perennial Grassland             | -                | -               | U         | -            | C         | ?            |
| Chaparral                       | -                | -               | -         | U            | U         | A            |
| Mid Elevation Environments      |                  |                 |           |              |           |              |
| Mixed Conifer Pine              | A                | A               | -         | U            |           | C            |
| Mixed Conifer Fir               | A                | A               | -         | A            |           | C            |
| Oak/Pine forest                 |                  |                 |           | U            |           | C            |
| Montane Chaparral               | U                | U               | -         | U            | -         | C            |
| Upper Montane Environments      |                  |                 |           |              |           |              |
| Subalpine Forest                | A                | A               | -         | -U           | -         | U            |
| Montane Meadows                 | C                | C               | -         | U            | -         | U            |
| Alpine                          | C                | A               | -         | -            | -         | -            |
| Great Basin Environments        |                  |                 |           |              |           |              |
| Sagebrush Steppe                | U                | -               | A         | -            | -         | -            |
| Juniper Woodland/Savanna        | -                | -               | A         | -            | -         | -            |
| Ponderosa Pine Woodland         | C                | U               | C         | -            | -         | **           |
| Rosaceous Shrubland             | -                | -               | C         | -            | -         | -            |
| Mesic and Hydric Environments   |                  |                 |           |              |           |              |
| Riparian Forests                | C                | C               | -         | C            | C         | C            |
| Freshwater Marsh                | -                | C               | -         | -            | U         | U            |
| Seeps and Springs               | C                | C               | -         | U            | U         | U            |
| Alkali Meadows                  | -                | ?               | -         | -            | -         | U            |
| <b>Vegetation types (total)</b> | <b>10</b>        | <b>11-12</b>    | <b>6</b>  | <b>12</b>    | <b>13</b> | <b>15-16</b> |

\*At low elevations usually dominated by Oregon White Oak (*Quercus garryana*) and at slightly higher to mid-elevations by California black oak (*Q. kelloggii*). Ponderosa pine (*Pinus ponderosa*) is common in both cases. Only Jeffrey pine (*P. Jeffreyi*) is at Redwood.

\*\*Ponderosa pine, which is common at Whiskeytown, is captured there under Oak/Pine woodlands.

As summarized in Table 9, those parks with greater complexity (Redwood and Whiskeytown) were allocated 40 matrix plots per visit. Those with intermediate complexity (Crater Lake, Lassen Volcanic, and Lava Beds) were allocated 30 plots. Oregon Caves was allocated 20 matrix plots, to include the expansion area. The large parks with riparian and wetland habitats were allocated 26 plots per visit for this sampling frame, while Oregon Caves was allocated 20 plots. Twenty-six plots were also allocated for sensitive high elevation habitat in Crater Lake and Lassen Volcanic, while 20 plots were allocated for the much smaller area of high elevation habitat at Whiskeytown. Due to recent concern about the possible danger of sampling vegetation in Whiskeytown because of the presence of marijuana cultivators, the matrix sampling frame at Whiskeytown will be limited to 25 plots along roads and trails, co-located with landbird sampling.

**Table 9.** Allocation of sampling effort for each of the 12 vegetation target populations within the Klamath Network. The sample size for each park has been selected with regard to desired precision and the size and vegetation complexity of the park. Sampling in the matrix at Whiskeytown has been suspended due to safety concerns.

| Environmental Stratum | Park            | Sample Size, n |
|-----------------------|-----------------|----------------|
| Riparian              | Crater Lake     | 26             |
|                       | Lassen Volcanic | 26             |
|                       | Oregon Caves    | 20             |
|                       | Redwood         | 26             |
|                       | Whiskeytown     | 26             |
| Matrix                | Crater Lake     | 30             |
|                       | Lava Beds       | 30             |
|                       | Lassen Volcanic | 30             |
|                       | Oregon Caves    | 20             |
|                       | Redwood         | 40             |
|                       | Whiskeytown     | 25*            |
| High Elevation        | Crater Lake     | 26             |
|                       | Lassen          | 26             |
|                       | Whiskeytown     | 20             |

\*40 matrix plots may be sampled at Whiskeytown in the future if safety concerns due to marijuana cultivation diminish.

## 2.8 Statistical Power

It is difficult to assess the statistical power of the future monitoring data. One reason is that data from repeat sampling are not yet available. We will do power analyses once these data are available. A rigorous power analysis may not be possible until after two to three rounds of sampling in each park. Another reason that power cannot be assessed is that vegetation changes may be very slow and gradual, except where episodic disturbances like fire or insect outbreaks occur. Stochastic changes can only be accounted for in *a priori* power analyses if the frequency and magnitude of the change can be modeled.

Appendix B summarizes the preliminary univariate power analysis for the Klamath Network vegetation protocol. The power analysis is based on the pilot study data collected at Crater Lake and US Forest Service Forest Inventory and Analysis (FIA) data from the Oregon Cascades near Crater Lake. Pilot data are from one sample period and FIA data are from two periods that were

1 year apart. The parameters analyzed were total tree basal area and saplings measured or estimated for sampling plots. Plot sizes were similar between data sources and all data were converted to per ha values for this analysis. A standard linear model was used to estimate power based on these limited data and the Network's temporal sampling scheme. Based on this, the sampling design seems sufficient to detect a 50% change with 80 percent power over 15 years for basal area, but it may take twice that long to detect 50% change in saplings, which exhibit greater spatial and temporal variation. The two variables selected should be representative of two relative extremes in terms of variability in vegetation structural and functional data (i.e., we suspect we will be able to detect 50% change with 80 percent power over a time period ranging from 15-30 years for most variables).

Much of the information and insight about temporal change will be contained in multivariate analyses of vegetation composition data in relation to environmental parameters. These analyses can be used to efficiently explore the data and identify progressive changes. Identification of such change is based on assessing cumulative plot dissimilarity over time (SOP #12: Reporting and Analysis of Data). Compositional changes can provide compelling evidence that a meaningful ecological event has occurred, or an ecological threshold has been exceeded, before these changes would be detected using other methods (Clarke et al. 2008).

