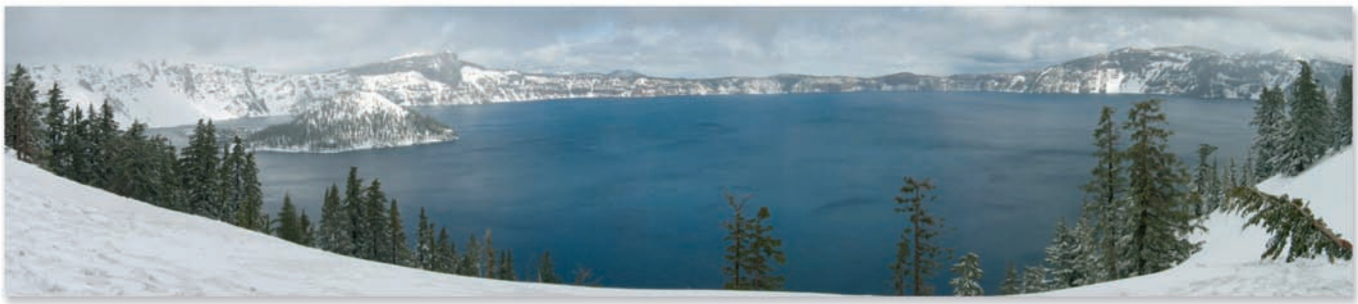
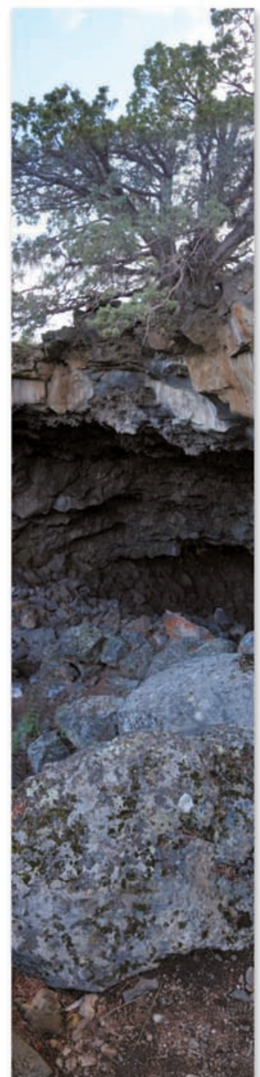
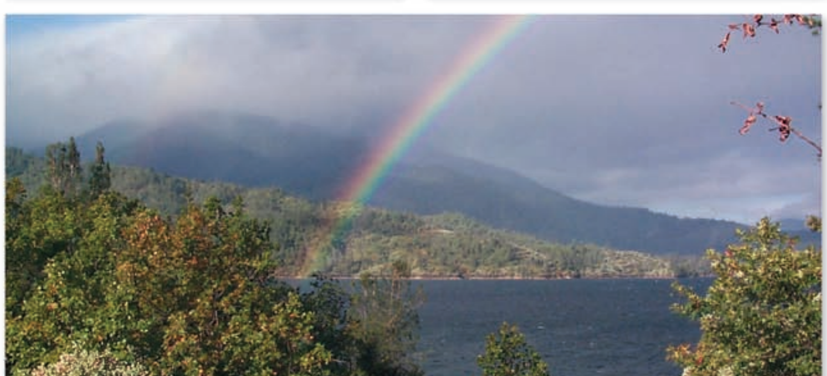
U.S. Department of the Interior
Natural Resource Program Center

Klamath Network
Vital Signs Monitoring Plan

Natural Resources Report NPS/KLMN/NRR-2007/016





ON THE COVER

Images from each of the Klamath Network's parks. Clockwise from top: Crater Lake National Park, Lava Beds National Monument, Whiskeytown National Recreation Area, Redwood National and State Parks, and in the center, left to right, Oregon Caves National Monument and Lassen Volcanic National Park.

NPS Photos.

Klamath Network

Vital Signs Monitoring Plan

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Daniel A. Sarr, Ph.D.
Klamath Network, National Park Service
1250 Siskiyou Blvd.
Ashland, OR 97520-5011

Dennis C. Odion, Ph.D.
Southern Oregon University
1250 Siskiyou Blvd.
Ashland, Oregon 97520-5011

Sean R. Mohren
Klamath Network, National Park Service
1250 Siskiyou Blvd.
Ashland, OR 97520-5011

Elizabeth E. Perry
Klamath Network, National Park Service
1250 Siskiyou Blvd.
Ashland, OR 97520-5011

Robert L. Hoffman
United States Geological Survey—Biological Resources Division
Forest and Rangeland Ecosystem Science Center
Corvallis, Oregon 97331

Laura K. Bridy
Klamath Network, National Park Service
1250 Siskiyou Blvd.
Ashland, OR 97520-5011

Andrew A. Merton, Ph.D.
Colorado State University
Fort Collins, Colorado 80523-1877

With Contributions from: Andrew Duff, Eli Sarnat, and Sean Smith, Southern Oregon University; Erik Beever, Great Lakes Inventory and Monitoring Program—National Park Service; Sarah Shafer, U.S. Geological Survey, Denver Corvallis; Robert E. Truitt, Mojave Network—National Park Service; Windy Bunn, Whiskeytown National Recreation Area; Judy Rocchio, Air Resources Division—National Park Service; Christopher Currens and Mary Ann Madej, U.S.G.S. Western Ecological Research Center. Layout and design: Barbara BC Gleason/BGleason Design & Illustration, LLC. Illustrations pages xv, 71, 94, and 112 ©2007 Andrea Carlson; and assistance with those of pages 32, 33, 35-37, 39-42.

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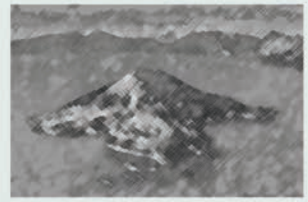
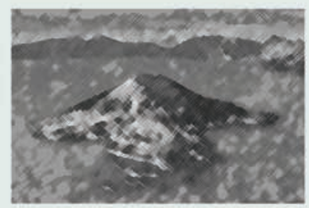
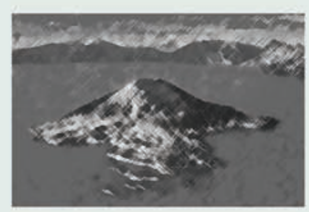






Tables

Executive Summary

Chapter 1: Introduction and Background

The Klamath Network (KLMN or the Network) encompasses six units managed by the National Park Service (NPS) in northern California and southern Oregon: Crater Lake National Park, Lassen Volcanic National Park, Lava Beds National Monument, Oregon Caves National Monument, Redwood National and State Parks, and Whiskeytown National Recreation Area. Together, these parks contain diverse terrestrial, freshwater aquatic, marine, and subterranean ecosystem domains with high ecological integrity and diversity. This plan is the culmination of a four year planning process for the Network to monitor the integrity of these ecosystems. The region's abiotic, biotic, and dynamic processes are described in Chapter 1, as well as threats to park ecosystems, park management priorities, and existing monitoring programs. The broad goals of the NPS and KLMN vital signs monitoring program are:

1. To determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions;
2. To provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management;
3. To provide data to foster better understanding of the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments;
4. To provide data to meet legal and Congressional mandates related to natural resource protection and visitor enjoyment; and
5. To provide a means of measuring progress toward performance goals.

Chapter 2: Conceptual Models

The Network has developed a hierarchical system of conceptual models to illustrate general relationships between the abiotic, biotic, dynamic, and human environments and park ecosystem domains. This integrated family of conceptual models guided the organization, prioritization, and selection of vital signs for monitoring.

Chapter 3: Selection of Vital Signs

From the empirical and conceptual foundation laid in Phase I of the vital signs process, the Network and partners developed a list of 33 monitoring questions and over 170 candidate vital signs. In Phase II of developing our Vital Signs Monitoring Plan, we selected vital signs with the highest priority for monitoring. This process required a broad multi-taxa, multi-ecosystem perspective and careful scientific review. The Network used two steps to prioritize vitals signs: 1) an extensive review with outside scientists in the region, and 2) a final internal review by network natural resources staff. The top 10 vital signs for the KLMN resulting from the two-step process are shown in Table 0.1.

Chapter 4: Sampling Design

The Network used a variety of spatial and statistical techniques to delineate sampling frames and target populations and to generate probabilistic sampling designs. Chapter 4 describes the terminology and general approaches for sampling across space and time. Grid-based sampling is described, which will be used for the vegetation, whitebark pine, and landbird vital signs protocols, as well as water quality and aquatic communities in streams. List-based designs are described that will be used for sampling water quality and aquatic communities of lakes, invasive species, and caves. Census techniques will be used for land cover and invasive species in the smallest park (Oregon Caves). The chapter also discussed how the sampling designs allow local precision and integration across ecosystem domains.

Table 0.1. Top 10 vital signs for the Klamath Network.

VITAL SIGN	MEASURABLE ATTRIBUTE
Non-native species	Distribution and abundance of invasive, non-native plants.
Keystone and sensitive plants and animals	Trends in populations of amphibians, whitebark pine, and common seastar.
Terrestrial vegetation	Structure, composition, and population trends. Focal types include riparian forests and high elevation vegetation.
Landbird communities	Landbird community composition and structure.
Intertidal communities	Intertidal community structure and composition.
Freshwater aquatic communities	Composition and structure of freshwater communities.
Cave collapse / entrance communities	Composition and structure of cave entrance communities.
Water quality (aquatic, marine, and subterranean)	Water temperature, chemistry, flow, and pollutant loads.
Land cover, use, pattern (roads)	Changes in land cover and use in and around parks.
Environmental conditions in caves	Temperature, air flow, and ice levels.

Chapter 5: Sampling Protocols

Brief protocol descriptions are provided for the 10 core vital signs and are presented along with parks affected, a justification statement, and objectives. Full protocol development summaries are provided in Appendix I.

Chapter 6: Data Management

The data management plan for the KLMN provides a comprehensive strategy for ensuring that monitoring data are collected and maintained under strict standards. The plan describes the flow of the data life cycle, roles and responsibilities for all staff working with data, and infrastructure for data management in the Network.

Chapter 7: Data Analysis and Reporting

This chapter describes the suite of analytical techniques and reporting tools that the Network will use to translate vital signs data into relevant information for the parks and the scientific community. General descriptions of data summary, determination of status and trends from univariate and multivariate data, and evaluation of system dynamics and abnormality are provided. Reporting tools are described along with the target audience(s), authors, and reviewers, as applies.

Chapter 8: Administration and Implementation of the Monitoring Program

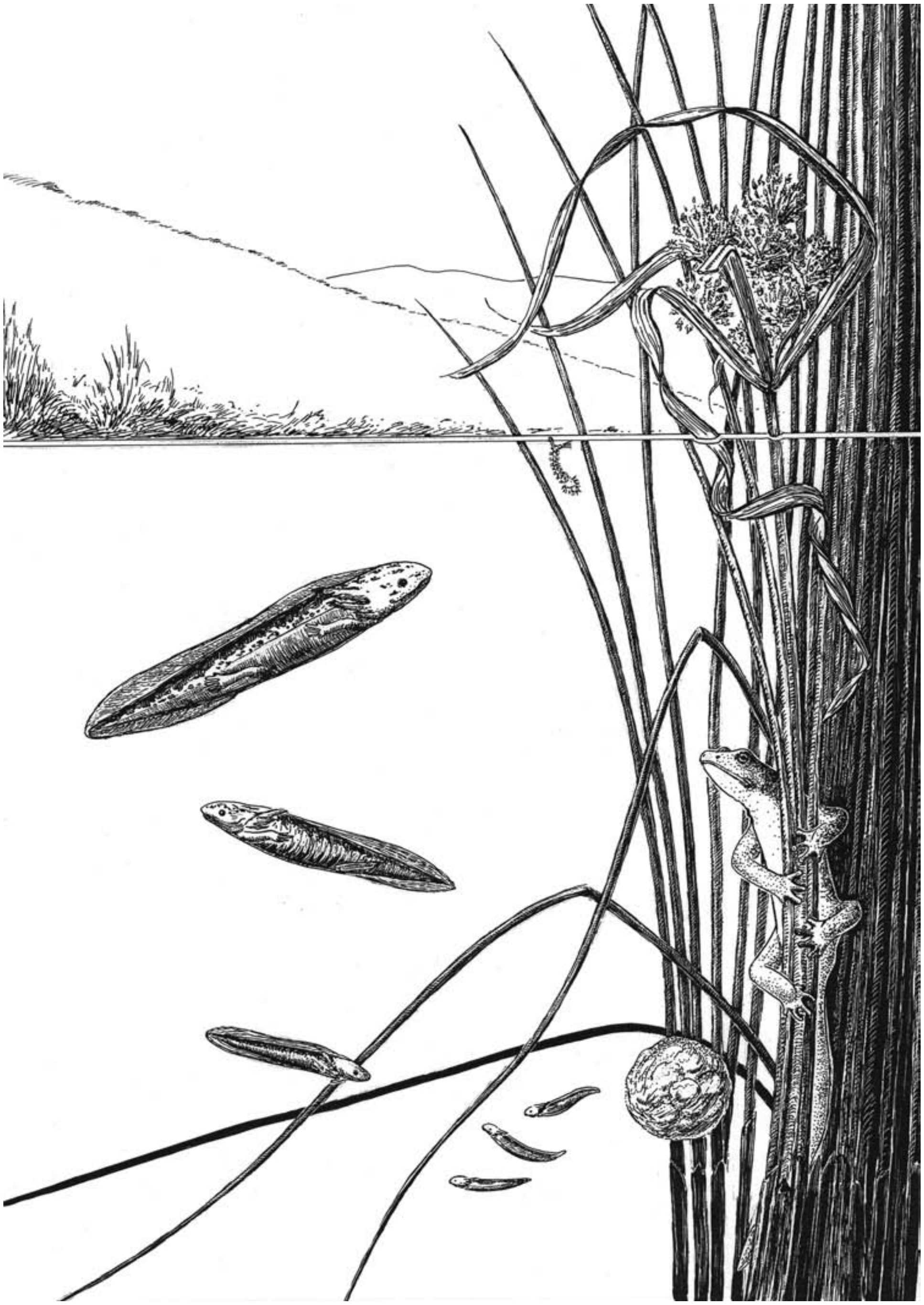
The Network has developed a governing structure of oversight committees headed by a Board of Directors, a staffing plan, and administrative support agreements with Redwood National and State Parks and Southern Oregon University. Additional collaboration is achieved through partnerships and agreements with the US Geological Survey Biological Resources Division, the Pacific Northwest and California Cooperative Ecosystem Studies Units, and nonprofit organizations, such as Klamath Bird Observatory.

Chapter 9: Schedule

A schedule for development and implementation of each vital sign protocol has been determined. Monitoring of two vital signs will begin in FY 2008, and monitoring of the remaining six vital signs will phase in through FY 2009 and 2010.

Chapter 10: Budget

Annual funding for the KLMN is $796,200, with an additional $76,000 coming from the NPS Water Resources Division for water quality monitoring. During our first five years of implementation, we anticipate allocating 46-64% of the budget annually to personnel. Expenditures on agreements will range between 13-20% of the annual budget during this five-year period. We expect operations/equipment to range between 10-15% of the annual budget. Travel is expected to consume 3-6%, and miscellaneous and contingency expenses between <1% and 9% of the annual budget.



Rough-skinned Newt

Acknowledgements

This report is the result of a cumulative, collaborative effort, including over three years of research and many more years conducting on-the-ground work in the network parks. Numerous people contributed to the report's successful completion.

First, we thank the Klamath Network Park Superintendents Steve Chaney (and predecessors Bill Pierce and Andy Ringgold), Mary Martin (and predecessor Marilyn Parris), David Kruse (and predecessor Craig Dorman), Craig Ackerman, Jim Milestone, and Chuck Lundy, for their support and guidance through the planning process. We applaud their enthusiasm to make our Network a tight-knit and collaborative team.

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We are indebted to the network staff that contributed to our Inventory Study Plan in 2001, which provided a body of work to review, update, and build upon: Bow O'Barr, Arnie Peterson, Sarah Koenig, Kelly Fuhrmann, Stassia Samuels, and Dave Best.

Participants in the network scoping workshops (too many to list here) added tremendously to our knowledge of park ecosystems. We greatly appreciate it. Howard Sakai, in particular, did a fine job organizing the Marine Scoping workshop for Redwood National and State Parks and writing up a summary report. Marcia Pinneau provided much appreciated copy editing of the draft reports.

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NPS D-033, September 2007

Chapter 1: Introduction and Background

The National Park Service (NPS) is charged with preserving some of the nation's most magnificent lands and waters. Early administrators often assumed that excluding logging, grazing, and mining would ensure that, in the words of Horace Albright, second NPS Director, parks would persist in "everlasting wildness." As early as the 1930s, however, occasional studies showed that declines in native species (especially predators), introductions of exotic species, and impacts from visitors, roads, etc. were occurring in seemingly pristine areas. Despite anecdotal or sporadic assessments of threats to park ecosystems, a consistent scientific program for monitoring and conserving park resources did not exist for many years. The Natural Resource Challenge (1999) is a major initiative to bring scientific knowledge to the parks and public, ensuring that park managers have the best science available. As the flagship program of the Natural Resource Challenge, the Inventory and Monitoring (I&M) Program provides critical information to guide this process. In this program, parks containing significant natural resources were organized into 32 networks; each network has been asked to develop detailed study plans for the inventory and monitoring of its parks. This document represents the culmination of the process to develop an integrated, long-term monitoring plan for the Klamath Network (KLMN or the Network) and lays out our goals, objectives, and design of a long-term monitoring program.

Natural resource monitoring is "the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective" (Elzinga et al. 1998, Oakley et al. 2003). This chapter describes the background for monitoring in the Klamath Network (Figure 1.1), including: 1) descriptions of the KLMN parks, resources, and environmental settings; 2) the need to monitor for changes in resources and supporting environments; and 3) the key information gaps that limit understanding of how to best achieve our monitoring goals. This information provides the backdrop for subsequent chapters that describe the development of a conceptual foundation for monitoring, the process for selection

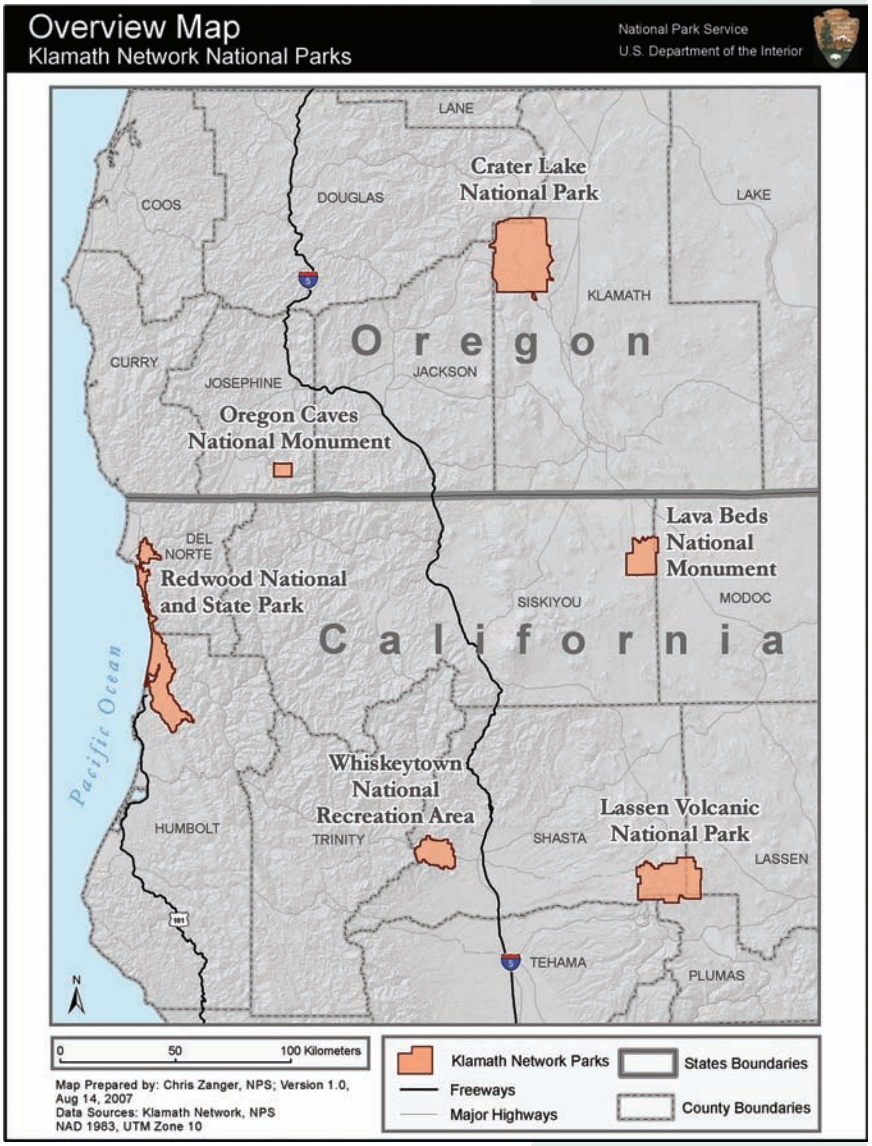


Figure 1.1. Klamath Network park units of southern Oregon and northern California.

of vital signs (key elements of park ecosystems that help detect ecological problems needing further research or management action), and specific monitoring plans for each vital sign and the program as a whole.

1.1. The Need for Long-term Monitoring of Park Lands

The NPS mission is to conserve unimpaired the natural and cultural resources and values of the park system for the enjoyment of this and future generations (NPS 1988). In 1992, the National Academy of Sciences analyzed NPS management and concluded that a fundamental metamorphosis was needed. They determined that a standardized inventory and monitoring program was vital to the NPS mission. As a result, legislation (National Park Omnibus Management Act of 1998) requires park managers to know the condition of natural resources under their stewardship. Therefore, a national framework for inventory and monitoring was developed. (See http://science.nature.nps.gov/im/monitor/NationalFramework.cfm)

The framework has three major components:

1. Completion of basic natural resource inventories in support of future monitoring efforts.
2. Creation of experimental prototype monitoring programs to evaluate alternative monitoring designs and strategies.
3. Implementation of operational vital signs monitoring in all natural resource parks.

The NPS has crafted policies in response to federal laws and directives mandating the linkage of inventory, monitoring, and management to fulfill the mission to conserve parks unimpaired. Appendix A summarizes these policies and the Klamath Network Charter.

Perhaps the most fundamental question that arises in understanding the legislative mandates and the importance and need for monitoring is: Who is interested in the information provided by monitoring and why? This section addresses this question.

Monitoring is needed not only to provide managers with assessments of what is changing, but also to improve their understanding of park ecosystems. These needs compliment and reinforce each other and inform park management and research. Well-informed, long-term monitoring of biological and physical phenomena in an integrated, multi-scale fashion across the parks will improve understanding of ecosystems. Such monitoring can identify additional inventory, monitoring, and research needs as well as appropriate and scientifically defensible management actions. Thus, the monitoring information is vital to managers and researchers, as well as other individuals and organizations sharing an interest in the Klamath Network parks and the greater landscape in which they reside.

1.2. Strategic Goals for Performance Management (GPRA Goals)

The Government Performance Results Act (GPRA 1993) insures that daily actions and expenditures of resources are guided by both long-term and short-term goals in pursuit of the park's primary mission. Goals must be quantifiable with measurable outcomes. Table 1.1 illustrates the progress toward major inventory and monitoring-related GPRA goals in the KLMN parks. The monitoring plan for the KLMN is a significant and specific step toward fulfilling GPRA Goal Category I (Preserve Park Resources) for the Network. The service-wide goal pertaining to Natural Resource Inventories specifically identifies the strategic objective of inventorying the resources of the parks as an initial step in protecting and preserving park resources (GPRA Goal Ib1). This goal tracks the amount of basic natural resources information that is available to parks and performance is measured by what datasets are obtained.

The service-wide I&M Program identified 12 basic inventory datasets as necessary for the foundation of a monitoring program. The KLMN has made considerable progress on the 12 basic inventories, with most of the inventories in the planning phase, underway, or complete as of September 2007 (Table 1.2).

1.3. Goals for Vital Signs Monitoring

The goal of this program is to identify and monitor vital signs of park ecosystems. The concept is similar to a human health examination, in which critical indicators (temperature, blood pressure, etc.) help detect health problems and determine remedies or focus diagnostic tests. Similarly, the NPS vital signs monitoring program is intended to monitor key elements of park ecosystems to help detect ecological problems that need further research or management action. It is recognized, however, that ecosystems, unlike humans, are open systems that often do not exhibit equilibrium.

Specifically, service-wide goals for vital signs monitoring are to:

- Determine status and trends in selected indicators of the condition of park ecosystems to help managers make better-informed decisions and work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions and impairment of selected resources to promote effective mitigation and reduce management costs.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other altered environments.

Table 1.1. GPRA goals that are specific to Klamath Network parks and relevant to the long-term Network monitoring plan.

GPRA GOAL	GOAL CATEGORY #	PARKS WITH THIS GOAL
Natural and cultural resources and associated values are protected, restored, and maintained in good condition and managed within their broader ecosystem and cultural context.	1a	All
Disturbed lands restored	Ia1A	All
Exotic vegetation contained	Ia1B	All
Threatened and endangered species and species of special concern	Ia2B, Ia2X	All
Air quality and wilderness values	Ia3	All
Water quality unimpaired	Ia4	LAVO, REDW, WHIS
Cultural landscapes in good condition	Ia7	All
The National Park Service contributes to knowledge about natural and cultural resources and associated values; management decisions about resources and visitors are based on adequate scholarly and scientific information.	Ib	All
Natural resource inventories	Ib1	All
Vital signs for natural resource monitoring identified	Ib3	All
Geologic resources inventory	Ib4A	All
Geologic resources mitigation and protection	Ib4B	LABE, LAVO
Aquatic resources (including cave ice)	Ib5	All

Park codes: Crater Lake National Park (CRLA), Lassen Volcanic National Park (LAVO), Lava Beds National Monument (LABE), Oregon Caves National Monument (ORCA), Redwood National and State Parks (REDW), and Whiskeytown National Recreation Area (WHIS).

Table 1.2. Status of 12 basic inventories for Klamath Network parks, September 2007

TITLE	PARK CODE					
	CRLA	LABE	LAVO	ORCA	REDW	WHIS
Air Quality	Complete	Complete	Complete	Complete	Complete	Complete
Air Quality Related Values	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress
Cartography	Complete	Complete	Complete	Complete	Complete	Complete
Climate	Complete	Complete	Complete	Complete	Complete	Complete
Geology Map	Partially Complete	Partially Complete	Partially Complete	Partially Complete	Partially Complete	Partially Complete
Natural Resource Bibliography	In Progress	Complete	In Progress	Complete	Complete	Complete
Soils Map	Complete	Planned	In Progress	Complete	In Progress	Planned
Species Distribution	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress
Species Lists	5/6 Certified	6/6 Certified	6/6 Certified	6/6 Certified	6/6 Certified	6/6 Certified
Vegetation Map	In Progress	In Progress	In Progress	In Progress	In Progress	Complete
Water Bodies Map	In Progress	Complete	In Progress	Planned	Planned	Complete
Water Quality Assessment	Planned	Complete	Complete	Complete	In Progress	Complete

- Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
- Provide a means of measuring progress towards performance goals.

The Klamath Network Inventory and Monitoring Program will pursue these goals and further focus the program's effort through the following provisions:

The majority of funding and efforts will be directed at monitoring vital signs that are relevant to multiple parks and are best served by the economies of scale provided by the network program.

- In cases where one or more parks are already monitoring vital signs indicators, and the Network assumes the cost of monitoring, the park agrees to reallocate park-based funds and staff to other natural resource efforts in that park.
- The Network program is designed to pursue strategic integration and quality of information for a core set of resource indicators, not simply to provide funding for disparate projects. Additional research and monitoring of park-specific aspects will continue, expanding the core set of network indicators.
- The Network will strive to maintain strong communication, integration, and cost-sharing (where appropriate) between inventory, monitoring, and research efforts in the KLMN parks. The Network anticipates that monitoring vital signs status and trends will provide a basis for developing and testing hypotheses for cause-and-effect research. It is the responsibility of the KLMN I&M Program to make key findings available to parks and research partners on reasonably frequent timelines and with adequate clarity. It is the responsibility of the Network's Natural Resource Advisory Committee, science staff, and their partners to conceive and locate funding for allied research projects.
- The Network will work to maintain close partnerships with other

landowners of the Klamath region to inform them of our inventory and monitoring efforts and findings. The Network views the national park lands to be among the more protected of the land allocations in each biophysical setting of the region, with value as bellwether sites for measuring synoptic environmental change, as well as reference sites for comparison with more heavily impacted areas.