## 2.9 Co-location of Other Vital Signs

The sampling design is integrated with the Landbird Monitoring and stream sampling (water quality and aquatic community) protocols, which will likewise provide detailed status and trend information on a 3 year sampling frequency. The vegetation protocol established a plot in the center of a randomly located Landbird Monitoring Protocol systematic sampling route. Six to twelve adjacent bird count sampling points are placed 250 m apart, according to a set of rules. These rules ensure that a grid is set up as closely around the same GRTS sample used to locate vegetation plots as possible, using a systematic, random approach within constraints in the sampling frame already defined (Figure 6). Not all sampling frames will be monitored in each park under the landbird protocol (Table 10). The stream sampling protocol is currently being developed and will include a number of sites co-located with vegetation monitoring plots.

**Table 10.** Number of landbird survey routes in each park that will be co-located with an individual vegetation monitoring plot and the sampling frames in which these routes will be placed. The exact number of routes per sampling frame has yet to be determined.

| Park            | Total sampling routes | Matrix | Riparian | High Elevation |
|-----------------|-----------------------|--------|----------|----------------|
| Crater Lake     | 35                    | x      | -        | x              |
| Lava Beds       | 25                    | x      | -        | -              |
| Lassen Volcanic | 25                    | -      | x        | -              |
| Oregon Caves    | 4                     | x      | x        | -              |
| Redwood         | 30                    | x      | -        | -              |
| Whiskeytown     | 30                    | x      | -        | x              |



## **3.0 Field Methods**

### **3.1 Field Season Preparation and Equipment Set-up**

Preparations for field work must begin several months before the season begins, in order for the field crews to be fully staffed. Details for the preseason preparation are included in SOP #1: Field Work Preparation. Details on observer training are provided in SOP #2: Observer Training. Roles and responsibilities are spelled out in detail below (5.1 Roles and Responsibilities). In general, it is the Field Crew Lead's responsibility to work with the Park Contacts to set up permits and to ensure availability of housing, keys, vehicles, radios, and computers when applicable. Sampling trips by Network crews will be scheduled and organized by the Field Crew Lead prior to the start of each field season. It is also the Field Crew Lead's responsibility to create a detailed work plan for each sampling trip prior to going into the field. In addition, the Field Crew Lead will ensure that the field crew is properly trained, has all the required gear, and has the most up-to-date field forms. SOP #1: Field Work Preparation, includes an equipment list, while SOP #6 lists supplies necessary for monumenting plots.

It is the Field Crew Lead's responsibility to make certain all databases (handheld and desktop applications) and field equipment (e.g., laser range finders, GPS units, etc.) are calibrated and properly set up prior to heading into the field (SOP #3: Setting up the Electronic Field Equipment). The Field Crew Lead will work closely with the Data Manager to get the equipment setup properly. The crew will be trained on the use of GPS units by the GIS Specialist. The Field Crew Lead will work with the field crew to make sure it is clear where everyone is going, what is expected to be completed, and timelines for when the work should be finished.

Prior to working in the field, each member of the field crew must review the entire protocol. The Field Crew Lead will provide training on safety, administrative procedures, and field methods for recording data following the Data Manager's specifications. All equipment and supplies shall be organized, prepared, and tested prior to the field season. All files needed for navigation will be loaded on to a GPS unit and on to a laptop, which will be taken to the park. SOP #3: Setting up the Electronic Field Equipment explains how to set up the current GPS units being used.

At least 1 month prior to when Network crews expect to visit the field sites, the Field Crew Lead will communicate with the Park Contacts at each park to assure that all logistical needs are addressed and on schedule. Each day, the Project Lead shall provide a briefing regarding any safety, plant identification, and park navigation issues of concern for the day. The Project Lead will also assign crew members to the search units for the day. Crew members will navigate to plots using the GPS unit, compass, and maps. Crews will be locating plots and revisited plots in the field following SOP #4: Site Set-up, Monumentation, and Description.

Prior to sampling in a park, the crew will spend a couple of days identifying plants throughout the park with the Project Lead. For new crew members who have not sampled a plot, all procedures will be demonstrated.

### **3.2 Collecting and Recording Data in the Field**

Data are to be collected using GPS units (Trimble XT, Garmin V), a laser rangefinder, and handheld computers (tablet computer). Instructions for using the GPS and ArcPad software are provided in SOP #3: Setting up the Electronic Field Equipment. If there is a problem with the

tablet computer that prevents its use, data will be recorded on standardized datasheets, which the crew will keep at their disposal. A description of how to enter the data is provided in SOP #10: Data Entry. Datasheets and electronic forms should be reviewed after each task is completed to make certain they are complete. At the end of a park-specific sampling trip, data forms and databases are submitted to the Crew Lead for review.

### **3.3 Post-field Season**

After the field season, a number of activities need to occur to finalize the year's sampling efforts and help ensure smooth start-up for the next field season (SOP #15: Post Field Season).

Equipment will be cleaned, inventoried, and stored. Any equipment that is found to be in need of repair or replacement will be identified and reported in writing to the Project Lead. A short report about the year's sampling shall be prepared by the field crew. If there are any special findings that are urgent for managers, such as a new invasive species, these will be described in a written briefing memo to be sent to parks by December 1<sup>st</sup> of the year of sampling (SOP #12: Reporting and Analysis of Data).

## **4.0 Data Management, Analysis, and Reporting**

This section will focus on all aspects of managing, storing, analyzing, and reporting monitoring data according to the Network's Data Management Plan (Mohren 2007) and the reporting schedule in the Klamath Network Monitoring Plan (Sarr et al. 2007). Methodological details are located in these plans and the SOPs referenced herein. It is crucial to successful monitoring that project personnel understand all necessary data management methodologies. This includes knowing who is responsible for implementing the methods and the timelines they are expected to follow when conducting data management.

### **4.1 Data Management**

Data management is a critical component of data collection and entry in the field (SOP #10: Data Entry), as well as data storage and archiving at the end of the field season (SOP #11: Data Transfer, Storage, and Archiving) and data analysis and reporting (SOP #12: Reporting and Analysis of Data). The data management cycle for the sampling year ends with a review of the yearly project activities. It is the responsibility of the Crew Lead to make sure all crew members are trained in proper data management protocols and procedures. It is also the responsibility of the Crew Lead to make sure all completed data have been transferred to the Data Manager. However, at least one of the crew members will be trained in data transfer to act as a backup. Data entry will be completed using electronic and paper formats for the initial years of the project. Unless stated otherwise, data entry will be uploaded from the tablet computer to the desktop database and backed up on a nightly basis. Data will be transferred from the field computer to the master database at the end of the field season after all quality control and quality assurance processes have been followed. It is the responsibility of the Crew Leader to make sure all electronic data collected during the field visit are transferred to the Data Manager, and that hardcopy datasheets are scanned and archived according to procedures detailed in SOP #10: Data Entry.

### **4.2 Metadata and Data Dictionary Procedures**

Details on the process to develop, update, distribute, and archive metadata are provided in SOP #13: Metadata Guidelines. For GIS files and databases, metadata will be completed at the onset of implementing the protocol. Metadata will be created using Environmental Systems Research Institute (ESRI) tools, the NPS Metadata tools and Editor, and the NPS Database Metadata Extractor. Metadata will be to Federal Geographic Data Committee (FGDC) and NPS standards where applicable. It is the responsibility of the Crew Lead to complete the Metadata Interview forms at the end of each field season to document changes to the metadata. If changes have occurred, it is the Data Manager's responsibility to archive and update the metadata for each database by March 1<sup>st</sup> following the previous season's changes. The Klamath Network Data Manager will upload new metadata to Reference Applications when applicable.

The data dictionary will be finalized at the onset of implementing the protocol. It is the Crew Lead's responsibility to update the data dictionary, if needed, at the end of each field season. In addition, the Metadata Interview form; which will be submitted at the end of each field season, will be used by the Data Manager to indicate if changes have occurred to the metadata or data dictionary.

In addition to the databases and GIS layers, metadata should be completed for all images and reports as described in SOPs #13: Metadata Guidelines and SOP #5: Photographing Plots and Photograph Management.

### **4.3 Overview of Database Design**

There are a variety of databases that have been developed by multiple agencies to store and manage vegetation data. The Klamath Network looked at several of these database but we were unable to find a database that could meet the majority of the needs of our project. Therefore, we have developed a database using the Natural Resource Database Template (NRDT) developed by the National Park Service. The NRDT:

- Provides both a data interchange standard and a standard MS Access database core that allows flexibility in application design.
- Serves as a starting point for application development that can be extended as necessary to accommodate any inventory or monitoring field sampling protocol.
- Standardizes location and observation data to facilitate the integration of datasets.
- Acts as a design platform for developing database applications in MS Access, allowing users to enter, edit, display, summarize, and generate reports for inventory or monitoring datasets.
- Integrates with other I&M data management systems and data standards including the NPS Data Store, Geographic Information System (GIS) tools and data, the NPS GIS Committee Data Layers Standard, and the NPS Metadata Profile.

The NRDT Front-end Application Builder (FAB) is a Microsoft Access file that is intended to be used by developers of NRDT applications to create a front-end (user-interface) to an NRDT v.3.2 back-end (database). The FAB comes with many built-in features, including:

- table linking utility
- data backup
- compaction
- lookup table management
- main menu
- standardized data entry forms for core NRDT v.3.2 tables
- standardized data "gateway" form for retrieving records
- standardized data summary reports
- standardized data exports (for statistical packages)

A project database will be provided to each crew at the beginning of the field season. Crews will use the project database (on a tablet computer) to enter data collected at each monitoring site. After validation and verification procedures have been followed, this database will be used to create summaries and conduct data analysis for annual reports. At the end of the year, the data from the project database will be uploaded to the master database for long-term storage and future analysis (SOP #9: Vegetation Database).

The master vegetation database will house all of the verified and validated data that are collected using this protocol. Members of the Klamath Network will have read-only access to this database and can use it to conduct multi-year data summaries and to develop Analysis and Synthesis reports or publications (SOP #9: Vegetation Database).

#### **4.5 Data Entry, Verification, Validation, and Editing**

Data entry will consist of nightly transferring data from field collection devices (currently tablet computers) to a desktop or laptop computer located in a stable environment. Forms have been created to be used in conjunction with the electronic collection devices that incorporate picklists; domain values; and automated, populated fields. In addition, for the initial years of data collection, hardcopy datasheets will be completed to help with verification process described below. Details on the data entry process are described in SOP #10: Data Entry.

*Data verification* is the process of ensuring the data entered into a database correspond with the data recorded on the hardcopy field forms and data loggers. After collecting for each separate task (i.e., when each datasheet is completed), before moving to the next task, the field crew will review all hardcopy and electronic datasheets to ensure they are complete and accurate. After the end of the sampling period in a park, the Crew Lead will review the data to make sure everything has been entered properly. In addition, the Crew Lead should examine the data after collection has occurred for 1 week, to ensure the field crew is following collection and data entry methods properly. At the end of the field season, a field crew member should cross-check the hardcopy field forms with the electronic data (SOP #10: Data Entry).

*Data validation* is the process of reviewing the finalized data to make sure the information presented is logical and accurate. Data validation requires a reviewer to have extensive knowledge of what the data mean and how they were collected. At the end of the season, the Crew Lead will compile data from all field surveys. This person should examine the data using general tools built into the database and their personal knowledge to ensure that the data are accurate.

Once all validation and verification methods have been implemented, the databases will be transferred to the Klamath Network Data Manager, who will upload them to the master database. While uploading the data into the database, the data will be subjected to an automated data quality process that will flag potential missing sites and invalid or improperly formatted data.

#### **4.6 Data Certification**

Data certification is a benchmark in the project information management process that indicates that: (1) the data are complete for the period of record; (2) they have undergone and passed the quality assurance checks; and (3) they are appropriately documented and in a condition for archiving, posting, and distributing. Certification does not necessarily mean that the data are completely free of errors or inconsistencies. Rather, it describes a formal and standardized process to track and minimize errors.