1.4. Biophysical Overview of the Klamath Network

The KLMN spans a region of exceptional complexity. Appendices B and C contain detailed descriptions of the biophysical environment of the Network and parks. The term Klamath region describes this area of northern California and southern Oregon. Steep climatic, geologic, and topographic gradients and varied disturbance regimes in the region yield biological diversity exceeded by few similar-sized areas within North America or temperate regions worldwide (DellaSala et al. 1999). Across the Network, terrestrial habitats range from mesic coastal redwood forests with biomass accumulations among the highest recorded in terrestrial ecosystems (Fujimori 1977, Sawyer et al. 2000) to barren alpine tundra and xeric sagebrush steppe. Aquatic ecosystems include Pacific marine habitats, the deepest natural lake in the U.S., man-made reservoirs, a diverse array of wetlands, and many streams and rivers. Other unique habitats include karst and volcanic caves, hot springs, and lava flows (Appendix D).

The following sections briefly discuss the most important natural forces that have shaped the ecosystems of the Klamath region: abiotic processes, biogeography and environmental history, biotic interactions, and disturbance processes.

Abiotic Processes

Abiotic processes are critical elements of the park landscapes and historic scenes, and they create the environment upon which all life depends (Gates 1980). They are fundamental to plant community (Merriam and Steineger 1890, Clements 1936) and species distributions (Whittaker 1960, 1965; Walter 1973; Neilson and Wullstein 1983; Woodward 1987; Ohmann and Spies 1998). Relationships between physical factors and species distributions or diversity have been noted for birds (Root 1988, Hansen and Rotella 2002), butterflies (Fleishman et al. 1998, Pyle 2002), amphibians (Bury and Pearl 1999), reptiles (Currie 1991, Shine et al. 2002), and bats (Erickson and West 2002). Consequently, an understanding of abiotic gradients and processes is important to interpret species diversity and distribution patterns.

Geology: The Klamath region encompasses two subregions with fundamentally different geological character. A rough line from Redding to Yreka, California and from Ashland to Roseburg, Oregon can be used to separate the complex and varied Klamath-Coastal subregion from the volcanic Cascade-Modoc subregion (Appendix B).

The Klamath-Coastal subregion, including Redwood, Oregon Caves, and Whiskeytown, is notable for its rugged topography and complex geology. These features derive from eons of plate processes and tectonics, namely the repeated accretion and compression of the ocean floor onto the westward edge of the North American landmass (Norris and Webb 1990, Wallace 1983). The geology and minerals of the subregion provide a wide variety of soils. Serpentine soils, derived from ultramafic rocks, contain high amounts of magnesium, chromium, and nickel (Walker 1954) and often sustain rare and endemic plants (Franklin and Dyrness 1988, Smith and Sawyer 1988).

The Cascades-Modoc subregion was created by relatively recent volcanism. Crater Lake and Lassen are in the

Sharp abiotic gradients as well as historical factors have made the Klamath region a globally significant area of biological diversity.

Cascades, while Lava Beds is on the Modoc Plateau. The Cascades' rocks include basalt, andesite, and dacite (Norris and Webb 1990, Orr and Orr 1999). The eastern edge of the Cascades is bordered by the Modoc Plateau basalt flows. Continued volcanism here created geomorphic and geothermal features, including cinder cones, pumice flats, lava tubes, and hot springs. The unique hydrogeology of the Cascades allows the abundant precipitation to percolate quickly into bedrock aquifers and emerge from springs. As a result, many creeks show stable baseflows and provide refugia for sensitive aquatic species.

Climate: The high topographic relief and proximity to the Pacific create steep climatic gradients in the Klamath-Coastal subregion. The general pattern of cool, wet winters and cool to hot, dry summers (Figure 1.2) is determined by the Pacific high-pressure and Aleutian low-pressure systems. Elevation and distance from the sea affect moisture and temperature regimes. Despite deep and late-lying snowpack in the mountains, winters are relatively mild and the ground rarely freezes. Summers are dry; less than 15% of the annual precipitation occurs between June and September. Therefore, the frequency and length of time a site is influenced by maritime air plays a major role in its ecology. Coastal slopes and valleys favorably oriented to northwest winds are bathed in summer fog and fog drip, keeping temperatures cool and providing a vital source of moisture for redwood trees (Burgess and Dawson 2004).

The Cascades-Modoc subregion is more isolated from the Pacific's moderating influence, resulting in a drier and less complex climate. At low to moderate elevations, summers are warmer and drier and winters are cooler (Figure 1.2). The Cascades' western slopes receive abundant precipitation from winter storms. Storm frequency increases with latitude; Crater Lake's Headquarters has nearly 50% more precipitation days a year than Lassen's Headquarters. Above 2000 m elevation, the snowpack reaches great depths. Snowfields currently persist year-round on Lassen Peak. The Cascades' eastern slopes and adjacent Modoc Plateau are much drier, reflected in their open vegetation. Summer thunderstorms are frequent along the range's crest and eastern slopes.

Water Resources: The KLMN has diverse aquatic resources. Crater Lake is the world's clearest and seventh deepest caldera lake and the park also contains deep lake thermal areas, small ponds, numerous streams and springs, and wetland areas. Lassen has the largest concentration of freshwater lentic systems in the Network (over 250 ponds and lakes) as well as several major stream drainages, geothermal areas, and peatlands. Lava Beds has limited surface water but has 28 known ice caves. At Oregon Caves, Cave Creek flows through the main cave and wet meadows and seeps are present in the upper canyon. Redwood has marine, estuarine, and freshwater aquatic resources. Whiskeytown contains Whiskeytown Lake, several clear mountain streams, and a unique spring ecosystem supporting the only known Howell's alkali grass *(Puccinellia howellii)* population (Levine et al. 2002).

Biogeography and Environmental History: The "Central Significance" of the Klamath Region

The sharp abiotic gradients as well as historical factors have made the Klamath region a globally significant area of biological diversity (DellaSala et al. 1999). In 1961, Whittaker noted the Klamath region's "central" significance to Pacific Coast plant geography, based on the intersecting vegetation types and high endemism levels. Sierran, Vancouverian, Californian, Great Basin, Columbia Plateau, Rocky Mountain, and Colorado Plateau floristic elements are all represented (McLaughlin 1989). This diversity is due to intersecting airmass boundaries (Mitchell 1976) (Figure

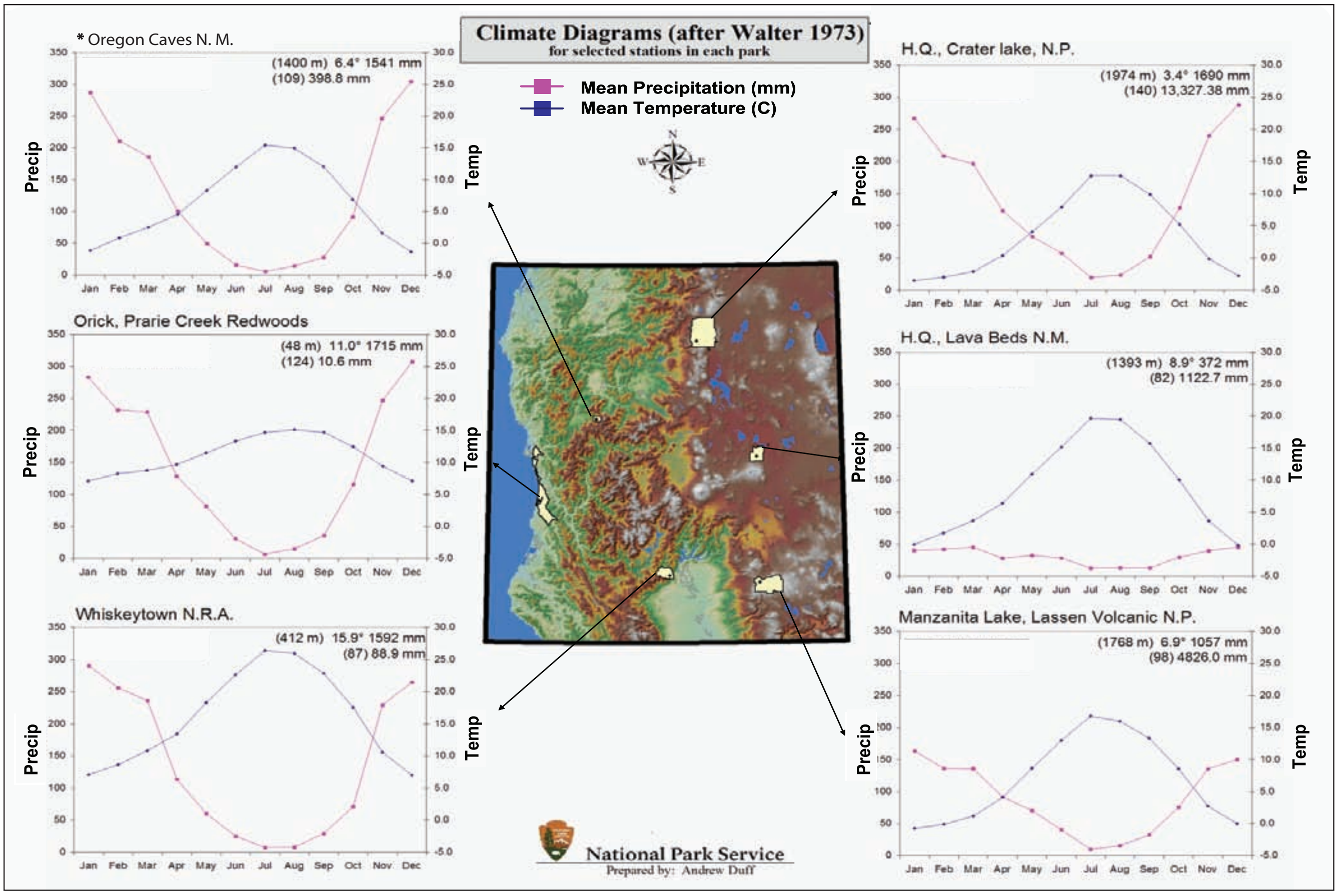


Figure 1.2. Climate diagrams of selected stations in the Klamath Network parks. All parks in the Network show a Mediterranean-type climate regime, with precipitation and temperature regimes perfectly out-of-phase. Summer drought is a defining feature, but is mitigated in parks with coastal fogs (Redwood) or late-lying snowpacks (Crater Lake and Lassen). Note the decrease in precipitation and increase in annual temperature variation (continentality) from the westernmost to easternmost parks.

1.3), high topographic and geological diversity (Roth 2000), and a history of environmental change that brought new species to the region or allowed new ones to evolve. The area is a globally recognized center of plant paleo-endemism (Whittaker 1961, Stebbins and Major 1965, Smith and Sawyer 1988). Many of the area's endemic species are associated with unique hydrologic or edaphic sites that provide refuge from competition or fire (Coleman and Kruckeberg 1999). Other taxa show distributional limits in the region, leading to high species richness (Appendix B).

Biotic Processes

Biotic processes amplify the complexity of the physical environment, increasing habitat and lifeform diversity. Abiotic and biotic variation often occur together, creating ecological zonation. This has long been recognized in terrestrial ecosystems (Merriam and Steineger 1890) and is evident in aquatic and wetland ecosystems too (Ricketts and Calvin 1939, Vannote et al. 1980, Mitsch and Gosselink 2000). We employ the zonation concept in the description of ecosystems and conceptual modeling (Chapter 2) for several reasons, including: (1) the number of ecosystem types in the KLMN has never been determined, there would likely be too many to describe in this report, and they would be largely redundant in gradients or dynamics; (2) zonation is consistent with the continuum concept (Gleason

1926) and gradient analysis (Whittaker 1956), which state that ecosystems are not categorically different, but vary in specific combinations of conditions; and (3) ecosystem boundaries rarely coincide for the wide-range species and processes that are of monitoring interest. Recognizing that park landscapes are a continuum provides a broad framework for understanding and quantifying environmental variation. Environmental variation often governs species distributions more directly than discrete ecosystem classifications imply. Identifying this variation is a fundamental part of developing a robust monitoring design.

Major Ecosystem Types

Marine Ecosystems: The Pacific waters off Redwood National and State Park contain some of the best remaining examples of midlatitude coastal habitats in the western U.S. The marine ecosystem domain includes areas of inland, enclosed, nearshore, and offshore waters (Ceres 2004). Five major zones have been described for these waters: 1) splash or supralittoral zone, 2) upper midlittoral zone, 3) lower midlittoral zone, 4) lowlittoral or infralittoral fringe, and 5) subtidal zone (adapted from Ricketts and Calvin 1939, Bakker 1971, Kozloff 1973).

Marine Flora and Fauna: In the splash zone, species adapted to terrestrial life dominate (Bakker 1971). Common plants are yellow sand verbena (*Abronia latifolia*), dunegrass (*Leymus mollis*), beach morning glory (*Calystegia soldanella*), and a variety of alga and lichens. Animals common in this zone include rock lice (*Ligia oceanica*), acorn barnacles (*Chthamalus dalli* and *Balanus glandula*), and limpets (*Collisella digitalis*) (Kozloff 1973). In the subtidal zone, phytoplankton thrives. In the intertidal zone, kelp forests are abundant, with purple sea urchins (*Stronglyocentrotus purpuratus*), California mussels (*Mytilus californianus*), common starfish (*Asterias forbesii*), and leaf and gooseneck barnacles (*Pollicipes polymerus* and *Lepas anatifera*, respectively). Zooplankton feeds on the phytoplankton and in turn provides food for fish, which are consumed by birds and mammals that inhabit these coastal habitats (Bakker 1971).

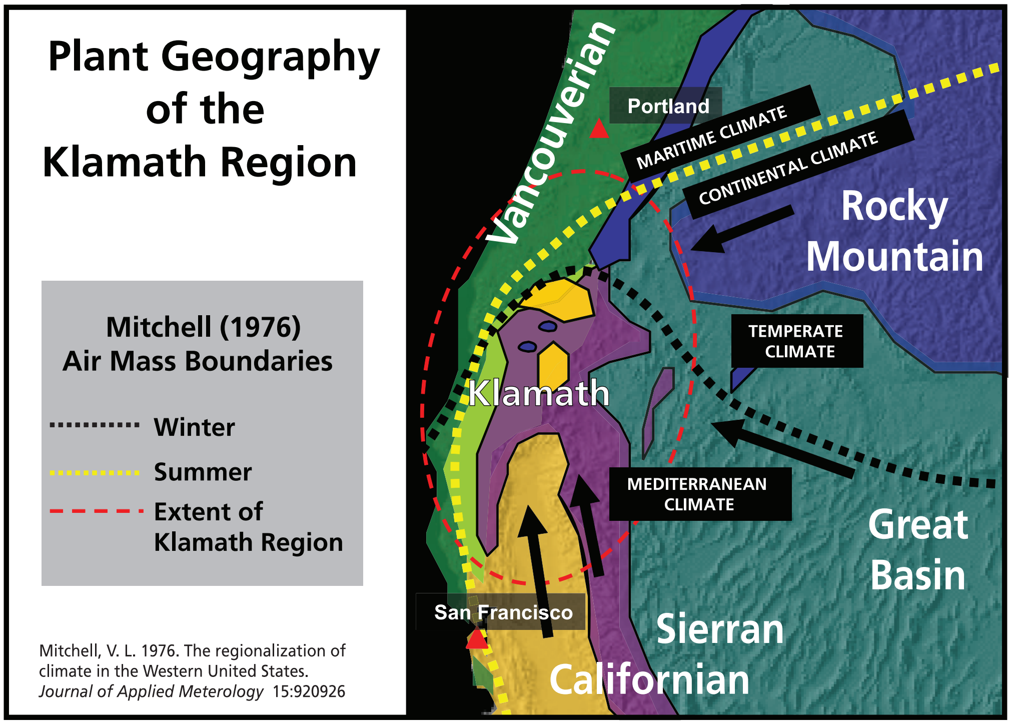


Figure 1.3. The major floristic provinces of the Klamath region and the location of major air mass boundaries (Mitchell 1976).

Freshwater Ecosystems: The freshwater aquatic environments in the KLMN include stream, lake, and wetland ecosystems that vary with climate zone and elevation. In addition to the diverse array of streams and lakes scattered throughout the parks, we also have ice caves, reservoirs, springs, seeps, and a caldera lake.

Despite their relatively small aerial extent, freshwater ecosystems of the KLMN are believed to be critical for landscape diversity where they occur. A number of aquatic ecosystems in the KLMN have been degraded by human activities (Appendices B and E).

Lake and Pond (Lentic) Ecosystems: Lake and pond environments are of particular interest in the KLMN. Crater Lake is a lentic ecosystem of global significance. Lassen holds most of the Network's lakes; park staff considers these aquatic environments and their edges to host the majority of the park's biological diversity. Lake zonation is similar to the coastal environment in many ways. The primary gradient in lakes is also the transition from the wave-influenced, well-illuminated, and seasonally variable littoral zone to the comparatively stable, but light-poor depths (Wetzel 1983). The lake depth and shoreline nature also strongly influence the water column and organisms present. This contrast is well-expressed by comparing the deep, rock-bottomed, and ultra-oligotrophic Crater Lake with the shallow, sedge-fringed eutrophic lakes and ponds of the Lassen highlands. Whiskeytown Reservoir presents a unique suite of monitoring issues, with its fluctuating shoreline, high visitor use, and largely non-native aquatic life.

Crater Lake.

Rocky intertidal habitat.

Stream and River (Lotic) Ecosystems: Flowing water (lotic) ecosystems transition predictably from headwaters downstream due to changes in the stream and riparian environment and corresponding climatic changes with declining elevation. The river continuum (Vannote et al. 1980) is an excellent conceptual model of this elevational pattern that is well expressed in streams of the KLMN parks. Intermediate-sized streams are less common but are of special interest because they have high visitor use and high habitat value for sensitive species.

Freshwater Flora and Fauna: Despite occurring in a region known for its floristic diversity and endemism (Whittaker 1961), the parks' aquatic and wetland flora remains poorly understood. Regionally rare species are often associated with wetlands, such as the California pitcher plant (*Darlingtonia californica*). The discovery of the world's only known population of Howell's alkali grass (*Puccinellia howellii*) in a saline seep at Whiskeytown hints at the floristic diversity these environments contain (Appendix D). The nonvascular aquatic flora also appears to be rich, though even less well known. Ultra-oligotrophic Crater Lake has a rich plankton flora (Larson et al.

Aquatic macrophyte vegetation at Horseshoe Lake, Lassen.

2007); scientists are just beginning to study a ring of bryophytes that occurs at intermediate depths around the submerged caldera walls. Comparable studies have yet to be implemented in most other lakes, ponds, and streams of the Network.

The Klamath region is rich in endemic runs of native salmonids (Moyle 2002); these species are important to stream ecology at Redwood (Appendix C). At higher elevations, fish have historically been absent, while amphibians such as Cascades frogs (*Rana cascadae*) and long-toed salamanders (*Ambystoma macrodactylum*) are locally important. The invertebrate fauna of freshwater ecosystems is well-studied in Crater Lake (Drake et al. 1990) and Redwood Creek (Iwatsubo and Averett 1981), but relatively little is published for the other parks.

Terrestrial Ecosystems: Despite the relatively close proximity of the park units to one another, the steep

Montane riparian system at Crater Lake.

environmental gradients across the region create unique biophysical environments and a variety of vegetation in each park (see Appendix F and Barbour and Major 1977, Franklin and Dyrness (1988), and Atzet et al. (1996)). Appendix B contains a table summarizing the vegetation types and their abundance within the parks. We did not use any single classification system, but a combination of vegetation types described in Franklin and Dyrness (1988) and Barbour and Major (1977).

The terrestrial fauna of the Klamath region is also diverse. Large mammals such as elk and deer are found in all parks. Among the large mammals that have been extirpated are potential keystone species such as grizzly bears (*Ursus arctos horribilis*), grey wolves (*Canus lupus*), and bighorn sheep (*Ovis canadensis*). The mountain lion (*Felis concolor*) is the largest remaining carnivore. The region harbors a varied avifauna that mirrors its habitat diversity (Appendix B). In addition, it has the highest richness in herpetofauna of any similar-sized mountainous region in the Pacific Northwest (Bury and Pearl 1999).

Subterranean Ecosystems: Karst caves and lava tubes are interesting subterranean features of the landscape. Oregon Caves is a karst cave network, while Lava Beds contains an abundance of lava tubes. Many processes occurring in the cave network are greatly influenced by air, water, and food exchange with the upland environment. Most karst caves are created by erosion, usually when rain or a stream, slightly acidified by carbon dioxide in the soil, seeps downward through cracks and crevices in limestone layers (Royo 2004). The mild acid gradually dissolves small passages; as rainwater continues to enter the system and more limestone is dissolved, the passages become micro-caverns that enlarge, forming caves.

Lava Beds has the largest concentration of lava tube caves in the U.S., containing over 700 caves (S. Fryer, Lava Beds

NM, pers. comm.). Lava tubes are former conduits through which hot, fluid lava travels beneath the surface of a flow. The lava forms a tube-like cave once flow ceases (White and Culver 2005). Many of the tubes at Lava Beds were formed around 30,000 years ago after an eruption at Mammoth Crater. Sometimes portions of a lava tube's roof collapse. These openings allow plants, animals, and precipitation to enter. A few tubes at Lava Beds are ice caves, where rain collects and the temperature remains at or below freezing.

Subterranean Flora and Fauna: The lava outcrops and tube collapse systems support a rich flora, from lichens to plants such as desert sage (*Salvia dorrii*). Fern species are present in cave entrances. The spreading wood fern (*Dryopteris expansa*) and the western swordfern (*Polystichum munitum*) are disjunct populations, well outside their climatically-determined range (Smith and Jessup in prep.).

Oregon Caves has over 160 cave animal species, including eight bats. Lava Beds has 14 bat species documented. It is seasonally home to the largest, northern-most Brazilian free-tailed bat population in the U.S. The massive colony numbers over 100,000 adult females, which give birth and nurture their young in the summer. There are at least 30 different known microbes in the subterranean features at Oregon Caves. Some produce black manganese stains, some appear lichen-like, and some look like white clay. Springtails and some beetles are soil animals, pre-adapted to live in caves. There are more than eight endemic cave species at Oregon Caves, more than any other cave system in the U.S.

Species of Special Concern: Rare, Endangered, and Sensitive Species

Rare, endangered, or sensitive species are a monitoring concern in all Klamath Network parks (Appendix D). Preliminary lists yielded over 200 species and taxa that were either Federal or State

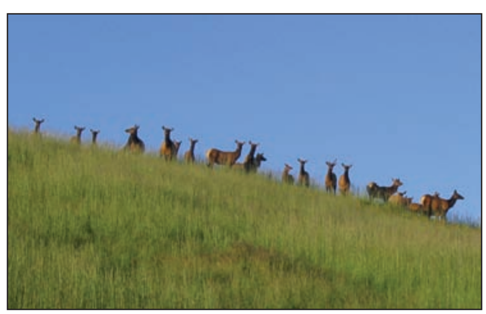
Ponderosa pine *(Pinus ponderosa)* woodland at Lava Beds.

listed or tracked by heritage programs or native plant societies in either California or Oregon (Appendix D). Many are threatened by regional factors such as habitat fragmentation, altered fire regimes, agricultural development, and urbanization.

Dynamic Processes

Change is essential for the integrity of ecosystems (De Leo and Levine 1997). Climatic and geological forces, predator / prey interactions, nutrient cycles, and disturbance dynamics have all played a role in creating the rich biological diversity and historic scenes that we value in our parks. Maintaining these values requires understanding and incorporating such dynamics in our monitoring.

Many dynamic processes may operate as disturbances. Disturbance is any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment (Pickett and White 1985). Disturbances of variable area,



Roosevelt elk *(Cervus elaphus roosevelti)* at Redwood.

frequency, and intensity also enhance habitat heterogeneity and regulate the dominance of competitive species, reducing competitive pressures. Both effects tend to increase diversity (Huston 1994, Spies and Turner 1999) and in part explain why diversity tends to be greatest with intermediate levels of disturbance (Connell 1978). Managing for appropriate disturbance levels may be especially important to maintain biological diversity and ecosystem function in disturbance-adapted ecosystems of the parks (Odion and Sarr 2007). Disturbance is also a key factor affecting exotic species invasions (Appendix G). Here, we describe natural disturbances for the major ecosystem types (see also Appendix B).

Marine Ecosystems: The Redwood coastal environments endure dynamics spanning a range of spatial and temporal scales, from the ebb and flow of tides and assault of winter storms and waves, to episodic phenomena such as earthquakes, rockslides, and tsunamis (Cox and McGary 2006). The relative importance of these factors varies sharply across the gradient from shore to sea. Along the strand or upper intertidal zone, inundation, desiccation, and the battering of waves and rafted debris (logs) create a template where aquatic and terrestrial life interface. In the middle intertidal zone, inundation is more reliable and species diversity greatly increases. Still, waves and tidal currents strongly govern the spatial and temporal patterns of species abundance in the intertidal zone. In the subtidal zone, stability in physical and biological conditions increases, with disruption of biological activity becoming more irregular and episodic. Disturbances such as large storms and extreme low tides are also likely to have important effects on many other organisms (Cox and McGary 2006).

Lake and Pond (Lentic) Ecosystems: Lakes and ponds are subject to a range of natural disturbances. Near shores, wave action results in differences in the flora and fauna populations on the windward vs. leeward shores and convex vs. concave shorelines. Climate variation can substantially change shoreline elevation and consequently affect the flora and fauna of littoral zones. Crater Lake has experienced fluctuations in surface elevation of over five meters (Redmond 1990). Many of the shallower lakes and ponds in Lassen dry up entirely during extended droughts (J. Arnold, Lassen Volcanic NP, pers. comm.). Whiskeytown Reservoir is drawn down three meters each fall. Most natural lakes and ponds in the Network occur at higher elevations where they may freeze over for much of the winter. Geothermal influences have been noted in Crater Lake (Collier et al.1990), but the effects of these on biological communities are presently unknown.

Streams and Other Flowing Waters: The Klamath Network parks have streams ranging from snowmelt rivulets to the Klamath River. Fires and associated debris flows, mass wasting, and large wood entrainment form infrequent but important disturbances (Montgomery 1999). As stream size increases, more powerful floods shape and impact the riparian environment and may lead to stream channel migration (Vannote et al. 1980).

Maintaining the appropriate disturbance regime for diversity is particularly challenging in stream systems. In degraded watersheds and fish-bearing streams, limiting sedimentation is a common management goal. However, we know that some disturbance is essential to maintaining biological diversity (Huston 1979, Nilsson et al. 1989, Sarr et al. 2005b, Odion and Sarr 2007). Studies of aquatic macroinvertebrates show they are highly mobile and resilient to brief mechanical or chemical disturbances (Lamberti et al. 1991). Disturbance effects on other less mobile groups (e.g., amphibians) appear to be more severe (Sarr et al. 2005b). Moreover, the nature and duration of disturbance appears to be important, with varying effects across taxa. For example, aquatic macroinvertebrate communities and fish are strongly impacted by protracted or repeated desiccation, whereas amphibians may survive and flourish without fish predation.

Because most streams in the Network are low order, high gradient streams, they are closely tied to the watershed characteristics through which they flow. Changes in fire regimes and impact from roads are likely to impact water quality and the resident and migratory biota in these systems (reviewed in Sarr et al. 2005b). However, infrequent severe fire was probably an important mechanism for periodically providing a flush of sediment and large wood into the stream systems (Naiman et al. 1992, May and Gresswell 2003).

Terrestrial Ecosystems: Large, infrequent landscape disturbances such as volcanic eruptions, earthquakes, and tsunamis have been historically important in the Klamath region. The region is home to active volcanoes such as Mt. Lassen, which last erupted from 1914-1921 (Strong 1973). Earthquakes are a significant feature in the coastal region due to the proximity of the San Andreas Fault. Tsunamis affect coastlines, such as at Redwood, and may flood nearby areas. The last substantial tsunami that affected northern California occurred in 1964; stratigraphic studies of lagoon sediments at Redwood demonstrate a history of these events.

Fire can also be a landscape-scale disturbance in the Klamath region; it is so important that the ecology of most terrestrial ecosystems cannot be understood apart from it (Bond and van Wilgen 1996). Fire affects too many ecosystem conditions to describe here (Odion et al. 2004). Whittaker (1960) summarized the importance of fire to forest vegetation in the region from Redwood to east of Oregon Caves, concluding that the plants “may be regarded as a fire-adapted vegetation of a summer-dry climate, in which fires of varying frequencies and intensities and varying sources occur…It may be understood in this case that the climax, or fire-climax, condition embodies a degree of population instability and irregularity resulting from fires affecting different areas in a patch-wise fashion at irregular intervals.” Such fire-caused variation allows more habitat types and species than would be possible with a fire regime that is relatively homogeneous in space and time. Moreover, the variation in climate and vegetation types fosters a corresponding diversity of historic fire regimes across the parks and region (Odion et al. 2004).