To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all data. The Crew Lead is primarily responsible for completing the Data Certification form, available on the KLMN web sites. This brief form is to be submitted with the certified data according to the timeline in SOP #10: Data Entry.

#### **4.7 Product Distribution**

It will be the Klamath Network Data Manager's responsibility to utilize the season's certified raw data along with the materials presented in the Annual report, Analysis and Synthesis report, data dictionary, and Metadata Interview form to populate or update the NPS I&M databases

including NPSpecies and Reference Applications. Details on distribution can be found in SOP #11: Data Transfer, Storage, and Archive. In general:

- All reports will be posted to Reference Applications and KLMN Internet and Intranet web pages.
- All reports will be sent to the Resource Chiefs of each park and to any park staff that are associated with the project.
- A short, one-page summary of the report will be sent to all park staff in the Network.
- One record will be created in Reference Applications for each Annual report, comprehensive report, and third year Analysis and Synthesis report and linked to the corresponding species in NPSpecies.
- Metadata for each database will be created and updated based on the Metadata Interview form and data dictionary provided by the Crew Lead each year. Metadata for the project database will be posted at the NPS Data Store.
- Photographs and metadata provided for photographs will be stored in the project folder located on the Klamath Network shared drive. The Data Manager moves copies of the images to the Network Image Library, where the images will be linked to the KLMN Photograph Database.
- After the holding period (4.7.1 Holding Period), all raw data, reports, GIS layers, scanned datasheets, and any other additional appropriate materials will be packaged together in a zipped file and posted to Reference Applications.

#### **4.7.1 Holding Period**

To permit sufficient time for the NPS to have the first priority to publish data, when data are distributed, it will be with the understanding that these data are not to be used for publication without permission obtained through the Network Contact. After each 3 year survey cycle, all certified, non-sensitive data will be posted to Reference Applications. Note that this hold only applies to raw data, and not to metadata, reports, or other products that are posted to NPS clearinghouses immediately after being received and processed.

#### **4.7.2 Sensitive Information**

Certain project information, for example, the specific locations of rare or threatened taxa, should not be shared outside NPS, except where a written confidentiality agreement is in place. Before preparing data in any format for sharing outside NPS, including presentations, reports, and publications, the Crew Lead should refer to the guidance in SOP #11: Data Transfer, Storage, and Archive. Certain information that may convey specific locations of sensitive resources or treatments may need to be screened or redacted from public versions of products prior to release (SOP #17: Sensitive Data). All official Freedom of Information Act (FOIA) requests will be handled according to NPS policy. The NPS Lead will work with the Data Manager and the FOIA representative(s) of the park(s) for which the request applies.

### **4.8 Reporting and Analysis of Data**

The Klamath Network has developed a comprehensive strategy for reporting and analysis of data from this protocol over the next 15 years. There will be two elements of reporting: (1) An annual report focusing on status information, and (2) analysis and synthesis reports submitted every third year that will focus on status of various aspects of vegetation composition, structure, and function in the first four versions, and then trends in vegetation composition, structure, and

function in the fifth report. These reports will specifically address the vegetation protocol objectives described in section 1.5.1 above. SOP #12: Reporting and Analysis of Data provides details on report contents summarized briefly here.

#### **4.8.1 Annual Reports**

The annual reports focusing on status of the two parks sampled in a given field season will be due on March 1<sup>st</sup> of the year following that field season. Appendix A is an example of an annual report prepared from the pilot study data. As in this example, the annual report will include a summary of the sampling accomplished and how long it took. There will be sections describing the status of vegetation composition, structure, and function respectively in the two parks sampled the prior season. Descriptions will use summary statistics and user-friendly graphics. For example, data summaries will be illustrated on bubble maps or using histograms and tables reporting means and standard errors. SOP# 12: Data Reporting and Analysis describes how data will be presented in further detail. Any unusual or special significance findings (e.g., new species documented for a park) will also be highlighted in annual reports.

#### **4.8.2 Analysis and Synthesis Reports**

Analysis and Synthesis reports will be prepared and distributed by May 1<sup>st</sup> of the year following a complete round of monitoring six parks every 3 years. Therefore, the first report will be issued 4 years following project commencement. Subsequent reports will be issued every 3 years thereafter.

The first Analysis and Synthesis report will focus on status in vegetation composition. Once data have been collected from each park, we will need to verify that the composition data being collected are adequate for the monitoring objectives. Another goal of the first report will be to refine the specific ordination methods to be most illustrative of patterns of vegetation composition in the Network from which changes can be detected later. Summaries of community composition will be developed using ordination and classification techniques to illustrate interrelationships among sites and parks (McCune and Grace 2002). A better understanding of the natural variation in species assemblages across the gradients in park ecosystems will be valuable for distinguishing categorically different units and quantifying spatial variation. Along with these general community analyses, variation of species within local replicates or across gradients and parks will be used for distinguishing spatial from temporal variation in subsequent trend detection analyses undertaken in report five (Philippi et al. 1998).

The second, third, and fourth Analysis and Synthesis reports will focus on the status of vegetation structure and function. Key components of vegetation structure and function identified in the protocol objectives include potential fire behavior, wildlife resources, and stand dynamics. These three reports will describe status of these in relation to environmental variables as described in SOP #12: Reporting and Analysis of Data.

The fifth Analysis and Synthesis report will present the first trend analysis based on methods refined in earlier reports. In year 15, we expect to have a sufficient time series to begin the detection of vegetation trends. Determination of significant trends in vital signs will require considerably more time than status.

General tools for the determination of trend for all the vital signs will range in complexity from application of general linear models (Manly 2001) for the determination of univariate trend direction in early years, to development of hierarchical models and time series analyses of longer-term datasets (Box and Jenkins 1976, Manly 2001).

Much of the information and insight about temporal change will be contained in multivariate analyses. Although detecting trends in multivariate data is more challenging than for univariate parameters, multivariate analyses are particularly effective in environmental monitoring and can demonstrate trends not apparent in univariate analyses (Clarke et al. 2008). One of the most fundamental types of detectable change in multivariate or multispecies datasets is the increase in dissimilarity over time, or “progressive change” (Philippi et al. 1998). Significance tests for progressive change can be determined with randomization or Mantel analyses (Philippi et al. 1998). Figure 9 illustrates an ordination diagram that shows a clear trend in progressive change in species composition over successive sampling intervals.

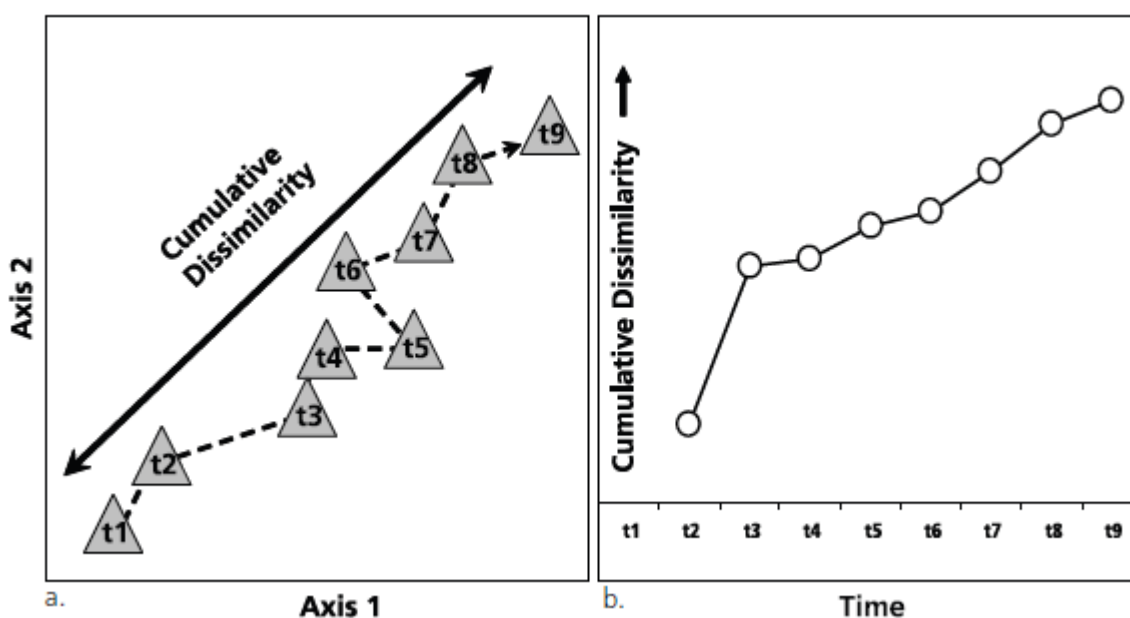


**Figure 9.** Cumulative change in species composition over nine sampling seasons. (A) An idealized two-dimensional ordination diagram illustrating the compositional position of a site at time one through nine where Euclidean distance between each year (i.e., time steps t1, t2...t9) is proportional to species dissimilarity. The solid two-headed arrow is an ordination that illustrates the cumulative dissimilarity (progressive compositional change) over the whole period. (B) A graph of cumulative dissimilarity between the first year sample and successive years (i.e., t1 to tn). Note that the change is positive and sustained, suggesting a clear trend of changing composition over time.

#### 4.8.3 Report Format

Annual reports and third year Analysis and Synthesis reports will use the NPS Natural Resource Publications template, a pre-formatted Microsoft Word template document based on current NPS formatting. Annual reports and third year Analysis and Synthesis reports and other peer-reviewed technical reports will be formatted using the Natural Resource Data Series (NRDS)

Report template. These templates and documentation of the NPS publication standards are available at: <http://www.nature.nps.gov/publications/NRPM/index.cfm>.

Reports will be posted in Reference Applications, KLMN Internet and Intranet web sites, and SOU's Bioregional electronic archive collection. They will also be sent to the Technical Advisory Committee and to park staff with particular interest in the monitoring results. These reports will be used to update NPSpecies.

#### **4.9 Data Storage and Archiving Procedures**

File structure, version control, and regular backups are carefully controlled to preserve the integrity of Network datasets (KLMN Network Data Management Plan [Mohren 2007]). As described above, all data are transferred to the Network Data Manager, where they are placed on a Network server and are subject to regular archiving and backup processes as described in the Network's Data Management Plan.

During the field season, field forms will be submitted to the Crew Lead and stored in cabinets at the end of each sampling trip. At the end of the field season, these datasheets will be scanned into PDF documents and stored in the Vegetation Monitoring project folder located on the Klamath Network server.

Prior to the start of a new field season, all products from the prior field season should have been transferred to the Network Contact (SOP #11: Data Transfer, Storage, and Archive). The Network Contact will work with the Data Manager to make certain that products are stored in their proper location on the KLMN server and posted to the proper distribution locations.



## 5.0 Personnel Requirements and Training

### 5.1 Roles and Responsibilities

Roles and responsibilities under this protocol are summarized in Table 11. The Network Coordinator will serve as the Project Lead with attendant oversight responsibilities. The Project Lead is responsible for representing the Klamath Network in all issues related to this protocol. The Project Lead should be in constant communication with project and park staff to make certain the protocol is being properly implemented. It is the responsibility of the Project Lead to be familiar with all aspects of the protocol and provide assistance to the Network and parks when necessary.

The Project Lead will hire and supervise a GS-7 temporary botanist or plant ecologist as the Crew Lead. The Crew Lead will oversee data collection, data entry, data verification and validation, as well as data summary, analysis, and reporting. The Network Data Manager designs and maintains the database, provides data verification and validation, and oversees data security, archiving, and dissemination. The Data Manager, in collaboration with the Crew Lead, also modifies data entry forms and other database features to assure data quality and to automate report generation. The Network Data Manager is responsible for building adequate quality assurance quality control procedures into the database management system and for following appropriate data handling procedures.