Mt. Lassen’s 1914 eruption.

Clark’s Nutcrackers, common at Crater Lake, are highly intelligent members of the jay family.

Other disturbances that create forest canopy gaps may be as important as those described above, in affected area over time. These include wind, disease, and insect agents. Gaps in upslope forests are created at rates from 0.2 to 2% of a stand per year, equivalent to a rotation period of 50-500 years (Runkle 1985, Spies et al.

1990). Gaps may cover 5-30% of a forest area at any given time. Such disturbances can be important for biodiversity (Sarr et al. 2005a). Wind disturbances also open large patches in forests (Hansen and Rotella 1999, Stinton et al. 2000). Climate, landform, stand conditions, disease, and other disturbances, including timber harvest, will increase the frequency of windthrow events.

Subterranean Ecosystems: Caves are generally stable when compared with surface ecosystems, showing remarkable consistency in temperature and humidity from day to day and year to year. This stability creates conditions for a highly specialized fauna (Stone et al. 2005). However, disturbances due to rock falls and flooding of subterranean streams provide some temporal variability (Groves and Meiman 2005). As one moves closer to the cave mouth, conditions become more variable and may be affected directly or indirectly by surface disturbances. Caves are very sensitive to anthropogenic disturbances, as described in the following section.

Human Effects on Park Ecosystems

Most of the fundamental threats to parks originate from humans, directly or indirectly, and managers must have accurate information to gauge the effects of management. The following section briefly discusses human threats to KLMN park ecosystems.

Historical Human Effects in the Klamath Network Parks: Since humans play such large roles for both good and ill in national parks, we must incorporate human desires, needs, and effects into monitoring. Although scientists are often inclined to view humans as ecosystem threats, humans have likely played a role in the ecology of the KLMN parks for millennia. Nearly all the parks provided critical resources or ceremonial sites for Native Americans and were often subject to their management practices. For example, aboriginal burning of the prairies and oak savannas of the Bald Hills in Redwood is believed to have been critical to developing the area's relatively open habitat. Although native peoples apparently avoided Crater Lake itself, they gathered in large numbers just west of the lake (York and Deur 2002).

Non-Native Species: Non-native invasions (Appendix G) are a major concern because they can potentially disrupt all ecological processes (Mack et al. 2000) and negatively affect all aspects of ecological integrity. The NPS has long been concerned about non-native species and has developed management guidance (NPS 2004a).

Non-native plants are consistently ranked among the highest priorities for biological inventory in the Network (Acker et al. 2002). Human manipulations of park environments, especially at low elevations, have led to high levels of invasion by non-natives. As these plants gain dominance, they can alter ecosystem integrity and function by diminishing the abundance of native species (Bossard et al. 2000). In general, disturbances favor the establishment of non-native plants (Rejmanek 1989, Hobbs 1991).

The threat of non-native fauna appears to be less widespread than that of plants. However, the bullfrog (*Rana catesbeiana*) occurs in all parks except Crater Lake and Lava Beds and is a chief non-native concern. It preys on and displaces native amphibians and fish. Most water bodies also contain non-native fish, mostly from deliberate introductions.

Non-native birds have expanded into the Network. Baseline information on their distribution and abundance is lacking. In general, as with plants, the worst problems are at lower elevations. The Brown-headed Cowbird (*Molothrus ater*), Starling (*Sturnus vulgaris*), and Wild Turkey (*Meleagris gallopavo*) are the most conspicuous interlopers. The Barred Owl (*Strix varia*) recently arrived because of a range expansion.

Non-native mammals appear to be less

problematic than the above groups. Most are associated with human-dominated areas. Feral pigs (*Sus scrofa*) could become a serious problem where oaks are important (e.g., Little Bald Hills and Whiskeytown).

Park Ecologist Jennifer Gibson using a drip torch in Whiskeytown's fire program.

There are two ongoing exotic pathogen epidemics in the parks, severely impacting native plant species: Port Orford cedar root rot, caused by the water mold *Phytophthora lateralis*; and white pine blister rust, caused by the fungus *Cronartium ribicola*. Nearby, there is also an emerging epidemic of concern, Sudden Oak Death (*Phytopthora ramorum*). Appendix G describes the ecology of these diseases and the implications for monitoring them.

Fire Suppression: As noted above, fire is a profoundly important ecological process in many park ecosystems, affecting vegetation, soil, and watershed dynamics. Over 70 years of fire suppression has altered natural fire patterns and processes. Resource managers want to return natural burn cycles, but there is uncertainty with restoring indigenous fire regimes and fuel loadings, as well as the potential interactions between fire and non-native species invasions.

Human/Visitor Use Impacts: Increased visitor use and the associated effects of trampling, roads, and pollution are major concerns. Humans impact the natural environments of our parks. Visitors may inadvertently or intentionally pollute or degrade rare habitats, destroying areas crucial to maintaining rare and endangered species. Thus, it is important to identify areas where these habitats exist and direct heavy visitor use away from them.

Human effects on lentic environments include effects of watercraft, pollutants, and human traffic on shorelines. Whiskeytown Reservoir presents a unique challenge, as it forms a biologically rich lentic environment where a lotic environment existed. As a national recreation area, its managers are charged with accommodating human uses of the lake. However, there is no baseline of biological integrity to maintain in this unnatural feature; the lake pool level is managed by the U.S. Army Corps of Engineers.

In relatively stable environments such as the karst caves at Oregon Caves and the lava tubes at Lava Beds, disturbances from foot traffic, changes in atmospheric conditions from in-cave structures or human breathing, rerouting of water or air flow, and disruptions from the behavior of cave fauna (e.g., hibernacula) are a concern. Larger scale human influences include purported effects of fire suppression on water flow (Herman 2005) and the effects of climate change on cave microclimates and water balance (Chapter 2).

Transboundary Issues: Most KLMN parks are small to moderate in size and especially vulnerable to outside influences. Timber harvest outside park boundaries is believed to influence geophysical processes and aquatic

Brazilian free tail bat *(Tadarida brasiliensis)* evening fly out from lava tube at Lava Beds.

organism viability within downstream watersheds. Pathogens on logging equipment in the surrounding national forest threaten Port Orford cedar stands in Oregon Caves. In high elevation parks, such as Lassen and Crater Lake, species such as elk (*Cervus elaphus*) may migrate to lower elevations in winter and be affected from interaction with humans or livestock on private land. Areas near the parks are also a prime source for invasive species encroachment.

More diffuse effects, such as air pollution, may pose threats to park biodiversity. Monitoring activities at Lassen revealed foliar symptoms of ozone injury to Ponderosa and Jeffrey pine; recent trends show that ozone levels are increasing in the park. Estimates of sulfur and nitrogen wet deposition there are well below the minimum levels generally associated with resource impacts; however, Lassen's high elevation lakes may be more sensitive to acidification than any other aquatic resources in the western parks (Sullivan et al. 2001). Whiskeytown, near Redding, California, may also be receiving impacts. No air quality monitoring has been conducted in the park, but Air Atlas estimates from nearby monitors indicate that the park has high ozone levels, which could impact vegetation (see NPS Air Resources Division 2002 and Appendix H).

Climate Change: Future climate change will significantly impact the Klamath region. Although there is uncertainty on the exact timing and magnitude of climate change, there is a growing scientific consensus that it is occurring and that human activities are contributing to it (Houghton et al. 2001, Parmesan 2006). For the western U.S., general circulation model simulations indicate that temperatures will likely increase in winter and summer (Giorgi et al. 2001). The Klamath region may experience warmer, wetter winters and warmer summers. Some studies also suggest an increase in the strength of upwelling along the Pacific Coast, which would help maintain the coastal fogs (Snyder et al. 2003).

Climate change impacts will have significant implications for KLMN parks. Species distribution shifts attributed to recent climate change have been identified (e.g., Parmesan and Yohe 2003). Of particular significance is the potential loss of freezing temperatures. Freezing temperatures control many plant and animal species distributions; loss of these temperatures would allow the expansion of certain native and non-native species, for example the mountain pine beetle at Crater Lake.

Climate change will also affect the hydrologic systems of the Klamath region. Combined changes in temperature and precipitation will alter the amount, seasonal timing, and duration of snowpack and stream flows. These alterations affect water quality and quantity. Several studies have simulated future changes in snowpack and runoff, indicating future decreases in snow (e.g., Leung et al. 2004) and changes in the timing of snowmelt runoff (e.g., Stewart et al. 2004) for the Klamath region.

1.5. The Klamath Network Parks

The KLMN encompasses six units in northern California and southern Oregon (Table 1.3, Figure 1.1). The Forest Service and Bureau of Land Management have jurisdiction over most lands bordering park units. There are also many agencies and non-profit groups managing lands in the Klamath region, such as the California Department of Fish and Game and The Nature Conservancy. To efficiently use all resources available, interagency collaboration will be essential. This partnership will enable comparison of trends in diversity and abundance not only within NPS units, but also in surrounding lands, giving information that may indicate regional ecosystem trends important in facilitating ecosystem management.

Table 1.3. Klamath Network park units and their sizes and elevations above sea level.

PARK UNIT	SIZE (HA/ACRES)	LOW ELEVATION (FT/M)	HIGH ELEVATION (FT/M)
Crater Lake National Park	73,775 / 182,298	4000 / 1219	8924 / 2720
Lassen Volcanic National Park	43,047 / 106,369	5200 / 1585	10,456 / 3187
Lava Beds National Monument	18,898 / 46,697	3937 / 1200	5528 / 1685
Oregon Caves National Monument	196 / 484	3681 / 1122	5479 / 1670
Redwood National and State Parks	42,700 / 105,469	0 / 0	3268 / 996*
Whiskeytown National Recreation Area	17,614 / 43,524	800 / 244	6211 / 1893

**The subtidal zone at Redwood National Park extends 0.5 km (0.25 miles) offshore to an unknown depth below sea level. The area of marine habitat is about 2240 ha (5533 acres).*

Table 1.4. Major natural resource concerns for each park in the Klamath Network.

NATURAL RESOURCE CONCERNS	PARK CODE					
	CRLA	LAVO	LABE	ORCA	REDW	WHIS
Air Quality	X	X*	X	X	X	X
Altered Fire Regime	X	X	X	X	X	X
Altered Succession and/or Species Composition	X	X	X	X	X	X
Boundary Issues	X	X		X*	X*	X
Cave Communities			X*	X*		
Disturbed Park Lands		X			X*	X
Freshwater Communities	X*	X*			X	X
Geology and Geologic Features	X		X	X		
Invasive and Exotic Species						
(Plants and Animals)	X*	X	X		X	X*
(Fungi and Disease)	X	X		X	X	X
Marine Communities					X	
Poaching	X	X				
Threatened, Endangered, Rare, and Sensitive Species	X	X	X	X	X	X
Visitor Use	X	X	X	X		
Water Quality	X	X			X	X

"X" indicates the park's primary natural resource concerns.*

Collectively, the six parks comprise nearly 200,000 ha with a considerable range in size and relief (Table 1.3). Nonetheless, there are management concerns common to all, including altered fire regimes (Odion et al. 2004), non-native and rare species (Appendicecs D and G), impacts from adjacent land practices, and visitor use. There are also park-specific management concerns (Appendix C). Here, we provide a brief summary of each park's purpose and history, biophysical setting, and major natural resource concerns (Table 1.4).

Crater Lake National Park

Wizard Island in the Crater Lake caldera.

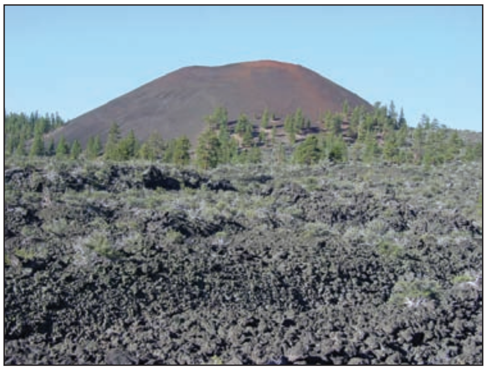
Crater Lake National Park was established on May 22, 1902 (32 Stat. 202), "dedicated and set apart forever as a public (park) or pleasure ground for the benefit of the people." The act also states that measures shall be taken for "the preservation of the natural objects...the protection of the timber... the preservation of all kinds of game and fish" and "that said reservation shall be open...to all...scientists, excursionists, and pleasure seekers." The park straddles the Cascade Mountains (Figure 1.1). The Crater Lake caldera (8x10 km) formed during the Mount Mazama eruption about 7000 years ago. Crater Lake is the deepest, clearest lake in the U.S. The park has a cool, mesic, varied climate and protects montane and subalpine coniferous forests, high montane meadows and wetlands, and pumice flats.

Lassen Volcanic National Park

Lassen Peak from Kings Creek Meadow.

Lassen Volcanic National Park was established by Congress on August 9, 1916 "for recreation purposes by the public and for the preservation from injury or spoliation of all timber, mineral deposits and natural curiosities or wonders within said park and their retention in their natural condition...and provide against the wanton destruction of the fish and game found within said park...." Incorporated into the park were Cinder Cone and Lassen Peak National Monuments (Presidential Proclamations 753 and 754, May 6, 1907) as part of the Lassen Peak Forest Reserve (Presidential Proclamation on June 5, 1905). In 1972, Congress designated 75% of the park as the Lassen Volcanic Wilderness. The park is in the Cascades near the junction with the Sierra Nevada Range with the Great Basin to the east (Figure 1.1). Several types of volcanoes and active thermal features dominate the landscape. Lassen Peak last erupted between 1914 and 1921, and is one of the world's largest plug dome volcanoes. The park is comprised of mid-elevation and subalpine conifer forests, undulating lake and meadowlands, and glaciated alpine terrain.

Lava Beds National Monument



Cinder Butte at Lava Beds.

Lava Beds National Monument was established by Presidential Proclamation No. 1755 on November 21, 1925 (44 Stat. 2591). "Whereas, lands of the United States within the area herein described… contain objects of such historic and scientific interest as to justify their reservation and protection as a National Monument…." Lava Beds is rich in natural and cultural resources. The area was home to the Modoc Indians and their ancestors for thousands of years and was the scene of the Modoc War during 1872 and 1873. Lava Beds lies at a geographic transition zone between the eastern Cascades Range and the Great Basin Desert (Figure 1.1) on the northern flank of the Medicine Lake shield volcano. It contains excellent examples of recent lava flows, cinder and splatter cones, over 700 lava tube caves, and many Great Basin vegetation communities.

Oregon Caves National Monument

Cave formations at Oregon Caves.

Oregon Caves National Monument was created by Presidential Proclamation in 1909 to protect a three mile cave "of unusual scientific interest and importance." The proclamation states that "the public interests will be promoted by reserving these caves with as much land as necessary for the proper protection thereof." From 1933 to 1942, the Civilian Conservation Corp landscaped a National Historic District and put in roads, trails, buildings, and the public water supply. A 1999 general management plan recommended protecting the monument's edges, scenic vistas, caves, and public water supply by adding 1381 ha (3410 acres) of adjacent late-successional Forest Service lands (these lands have not been incorporated). Situated in the Siskiyou Mountains, Oregon Caves is a small but ecologically diverse unit, due to its relief, high soil and vegetation heterogeneity, and presence of karst cave environments. Old-growth conifer forest, montane meadows, oak woodlands, and endemic cave-dwelling species are resource highlights.

Redwood National and State Parks

Redwood coastline.

Redwood National Park was established in 1968 and expanded in 1978. The national park, Prairie Creek (1923), Del Norte Coast (1925), and Jedediah Smith (1929) Redwoods State Parks were established to preserve significant examples of primeval coastal redwood forests and the prairies, streams, and seashore with which they are associated for public inspiration, enjoyment, and scientific study, and to preserve all related scenic, historical, and recreational values. The park is composed of four units located along the Pacific coast (Figure 1.1) with elevations ranging from below sea level to 996 m (3267 ft). Its prime resources are its 15,782 ha (38,982 acres) of old-growth redwood forests, anadromous fish runs, and relatively pristine coastline.

Whiskeytown National Recreation Area

Aerial view of Whiskeytown Reservoir.

The Whiskeytown Unit is part of the Whiskeytown-Shasta-Trinity National Recreation Area. Congress established Whiskeytown on November 8, 1965 (Public Law 89-336), stating in the enabling legislation that the park was to "provide...for the public outdoor use and enjoyment" of the reservoirs and surrounding lands "by present and future generations, and for the conservation of scenic, scientific, historic, and other values contributing to public enjoyment of such lands and water." Whiskeytown is located at the southeastern edge of the Klamath Mountains and contains an exceptional diversity of plant communities, including a variety of xeric shrublands, oak woodlands, and montane forests surrounding Whiskeytown Lake. It is also home to the only known population of Howell's alkali grass (*Puccinellia howellii*). Clear Creek is an important tributary to the Sacramento River from which anadromous fish come to spawn below the reservoir.

1.6. Summary of Existing Monitoring Efforts

Past and Present Monitoring

The Klamath Network's Phase II Monitoring Plan (Odion et al. 2005) provides a comprehensive breakdown of monitoring that has been done and that is ongoing in the Network. A brief summary is provided here.

Air Quality: With the Clean Air Act Amendments of 1977, Congress increased protections for 48 park units designated as Class I areas, along with additional measures to protect the remaining units—Class II areas. The KLMN includes four Class I areas (Crater Lake, Lassen, Lava Beds, and Redwood) and two Class II areas (Oregon Caves and Whiskeytown). The majority of NPS air resources monitoring occurs in the Class I parks, while the Class II parks often obtain air quality data from cooperating agencies. The four Class I parks all have at least one air quality monitoring station in the park. The two Class II parks have no within-park air quality monitoring stations. Lassen has the most extensive air quality monitoring program in the Network. The history of monitoring at each park unit can be found on the NPS Air Resources website: http://www2.nature.nps.gov/air/Monitoring/MonHist/index.cfm. For park units without on-site monitoring, estimates of many air quality parameters can be found in the NPS Air Atlas: http://www2.nature.nps.gov/air/Maps/AirAtlas/index.htm. More detailed information on air resources is contained in Appendix H.

Water Quality: In 2003, the Network began summarizing years of water quality data (Odion et al. 2005). Some areas (e.g., Crater Lake and the Redwood Creek Watershed) clearly have been the focus of intense scientific study for many years, whereas other areas (e.g., Lassen lakes or the Redwood shoreline) have received comparably little study. There is much to be done in inventory and establishment of baseline conditions for water quality monitoring. With funding from the NPS Water Resource Division, baseline inventories in Lava Beds, Lassen, and Oregon Caves were completed in 2005.

Outstanding Waters: There are no designated Outstanding Resource Waters within the Klamath Network. However, Crater Lake NP is petitioning the Oregon Department of Environmental Quality for designation for Crater Lake.

Protection Areas: The North Coast Regional Water Quality Control Board identified Redwood as a State Water Quality Protection Area, designated by the California State Water Board.

Clean Water Act Section 303d Impaired: There are four listed 303d impaired waters in the Klamath Network. Two of these are in Redwood (Redwood Creek and the Klamath River) due to adjacent upstream land use practices (e.g., road building and reduced vegetation cover associated with logging). There are two 303d waters in Whiskeytown: Willow Creek (associated with past mining activities) and the designated swim beaches.

The KLMN vital signs scoping process incorporated water quality issues (Chapter 3). We held separate workshops for marine issues and an aquatic working group (Appendix E) at the Network vital signs workshop. Consequently, our general monitoring questions and candidate vital signs address elements of water quality along with more general concerns about aquatic ecosystems. Similarly, we developed general conceptual models for marine and freshwater lentic and lotic ecosystems (Chapter 2), but not specifically for water quality.

Monitoring by Other Agencies and Institutions: Table 1.5 presents a summary of the agencies in the area that have established monitoring programs. Partnerships with these agencies may be formed to strengthen monitoring in the KLMN and of surrounding areas.

1.7. Formation of the Network and Approach to Planning

General Approach to Vital Signs Monitoring

The Klamath Network is following the basic seven step approach to designing a monitoring program. It is described in detail in the recommended approach for developing a network monitoring program at: http://science.nature.nps.gov/im/monitor/index.cfm

1. Form a network Board of Directors and a Science Advisory Committee.
2. Summarize existing data and understanding.
3. Prepare for and hold a scoping workshop.
4. Write a report on the workshop and have it widely reviewed.
5. Hold meetings to decide on priorities and implementation approaches.
6. Draft the monitoring strategy.
7. Have the monitoring strategy reviewed and approved.

Table 1.5. Selected agencies and institutions in the Klamath region that have established monitoring programs that may assist in the Klamath Network's monitoring goals.

AFFILIATION	AGENCY OR INSTITUTION NAME	EXAMPLES OF PROGRAMS OF INTEREST TO THE KLAMATH NETWORK
Federal	USDI Bureau of Land Management (BLM)	Noxious weeds, fire, special-status-plants programs, rangeland health; Northern Spotted Owls monitoring; and watershed analysis.
Federal	USDA Natural Resource Conservation Service	Soils mapping; surveys; and the Snow Survey Program.
Federal	USDA Forest Service	Manipulative experiments and longer-term studies of ecosystem components. The Forest Information and Analysis program maintains forest inventory plots in all the Network parks except Oregon Caves.
Federal	USDI Geological Survey	Expertise in conservation genetics, invasive plants, herpetofauna, contaminants, wetland and rangeland ecology, and biogeochemistry.
Federal	Environmental Protection Agency	Environmental Monitoring and Assessment Program's ability to design and modify protocols for multi-scale sampling of aquatic ecosystems.
Federal	USDI Fish & Wildlife Service	National Wetlands Inventory.
State	Oregon Department of Fish and Wildlife	Significant contributions to book on 593 wildlife species and their relationships with the 32 habitat types of Oregon and Washington (Johnson and O'Neil 2001).
State	California Department of Fish and Game	Monitoring assessing species and their habitats. Of particular interest is their Resource Assessment Program (CDFG 2001); available at http://www.dfg.ca.gov/habitats/rap/pdf/reassessprogram.pdf
State	California and Oregon State Parks	Monitoring performed to ensure a management action's efficacy or in collaboration with another agency or organization.
Other	Partners in Flight	Breeding Bird Surveys, occurring extensively both in time and space.
Other	The Klamath Bird Observatory	Bird monitoring in the Network parks, private, and federal lands.
Other	The Nature Conservancy	Purchases high-integrity landscapes or creates conservation agreements balancing human needs with long-term resources conservation.

These steps are incorporated into a three-phase planning and design process for the NPS monitoring program. Phase I involves assembling the Network team; defining the project scope, goals, and objectives; beginning to identify, evaluate, and synthesize existing data; developing draft conceptual models; and completing background work before selecting the initial vital signs. Phase II involves prioritizing and selecting vital signs for the initial monitoring program. Phase III entails the detailed design work to implement monitoring, such as developing specific monitoring objectives for each vital sign, sampling protocols, statistical sampling design, data management and analysis plans, and determining the type and content of products of the monitoring effort such as reports and websites.

Organizational Structure and Function of the Klamath Network

The KLMN has an eight-member Technical Advisory Committee composed of Natural Resource Chiefs from each of the six parks, the Network Coordinator (Committee Chair), and the Data Manager. The Committee meets annually to discuss and make decisions on the technical aspects of designing and implementing the program and to find ways to integrate inventory and monitoring with other research or management efforts. For decisions regarding hiring permanent staff, significant allocations of funds, or the overall direction of the program, the Committee makes recommendations to an eleven-member Board of Directors. A Science Advisory Committee composed of the Technical Advisory Committee and additional NPS and USGS scientists meet on an *ad-hoc* basis to provide scientific reviews, comments, and advice to the program.

The Board of Directors includes all six Park Superintendents, two rotating Natural Resource Chiefs, and the Regional and Network Coordinators. The Board meets each year after the Technical Advisory Committee meeting to facilitate fast action on any recommendations. Final authority on the overall program rests with the Board. The bylaws and decision-making process of the Technical Advisory Committee and Board of Directors are detailed in a charter signed by the Superintendents. A discussion of the program's administrative structure is provided in Chapter 10 and Appendix A.

1.8. Vital Signs Scoping Process

The process for identifying vital signs occurred in the parks over the last several years and a network-wide effort began in 2002. Most of the intensive activity occurred in early to mid 2004 and is described in Odion et al. (2005). This process involved scoping workshops among park resource staff, outside experts, and Klamath Network staff.

1.9. Monitoring in the Klamath Network

Identification of Monitoring Concerns and Vital Signs

Identifying vital signs for monitoring ecological integrity of the Klamath Network parks has entailed many steps and is an ongoing process. Vital signs scoping workshops were initially held for each park before formal establishment of the Klamath Network (Odion et al. 2005). After establishment, three workshops were held in 2004, covering 1) the geology and soils; 2) terrestrial, freshwater, and subterranean ecosystems across the Network; and 3) the marine environment at Redwood. The efforts culminated in the identification of numerous monitoring questions and associated potential vital signs. These were put into the National Vital Signs Framework and are presented, along with workshop and scoping process details, in Chapter 3 and Odion et al. (2005).

Monitoring Ecological Integrity

The Klamath Network has interpreted the guidance and intent of the Vital Signs Monitoring Program to provide accurate, ecologically meaningful, and defensible estimates of park ecosystem integrity. Monitoring is critical to adaptive management of park ecosystems, where management actions are viewed as ecological experiments in an iterative process of maintaining or improving ecological integrity. However, as Pickett and White (1985) state, "An essential paradox of wilderness conservation is that we seek to preserve what must change." Ecological integrity can be defined as a measure of ecosystem wholeness, including the presence of appropriate species, populations, and communities and the occurrence of ecological processes at appropriate rates and scales (Karr 1991, Angermeier and Karr 1994, De Leo and Levin 1997) as well as the environmental conditions that support these taxa and processes (Dale and Breyeler 2001). Although varied definitions exist, ecological integrity is clearly a multifaceted concept that includes variation in species' life histories, ecosystem structures and processes, and human perceptions of value and wholeness (De Leo and Levin 1997). Because of its multifaceted nature and since park landscapes are spatially and temporally variable, an ideal monitoring program for ecological integrity would be both complex and expensive. The natural range of variability for ecosystems may be

impossible to define, so determining an acceptable range of variation, may be a more attainable goal (Holling and Meffe 1996, Parrish et al. 2003). A network vital signs program can only afford to monitor a subset of the potentially important species or other parameters. Therefore, the careful selection of species, measurements, or focal ecosystems is essential.

Selecting Vital Signs

Given the very real funding and operation limitations of any monitoring program, there is an understandable temptation to look for proxies or surrogates for measurement of integrity through designation of indicator species or parameters. A host of terms and concepts have been proposed (Niemi and McDonald 2004). The "umbrella" or "indicator" species concept (Landres et al. 1988, Niemi et al. 1997, Fleishman et al. 2000) implies that changes in distribution and abundance of one species effectively indicate changes in a broader host of species because of broader habitat amplitudes or covariation in ecological response. A related approach, the identification of ''keystone'' species (Simberloff 1998) or ''ecosystem engineers'' (Jones et al.1994) seeks to pinpoint species that have disproportionate effects on ecosystem structure and function. ''Flagship'' species (Western 1987, Simberloff 1998), which capture the most socially-valued of a similar group of species, have also been proposed. All these concepts have potential merit in developing a monitoring program with ecological and social support. However, they also hinge on the assumption that individual species or ecosystem parameters can indicate the abundance or distribution of other species or the condition of a larger ecosystem, an assumption that has been widely challenged (Landres et al. 1988, Strong 1990, Swanson 1998, Lindenmayer et al. 2002, Niemi and McDonald 2004).

These concerns by the scientific community match with our local experiences. Although most participants attempted to avoid obvious conflicts of interest, it was clear that the species and issues selected were often limited by the disciplinary perspectives of scoping groups. Despite its intuitive and practical appeal, we decided it was unlikely that changes in the integrity of park ecosystems can be adequately described by changes in one or even several species or elements if they are too similar in distribution or ecology. Manley et al. (2004) also considered the indicator species approach to be an "eggs in one basket" alternative, with the obvious implied risks.

Given these concerns, we decided early in the formation of the KLMN Vital Signs Monitoring Program to pursue broad, diversified vital signs to the degree that financial and human resources allow. We reasoned, as did Manley et al. (2004), that the chance that changes consistent with ecological integrity would be captured is increased when the diversity of organisms or parameters is increased in individual samples and particularly when multiple species or measurements are available and can be arranged in monitoring portfolios (Karr and Chu 1999, Manley et al. 2004).

We used a portfolio approach to consider and evaluate potential vital signs. The purpose of a diversified investor's portfolio is to ensure moderate financial returns while minimizing risk of asset loss (Costanza et al. 2000). Similarly, we saw a diversified monitoring portfolio as essential to ensure that we are collecting information about ecological integrity and minimizing the risk that changes affecting integrity go undetected. In such a portfolio approach, the individual species or elements can be less important than their complementarity and comprehensiveness in information content overall. An emphasis on complementarity and comprehensiveness tends to diminish the explicit or implicit sources of taxonomic, spatial, or ecosystem biases that are often present in monitoring programs. For example, in nearly all environmental monitoring programs, there are likely to be some elements that are included because of historical precedent, legal mandate, an appeal to the public or current managers, etc. Building from such required monitoring elements to create a diverse and integrative monitoring program requires an effort to achieve a balanced “sample” of the ecosystems in question by choosing indicators with different characteristics, such as both physical and biological parameters, and species with varying life history traits, habitat requirements, and trophic positions.

Selecting Ecosystems

In the spatially complex environments of the KLMN parks, there are many potentially important species and ecosystem types. For the most part, we did not place great emphasis on selecting specific ecosystem types (e.g., ponderosa pine or stream pool ecosystems) for monitoring. Such an approach would have been infeasible in our Network because of the sheer number of such types and would have emphasized distinctive approaches in each park. Instead, we emphasized monitoring of broad qualitatively distinct ecosystem domains, namely terrestrial, subterranean, freshwater, and marine domains that, in most cases, allowed for conceptual integration across the park landscapes and among the varied parks in our Network. Consequently, it is expected that some of the more localized and unique ecosystem types in each ecosystem domain may need to be excluded from our monitoring inferences because they will be missed or undersampled in broad spatial sampling designs or their ecological dynamics may be qualitatively distinct. The selection of broad domains ensures that we will be able to provide meaningful inferences about ecological integrity in each ecosystem domain of the KLMN with the modest funding provided by the I&M Program.

In summary, we aimed to develop monitoring portfolios of diverse ecological elements within and across our vital signs to inform us about the status, condition, and trends in the broad ecosystem domains of the KLMN. This broad, idealized approach was tempered by funding and other logistical realities, but nonetheless was a central organizing strategy that appears throughout this plan.

2.1. Introduction

Service-wide guidelines for establishing I&M Network Vital Signs Monitoring Programs in the national parks call for developing conceptual models that "provide a summary of the understanding of the park ecosystem" (NPS 2004b). The conceptual models and the process of developing them are considered key steps meant to improve understanding of and communication about complex systems and to assist in designing a vital signs monitoring program (Gross 2003). Conceptual models also help provide consistent principles around which the vital signs report can be organized.

A conceptual model is a visual or narrative summary that illustrates the important ecosystem components and interactions. Effective conceptual models help scientists convey complex principles with impact and economy, promoting integration and communication among scientists and managers from different disciplines. Developing conceptual models also helps the monitoring program designers better understand how the many components of ecological systems interact. This chapter describes the KLMN process for developing conceptual models to guide this Vital Signs Monitoring Plan. The goal of these conceptual models is to explain our understanding of the drivers of change in park ecosystems so that the vitality of these systems can be monitored.

2.2. A Conceptual Basis for Monitoring in the Klamath Network

Monitoring can inform land management by providing practical details relevant to park operations and critical information for conserving biological diversity (Noon et al. 1999, Busch and Trexler 2003). The need for a conceptually sound and quantitative basis for gauging park ecosystem status and trends has been proposed by numerous reviews of NPS policies and actions (National Academy of Sciences 1992, reviewed in Sellars 1997 and Appendix A). This chapter aims to communicate such a conceptual foundation for identifying vital signs of the ecosystems of the Klamath Network.

Ecosystem Structure, Composition, and Function

Franklin et al. (1981) recognized three primary characteristics of ecosystems: composition, structure, and function. These can be used to assess the ecological integrity of park ecosystems. 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. Function refers to the many processes that ecosystems require and provide through time, such as nutrient cycling, carbon cycling, hydrologic cycling, etc. Noss (1990) modified this classification to describe potential indicators of biodiversity, creating a conceptual model illustrating how composition, structure, and function might be expressed across a hierarchy of spatial scales and biological organization (Figure 2.1).

In the Klamath Network, the NPS protects and manages landscapes with exceptional levels of species richness, endemism, and rarity (DellaSala et al. 1999, Section 1.4). A major challenge is to maintain this biodiversity through time. The three-part framework describes the system's fundamental dimensions at all scales, providing a comprehensive framework for identifying the vital signs of a biophysical system (Chapter 3).

Multiscale and Multispecies Integration

A monitoring program must also have an approach to measuring park phenomena and relevant issues that span multiple

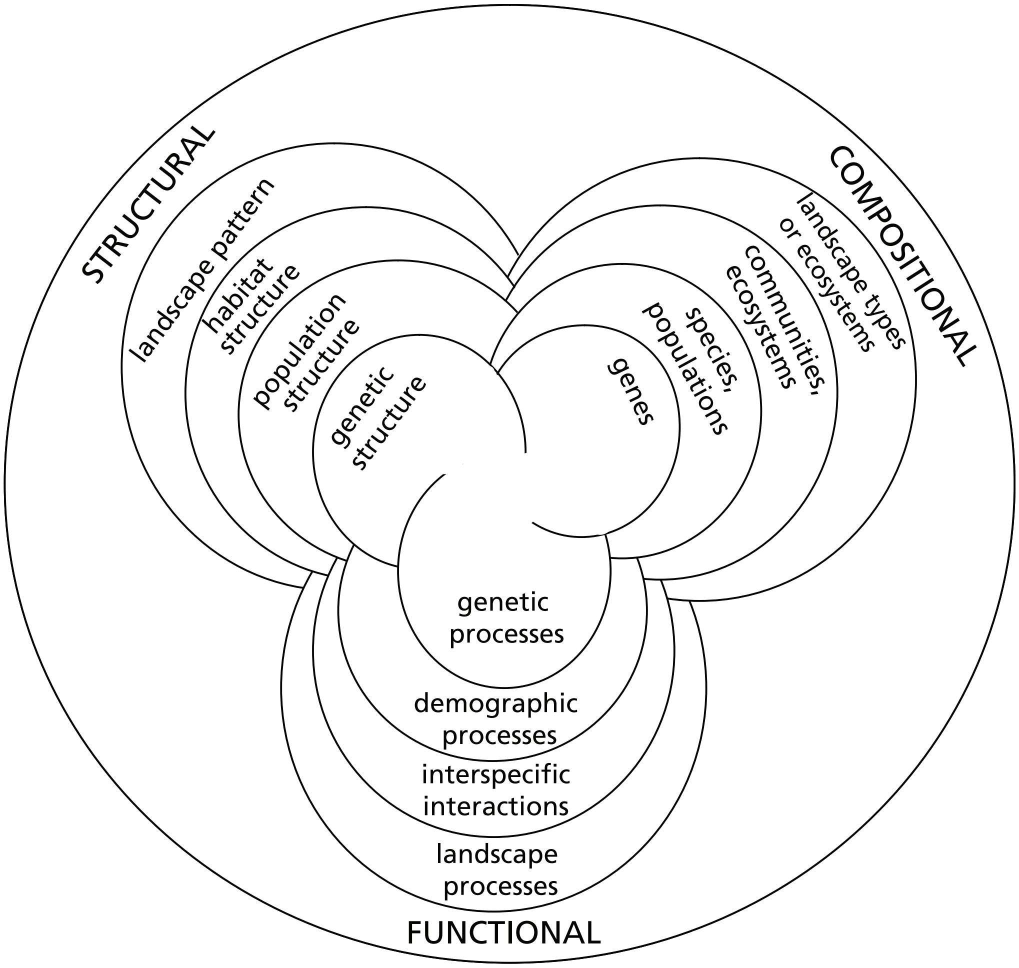


Figure 2.1. Conceptual model of the multiscale hierarchy of biodiversity indicators that describe composition, structure, and function at each level of scale and biological organization (from Noss 1990).

scales. A growing body of ecological literature illustrates that the relative importance of different controls on species abundance and diversity varies across spatial and temporal scales (Holling 1992, Whittaker et al. 2001, Bestelmeyer et al. 2003, Sarr et al. 2005a). Therefore, monitoring must provide information across spatial and temporal scales, relevant for the organisms present.

Assessing human impacts also requires a multiscale perspective and diversity in sampling approaches. Impacts to specific habitats may require more focused attention than occurs in a park or network-wide sampling grid. Impacts of larger scale influences will require partnership and information sharing with regional, national, or international partners (see Section 1.6).

Monitoring must effectively integrate information across species, life forms, and ecosystems. Approaches that monitor the status and trends in structure and variation on three levels (environmental factors, species populations, and community characteristics (Whittaker 1967)) may be needed to determine trends in ecological integrity. Such approaches place greater emphasis on the types and degrees of relationships among different organisms in a community than more taxon-specific approaches. In particular, we suggest that monitoring multiple species or attributes together may track changes in ecosystem structure, function, and composition better than single entities (see Section 1.9). Gradients along which these assemblages change may be apparent, as shown in the conceptual models presented here. Additionally, multivariate approaches for comparing samples may cause gradient relationships to emerge from the data. How these relationships change over time may be a vital sign of ecological integrity.

2.3. Conceptual Model Development

The Klamath Network conceptual modeling process involved literature review, discussion among network staff, consultation with national I&M staff, and comment solicitation on draft models in scoping meetings with the parks (see Odion et al. 2005). The KLMN first surveyed models prepared by other networks. We identified two basic strategies for modeling complex systems affected by human activities: 1) incorporate human impacts directly from the outset (stressor-based models); and 2) develop models based on a biophysical understanding of the system without human impacts (ecosystem-process models) first, then incorporate human impacts. Initially, we chose the latter.

We considered developing conceptual models for each major ecosystem in the Network, but dismissed that approach when it became apparent that it would produce a large, redundant family of conceptual models. Rather than approach the ecosystems as discrete pieces, we chose to portray them as broader ecosystem domains (marine, freshwater, terrestrial, and subterranean), structured into ecological zones by environmental gradients. We also debated how to have consistent levels of detail in the various models and addressed this by constructing a hierarchical family of models ranging from broad and comprehensive to focused and detailed. This approach provided general models for communication with non-scientists and allowed us to construct submodels with sufficient detail for a particular problem or highly specialized audience.

Of the conceptual models we reviewed, we were particularly impressed with the ones developed by the Southwest Alaska Network (SWAN) (Bennett et al. 2003). Their models were hierarchical, visually appealing, interesting, and covered a suite of broad concepts. In their Phase I Report, SWAN introduced the holistic conceptual model, with submodels describing specific elements. We incorporated three major organizing features and design elements from their conceptual models: 1) the use of the hierarchical structure employing one holistic model with a family of submodels, 2) a broad classification of park ecosystems, and 3) an attempt to create visually-engaging models.

As we developed our models, we worked from general to specific. We began by considering the primary environmental influences on ecosystem structure, composition, and function in the parks. The holistic conceptual model is a simple diagram portraying these abiotic, biotic, human, and dynamic environments. Submodels are simply components of the holistic model in greater detail. The hierarchical, nested set of models developed for the Klamath Network includes: 1) a holistic conceptual model of ecosystem domains showing the major influences on park ecosystems and 2) submodels of park ecosystems, illustrating the influences in greater detail.

2.4. Conceptual Models

A Holistic Conceptual Model of Influences on Klamath Park Ecosystems

Our holistic conceptual model (Figure 2.2) was developed through discussions with network and park-based science staff and recognizes and encapsulates our view of the major influences on park ecosystems. These influences are summarized as the abiotic, biotic, dynamic, and human environments that shape the structure, function, and composition of park ecosystems. We then divided park ecosystems into four domains: marine, freshwater,

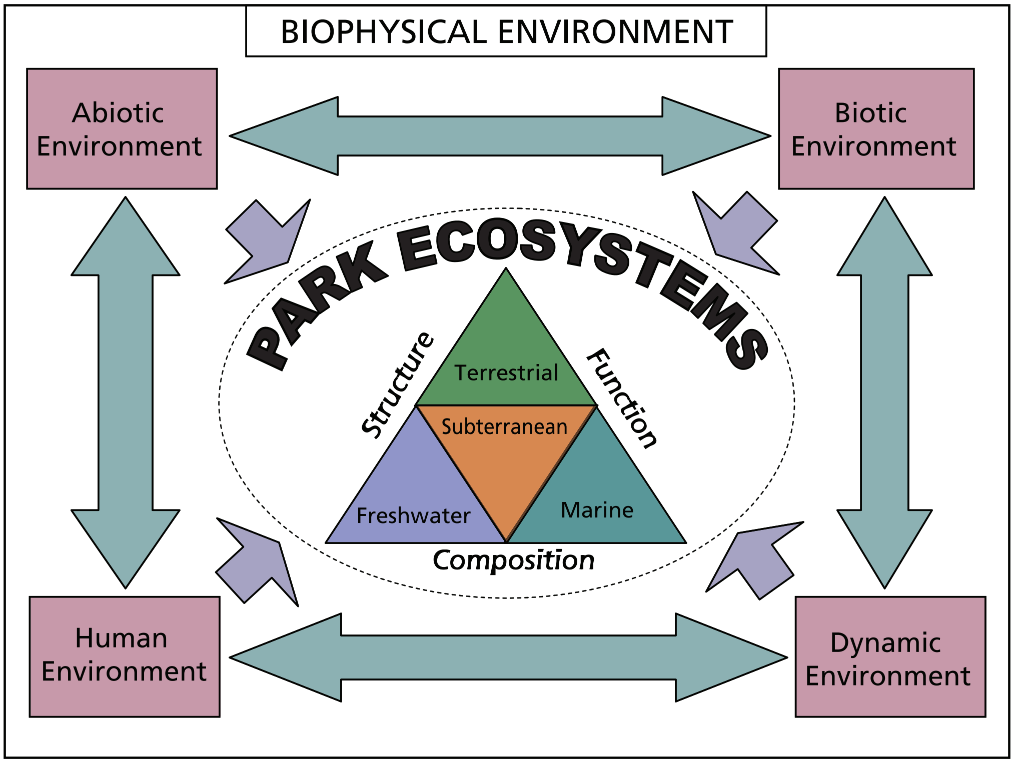


Figure 2.2. A holistic conceptual model of influences on Klamath park ecosystems.

terrestrial, and subterranean. We did not aim to provide a definitive ecosystem classification. Rather, we wished to portray four major domains that are intuitive and, as needed, allow subdivision. We encouraged participants at the vital signs workshops to consider the conceptual model in the nomination and selection of vital signs.

In the following section, we provide a short justification for each of the holistic conceptual model's major components. We then present conceptual submodels illustrating the influence of each major component in the park ecosystem domains. Three sets of conceptual submodels result: 1) models of ecological zonation along biotic and abiotic gradients, 2) models of natural ecosystem dynamics, and 3) models of human-caused influences on ecosystem dynamics.

Assumptions and Approach to Submodels

Gradient Models (Abiotic and Biotic Environments): Much of the geographic variation in the Klamath region arises from ecological zonation across steep abiotic gradients. Because the region's landscape gradients are so pronounced (Whittaker 1960) and such strong drivers of ecosystem patterns and processes, we assumed this gradient structure would provide an ideal background upon which to conceptually portray biotic variation across the terrestrial landscape. There are also strong gradients and pronounced zonation in marine and freshwater ecosystems, underscoring the generality of the gradient model approach.

Zonation has long been recognized in terrestrial ecosystems (Merriam and Steineger 1890) and is evident in aquatic and wetland ecosystems too (Ricketts and Calvin 1939, Vannote et al. 1980, Mitsch and Gosselink 2000). We employ the zonation concept in the first set of ecosystem submodels for practical reasons. First, the nature of spatial patterns in the region suggests they can be linked to biophysical drivers (e.g., climate, geology, and wave action), which form the fundamental controls on ecosystem processes and living organisms. Second, development of individual ecosystem models was decided to be intractable. Finally, the gradient models are fairly simple and straightforward so that they may be more engaging to readers of the plan.

Dynamic Environment Models: A range of natural processes structure the park ecosystems and maintain ecological integrity. Major system dynamics range from place to place, encompassing climatic, geologic, and oceanographic processes. Disturbance dynamics are fundamental to ecosystem function and diversity in all the ecosystem domains. Landscape disturbances are highly variable across the range of environments of the Network, but have measurable statistical characteristics (e.g., mean sizes, recurrence intervals, intensities with characteristic ranges). Organisms may be as affected by extreme events (e.g., droughts, floods, crown fires) as they are by average conditions, so our understanding must include a grasp of the range, variation, and periodic nature of system dynamics. Our models illustrate the major dynamic processes structuring major ecosystem types and ecological zones.

The Human Environment Models: Although our Holistic Conceptual Model clearly includes humans as part of the Klamath biophysical environment, we developed human environment models for each major ecosystem to explore how human stressors can impact park ecosystems. We portray these relationships in one overview model and several submodels. All of them distinguish far-field influences propagating across landscapes (e.g., air pollution, climate change, fire suppression) from near-field influences causing more local, but potentially cumulative impacts (e.g., visitor use impacts, local disturbances, point source pollution). In the submodels, we portray major human influences; intermediate linking mechanisms or processes (e.g., abiotic and biotic gradients, ecosystem processes) driving ecosystem structure, function, and composition; and several focal elements of value to the parks.

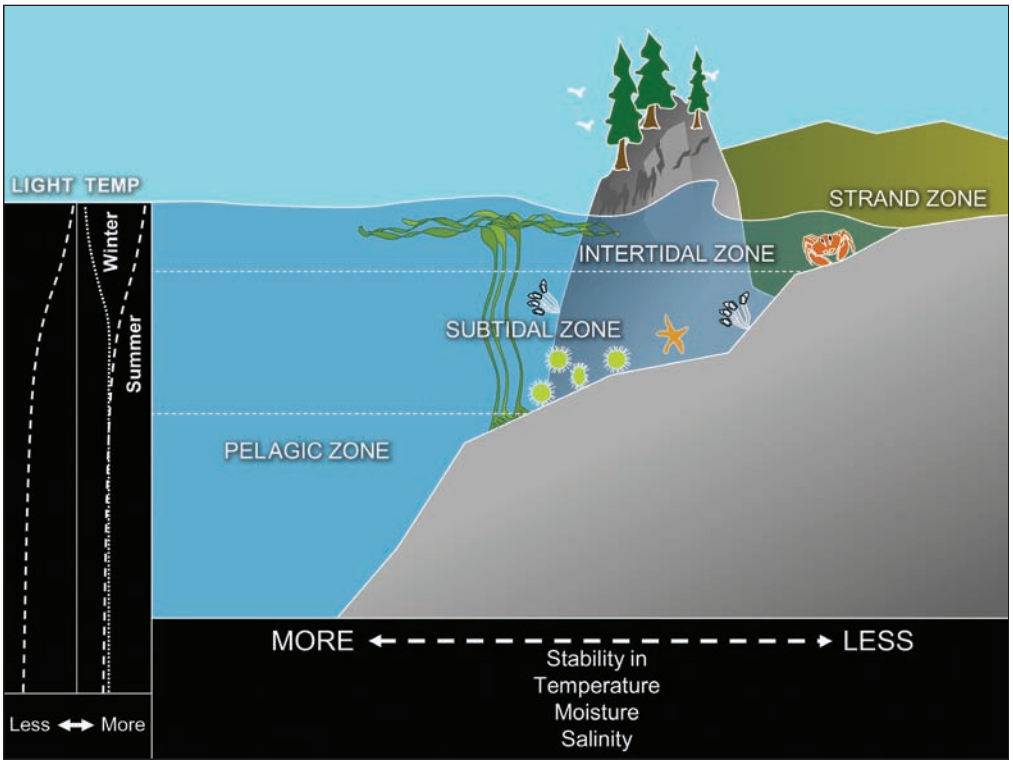
Major Ecosystem Domains of the Klamath Network

Here, we outline the region's major ecosystem domains and discuss the fundamental gradients shaping the biophysical environment and the intrinsic ecosystem dynamics.

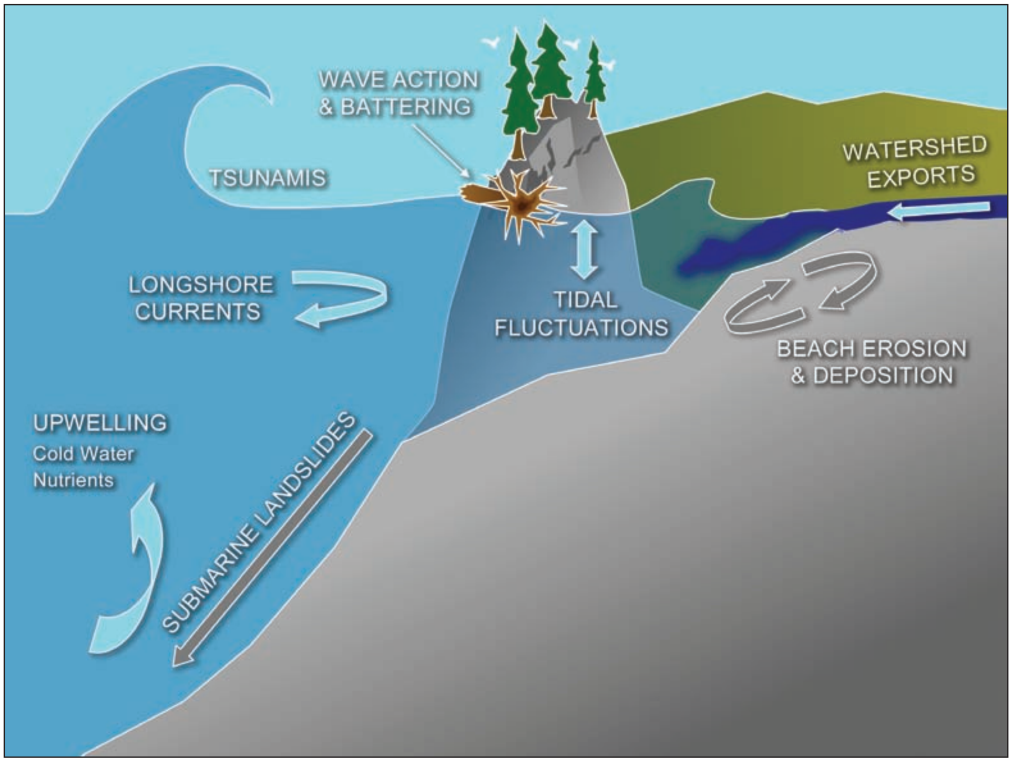
Marine Ecosystems: Near-shore marine environments have some of the sharpest zonation known (Ricketts and Calvin 1939, Bakker 1971). There are several major zones along the gradient from dry sand to deep water. Ricketts and Calvin (1939) also emphasized the importance of wave shock as a control on organism richness and distribution. The substratum type complicates these gradients, creating relatively distinct environments. A conceptual model of the marine environment (Figure 2.3a) illustrates the stability and abiotic conditions gradients.

Across the ecological zones from strand to sea, there are important changes in ecosystem dynamics, especially disturbance type and intensity (Figure 2.3b). Near the shoreline, wave action shapes species distributions. Especially powerful storm waves can strongly influence the intertidal zone, an area chosen for future monitoring (Chapter 3). These disturbances can be particularly forceful when aided by driftwood or other debris. Extreme tides also form disturbances through atypically long periods of inundation or desiccation. Along the northern California coast, tsunamis have occurred and undoubtedly change abiotic and biotic conditions. Farther out to sea, larger scale marine processes, such as upwelling, currents, and ocean temperature oscillations become primary controls on organism distribution and abundance.

Effective conceptual models help scientists convey complex principles with impact and economy, promoting integration and communication among scientists and managers from different disciplines.

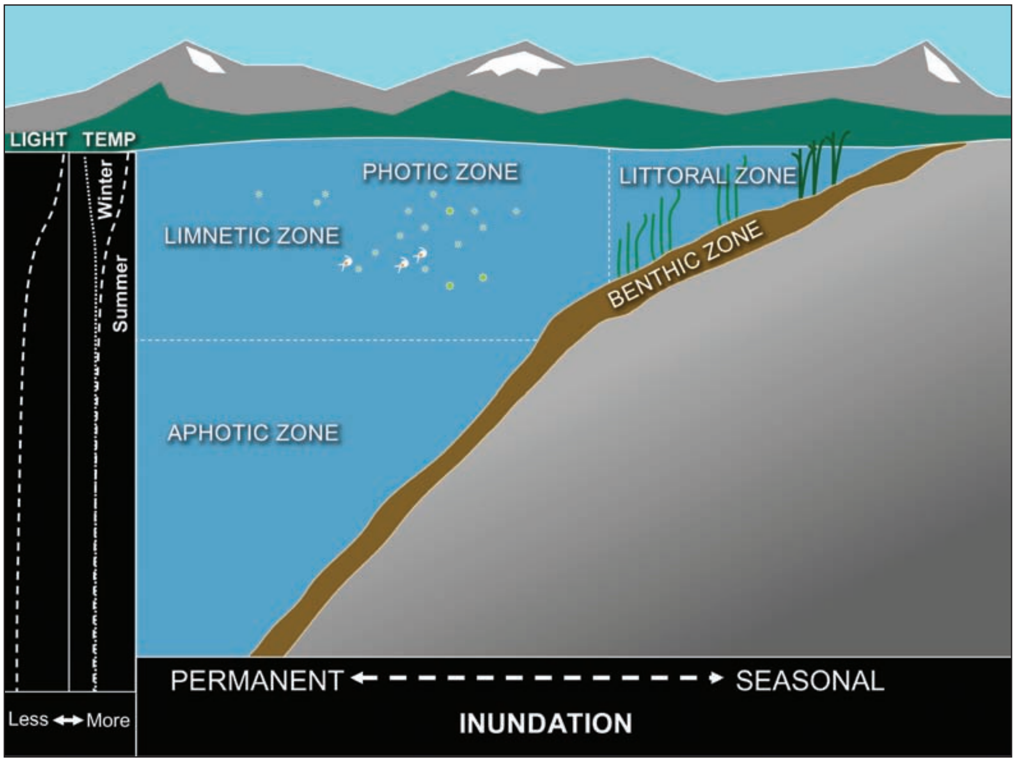


a.

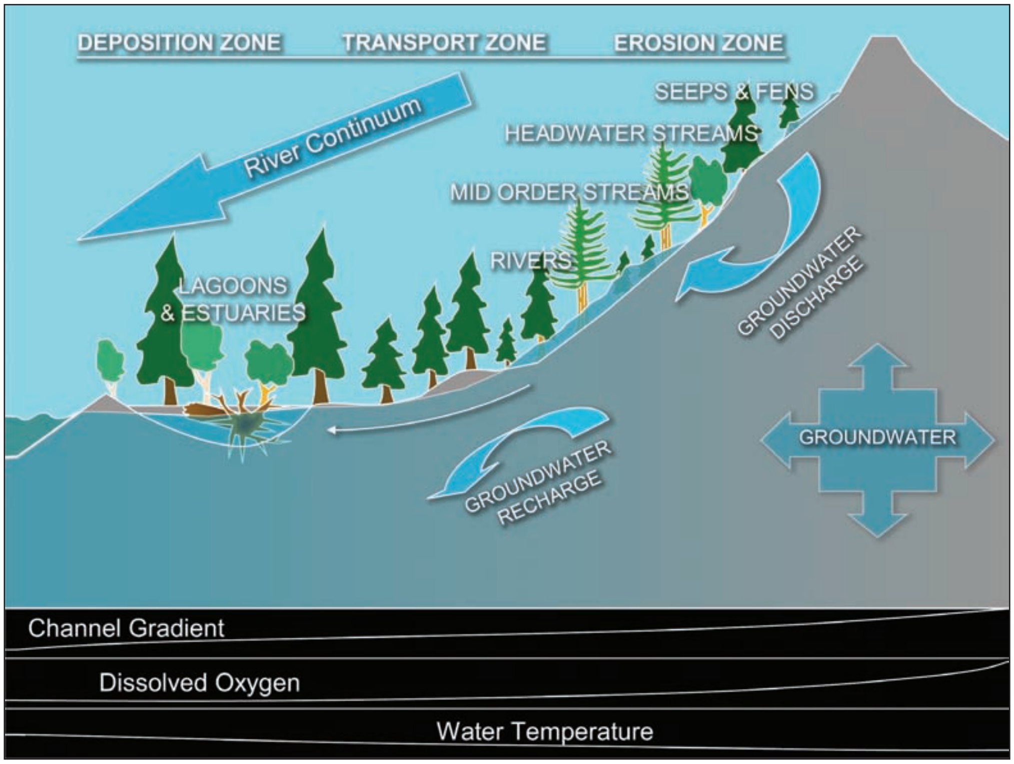


b.

Figure 2.3 a and b. Conceptual model of marine ecosystems, showing a.) major abiotic gradients and ecological zonation (changes in abiotic conditions with increasing depth are portrayed in vertical line graphs), and b.) major dynamic processes.



a.



b.