**Table 11.** Roles and responsibilities for implementing the Klamath Network Vegetation Monitoring Protocol.

| Role         | Responsibilities                                                                                                             | Position                     |
|--------------|------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| Project Lead | Project oversight                                                                                                            | Klamath Network Coordinator  |
|              | Administration and budget                                                                                                    |                              |
|              | Consultant on all phases of protocol review                                                                                  |                              |
|              | Evaluates progress toward meeting objectives                                                                                 |                              |
|              | Facilitate communications between NPS and parks                                                                              |                              |
|              | Research on invasion ecology                                                                                                 |                              |
|              | Interpretation of monitoring results                                                                                         |                              |
|              | Report preparation                                                                                                           |                              |
|              | Protocol revision                                                                                                            |                              |
|              |                                                                                                                              |                              |
| Data Manager | Oversees all data management activities                                                                                      | Klamath Network Data Manager |
|              | Makes certain data are posted                                                                                                |                              |
|              | Makes certain all products and deliverables are reviewed, submitted, stored, and archived                                    |                              |
|              | Maintain and update database application                                                                                     |                              |
|              | Provide database and data management training as needed                                                                      |                              |
|              | Consultant on GPS/GIS use                                                                                                    |                              |
|              | Work with Project Lead to prepare and analyze data                                                                           |                              |
|              | Ensures metadata have been developed for appropriate project deliverables (e.g., databases, GIS/GPS documents, images, etc.) |                              |
|              | Primary steward of Access database and GIS data and products                                                                 |                              |

**Table 11.** Roles and responsibilities for implementing the Klamath Network Vegetation Monitoring Protocol (continued).

| Role                                                        | Responsibilities                                                                                                 | Position                                          |
|-------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|
| GIS Specialist (Data Manager and/or Project Lead in future) | Provide spatial data analysis that may be needed (e.g. GRTS)                                                     | Klamath Network GIS Specialist                    |
|                                                             | Develop metadata for spatial data products                                                                       |                                                   |
|                                                             | Maintain GPS units                                                                                               |                                                   |
|                                                             | Help train crew members on GPS use                                                                               |                                                   |
|                                                             | Prepare maps for field crews                                                                                     |                                                   |
| Crew Lead                                                   | Prepare maps and graphics for reports                                                                            | GS-7 Term Botanist                                |
|                                                             | Suggest changes to protocol                                                                                      |                                                   |
|                                                             | Maintain research permits                                                                                        |                                                   |
|                                                             | Coordinate hiring of field crews                                                                                 |                                                   |
|                                                             | Coordinate scheduling, travel and accommodations                                                                 |                                                   |
|                                                             | Acquire and maintain field equipment                                                                             |                                                   |
|                                                             | Train field teams on vegetation sampling techniques, plant identification, and any other aspects of the protocol |                                                   |
|                                                             | Perform data summaries and analyses, and provide text for reports                                                |                                                   |
|                                                             | Maintain and manage voucher specimens                                                                            |                                                   |
|                                                             | Maintain and archive project records                                                                             |                                                   |
|                                                             | Certify each season's data for quality and completeness                                                          |                                                   |
|                                                             | Creates metadata for products in GIS, GPS, image, and document format                                            |                                                   |
|                                                             | Maintain research permits                                                                                        |                                                   |
|                                                             | Collect, record, enter and verify data                                                                           |                                                   |
|                                                             | Provide recommendations to improve protocol operational efficiency                                               |                                                   |
| Administrative contact                                      | Arrange vehicles                                                                                                 | Klamath Network Administrator                     |
|                                                             | Timesheets, purchasing, and reimbursements                                                                       |                                                   |
|                                                             | Copy editing and report production                                                                               |                                                   |
|                                                             | Equipment checkout                                                                                               |                                                   |
| Park Contact                                                | Consultant on protocol implementation                                                                            | Park botanist, plant ecologist, or Resource Chief |
|                                                             | Facilitate logistics planning and coordination                                                                   |                                                   |
|                                                             | Help interpret management implications of results                                                                |                                                   |
|                                                             | Review reports, data and other project deliverables                                                              |                                                   |

Each park within the Klamath Network has a designated Park Contact for this protocol. It is the responsibility of the Network Contact or Project Lead to contact the Park Contact when necessary. Park Contacts will help support the Vegetation Monitoring, when necessary, by participating in meetings, helping with logistical planning at their park, and providing assistance with other miscellaneous tasks to ensure that the crew can perform the work efficiently in their park.

The field work, seasonal data management, and data entry activity to be completed under this protocol will be conducted primarily by the field crew. They will work under the direct supervision of the Crew Lead. When and where feasible, the Network will explore means to supplement this core staffing with park-based employees or volunteers, or assistance from the

Project Lead or Network Contact during critical periods, but ultimately the scope and complexity of the field monitoring will be designed specifically for the capabilities of the assigned seasonal employees.

## **5.2 Qualifications and Training**

Competent, observant, and detail-oriented observers are essential for collecting credible, high-quality vegetation data. The Crew Lead must have strong botanical, organizational, and leadership skills to ensure the crew is well outfitted, scheduled, adequately trained, and motivated to do their best work. The crew members must take initiative to read and understand the protocol elements for which they will be responsible and ask for clarification from the Crew Lead when questions arise. All field crew members must possess sufficient botanical skill to accurately recognize many of the species encountered and to identify nearly all of the remainder with the help of species lists, photographs, keys, etc. Field crew members must also be competent with GPS navigation, compass use, estimating plant cover, and data collection. All crew members should be well organized, function well as team members, be comfortable in the field, and work methodically under difficult conditions. Field crew members need to be able to work in the field with another crew member for long periods of time. They must also be willing to work flexible schedules that may include long work days in inclement weather.

Training is essential for developing competent observers, both at the initiation of the field season and thereafter. At the start of the season, observers will review plant identification using interpretive materials developed by the Network, as well as herbarium specimens, keys, photographs and a field visit to each park immediately prior to sampling. The Project Lead will ensure that training is adequate and provide a refresher on invasive plant identification, GPS navigation, etc. at the start of the season (SOP#2: Observer Training). The Project Lead should work closely with the Data Manager to train field crews on all data collection devices and data management methods. As data are recorded or uploaded, additional training will ensure that data are recorded accurately, errors identified in a timely fashion, and all data are backed up in the most efficient and secure way in each park.