Figure 2.4 a and b. Conceptual model of freshwater ecosystems, showing a.) major abiotic gradients and ecological zonation in lake (lentic) ecosystems, and b.) major abiotic gradients in flowing freshwater (lotic) ecosystems.

Freshwater Ecosystems: The primary lake gradient is from the wave-influenced, well-illuminated, and seasonally variable littoral zone to the comparatively stable, but light-poor depths (Figure 2.4a). The lake depth and shoreline nature also influence the water column and organisms present. Shallow lakes, such as many in Lassen, have littoral zones with high productivity, extensive wetland development, and tight coupling to the surrounding terrestrial environment. In deeper lakes (e.g., Crater Lake), open water (pelagic) processes are most important; productivity is lower with a very large aphotic (no light penetration) zone.

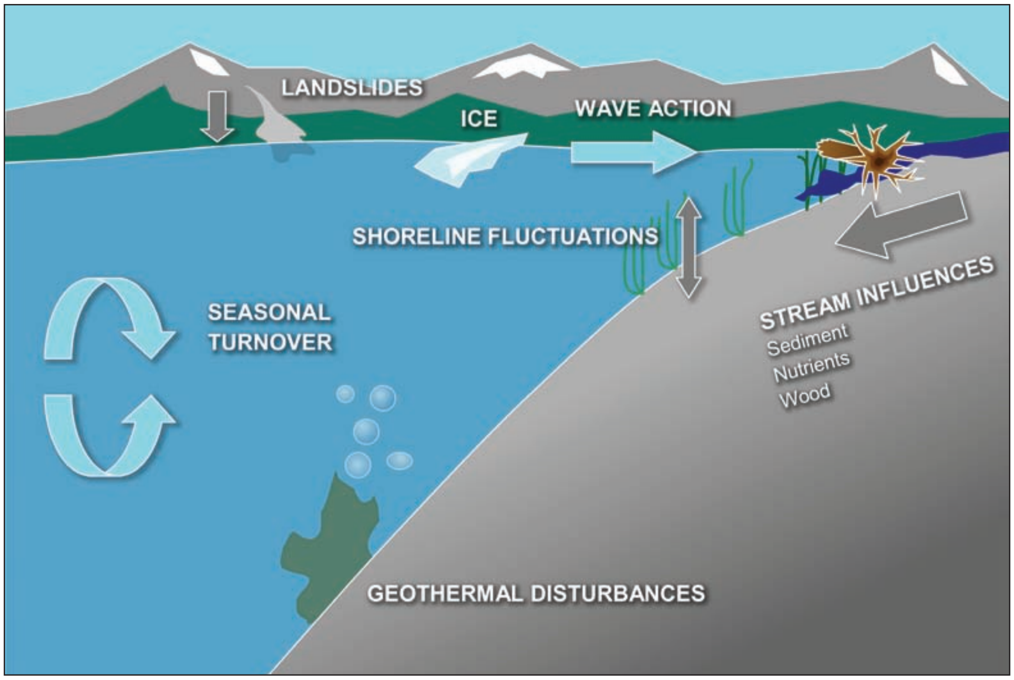
Flowing water (lotic) ecosystems change predictably from headwaters to downstream. The river continuum (Vannote et al. 1980) depicts this pattern and is expressed in lotic ecosystems in the Network (Figure 2.4b). Typically, there are predictable increases in water temperature and within-stream carbon production and decreases in dissolved oxygen and average substrate size along the continuum. These abiotic changes drive changes in aquatic biotic composition along the same gradient. In the future, we will be monitoring water quality and freshwater aquatic communities (Chapter 3).

Freshwater ecosystem dynamics show variation across ecological gradients. From the littoral to pelagic zones, major lake dynamics shift from wave influences and effects of landscape disturbances to seasonal currents that mix the water column (Figure 2.5a). Although lakes are dynamic, relatively less of their spatial and temporal variation fits Pickett and White's 1985 definition of disturbance. Seasonal temperature fluctuations, such as fall turnover, are essentially regenerative processes, as are the sequential phytoplankton and zooplankton blooms that drive seasonal shifts in water clarity and nutrient availability. The effects of more typical disturbances (e.g., ice movement) and watershed influences (e.g., floods and debris flows) are less understood.

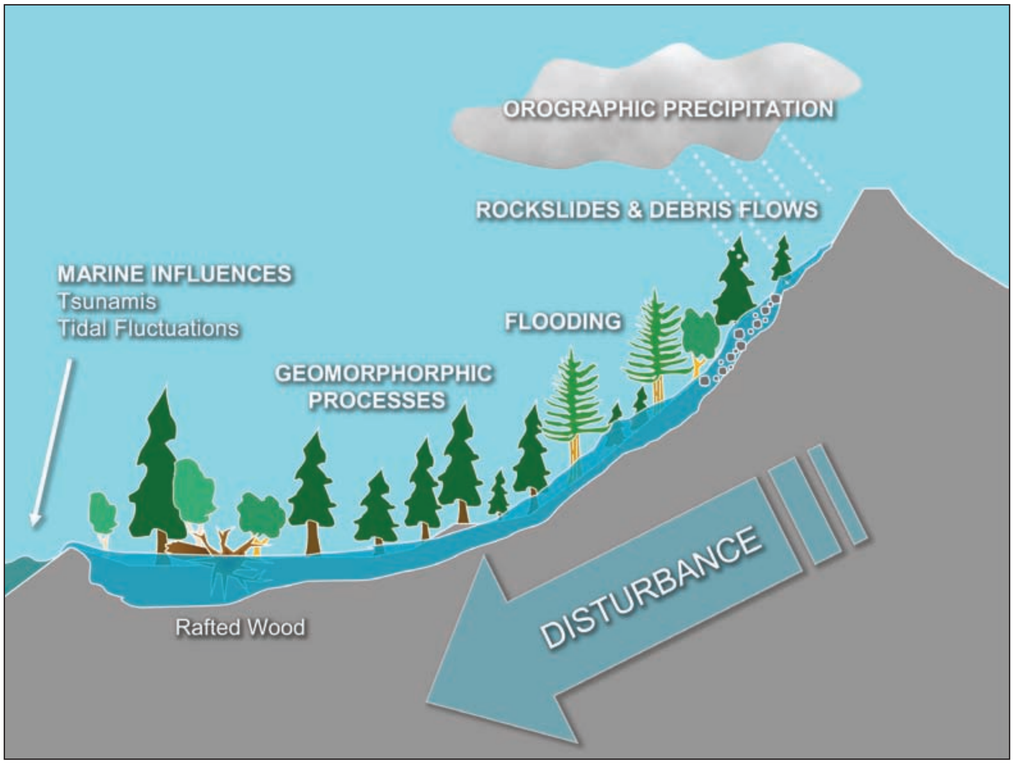
In contrast to lakes, streams are particularly dynamic, with stochastic disturbances being primary organizing processes. A host of factors can disturb the stream and its riparian corridor (Figure 2.5b), including debris flows, floods, and geomorphic processes such as channel migration. Although initial conservation efforts sought to minimize stream disturbances, a nonequilibrium paradigm (Reeves et al. 1995) proposes that understanding watershed and stream disturbances is fundamental to understanding the integrity of these ecosystems.

Terrestrial Ecosystems: The Klamath Network encompasses landscapes with steep climate gradients associated with proximity to the Pacific Ocean air masses (see Chapter 1 and Appendix B). The decreasing maritime influence from west to east is associated with declines in precipitation, greater ranges in daily and annual temperature, and increases in solar radiation (Figure 2.6a). A preliminary landscape classification for the region (Sarr et al. 2004) recognizes five climate and eight elevation zones. Temperatures decline with elevation in all climate zones and deep snows accumulate above 2000 m elevation. The coastal climate zone shows a sharp temperature inversion in summer, associated with coastal fogs, so that areas lower than 500 m are much cooler than corresponding interior areas. Network-wide, the abiotic changes in ambient climate and elevation are mirrored in a variety of vegetation types (see Chapter 1 and Appendix B).

In terrestrial ecosystems, landscape dynamics also show important variation across the region (Figure 2.6b). Windthrow may be the most important disturbance in the moist, storm-battered coastal forests, while fire is the preeminent landscape-scale disturbance at many noncoastal sites (Franklin and Dyrness 1988 and see also Odion et al.

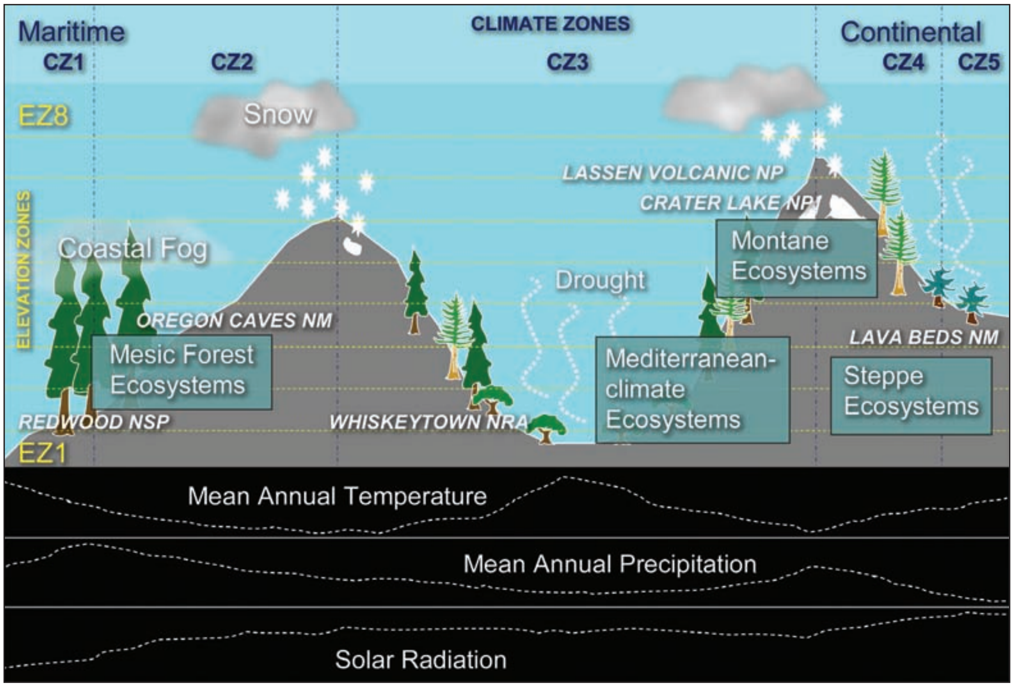


a.

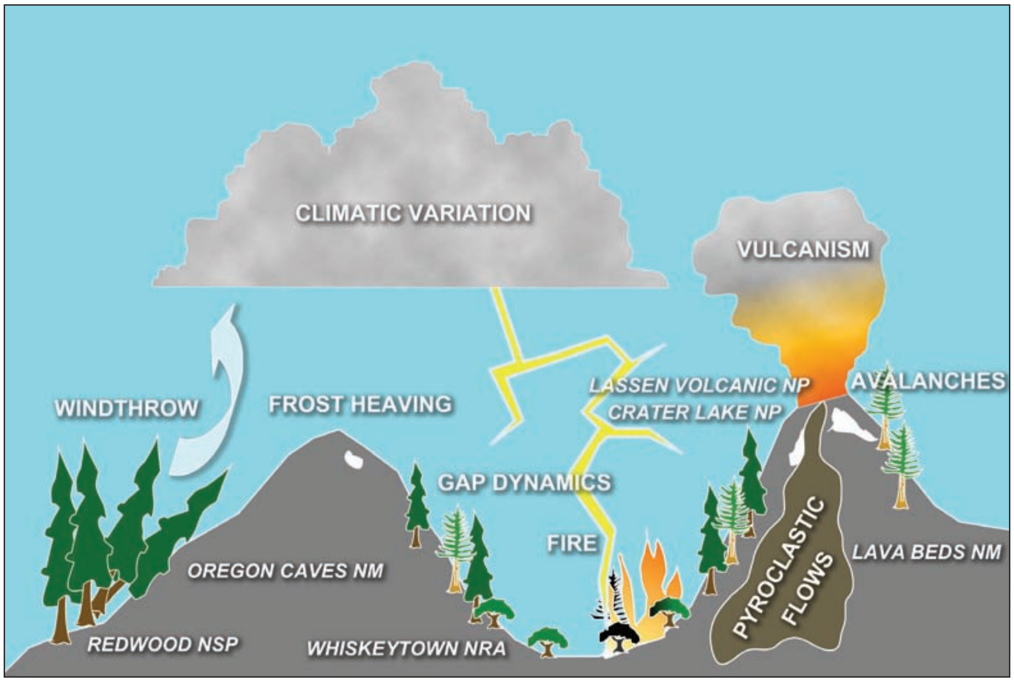


b.

Figure 2.5 a and b. Conceptual model of major dynamic processes in freshwater ecosystems: a.) lake (lentic) ecosystems, and b.) flowing freshwater (lotic) ecosystems.

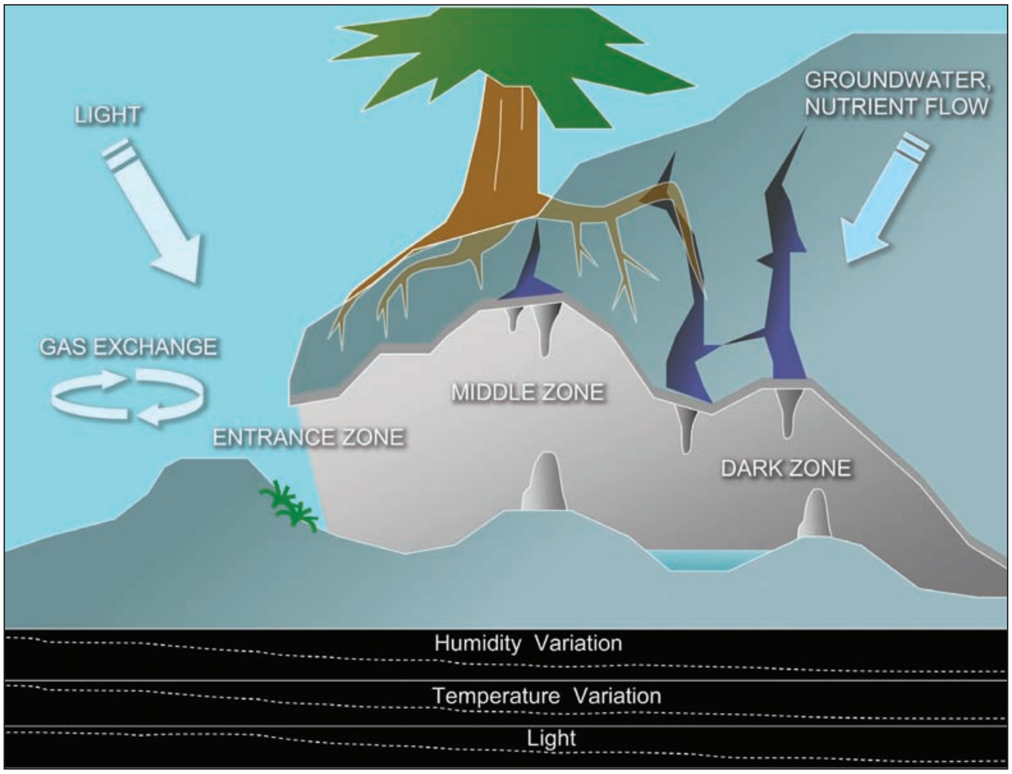


a.



b.

Figure 2.6 a and b. Conceptual models of terrestrial ecosystems, showing: a.) major abiotic and ecological zonation (variation in major ecological parameters portrayed in horizontal line graphs; elevation and climate zones (from a draft landscape classification) break the region into five climate zones and eight elevation zones), and b.) major dynamic processes.



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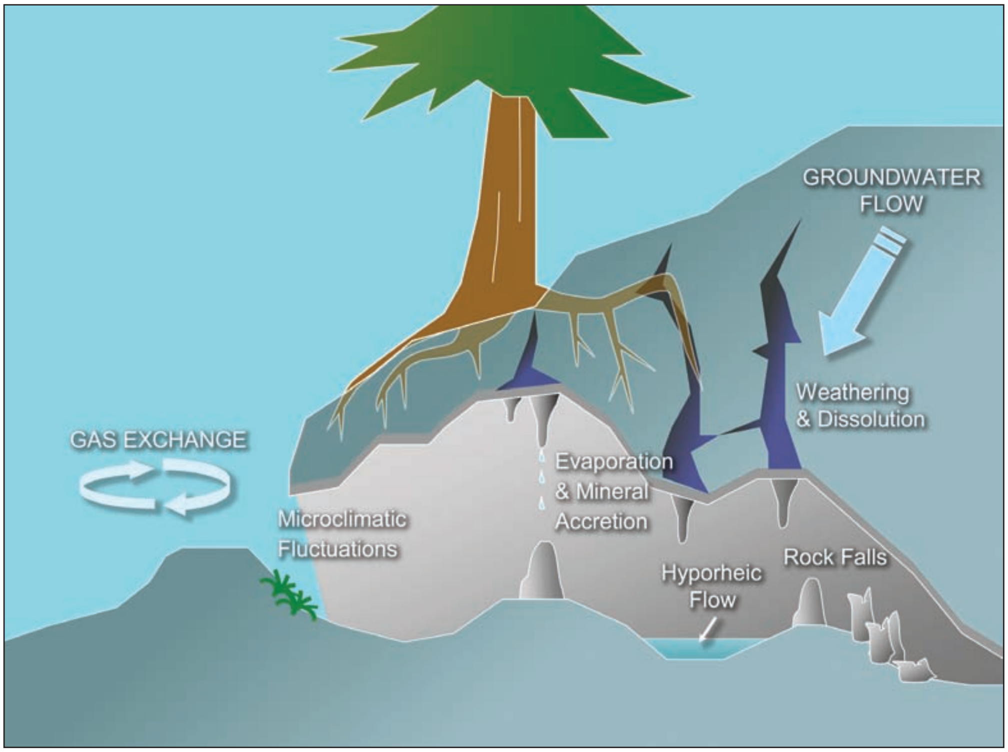


b.

Figure 2.7 a and b. Conceptual models of subterranean ecosystems, showing: a.) major abiotic gradients and zonation (variation in conditions is portrayed in horizontal line graphs), and b.) major system dynamics.

2004). Other, finer-scale disturbances, such as local root rot infestations, insect outbreaks, and landslides, are also found in unique vegetation types and topographic positions.

Subterranean Ecosystems: The caves of the KLMN parks are spatially structured habitats with clear gradients in light, humidity, airflow, and air chemistry from the cave mouths inward (Figure 2.7a). Generally, environmental variability declines with increasing distance into the cave (Hobbs 2005). As outside conditions affect caves, so do the unique, cool microclimates near cave mouths influence the adjacent terrestrial environment, creating important habitat for many species at Lava Beds. Processes that occur in caves are fundamental to the cave's development and structure, although they often occur slowly. Groundwater flow, and associated processes of mineral dissolution and accretion, create and maintain karst features (White and Culver 2005). Similarly, seepage and freezing of water are necessary for the formation of ice caves, as are the summer temperature inversions that maintain them.

Caves appear to be quite stable environments when compared with surface ecosystems, often showing remarkable consistency in temperature and humidity from day to day and year to year (Hobbs 2005). However, disturbances caused by rock falls or the flooding of subterranean streams do provide some temporal variability. As one moves closer to the cave mouth, environmental conditions become more variable and may be affected directly or indirectly by surface disturbances (Figure 2.7b). (Hobbs 2005). Viewed on longer time scales, cave ecosystems are highly dependent upon hydrogeologic and atmospheric processes (Stone et al. 2005). Cave environments and communities will be monitored in the future (Chapter 3).

Human Influences on Park Ecosystems

Humans have been elements of the Klamath Network park ecosystems for millennia. Thus, they are considered in our holistic model (Section 2.4). Their influences have changed dramatically with changes in technology, culture, population densities, and park development. Although large parts of several parks are considered wilderness, the majority of the parks are, in fact, human-dominated ecosystems (Vitousek and Mooney 1997), and will continue to be for the foreseeable future.

A central goal of the long-term monitoring program is to detect changes we suspect are caused by detrimental human actions. Potential sources of harm can come from near-field activities (e.g., campgrounds, local management actions, point-source pollution) or from far-field effects (e.g., off-site pollution, climate change, and invasive species). Together, these stressors can affect the structure, function, and composition of park ecosystems, endangering their diversity and integrity (Figure 2.8).

Marine Ecosystems: Human influences on the Network marine environments include far-field factors (e.g., deepwater fishing, pollution, disturbance to shorebirds) and local effects (e.g., beach recreation, rock climbing) (Figure 2.9). Trash is also abundant in marine systems. These factors influence the gradients and processes that maintain habitat for focal, keystone, and rare and sensitive coastal species.

Freshwater Ecosystems: Recreational lake use is a dominant influence and management objective in the parks (Figure 2.10a). This is especially true in Whiskeytown, where summer use of mechanized watercraft can be nearly constant. Major activities in the parks include boating, water skiing, swimming, and fishing. Nearly all of these have the potential to impact the aquatic ecosystem. Other major influences include effects of air and water pollution of local diffuse and point source origin, non-native plant and animal species, and surrounding land use. These factors influence the major mechanisms and processes of lake

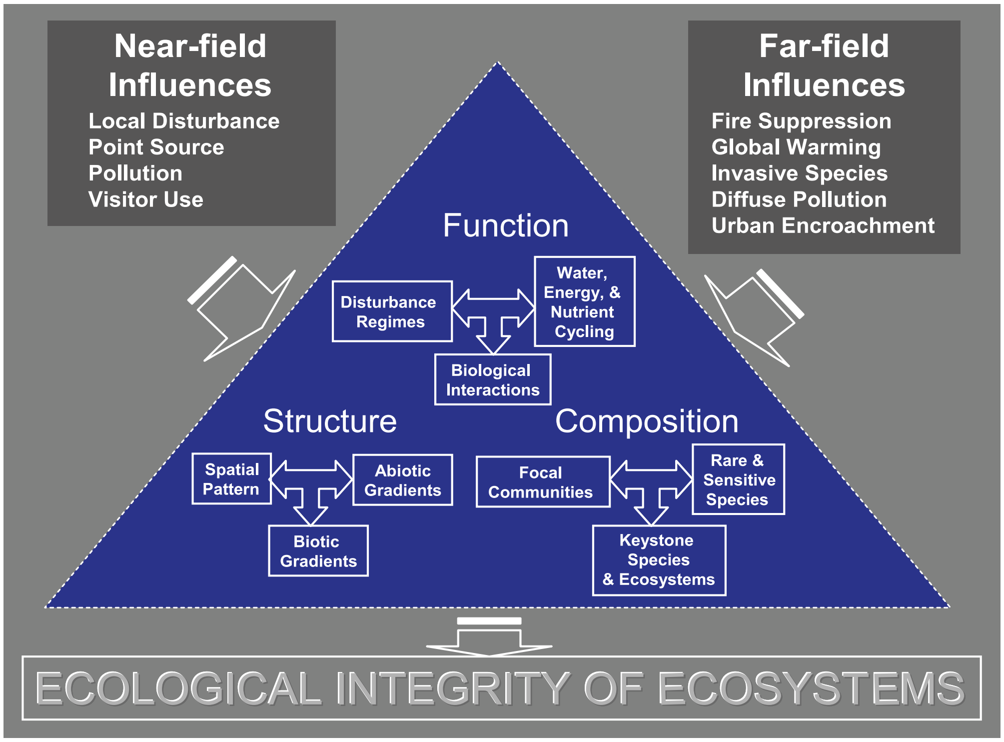


Figure 2.8. Human Influences on the structure, function, and composition of ecosystems.

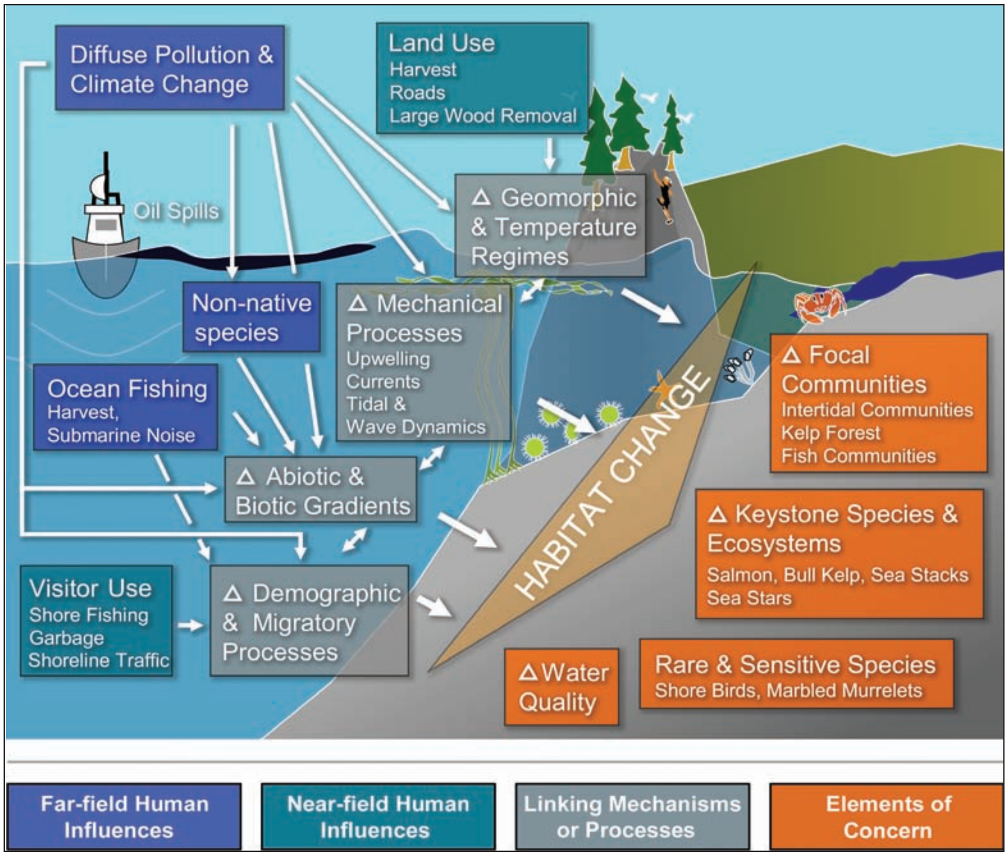
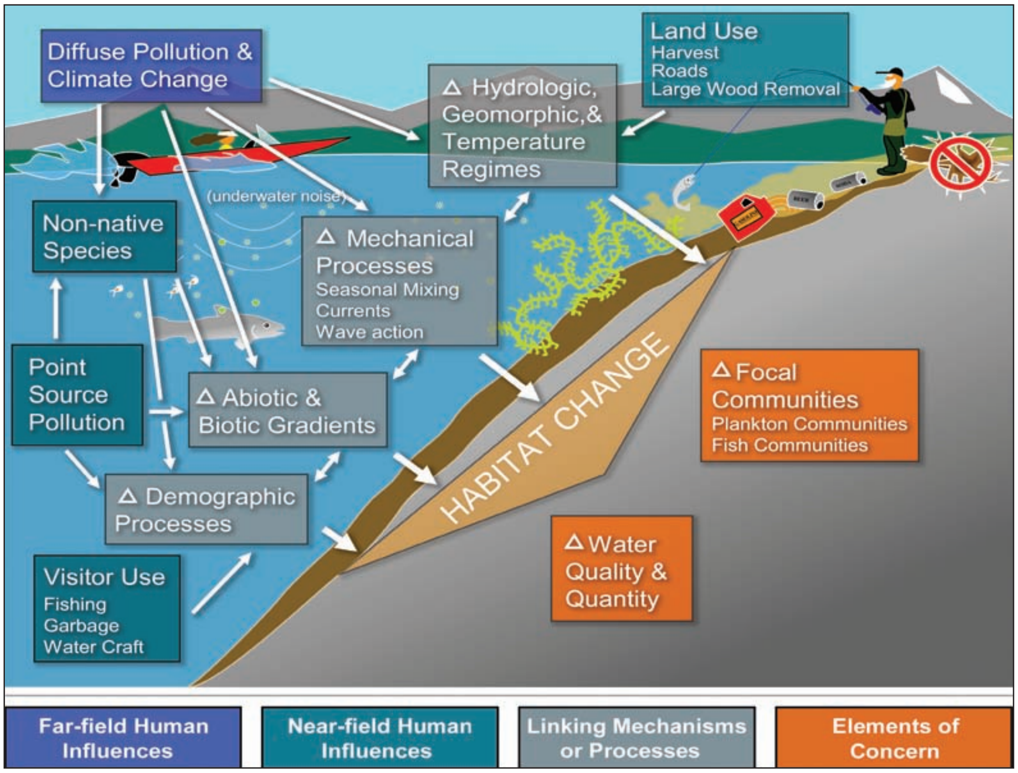
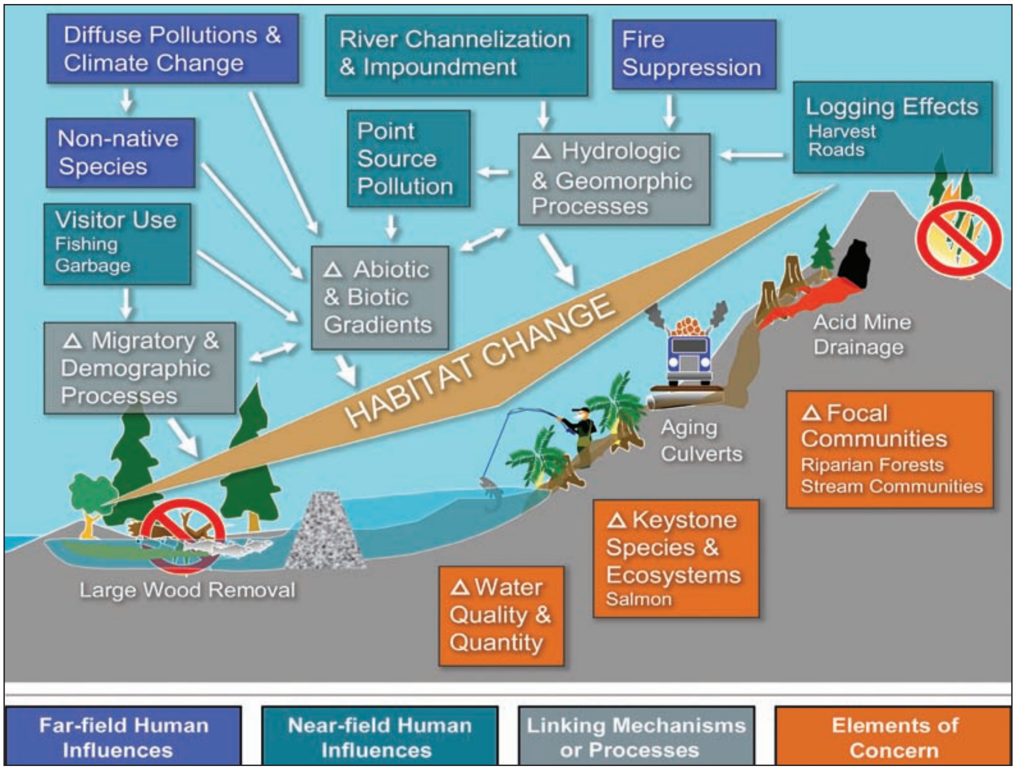


Figure 2.9. Conceptual model of human Influences on marine ecosystems.



a.



b.

Figure 2.10 a and b. Conceptual model of human influences on freshwater ecosystems: a.) lake (lentic) ecosystems, and b.) flowing water (lotic) ecosystems.

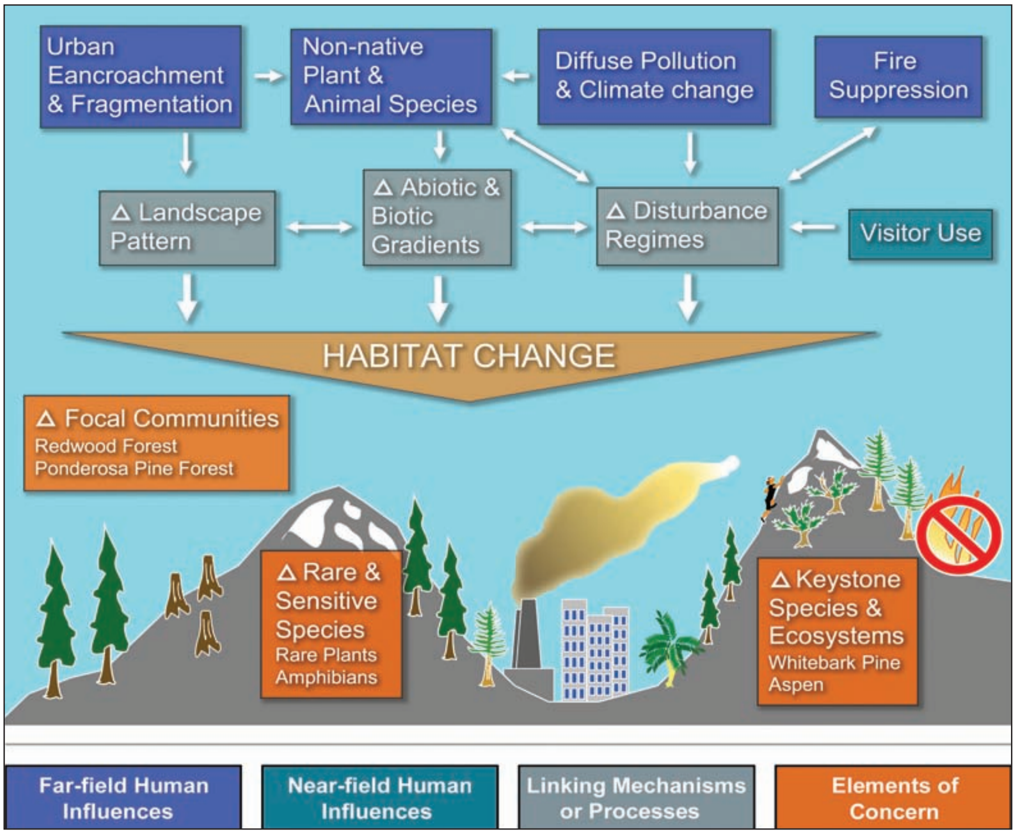


Figure 2.11. Human influences on terrestrial ecosystems.

ecosystems and affect both water quality and aquatic communities.

The stream ecosystems of the KLMN parks are particularly vulnerable to human influences throughout the watersheds (Figure 2.10b). Diffuse and point source pollution, fire suppression effects on hydrology, and human demands for water all strongly affect the stream and its residents. Stream and riparian environments are also particularly vulnerable to invasion by non-native species (DeFerrari and Naiman 1994). Collectively, these threats influence the gradients and processes that maintain riparian habitat and stream fish communities, as well as water quality for human uses downstream. Our future monitoring of aquatic communities and water quality (Chapter 3) will help better assess these threats and their impacts.

Terrestrial 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 (Figure 2.11). Although fire exclusion is commonly viewed as a major stressor of terrestrial ecosystems, the broader issue of fire and fuels management has potentially far-ranging effects on terrestrial environments. 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.

Subterranean Ecosystems: Human influences on the subterranean environment include effects of excessive visitor use on cave biota through off-trail travel, nutrient enrichment through addition of lint or food crumbs, touching

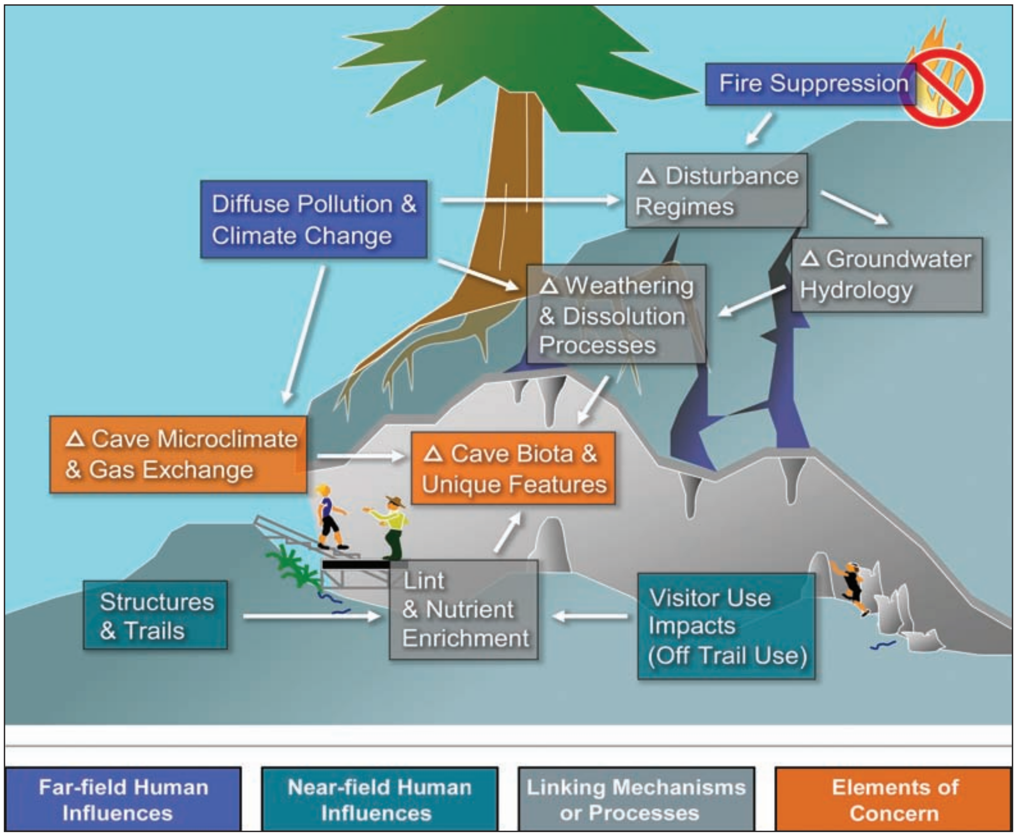


Figure 2.12. Human influences on subterranean ecosystems.

of sensitive geological formations, and disruption of bat hibernacula (Figure 2.12) (Murray and Kunz 2005). Changes in microclimate caused by excavation of new passageways or development of visitor facilities are also potentially harmful. Fire suppression may threaten Oregon Caves because the increased vegetation growth (i.e., afforestation) may affect cave water balance (Stone et al. 2005). In addition, far-field influences, such as climate change and pollution, may affect the intricate balance of chemical (Herman 2005) and atmospheric processes that foster the growth of cave formations.

Taken together, these conceptual models stimulated discussion among network and park staff and our scientific partners and played an important role in preparing for the selection of vital signs. In particular, they ensured that we were maintaining a broad, integrative view of the major ecosystem domains in the parks, that we considered their spatial and temporal characteristics, and that we explored how they might be affected by human activities.

Chapter 3: Vital Signs

3.1. Introduction

The concept of ecological integrity provides a framework for evaluating changing environmental conditions and biodiversity through monitoring (Karr 1991, Dale and Breyeler 2001). Known or hypothesized stressors may affect ecological integrity (see Chapters 1 and 2). The vital signs selected to monitor effects on ecological integrity are factors that reflect the park ecosystem's structure (the organization or pattern of the system), function (ecological processes), and composition (the variety of elements in the system). The vital signs are a subset of the total suite of natural resources that park managers are directed to preserve unimpaired for future generations, including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization, including landscape, community, population, or genetic.

The conceptual models in Chapter 2 figured prominently in our vital signs scoping process. We used them to organize workshop participants into breakout groups for the vital signs scoping workshop in May 2004 (and to provide a framework for the discussion in Chapter 1). Throughout the workshop, network staff consulted the conceptual models to develop monitoring questions and vital signs, or used them as a backdrop for considering the issues. Workshop participants, in turn, provided many useful comments for improving the models. The Klamath Network Phase II Monitoring Plan (Odion et al. 2005) contains a report on the vital signs scoping workshop results.

Conceptual models are iterative. Although they should be based on fundamental and enduring principles of ecology, they should also be sufficiently flexible to allow refinement as the results of monitoring or other empirical or theoretical advances improve our understanding of the elements and processes of park ecosystems. In developing the models, our goal was to illustrate the primary influences on park ecosystems. We added details to illustrate the primary gradients, dynamics, and human influences structuring the major ecosystem domains. By design, we did not develop models of special habitats or focal populations (see Section 1.9).

The scoping meetings and conceptual modeling described in Chapters 1 and 2 resulted in a list of monitoring questions and potential vital signs. This chapter describes: 1) the process by which the potential vital signs were analyzed, rated, and prioritized; and 2) the vital signs that were determined to be highest priority for monitoring by the Network.

3.2. Prioritization of Vital Signs

The foundation of the Klamath Network's approach was to identify the most important monitoring questions to answer in relation to potential trends in ecosystem structure, function, and composition. The full set of questions identified through the conceptual modeling and scoping processes is in our Monitoring Plan Phase II report (Odion et al. 2005). Each of these questions identified possible related vital signs to monitor. Many were based on conceptual modeling of gradient structure, processes, and stressors in the Network ecosystems (Chapter 2). Monitoring questions were developed specifically for each of the four main ecosystems in the Klamath Network (terrestrial, freshwater, marine, and subterranean). We did not use a park-by-park approach, although that approach was used by USGS in identifying water quality vital signs (Appendix E). Some ecosystems or communities are present in only one park (e.g., marine in Redwood) but were not considered less important.

Vital Signs Ranking, Step 1

Rating monitoring questions: We asked 130 experts representing a broad array of scientific disciplines, many of whom

had participated in vital signs scoping, to rank candidate vital signs. We sent these experts a database containing questions and vital signs to rank, as well as the specific criteria to use for ranking. The affiliations and disciplines of the 44 experts who responded to our request are shown in Table 3.1.

As these numbers show, respondent's affiliations were weighted toward NPS and other government organizations, while disciplines were most often in terrestrial plant and animal ecology and systematics. There were no cave science respondents and relatively few respondents from academia. Many people were not comfortable rating phenomena outside their particular area of expertise. Nonetheless, we feel that the rating provided useful guidance, except that the importance of cave resources may have been under-represented, despite their central ecological and management significance in Lava Beds and Oregon Caves. However, by identifying subterranean ecosystems as one of the four Klamath Network ecosystem types in our conceptual modeling and throughout Chapters 1 and 2, we helped ensure that these resources would not be overlooked in determining vital signs for monitoring.

To reduce the large list of questions down to the top priorities that could be feasibly monitored, we first removed or rephrased some research questions. Then, from the remaining monitoring questions, we selected a list of 33 that were most frequently identified as important in the scoping process (Table 3.2).

Table 3.1. Affiliations and expertise of the 44 respondents to the questionnaire sent out to rate monitoring questions and associated vital signs.

AFFILIATION	COUNT
Federal (non-NPS)	6
Non Profit	2
NPS (Klamath parks)	20
NPS (regional/national)	7
Other	2
University	5
AREA OF EXPERTISE	**COUNT**
Aquatic Ecology and Systematics-Animals	3
Aquatic Ecology and Systematics-Plants	1
Geography-Biological	2
Microbiology	1
Natural Resources	9
Physical Science-Air Resources	2
Physical Science-Geology and Soils	5
Physical Science-Water Resources	1
Terrestrial Ecology and Systematics-Animals	8
Terrestrial Ecology and Systematics-Plants	12

Management and Ecological Significance: Experts were asked to rate the management and ecological significance of the 33 monitoring questions on the short list according to the criteria and scoring shown in the box below: to ecosystem composition that may occur.

Ranking Results—Monitoring Questions: Prioritizing vital signs was then accomplished through a formal ranking exercise and workshop. The process was designed to produce an unbiased list of monitoring projects supported to the extent possible by group consensus. We removed or rephrased some of the research questions on the long list. From these modified and reduced questions, we selected a short list of 33 that were most frequently identified in the scoping process as being important (Table 3.2).

Ranking vital signs associated with monitoring questions: Respondents also rated the relevancy and suitability of vital signs associated with each monitoring question. Our Monitoring Plan Phase II report (Odion et al. 2005) has the list of 172 vital signs associated with the 33 monitoring questions. Table 3.3 shows vital signs and associated questions from the final list of selected vital signs. Relevancy was ranked on a 0-4 scoring system based on the criteria and scoring in the following box.

In addition to providing a ranking of monitoring questions and associated

MANAGEMENT SIGNIFICANCE CRITERIA
The question addresses the need for information to be used in adaptive management aimed at maintaining ecological integrity in the Klamath Network.
The question addresses the kind of ecosystem changes that managers, policy makers, researchers, and the public will recognize as important to ecological integrity.
The question addresses the need to provide an early warning of loss of ecological integrity that can be addressed through management actions.
The question addresses National Park Service performance goals.
The question addresses important information gaps in our understanding of how to manage and maintain the integrity of ecosystems of the Klamath Network.
ECOLOGICAL SIGNIFICANCE CRITERIA
The question addresses important changes to ecosystem structure that may occur.
The question addresses important changes to ecosystem function that may occur.
The question addresses important changes to ecosystem composition that may occur.
The question addresses the need to provide early warning of changes to ecosystem structure, function, and composition that may occur.
Reference conditions exist or may be defined against which monitored changes can be measured or interpreted to describe changes in ecological integrity.
SCORING
4 - Very high: Strongly agree with all 5 statements
3 - High: Strongly agree with at least 4 statements
2 - Medium: Strongly agree with 2- 3 statements
1 - Low: Strongly agree with only 1 statement
0 - None: Strongly agree with none of these statements.

Table 3.2. The 33 monitoring questions on the short list with their ranking scores.

MONITORING QUESTION	RANK	ECOLOGICAL SIGNIFICANCE AVERAGE	MANAGEMENT SIGNIFICANCE AVERAGE	AVERAGE OF BOTH SCORES
What are the trends in distribution and abundance of non-native species through time?	1	3.43	3.46	3.44
What are status and trends in structure, function, and composition of focal communities?	2	3.44	3.14	3.29
What are the status and trends in anthropogenic disturbance?	3	3.21	3.35	3.28
What are status and trends in focal taxa groups (e.g. birds, fish, and amphibians)?	4	3.38	3.15	3.26
What are status and trends in focal species?	5	3.22	3.28	3.25
What are status and trends in surface waters (including pristine and 303d listed waters)?	6	3.26	3.07	3.16
What are the status and trends in natural disturbance events (e.g. fire, floods)?	7	3.28	3.03	3.15
What are status and trends in human impacts near sensitive plant and animal populations and habitats?	8	3.03	3.28	3.15
What are status and trends in pollutants (chemicals, nutrients, effluents, and trash)?	9	3.08	3.20	3.14
How are connectivity, fragmentation, and level of park "insularity" changing with land use change in and around the parks?	10	3.20	3.00	3.10
What are the long term trends in the predominant habitat types?	11	3.18	2.89	3.04
What are status and trends in pollutants (e.g. ozone, N, S, particulates)?	12	3.17	2.66	2.91
What are status and trends in ground waters?*	13	2.74	2.70	2.72
Are climate associated ecotones changing through time?	14	3.13	2.28	2.70
What are the trends in harvesting of park resources?	15	2.49	2.87	2.68
Have rates, extent, location, or types of erosional and depositional processes changed?*	16	2.76	2.59	2.68
What are the trends in diseases or parasites (including forest insects) through time?	17	2.92	2.42	2.67
How are snowpack dynamics changing over time?*	18	3.03	2.31	2.67
How is cave air flow (quantity and quality) changing through time?	19	2.60	2.48	2.54
What is timing and duration of key climate-related phenological events?*	20	2.95	2.05	2.50
How is sea level and ocean temperature changing?	21	3.00	2.00	2.50
How is woody debris production and storage changing over time?*	22	2.62	2.31	2.46
What are status and trends in soils?*	23	2.65	2.20	2.42
How are ocean and nearshore processes changing through time?*	24	2.77	2.00	2.38
What are the trends in pollinators?*	25	2.75	2.00	2.38
What are status and trends in subterranean water and ice?	26	2.43	2.29	2.36

Table 3.2. The 33 monitoring questions on the short list with their ranking scores (continued).

MONITORING QUESTION (continued)	RANK	ECOLOGICAL SIGNIFICANCE AVERAGE	MANAGEMENT SIGNIFICANCE AVERAGE	AVERAGE OF BOTH SCORES
What are the status and trends of biotoxin accumulation?*	27	2.57	2.10	2.34
What are status and trends in fog?*	28	2.61	1.77	2.19
What are status and trends in visibility?*	29	1.89	2.16	2.03
What are changes in extent of soil crust?*	30	2.19	1.84	2.02
What are the status and trends in subterranean geologic processes?	31	1.95	1.80	1.88
What are the status and trends in marine geologic processes?*	32	2.00	1.54	1.77
What is the effusion rate of geothermal groundwater into the surface environment?*	33	1.55	1.32	1.43

**Indicates questions that are not addressed by vital signs proposed for monitoring by the Klamath Network because of this ranking process. Additional ranking and considerations described below.*

RELEVANCY CRITERIA
Measurable: Capable of being defined and measured.
Interpretable: Changes in the vital sign and their significance will be apparent.
Resource at risk.
Sensitive to change.
Comprehensive: indicator of broad-scale changes.

SCORING
4 - Very High: meets all 5 criteria
3 - High: meets at least 4 criteria
2 - Medium: meets 2- 3 criteria
1 - Low: meets only 1 criterion
0 - Very Low: meets none of the criteria
(Blank) - No opinion, or did not score this vital sign

vital signs (Odion et al. 2005), many respondents provided insightful comments, which were encouraged by the questionnaire's design. These comments are included in Odion et al. (2005).

Vital Signs Ranking, Step 2

The next step was to consider legal/policy mandate and cost/feasibility of potential vital signs and to address factors from the literature and lessons learned in other ecological monitoring. This step was accomplished at a workshop in Redding, California, on April 27-28, 2005, where the final vital signs were selected. The workshop's specific purpose was to review and evaluate the ranking generated by the questionnaire and subsequent Klamath Network staff modifications. Technical Advisory Committee members and resource specialists from all six parks attended.

To guide the process of identifying final vital signs, Daniel Sarr, Klamath Network Coordinator, provided a brief overview of lessons from the Northwest

Forest Plan monitoring. He focused on lessons germane to the KLMN, noting the tremendous expense of monitoring a single species throughout the Pacific Northwest (e.g., more than $25 M for the Northern Spotted Owl over ten years). He also presented several possible shortcomings with species-oriented monitoring: 1) individual or focal species may be poor indicators because they have not been tested in many cases and cannot be assumed to describe changes among other species; and 2) despite their obvious conservation significance, rare species may not be good choices because they require excessive sampling intensity to detect changes (Manley et al. 2004). He suggested some of these concerns could be addressed, in part, by sampling multimetric or community indices and using multivariate data analysis approaches (e.g., Index of Biotic Integrity, etc. Karr (1981), Karr and Chu (1999)), such as control chart analysis (Anderson and Thompson (2004) and also see Chapter 7).

Additional concepts identified for consideration during vital signs selection included:

1. *Conceptual Relevance*—Is the indicator relevant to the assessment question (management concern) and to the ecological resource or function at risk?
2. *Feasibility of Implementation*—Are the methods for sampling and measuring the environmental variables technically feasible, appropriate, and efficient for use in a monitoring program?
3. *Response Variability* —Are human errors of measurement and natural variability over time and space sufficiently understood and documented?
4. *Interpretation and Utility*—Will the indicator convey information on ecological condition that is meaningful to environmental decision-making?

Together, the above considerations provided sideboards to guide final vital signs selection. Other issues included scope, cost-effectiveness, and collaboration potential.

Because of the large number of vital signs (172), a tentative ranking based on these two criteria was developed by network staff before the workshop. Their criteria for ranking vital signs based on legal and policy factors were essentially the same as recommended by the National I&M Program, explained in the upper box on page 49.

The criteria for ranking vital signs based on cost and feasibility factors, as well as the scoring are described in the lower box on page 49.

The overall ranking that resulted from considering all four criteria is shown in Odion et al. (2005). This ranking was based on weighting of each criterion's score using the following equation:

(0.3 * Management Significance score)
(0.3 * Ecological Significance score)
(0.1 * Relevancy score)
(0.1 * Legal Mandate score)
+ (0.2 * Cost and Feasibility score)

= Final Score

The effects of changing the weightings of each component score were explored both before and during the workshop.

The ranking in Odion et al. (2005) was the starting point for the workshop attendees to select vital signs to be monitored. Following an explanation and review of the ranking results, two groups were formed to independently adjust the influence of legal mandate and cost and feasibility issues in the overall ranking.

Each group began adjusting the vital signs ranking by giving legal mandate/policy a weight of zero. Both felt we should recognize what we are mandated to monitor, but that the ranking criteria and scores for legal/policy mandate

LEGAL AND POLICY MANDATE RANKING CRITERIA

Very High: The park is required to monitor this specific resource/indicator by some specific, binding, legal mandate (e.g., Endangered Species Act for an endangered species, Clean Air Act for Class 1 airsheds), or park enabling legislation.

High: The resource/indicator is specifically covered by an Executive Order (e.g., invasive plants, wetlands) or a specific Memorandum of Understanding signed by the NPS (e.g., bird monitoring), as well as by the Organic Act, other general legislative or Congressional mandates, and NPS Management Policies.

Moderate: There is a Government Performance and Results Act (GPRA) goal specifically mentioned for the resource/indicator being monitored, or the need to monitor the resource is generally indicated by some type of federal or state law as well as by the Organic Act and other general legislative mandates and NPS Management Policies, but there is no specific legal mandate for this particular resource.

Low: The resource/indicator is listed as a sensitive resource or resource of concern by credible state, regional, or local conservation agencies or organizations, but it is not specifically identified in any legally-binding federal or state legislation. The resource/indicator is also indirectly covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management Act and GPRA, and by NPS Management Policies.

Very Low: The resource/indicator is covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management Act and by NPS Management Policies, but there is no specific legal mandate for this particular resource.

The criteria for ranking vital signs based on legal and policy factors are shown above.

COST AND FEASIBILITY RANKING CRITERIA

Sampling and analysis techniques are cost-effective. Cost-effective techniques may range from relatively simple methods applied frequently or more complex methods applied infrequently (e.g., data collection every five years results in low annual cost).

The indicator has measurable results that are repeatable with different, qualified personnel.

Well-documented, scientifically sound monitoring protocols already exist for the indicator.

Implementation of monitoring protocols is feasible given the constraints of site accessibility, sample size, equipment maintenance, etc.

Data will be comparable with data from other monitoring studies being conducted elsewhere in the region by other agencies, universities, or private organizations.

The opportunity for cost-sharing partnerships with other agencies, universities, or private organizations in the region exists.

SCORING

4 - Very High: Strongly agree with all 6 of the statements above.

3 - High: Strongly agree with 5 of the statements above.

2 - Medium: Strongly agree with 4 of the statements above

1 - Low: Strongly agree with 3 of the statements above.

0 - Very Low: Strongly agree with 2 of the statements above.

0 - None: Strongly agree with 1 or fewer of the statements above.

The criteria for ranking vital signs based on cost and feasibility factors are shown above.

were difficult to assign. They then categorized each vital sign according to its applicable ecosystem (terrestrial, aquatic, marine, or subterranean). Both groups combined and selected vital signs that together would cover all four KLMN ecosystems. Rare species were discussed and considered for inclusion in monitoring keystone and sensitive species, despite the statistical challenges they pose, because of "management mandate." Management mandate also elevated water quality vital signs. Thus, legal/policy mandate did come into play, but only concerning these specific vital signs. Each group was successful in combining and reducing the number of vital signs, and in picking the top 10-11 with coverage of all four ecosystems.

The Top Ten Network Vital Signs

The two groups reconvened and from the two lists of vital signs were able to select the top 10, representing the consensus of the meeting, as shown in the Table 3.3. Based on subsequent budget analyses and meetings with park resource staff, the Network concluded that it could include the three top rated items under a multifaceted keystone and sensitive plants and animals vital sign: aquatic amphibians, whitebark pine, and aspen. It was further decided that the status and conditions of aspen groves needed study before this community could be justified as a vital sign.

Justification for Vital Signs Selected and Linkage to Conceptual Models

Identifying consensus on the top ten vital signs for monitoring resulted in a strong consolidation of many discrete vital signs into very broad ones, all of which are a high monitoring priority (Table 3.3). This consolidation proved to be a good strategy for progress and allowed the group to think programmatically, identifying vital signs groups that could clearly be implemented as an I&M subprogram. We also sought to develop a complementary list, recognizing the need to monitor a broad and multifaceted suite of vital signs to effectively track ecological integrity of the KLMN's four ecosystem domains (see also Chapter 4). Thus, the vital signs are directly linked to the four major influences on park ecosystems: abiotic, biotic, dynamic, and human (Figure 2.2).

The vital signs selected have considerable breadth in the park ecosystems and key monitoring questions they can address (Figure 3.1). In addition to involving all four major ecosystem types, the vital signs address 20 of the 33 monitoring questions in the questionnaire, either directly or indirectly (Table 3.2, all questions listed except those with an asterisk). Each of the top 12 monitoring questions is addressed, often by more than one vital sign. The vital signs selected were also all identified in conceptual modeling (Chapter 2). More detailed justifications for each vital sign are described in the protocol development summaries (Appendix I).