## **5.3 Safety**

The field crew will be working in some remote areas; it is therefore essential that everyone be prepared for emergency situations. The Klamath Network has developed job hazard assessment documents specific to each park, to which crew members will strictly adhere while working at the parks (Appendix C). The safety appendix addresses known hazards (e.g., poison oak, rocky terrain, etc.), wildlife issues, communications, first aid, and an emergency response plan. Prior to going into the field, as part of observer training (SOP #2: Observer Training), the Crew Lead shall review safety procedures and job hazard analyses (Appendix C) with all field crew personnel.



## 6.0 Operational Requirements

### 6.1 Annual Workload and Implementation Schedule

The annual schedule for implementing the protocol is shown in Table 12.

**Table 12.** Annual schedule of major tasks and events for the Klamath Network vegetation monitoring protocol.

| Month     | Administration                                                                       | Field                                                                                                | Data Management/Reporting                                                                                               |
|-----------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| January   | Annual report and work plan complete. Begin recruiting and hiring seasonal personnel | Hire seasonal staff and schedule field visits, reserve campgrounds, and vehicles.                    | Data analysis from previous year. Prepare Annual report and/or Analysis and Synthesis report(s) from previous season(s) |
| February  | Administer and modify existing agreements, if necessary                              |                                                                                                      | Data analysis. Finish annual report. Prepare Analysis and Synthesis report                                              |
| March     | Final protocol modifications (if any)                                                | Inventory field equipment and resupply where needed.                                                 | Prepare Analysis and Synthesis report                                                                                   |
| April     |                                                                                      | Prepare field and GPS/electronic equipment. Train field crew (Whiskeytown and Lassen Sampling Years) | Finish Analysis and Synthesis report                                                                                    |
| May       |                                                                                      | Train field crew (Lava Beds/Redwood and Oregon Caves/Crater Lake sampling periods.                   |                                                                                                                         |
| June      |                                                                                      |                                                                                                      |                                                                                                                         |
| July      |                                                                                      | Field work                                                                                           |                                                                                                                         |
| August    | Prepare budget for new fiscal year                                                   |                                                                                                      |                                                                                                                         |
| September | Close out of fiscal year                                                             | Finish field work. Field season closeout.                                                            | Metadata production,                                                                                                    |
| October   | Network Annual Report and Workplan drafted.                                          | Data verification, briefing report                                                                   | Data certification, check in, and archival                                                                              |
| November  |                                                                                      |                                                                                                      | Data analysis                                                                                                           |
| December  |                                                                                      |                                                                                                      |                                                                                                                         |

The monitoring workload will vary from year to year. During the years in which Whiskeytown and Lassen Volcanic are to be monitored, the greatest number of plots will be sampled (153), followed by the Crater Lake and Oregon Caves years (122), and then Redwood and Lava Beds (96). These numbers do not include 15 additional plots in the matrix at Whiskeytown that currently cannot be monitored due to safety concerns related to marijuana cultivation. In addition to year to year variation, budgeting is complicated by sampling of whitebark pine in Crater Lake and Lassen Volcanic. During years in which these parks are sampled, the whitebark pine protocol is expected to provide additional field crew members. It is anticipated that about half of the high elevation plots, or 13, can be sampled by these crews per year. Therefore, the plot total at Whiskeytown and Lassen Volcanic that will be monitored by vegetation crews is 119, while this number is 99 for Crater Lake and Lava Beds. The Analysis and Synthesis reports will be prepared by the Network Contact and Project Lead after sampling of the Redwood and Lava Beds, which will require the shortest field season.

Based on the pilot study, it is estimated that a two person crew can complete about five plots per week of sampling, or ten plots per pay period. Each crew will need an additional week before the field season for preparation, and a week after the field season for data entry and other post-season activities. The Crew Lead is a term employee who will spend at least 8 weeks in

preparation for the season and in data validation and report preparation afterwards. The budgets for each year are detailed in Tables 13a-d.

The following assumptions are made in these budgets: The first field season assumes that that we will employ one GS-7 Crew Lead and three additional GS-5 field technicians. These will compose two field crews, which will each work 3.5 months total (except for the Crew Lead). Work during the sampling seasons that pair Redwood and Lava Beds (Table 13a and 13d) will be completed by two 2-person crews, consisting of one GS-7 crew leader and three GS-5 field technicians. The field work will be completed over a 3.5 month season, from June through mid-September. The next field season involving Whiskeytown and Lassen Volcanic is the most field work intensive. During this season, we will employ one GS-7 Crew Lead and three additional GS-5 field technicians as the long-season crews, which will work a total of 4.5 months. A second two person GS-5 field crew will work for 2.5 months on vegetation monitoring to supplement the plot total. It is expected that this crew will also conduct whitebark pine monitoring for approximately 5 weeks. The third field season in which Crater Lake and Oregon Caves will be sampled assumes that that we will employ one GS-7 Crew Lead and three additional GS-5 field technicians as the two long-season crews, which will work a total of 3.5 months. A second two person GS-5 field crew will work for 2 months on vegetation monitoring to supplement the plot total. It is expected that this crew will also conduct whitebark pine monitoring at Crater Lake for approximately 5 weeks. The fourth field season (Table 13d) will be the same as the first, but the first Analysis and Synthesis report will also be prepared. The budget accounts for this with increased time spent by the Network Coordinator (as Project Lead), and \$5,000 for help with statistics and writing.

In addition, office staff and volunteers may assist with sampling during “crunch” times when vegetation in multiple parks is ready for monitoring (typically late May, early June in Whiskeytown, Lava Beds, and Redwood, and late July, August in Lassen Volcanic and Crater Lake), or in the event of injuries or logistical challenges. Positions will be announced during the winter prior to a field season. Crews will be hired during early spring to enable training by mid-spring and sampling by late spring (SOP #1: Field Work Preparation).