Staff Assignments for Vital Signs

When final vital signs were selected, staff assignments were made for each vital sign (Figure 3.2). For each vital sign, a Network Contact was assigned and given the role of conducting background research on the vital sign, locating partners for long-term monitoring (as needed), and providing general scientific and administrative oversight for the vital sign's monitoring, data management, analysis, and reporting. In the cases where sampling will be conducted by NPS staff, the Network Contact will also serve as Project Manager. In cases where an outside partner will be conducting the work, the Network Contact will serve as the primary NPS person responsible for planning, contract or cooperative agreement budgeting, and annual administrative review duties. The Network Coordinator provides oversight for other Network Contacts.

Table 3.3. Klamath Network top ten vital signs and the portions of the NPS Ecological Monitoring Framework in which they occur. Each vital sign is presented-with its ranking score and associated monitoring questions that would be directly or indirectly addressed. These questions are numbered according to their-rank, with the main question listed first. Others that would be addressed indirectly are then listed. These may not directly pertain to the national framework categories. National framework categories that contain no vital signs are not shown.

NATIONAL I&M LEVEL 1	NATIONAL I&M LEVEL 2	NATIONAL I&M LEVEL 3	VITAL SIGN	VITAL SIGN SCORE	MONITORING QUESTIONS ADDRESSED	AFFECTED ECOSYSTEMS
BIOLOGICAL INTEGRITY	Invasive Species	invasive / exotic plants invasive / exotic animals	Non-native species	3.52	1. What are the trends in distribution and abundance of non-native species through time? 2. What are status and trends in structure, function, and composition of focal communities? 11. What are the long term trends in the predominant habitat types?	T, F, M, S
	Focal Species or Communities		Keystone and sensitive plants and animals (amphibians, whitebark pine, aspen)	3.39	5. What are the status and trends in focal species? 4. What are the status and trends in taxa groups? 15. What are the trends in harvesting of park resources? 17. What are the trends in diseases or parasites (including forest insects) through time?	T, F, M, S
		grasslands scrublands forests	Terrestrial vegetation (major habitat types)	3.39	2. What are status and trends in structure, function, and composition of focal communities? 11. What are the long term trends in the predominant habitat types? 1. What are the trends in distribution and abundance of non-native species through time? 14. Are climate associated ecotones changing through time?	T
		birds	Landbird communities	3.38	2. What are status and trends in structure, function, and composition of focal communities? 1. What are the trends in distribution and abundance of non-native species through time? (e.g. Barred Owl)	T, F, M
		intertidal communities	Intertidal communities	3.33	2. What are status and trends in structure, function, and composition of focal communities? 8. What are status and trends in human impacts near sensitive plant and animal populations and habitats? 3. What are status and trends in anthropogenic disturbances? 14. Are climate associated ecotones changing through time? 21. How is sea level and ocean temperature changing?	M
		aquatic vegetation wetland communities	Aquatic communities	3.27	2. What are status and trends in structure, function, and composition of focal communities? 1. What are the trends in distribution and abundance of non-native species through time? (e.g. bullfrogs). 6. What are status and trends in surface waters? 8. What are status and trends in human impacts near sensitive plant and animal populations and habitats?	F
		cave communities	Cave entrance communities	3.10	2. What are status and trends in structure, function, and composition of focal communities? 5. What are status and trends in focal species? 8. What are status and trends in human impacts near sensitive plant and animal populations and habitats?	S

Affected ecosystems: (T = terrestrial, S = subterranean, F =freshwater aquatic, M=marine).

Table 3.3. Klamath Network top ten vital signs and the portions of the NPS Ecological Monitoring Framework in which they occur (continued).

NATIONAL I&M LEVEL 1	NATIONAL I&M LEVEL 2	NATIONAL I&M LEVEL 3	VITAL SIGN	VITAL SIGN SCORE	MONITORING QUESTIONS ADDRESSED	AFFECTED ECOSYSTEMS
WATER	Water Quality		Water Quality	3.30	9. What are status and trends in pollutants? 6. What are status and trends in surface waters?	F, M, S
ECOSYSTEM PATTERN AND PROCESS	Landscape Dynamics		Land cover, use, pattern (roads)	3.28	10. How are connectivity, fragmentation, and level of park "insularity" changing with land use change in and around the parks (human disturbance dynamics)? 3. What are status and trends in anthropogenic disturbances? 7. What are status and trends in natural disturbances? 2. What are status and trends in structure, function, and composition of focal communities? 5. What are the long term trends in the predominant habitat types?	T
GEOLOGY AND SOILS	Subsurface Geologic Processes		Environmental conditions in caves	2.50	19. How is cave air flow (quantity and quality) changing through time? 2. What are status and trends in structure function and composition of focal communities? 8. What are status and trends in human impacts near sensitive plant and animal populations and habitats? 22. What are status and trends in subterranean water and ice? 31. What are the status and trends in subterranean geologic processes?	S

Unfunded Vital Signs

Two vital signs that were frequently discussed but were not selected as core vital signs were climate and air quality (Table 3.4). Climate change was viewed as a topic of extreme ecological importance, but low management significance, because it was considered largely beyond the control of park managers. It was also felt that climate monitoring is well-addressed by existing park climate stations and synoptic scale monitoring conducted by the National Weather Service, Western Regional Climate Center, and other entities. Similarly, air quality was considered to be very important, but the Network felt that the efforts of the existing Air Resources Program were equal to our current information needs. Therefore, climate and air quality have been designated as unfunded vital signs; their trends will be periodically summarized in collaboration with the appropriate sampling organizations. The Network Data Manager will take the lead on collating relevant information at appropriate intervals to serve the information needs of the Network.

The 10 funded and two unfunded vital signs selected during scoping and prioritization form the basis for the Klamath Network Vital Signs Monitoring Program. Subsequent chapters in this report describe the various activities the Network will undertake to implement the program.

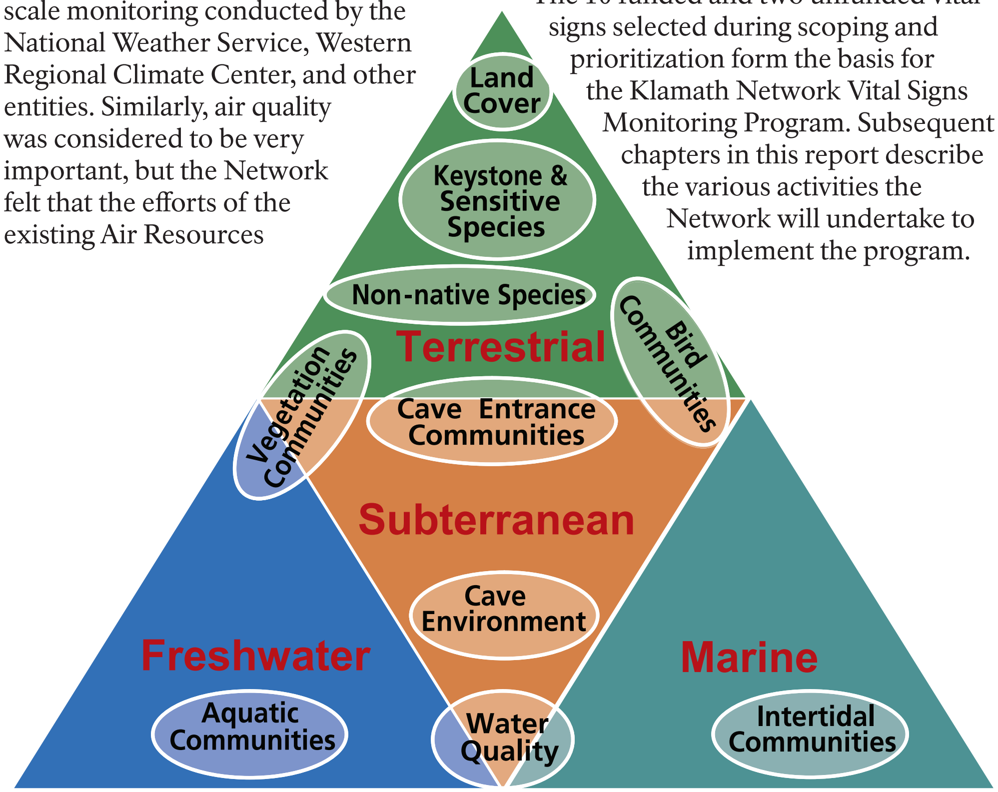


Figure 3.1. Conceptual model showing four major ecosystems and the top ten vital signs. Spheres in which vital signs are located indicate which ecosystems would be monitored and illustrate generally how thorough monitoring would be in each of the major ecosystem types.

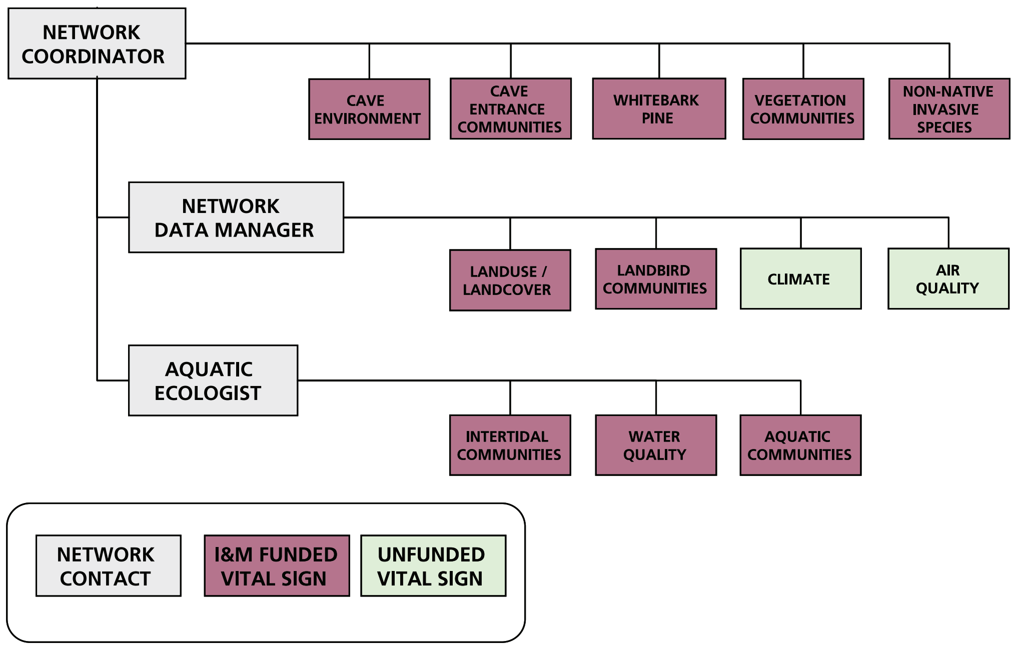


Figure 3.2. Staff assignments for each vital sign. Each vital sign has a preliminary Network Contact.

Table 3.4. Klamath Network vital signs identified as unfunded (by I&M) but important enough for periodic data summary and analysis.

VITAL SIGN	REASON FOR LOW PRIORITY RANKING	ESTABLISHED MONITORING PROGRAMS	AFFECTED ECOSYSTEM
Climate	Beyond control of park managers	National Weather Service; Western Regional Climate Center	T, S, F, M
Air Quality	Outside monitoring efforts satisfy our current information needs	NPS Air Resources Program	T, S, F, M

Affected ecosystems: T = terrestrial, S = subterranean, F = freshwater aquatic, M = marine.

Chapter 4: Sampling Design

The sampling design and data analyses (Chapter 7) selected for vital signs monitoring address three of the main goals of monitoring in the Klamath Network: 1) to determine the status and trends in the Network's vital signs, 2) to provide early warning of abnormal conditions or impairment of select resources, and 3) to provide quality data to foster a better understanding of the dynamic nature and condition of park ecosystems. The sampling design and analyses are also based on the specific objectives for monitoring of each vital sign (Chapter 5). The final sampling designs reflect budget limitations and represent tradeoffs among spatial and temporal sampling intensity, efficiency, and safety. Complete details of the individual sampling designs are to be provided within individual monitoring protocols developed in accordance with Oakley et al. (2003).

The purpose of this chapter is to provide an overview of the statistical sampling design for monitoring vital signs in the Klamath Network. This sampling design is one of the major means through which the Network ensures scientific rigor, utility, and feasibility of our program. In the following section, we briefly define key sampling concepts and terminology. In subsequent sections, we describe the different procedures used to allocate sampling units in space and time and how these will be used for each vital sign.

4.1. Concepts and Terminology

For our purposes in this chapter, we focus the general definition of natural resource *monitoring* provided in Chapter 1 to define monitoring as the collection and analysis of repeated observations or measurements over a period of time to document the *status* and *trends* in *parameters of vital signs linked to ecosystem integrity*. Vital signs were chosen in the Klamath Network scoping process (Chapter 3). The monitoring program attempts to collect objective and scientifically defensible data to address specific monitoring questions and objectives. Monitoring objectives have been clearly defined for each of the Klamath Network vital signs (Chapter 5).

The term *population* is used to denote the aggregate of elements from which a sample is to be drawn. According to the principles of finite population sampling, the population must be divided into parts that are called *sampling units* so that every element in the population belongs to one and only one unit (Cochran 1977). The *sampling frame* refers to the composite of all sampling units. The *sampled population* is a subset of sampling units from the sampling frame that is selected to represent the population about which information is desired, i.e., the *target population*. Sometimes, due to safety or accessibility, our sampled population does not fully represent the target population. In these cases, it is important to emphasize that inferences apply only to the sampled population.

In some sampling designs, sample units will be discrete entities, such as lakes or individuals. In other designs, sample units will be fixed areas in which numerous measurements are taken. Examples include vegetation plots, portions of image data, etc. When the sample units are randomly selected from a sampling frame, they are known as a *probabilistic sample*. Probabilistic sampling is the preferred method for sampling park vital signs because it allows valid statistical inferences to be made to the larger target population. The actual locations that are selected in a probabilistic sampling design for will be referred to hereafter as monitoring sites.

The primary monitoring goal for the Network is to determine status and trends in selected vital signs over time (Chapter 5). *Status* is defined as some statistic (e.g., a mean or a proportion) of a vital sign over all monitoring sites within a single or well-bounded window of time. Status will always have some measure of statistical precision (e.g., a confidence

Probabalistic Sample: randomly selected sampling units from a sampling frame… a prefered method for park vital sign samples…

interval, standard error, variance) that is affected by the sampling design. Accurate information about the status of park resources may provide important information for guiding management activities and planning needs and for increasing scientific understanding.

Trend can be defined as a non-cyclic, directional change in a response measure that can be with or without pattern (Urquhart et al. 1998). For example, an ascending line has trend but no pattern, while a sine curve has pattern but no trend. From a statistical perspective, complex patterns of change through time are challenging, but understanding such patterns is an important goal for a long-term monitoring program. A major consideration in monitoring designs is the *statistical power*, hereafter *power*, of the design for trend detection, which can be defined as the probability that the statistical test applied on the monitoring data will accurately reject a false null hypothesis (i.e., will detect a real trend). Often, power is strongly affected by the magnitude of the trend, the variability within and across samples, and sample sizes. *Detection of abnormality* requires an understanding of expected variability in natural processes in park ecosystems over time and space (Landres et al. 1999), from which extreme values or rates of ecological change can be measured.

"The primary monitoring goal for the Network is to determine status and trends in selected vital signs over time."

The allocation of sampling effort in space and time has important implications for the abilities to determine status and trend. Most sample designs the Network proposes for monitoring rotate field sampling efforts through various sets of sample units over time. In this situation, it is useful to define a panel of sample units to be a group of units sampled during the same sampling occasion or period (Urquhart and Kincaid 1999; McDonald 2003). The way in which units in the target population become members of a panel is called the membership design (McDonald 2003).

The membership design specifies the procedure for drawing a probability sample. The development of the membership design will be affected by what is measured at each site, the *response design*. Elements of the response design, such as plot size, and the intensity and type of measurements taken, must be considered iteratively with sample size needs, variability in the data obtained, skills of field samplers, and available resources. The temporal scheduling of sampling requires a *revisit design* (Urquhart and Kincaid 1999; McDonald 2003) to assure that for each sampling visit, the data collected are useful for both status and trend determinations over time. In some cases, a split-panel design, where the revisit schedule varies among sample locations, is developed. The Klamath Network has chosen to use split panels for several vital signs described in this chapter. In all our split-panel designs, we term locations that will be sampled on each revisit *index sites*, and use the term *survey sites* for other locations that will be revisited less frequently or not at all.

4.2. Clarity, Utility, and Feasibility

Monitoring the status and trends in vital signs is intended to inform park management and conservation. To accomplish this goal, monitoring must address issues of ecological and management significance (Chapter 3). Because management priorities and environmental conditions change through time, a sampling design must be sufficiently flexible to provide relevant information for NPS managers now and well into the future.

The sampling design of a long-term monitoring program must consider carefully the financial, human, and other resources that will be available to the program over time. Wherever possible, sampling designs must be appropriately straightforward and accessible to ensure that they can be understood and accurately implemented by park staff with projected funding levels. Overly complex designs that do not match with network or park capabilities are likely to increase sampling, data management, and analysis challenges, all of which increase the risk of failure. Therefore, the Klamath Network monitoring program has pursued simplicity, clarity, and transparency along with statistical rigor in our sampling designs.

4.3. Estimating Status and Trends

The estimation of the status and trends in park vital signs involves a variety of spatial and temporal trade-offs with respect to sample intensity. To assess the status of various vital signs with precision, it is critical that sufficiently large sample sizes be selected to represent the target population at a given period in time. In contrast, detection of trend requires re-sampling the target population over time in a comparable manner. The critical issue for sampling across time is to determine the required frequency of re-sampling in order to effectively detect change. Under the best of circumstances, the program would collect large samples of each target population at frequent points in time. Unfortunately, the financial resources available to the Network limit sample intensity in time and space.

To determine status and trend with limited resources requires careful consideration of the allocation of sampling effort. Figure 4.1 (page 58) illustrates some of the trade-offs associated with sampling with finite sampling resources in different ways. Suppose that the mean of a particular parameter under study (e.g., an invasive species) is increasing by 2.5% of the natural variance per year (where the variance is assumed to be constant with respect to time). The null hypothesis is that no change is occurring. Presume also that resources limit monitoring this invasive to 10 samples per year that can either be used annually or aggregated into less frequent sampling to increase sample size, e.g., 20 samples bi-annually or 30 samples tri-annually. The first panel plots the trajectory of 95% confidence intervals of the mean over a 24 year period for a fixed sample size of 10. The remaining panels plot similar trajectories using bi-annual and tri-annual sampling with the larger sample sizes. Note that each plot tracks the "trend" with respect to time but that the confidence intervals in the latter panels are considerably smaller. A clear advantage of pooling resources to increase sample size is that the parameter estimates are more precise at the observed times, i.e., they more accurately describe status. (See Figure 4.1.)

Because sampling occurs every year in the first case and every two or three years in the latter cases, respectively, it is important to see if the improved precision in status determination comes at the cost of lessened power to detect trend. This can be determined by estimating the change in statistical power over time (recall that statistical power is the probability of correctly rejecting the null hypothesis). Continuing with the above simulation, where the mean abundance of the invasive species increases by 2.5% of the natural variance per year (with constant variance with respect to time), data were simulated at each time step for the three sampling schemes and a simple linear model fit. If the slope is determined to be non-zero at the (< or = 0.05 significance level, the null hypothesis is rejected. Figure 4.2 illustrates the comparative power of the three designs over the first few years of sampling. Although the three designs are comparable for the first several years, the power actually increases slightly when the resources are pooled. This indicates that the increase in precision of the parameter estimate outweighs the information provided by annual sampling relative to power. Therefore, the less frequent sampling with larger sample sizes appears to be the superior method for allocation of effort with limited resources.

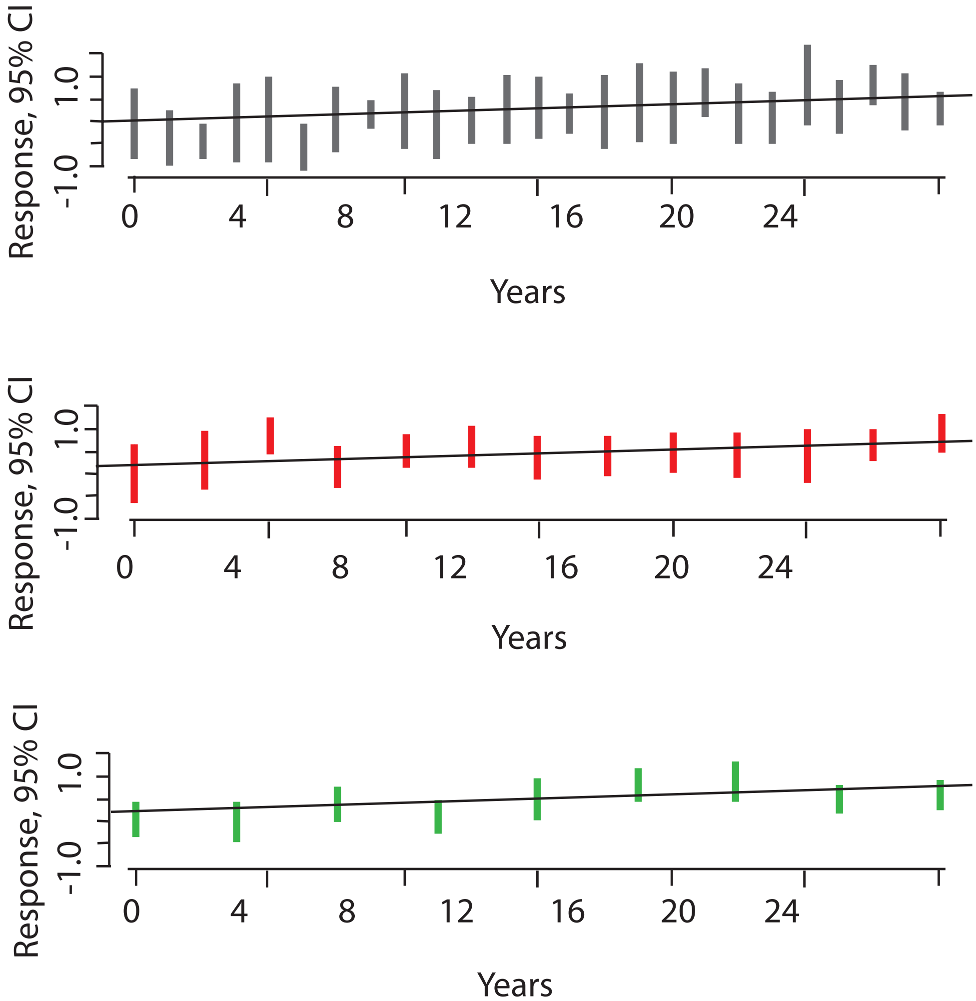


Figure 4.1. Simulation of sampling a response variable whose mean increases by 2.5% of the natural variance per year where the variance is assumed to be constant with respect to time.

(The grey line tracks the actual change in the mean.) The top panel plots individual 95% confidence intervals for annual samples of size 10. The second and third panels plot 95% confidence intervals for bi-annual and tri-annual sampling with sample sizes of 20 and 30, respectively. Note that all three sampling schemes track the trend well but the mean width of the confidence intervals decreases as sample size increases.

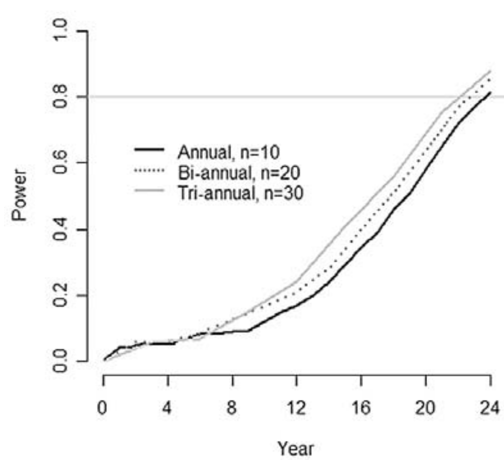


Figure 4.2. Estimated power as a function of sampling scheme.

The mean of the simulated response increases by 2.5% of the natural variance per year (constant variance assumed across time) and significance level was set to (= 0.05. The results presented here are based on 1000 Monte Carlo simulations.

The Klamath Network has conducted similar analyses as above when allocating sampling resources to each population under study. In particular, special attention was paid to ensure that sample sizes within a given sampling season were sufficient to provide precise parameter estimate(s). These efforts to develop appropriate sample sizes for detection of status and trends were weighed against practical needs for sampling frequency. In most cases, we determined that less frequent sampling to obtain adequate sample sizes was appropriate for our long-term goals.

4.4. Considerations for Sampling Across Space

As we have discussed, our selection of the appropriate spatial sampling design depends upon our goals and objectives, resource limitations, statistical power considerations, spatial characteristics of the population being sampled, and practical concerns related to ease of access and safety. A preliminary step in developing a sampling design was to delineate sampling frames. Because of safety and access concerns in the rugged terrain of the Network, not all elements in the target population can be feasibly monitored with available resources. Figure 4.3a illustrates the travel times to various points in Crater Lake. The GIS model we used to estimate travel times includes effects of slope, obstacles such as streams or lakes, the presence of a road or trail, and land cover. It is readily apparent that some areas are much more time consuming to reach than others. We are refining the model to account for the challenges of off-trail travel through particular vegetation types, such as chaparral and old-growth redwood, that are exceptionally time consuming.

For our vegetation and bird monitoring, we developed a sampling frame that includes locations between 100 m and 1000 m from the road and trail network in each park. Figure 4.3b illustrates the sample frame for Crater Lake. Because our parks are small to medium in size and the road and trail networks bisect the major environmental gradients in the parks, the sampling frames are broadly representative of the parks. Although they average between 57% and 63% of the total park area, the sampling frames for the different parks cover a comparable range in biophysical conditions as the parks overall (Figure 4.3a and b). Although not every area and potential vegetation type in the park will likely be sampled, the sampling frame is consistent with our vegetation monitoring objectives in that it does not appear to introduce a systematic bias in the vegetation environments sampled (Figure 4.4a and b). We will also be using the vegetation sampling frame to guide sample designs for landbird and aquatic community monitoring.

"Monitoring the status and trends in vital signs is intended to inform park management and conservation."

For intertidal monitoring, we chose to participate in the larger sample frame of the MultiAgency Rocky Intertidal Network (MARINe). This is because the number of suitable, accessible sites for intertidal monitoring is limited at Redwood and we desired to participate in the broader MARINe monitoring program that includes much of California and Oregon. Our twice yearly sampling of three sites in the park will be our contribution to a sampling frame that contains over 80 sites in California and Oregon.

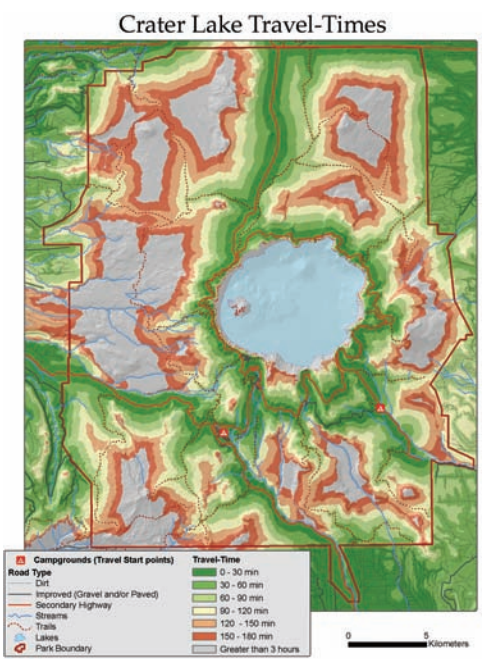
4.5. Spatial Sampling Designs

The choice of spatial sampling design depends in large part upon the geographic characteristics of the population being sampled and their representativeness or uniqueness in the larger park landscape. Below, we specify probabilistic sample designs for representative populations that are spatially extensive (vegetation) or relatively discrete units with in the landscape (lakes). We also discuss nonprobabilistic sampling approaches (see also Appendix E for additional water quality information) for distinctive sites that are nonrepresentative of the park as a whole, are of particular management interest, or are where the populations may be fully measured without the requirement for subsampling. (See Figure 4.3 a & b, below.)