## **6.2 Facility and Equipment Needs**

Equipment and facility requirements for this protocol are modest. The crew will typically require housing or camping facilities in each park for several weeks every 3 years. The Crew Lead will contact the Park Contact the winter before field work begins so arrangements can be made (Table 12). The vegetation monitoring field work requires two high clearance 4WD vehicles, computers, GPS units, handheld computers, a laser rangefinder, a concave (standard) densiometer, taxonomic guides, tape measures, a plant press, hand lenses, identification material, and a digital camera. For safety purposes, crews will also carry radios and/or cell phones to communicate, if necessary, with park staff in the event of emergency. SOP #1: Field Work Preparations provides complete lists of all sampling and personal supplies that crews will need. During the off-season, equipment will be kept and maintained at the Klamath Network office on the lower Southern Oregon University campus office.

## **6.3 Startup Costs and Budget Considerations**

Startup costs include the purchase of equipment and supplies as well as maintenance and or replacement of equipment shared among multiple projects (e.g., GPS units, cameras, vehicles).

All equipment that needs to be purchased will be acquired prior to the implementation of this protocol, tentatively scheduled for FY 2010. Additional monies are budgeted each year of data collection to cover equipment repair or replacement for this specific protocol.

This protocol will have an annual budget ranging from 129K to 157K per year (Table 13). Most of the budget will pay for field work, but a significant portion (approximately 26%) is designated to the Project Lead, Data Manager, and Crew Lead (2 months) for off-season data management, analysis, report writing, and other duties in support of field work. If in-season activities are included, data management and analysis activities will total between 35% and 40% of the budget each year. We expect that the annual budget will increase modestly due to inflation of general costs and cost of living increases for salaried staff. These increases will be addressed in part by scheduled cost of living increases for the KLMN monitoring budget based upon agency staff employed.

**Table13a-d.** Estimated startup costs and annual budgets for the first four field seasons of Klamath Network vegetation monitoring.

| a. Year 1, Lava beds and Redwood (96 Plots) |                           |               |          |          |                   |
|---------------------------------------------|---------------------------|---------------|----------|----------|-------------------|
|                                             | Item                      | Person-Months | Salary   | Benefits | Total             |
| Personnel                                   | Network Program Manager   | 1.5           | 6416     | 2406     | 13,233.00         |
|                                             | Network Data Manager      | 2             | 5200     | 1950     | 14,300.00         |
|                                             | Field Crew Leader, GS-7   | 9.0           | 3,973.15 |          | 48,988.94         |
|                                             | Field Crew, GS-5          | 11.0          | 2,626.00 |          | 31,196.88         |
| Other                                       | Supplies                  |               |          |          | 4,000.00          |
|                                             | Travel                    |               |          |          | 10,000.00         |
|                                             | Vehicles                  |               |          |          | 8,000.00          |
|                                             | Subtotal (Fieldwork Only) |               |          |          | <b>53,196.88</b>  |
|                                             | <b>Total</b>              |               |          |          | <b>129,718.82</b> |

| b. Year 2, Whiskeytown and Lassen (153 plots) |                           |               |          |          |                   |
|-----------------------------------------------|---------------------------|---------------|----------|----------|-------------------|
|                                               | Item                      | Person-Months | Salary   | Benefits | Total             |
| Personnel                                     | Network Program Manager   | 1.5           | 6416     | 2406     | 13,233.00         |
|                                               | Network Data Manager      | 2             | 5200     | 1950     | 14,300.00         |
|                                               | Field Crew Leader, GS-7   | 9.0           | 4,172.00 |          | 51,440.76         |
|                                               | Field Crew, GS-5          | 18.5          | 2,704.00 |          | 54,025.92         |
| Other                                         | Supplies                  |               |          |          | 4,120.00          |
|                                               | Travel                    |               |          |          | 10,600.00         |
|                                               | Vehicles                  |               |          |          | 10,000.00         |
|                                               | Subtotal (Fieldwork Only) |               |          |          | 78,745.92         |
|                                               | <b>Total</b>              |               |          |          | <b>157,719.68</b> |

| c. Year 3, Crater Lake and Oregon Caves (122 plots) |                         |               |          |          |           |
|-----------------------------------------------------|-------------------------|---------------|----------|----------|-----------|
|                                                     | Item                    | Person-Months | Salary   | Benefits | Total     |
| Personnel                                           | Network Program Manager | 1.5           | 6416     | 2406     | 13,233.00 |
|                                                     | Network Data Manager    | 2             | 5200     | 1950     | 14,300.00 |
|                                                     | Field Crew Leader, GS-7 | 9.0           | 4,381.00 |          | 54,017.73 |
|                                                     | Field Crew, GS-5        | 14.5          | 2,785.00 |          | 43,613.10 |
| Other                                               | Supplies                |               |          |          | 4,250.00  |

|                           |                   |
|---------------------------|-------------------|
| Travel                    | 10,630.00         |
| Vehicles                  | 10,000.00         |
| Subtotal (Fieldwork Only) | <b>68,493.10</b>  |
| <b>Total</b>              | <b>150,043.83</b> |

**Table13a-d.** Estimated startup costs and annual budgets for the first four field seasons of Klamath Network vegetation monitoring (continued).

d. Year 4, Lava beds and Redwood, second visit (96 Plots)

|           | Item                                        | Person-Months | Salary   | Benefits | Total             |
|-----------|---------------------------------------------|---------------|----------|----------|-------------------|
| Personnel | Network Program Manager                     | 3             | 6416     | 2406     | 26,466.00         |
|           | Network Data Manager                        | 2             | 5200     | 1950     | 14,300.00         |
|           | Field Crew Leader, GS-7                     | 9.0           | 3,973.15 |          | 48,988.94         |
|           | Field Crew, GS-5                            | 11.0          | 2,626.00 |          | 31,196.88         |
| Other     | Supplies                                    |               |          |          | 4,000.00          |
|           | Travel                                      |               |          |          | 10,000.00         |
|           | Vehicles                                    |               |          |          | 8,000.00          |
|           | Subtotal (Fieldwork Only)                   |               |          |          | <b>53,196.88</b>  |
|           | Analysis and Synthesis<br>Report Assistance |               |          |          | 5,000.00          |
|           | <b>Total</b>                                |               |          |          | <b>142,951.82</b> |

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