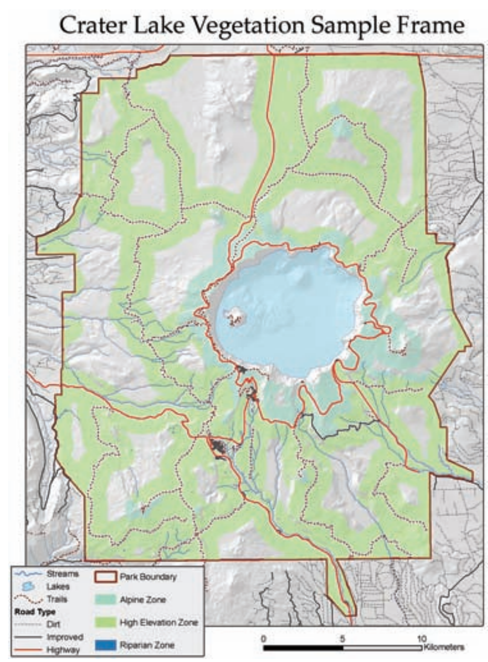
Grid-based Sampling

For extensive target populations that cover large areas within the individual parks, a continuous sampling frame of landscape units is needed. In such cases, a means to obtain broad dispersion or spatial balance of samples, such as a systematic or stratified-random approach, is desirable (Smartt and Grainger 1974). These approaches are often termed grid-based designs (McDonald and Geissler 2004). Within parks of the Network, vegetation, landbirds, and aquatic resources have spatially extensive target populations and will be sampled with grid-based designs. We have used the Generalized Random Tessellation Stratified (GRTS) method (Stevens and Olsen 2003, 2004) to develop sampling grids for each park. GRTS generates spatially balanced designs for one-dimensional (river or stream), two-dimensional (an alpine region), or other dimensional (network of streams and rivers) spatial structures.

A particularly attractive feature of GRTS is the ability to accommodate unequal probability sampling by allowing the probability for individual sampling units to vary. It is often necessary to assign low or zero probability to dangerous or inaccessible areas, or a high probability to special interest areas. GRTS also produces a spatially balanced over-sample (i.e., a list of additional sites to sample if sample points need to be replaced or added). Figure 4.5 illustrates a spatially balanced sample design obtained from GRTS for matrix, riparian, and high elevation populations of vegetation at Crater Lake. Because the GRTS method creates spatially balanced and well dispersed sample sites, it minimizes spatial autocorrelation among sites and maximizes the effective sample size for a given number of field sites.

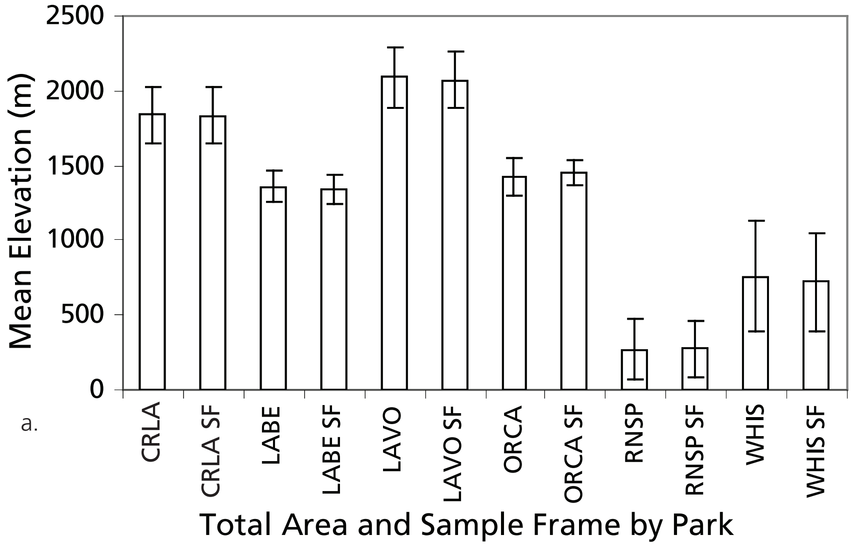


a.



b.

Figure 4.3 a and b. a.) Travel times to various locations in Crater Lake National Park, based on a cost-surface model that employs slope, the presence of a road or trail, land cover type, and the presence of obstacles (e.g., streams and lakes); and b.) Sample frame for vegetation monitoring at the park that limits potential sample areas to locations >100 m and <1000 m from the road and trail network of the park.



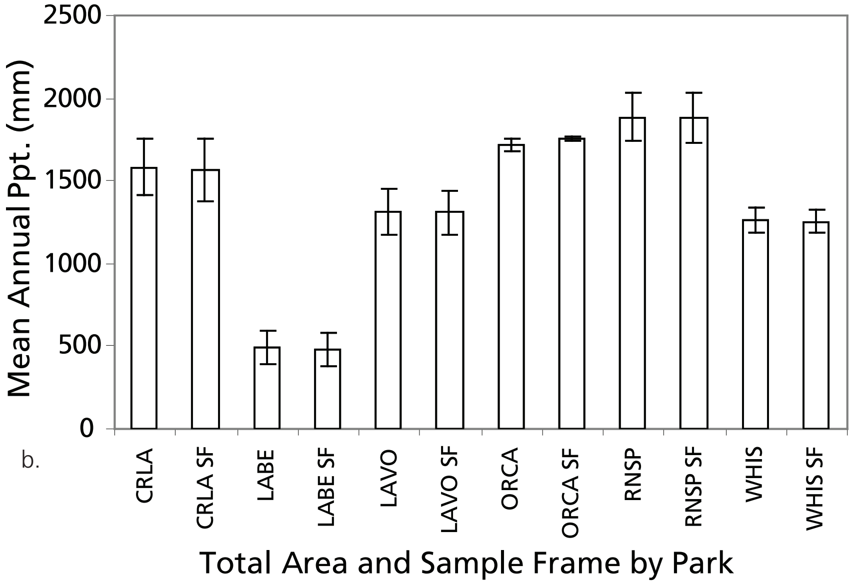


Figure 4.4 a and b. Mean and standard deviations for a.) elevation, and b.) mean annual precipitation for the total park area and the sample frame for each park in the Klamath Network. The sample frame is denoted by "SF" after the park acronym. Note that means and standard deviations for total park area and sample frames are comparable, suggesting they contain a comparable range of biophysical conditions.

List-based Sampling

For vital signs that occur in relatively small and discrete landscape features, such as aquatic communities and water quality in lakes and communities and environmental conditions in caves, a list-sampling approach will be employed (see Appendix E). This approach is an effective complement to more extensive grid-based designs, which tend to undersample localized, naturally fragmented environments (Smartt and Grainger 1974). The approach involves constructing a sampling frame composed of a list of discrete units in the target population of interest from which random sample of units can be drawn. Where important variation in the population is expected due to geographic variation such as elevation or internal differences (e.g., lake size), the list can be stratified to ensure that sampling effort

is allocated efficiently across different classes of sites. Figure 4.6 illustrates a grid-based design for streams and a list-based design for lakes in Lassen Volcanic National Park.

Judgment Sites

Judgment sites are subjectively placed sampling sites that are often selected because they have a history of sampling, are accessible, or the target population is very specialized or unique. In other cases, a particular threat, such as water contamination, may be localized and best monitored at a judgment site near the impact. The intensive measurements possible at judgment sites (e.g., day to day variability in water temperature or pH) may also complement the less intensive measurements collected

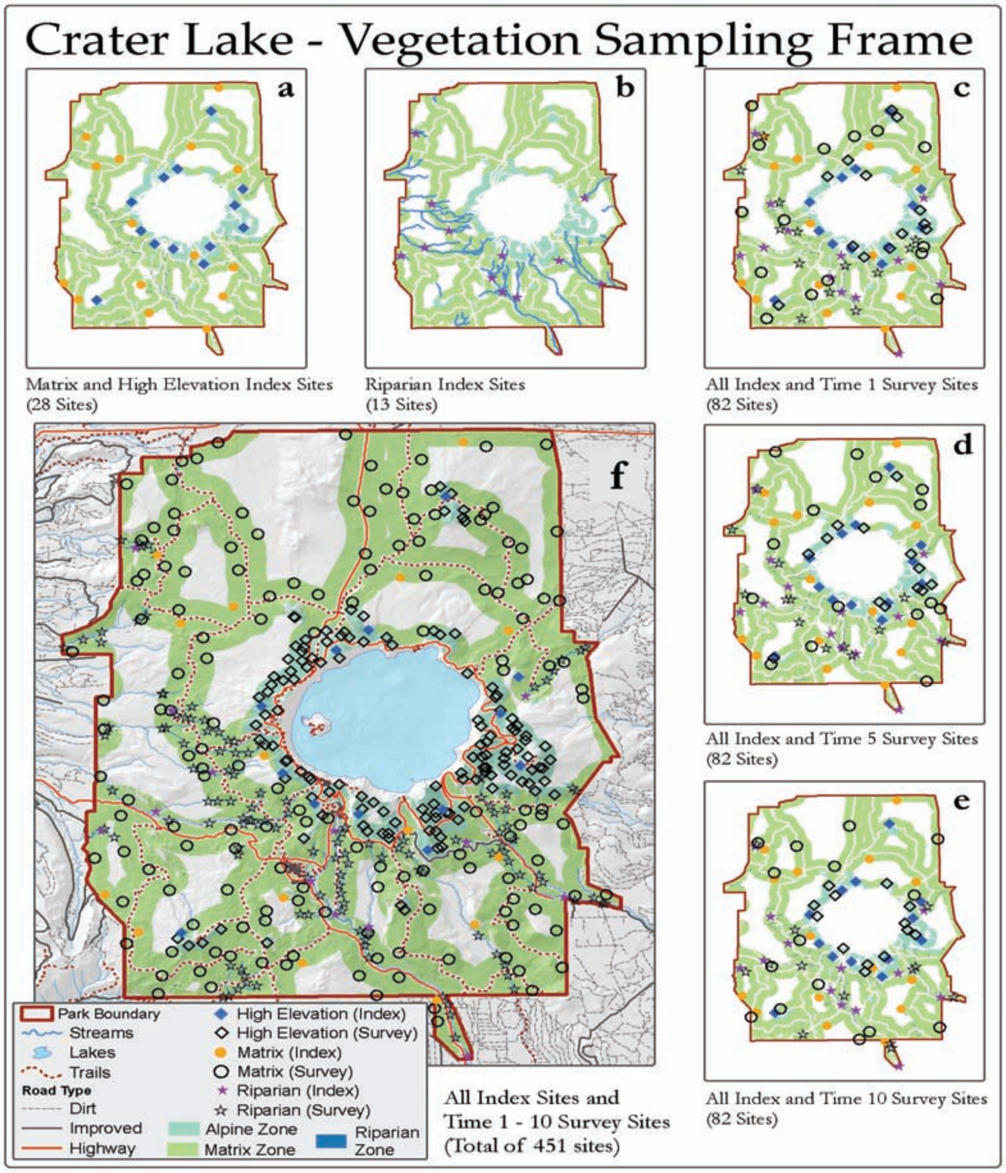


Figure 4.5 a-f. GRTS-based vegetation sampling design for Crater Lake National Park. a-b.) Panels of index sites for a.) matrix and high elevation target populations, b.) riparian target population with perennial streams; c-e.) Full Panels that include index and survey sites for a given revisit at c.) Time 1, d.) Time 5, e.) Time 10; and f.) cumulative sample of index and survey sites after 10 revisits to each target population. Note that all panels are spatially-balanced at each revisit and in the cumulative sample.

at other sites. Although they do not provide valid statistical inference to other locations, accessible or historical judgment sites that provide complementary information to less accessible, probabilistically sampled sites can strengthen the conceptual integrity of the overall sampling design. Judgment sites will be utilized for our aquatic communities and water quality vital signs (Appendix E) and for cave monitoring.

Census Data

When available, complete census datasets are valuable in that they eliminate the need to develop sample designs and to make inferences (at the appropriate resolution scale) (Sutherland 1996). Currently, we expect to analyze continuous satellite image data across our parks as a complete census for the land cover vital sign. We also expect to be able to perform complete censuses of the selected park roads and trails over time for our invasive plant early detection protocol.

4.6. Sampling Across Time

As with a spatial sampling, the allocation of sampling over time must strike a balance between statistical needs and operational constraints. Fiscal resources rarely allow sampling of all vital signs measurements at the ideal time frame, but require careful consideration of the trade-offs in frequency and intensity of sampling to determine status and trend, the expected daily and seasonal variability in the vital signs (e.g., bird abundance), and the temporal scale at which change will be considered a management concern.

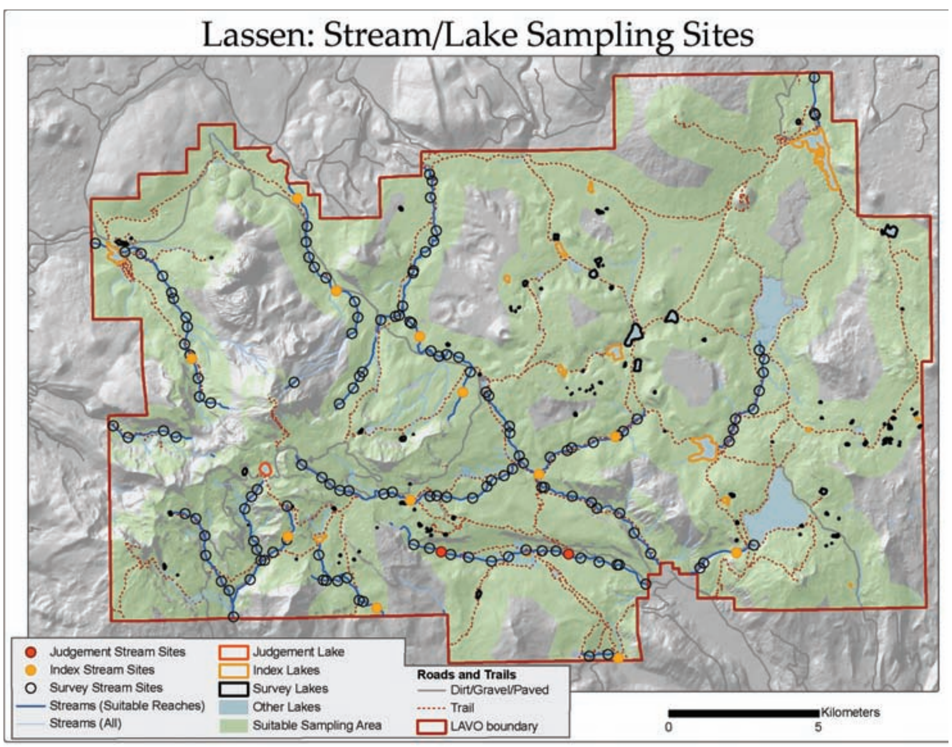


Figure 4.6. Sampling design for lakes and streams of Lassen Volcanic National Park <1 km from a road or trail and in suitable terrain (slope <30 degrees). The stream sampling sites are a split-panel arrangement based on a grid-based design developed with GRTS. The lakes are a split-panel design randomly selected from a list-based sample frame of all lakes in the park.

Sampling Across Years

All the Klamath Network vital signs will involve revisit designs for sampling across years, often as part of a larger panel of sites. The Network has adopted McDonald's (2003) proposed notation for revisit designs for brevity and consistency with its general usage in the I&M program. Under this notation, the revisit plan is represented by a pair of digits, the first of which is the number of consecutive occasions a panel will be sampled and the second of which is the number of consecutive occasions a panel is not sampled before repeating the sequence. The total number of panels in the rotation design is normally the sum of digits in the notation. For example, using this notation the digit pair [1-2] means that members of three panels will be visited for one occasion, not visited for two occasions, visited again for one occasion, not visited for two occasions, and so on (Table 4.1). A single panel visited every sample occasion would be [1-0], revisiting on an alternating schedule would be [1-1], and a panel visited only once would be [1-n]. A split-panel, such as [1-0, 1-5], is where one panel will be visited every occasion, while units in six other panels will be visited once every six years.

"The sampling design of a long-term monitoring program must consider carefully the financial, human, and other resources that will be available to the program over time."

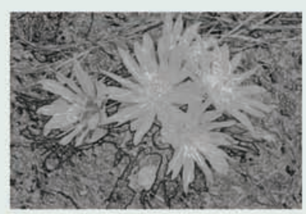
The revisit designs for our vital signs have been selected for practical considerations, such as the ability to tie in with larger sampling programs (intertidal), and their abilities to provide precise estimates of status and rapid detection of trend. Generally, fully randomized surveys at each revisit are best for status estimation, whereas resampling of permanent plots is best for determining trends (Scott 1998, Elzinga et al 2001). Split-panel designs, a form of sampling with partial replacement of sites at each revisit, is a hybrid design that incorporates elements of each approach (Scott 1998, McDonald 2003). The Klamath Network will be using split panels for our vegetation and aquatic community vital signs. The designs will allow us to gather information about change at specific index sites that will be revisited on each sampling interval and to also gain information from a companion set of survey sites that are sampled infrequently (once every 30 years) or never revisited. Figures 4.5 and 4.6 illustrate index and survey sites for vegetation monitoring in Crater Lake, and aquatic monitoring in Lassen Volcanic, respectively. Table 4.1 shows annual and cumulative sample sizes for a split panel design for aquatic communities of streams at Lassen Volcanic. It can be seen from the figures and table that the survey sites greatly improve the overall spatial coverage and sample size over time as new survey samples are added to the design during each revisit.

Sampling Across Seasons

The decision of when to sample within a sample season for a revisit design (e.g., the given month, week, or day during a year, or a particular hour during a 24-hour period at which measurements will be taken) is specified in each vital sign protocol. Most of our vital signs show important seasonal, diurnal, or hourly variation (e.g., vocalizations of breeding birds); therefore, the timing of sampling must be carefully chosen. For each vital sign, a target season and timing for sampling will be specified for each sample site in each park to ensure that measurements across years are comparable. For example, we will sample vegetation in low elevation parks in early summer and in late summer in high elevation parks. Breeding bird point count monitoring will be conducted between May and June in all parks and will begin 15 minutes after local sunrise, continuing for 3-4 hours.

Table 4.1. Yearly and total sample sizes over ten sampling years for index and survey sites in a split-panel, revisit design for aquatic communities and water quality monitoring at Lassen Volcanic National Park. The index sites will be visited every third year [1-2], with the survey sites visited once every 30 years [1-29].

		SAMPLE OCCASION										
PANEL		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	TOTAL SAMPLE SIZE
1	Index Sites (1-2)	12	12	12	12	12	12	12	12	12	12	12
2	Survey Sites	14										
3			14									
4				14								
5					14							
6						14						
7							14					
8								14				
9									14			
10										14		
11											14	
YEARLY SAMPLE SIZE		26	26	26	26	26	26	26	26	26	26	152



4.7. Overview of Sampling Designs for Klamath Network Vital Signs

The overall sampling design for each vital sign in the Klamath Network consists of four important components: the definition of the target population, membership design, response design, and revisit design. These components are described in the following table (Table 4.2), with the exception of the unfunded vital signs (air quality and weather and climate). In the latter cases, we will be collecting summary information from other programs at periodic intervals, but will not have a role in the sampling designs for any data collected. More detail on the response designs is provided in the protocol development summaries (Appendix I).

Table 4.2. Sampling designs by vital signs.

VITAL SIGN	TARGET POPULATION	MEMBERSHIP DESIGN	RESPONSE DESIGN	REVISIT DESIGN
1. Non-native, Invasive Species	Invasive plant species along roads, trails, powerline corridors, dunes, and campgrounds. All parks sampled except LABE, which has its own monitoring program.	Complete census (campgrounds, dunes, roads, and trails at ORCA), or list-based selection of road, trail, and powerline segments in large parks. Unequal probability will select mostly trail segments near trailheads or with road access.	Map presence and absence of prioritized invasives in environments sampled. Measure covariates in both presence and absence plots and via GIS data for modeling.	1-1
2. Whitebark Pine	Whitebark pine communities in accessible subalpine environments of CRLA and LAVO where slopes are less than 30 degrees.	Subsample of GRTS sample for high elevation vegetation with additional sites randomly selected within whitebark pine stands, as needed, to attain appropriate sample size.	Measure disease symptoms on trees in a 10 x 50 m transect placed randomly on one side of the long dimension of the 20 x 50 m vegetation plot.	1-2
3. Terrestrial Vegetation	Vegetation communities in safe and accessible areas of the Klamath Network parks where slopes are less than 30 degrees.	GRTS sample grid for subalpine, alpine, riparian, and matrix (all other) plant communities. By not revisiting half of the plots for 30 years, a large sample size is obtained.	Composition and structure of vegetation. Down wood and other fuel measurements. A 20 x 50 m plot will be used.	1-2, 1-29
4. Landbird Communities	Bird communities in safe and accessible areas of the Klamath Network parks where slopes are less than 30 degrees.	Subsample of GRTS sample grid for terrestrial vegetation in matrix environments.	Variable radius point count surveys along permanent transects consisting of 9-12 points.	1-1
5. Intertidal Communities	Intertidal communities of the region that includes REDW.	Stratified random sample of suitable sites within and outside the park.	Cover of invertebrates, algae, and surfgrass measured twice per year in permanent plots along transects.	1-0
6. Aquatic Communities	Aquatic communities in safe and accessible areas of the Klamath Network parks.	GRTS sample grid for streams and list-based random sampling of lakes in the Klamath parks. Co-location, co-visitation with Water Quality.	Parameters to be measured at all sites include benthic macroinvertebrates, amphibians, and fish. In addition, samples for chlorophyll and zooplankton analysis will be collected at lentic sites and periphyton samples will be collected at lotic sites. Fecal indicator bacteria also will be collected at two lotic sites (ORCA and WHIS).	1-2
7. Cave Entrance Communities	Ecological communities in the entrance areas of safe and accessible caves and lava tubes of ORCA and LABE.	List-based sample for LABE, judgment sites for ORCA. Co-location, co-visitation with cave environmental conditions.	Plots to sample plant and animal communities at entrance to caves.	TBD

Table 4.2. Sampling designs by vital signs (continued).

VITAL SIGN	TARGET POPULATION	MEMBERSHIP DESIGN	RESPONSE DESIGN	REVISIT DESIGN
8. Water Quality	Water quality in accessible streams and lakes of the Klamath Network parks.	GRTS sample grid for streams and list-based random sampling of lakes in the Klamath parks. Co-location, co-visitation with Aquatic Communities.	Parameters to be measured at lentic and lotic sites include alkalinity, cations and anions, total nitrogen, ammonia, nitrate/nitrite, total phosphorus, silica, total suspended solids, and dissolved organic carbon.	1-2
9. Land Cover, Use, Pattern	Landscapes of the Klamath Network parks and transboundary areas.	Complete census of imagery over park and transboundary area.	Quantify status and trends in the composition, configuration, and connectivity of land cover classes.	1-4
10. Environmental Conditions in Caves	Environmental conditions in safe and accessible caves and lava tubes of ORCA and LABE.	List-based sample for LABE, judgment sites for ORCA. High and low visitor use caves will be compared. Co-location, co-visitation with Cave Entrance Communities.	Monitor bat and invertebrate populations as well as cave formations.	TBD
11. Air Quality	Collect, archive, and analyze data from region.	n/a	n/a	
12. Weather and Climate	Collect, archive, and analyze data from region.	n/a	n/a	

4.8. Sampling and Data Integration

The vital signs program monitors ecosystem integrity and park health through a modest set of measurements. The strength of any single measurement that is intended as an ecosystem vital sign is increased when considered in concert with other information. With this in mind, our sample designs will use various means to provide a comprehensive, integrative view of our ecosystems. In some cases, this will arise through multivariate sampling of single or integrated pairs of vital signs. In other cases, it will occur through integration of data collected from similar sites or time periods (see Chapter 7). In still other cases, integration across taxa groups will occur when evaluating several lines of evidence from an ecosystem domain (e.g., changes in vegetation and landbird composition).

Integrated Sampling

The Klamath Network sample designs use both co-location (monitoring multiple vital signs at the same physical locations) and co-visitation (recording observations on multiple vital signs during a sampling occasion) to increase the potential for integration of vital signs monitoring information. In some cases, the operational efficiencies of co-sampling are self-evident and are captured in integrated sampling protocols. For instance, we are developing our water quality and aquatic communities sampling protocols to be collected together by the same field crew at each selected sample site (Appendix E). We also anticipate that cave communities and environmental conditions will be collected together in an integrated sampling protocol. In other cases, we have shared sampling frames to ensure that measurements for specific regions or habitats of the parks provide quantitative information from several vital signs. For example, the terrestrial vegetation, bird community, and water quality and aquatic communities will all share a similar sample frame. Although the different vital signs will be sampled with different intensities, inferences to the sample frame will be shared and interpreted together.

Integrating Across Ecosystem Domains

Data from the single and integrated vital signs protocols will be analyzed and synthesized to provide broad, multivariate assessment of ecological integrity of each of the four ecosystem domains (terrestrial, aquatic, marine, subterranean) within the Klamath Network. These domains represent the largest functional units in park landscapes at which assessments will be made. In essence, this will involve a multiscale array of monitoring information that ranges from precise measurements of single organisms or parameters at single sites to integrative, multimetric assessments at the largest scales (Figure 4.7). Single measurements will be placed in a context provided by park- or network-wide gradients in climate, geology, and disturbance patterns to facilitate the detection and differentiation of spatial and temporal patterns and trends. Integrated assessments are typically more stable than individual measurements in space and time and provide stronger evidence for general patterns of ecosystem change (Karr and Chu 1999, Manley et al. 2004).

Representativeness, Complementarity, and Comprehensiveness

As discussed in Chapter 1, the likelihood that field measurements represent a site, or in our case an ecosystem domain, increases with the diversity of organisms or parameters sampled (Manley et al. 2004). Our vital signs were selected to provide at least modest representation of the ecosystem domains of the Klamath Network parks through a diversity of measurements in each domain (Figure 3.1). Representativeness is also sensitive to complementarity in ecological characteristics. For example, two groups of species better represent a terrestrial

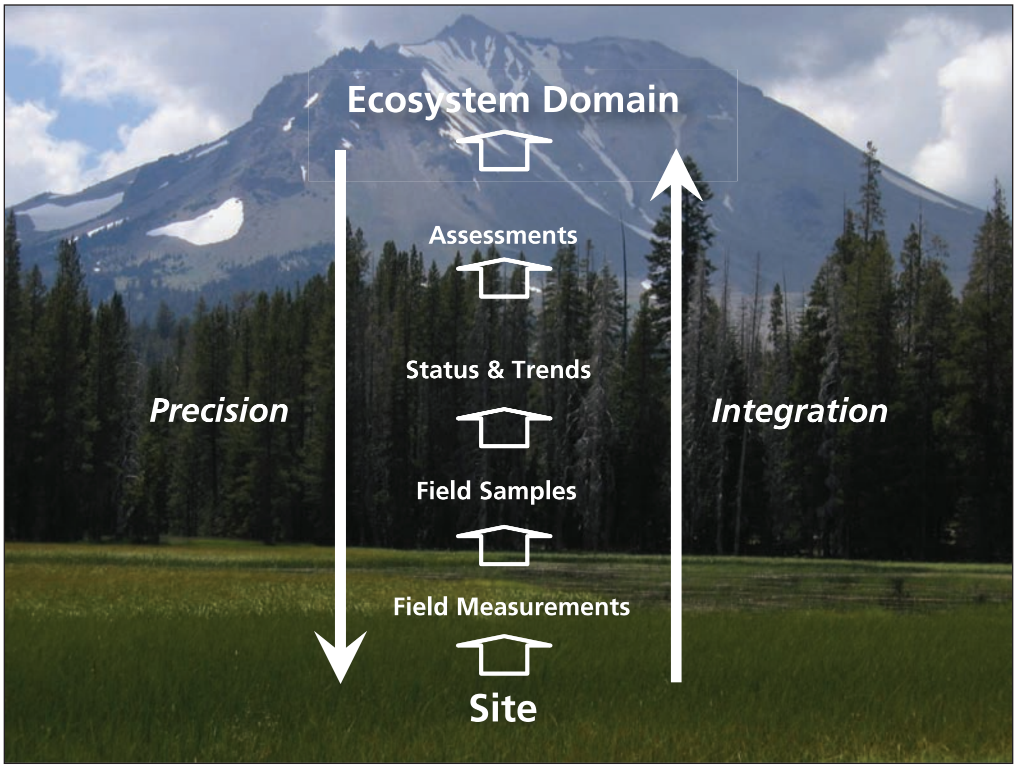


Figure 4.7. Relationship between measurement precision and integration for Klamath Network vital signs monitoring.

ecosystem of interest if their life histories differ. In a similar way, physical stream measurements are likely to complement biological measurements if they capture different types of information or different patterns of spatial and temporal variation in water quality. Therefore, we will be collecting a carefully selected suite of biological and physical features under each vital sign and at least two vital signs will be sampled in all the ecosystem domains except the marine environment.

By selecting a diversity of complementary measurements in each ecosystem domain, we hope to develop as comprehensive a program as is feasible given the current fiscal and staffing constraints of the program. Such a program will alert us to major changes in our ecosystem domains, and when assessed together, an emergent view of the ecological integrity of our parks.

Adaptive Design

Although this plan and associated protocols represent a substantial planning effort, the program must anticipate and accommodate change. We can expect changes in field staffing from season to season as well as larger shifts in program leadership and agency goals. Maintaining continuity and responsiveness to such changes will be critical for the survival of the program and its ability to provide relevant information over the long-term. Ecological surprises, such as large fires, pathogen outbreaks, and volcanism have the potential to occur and a dynamic program should allow some opportunistic change to learn about the implications for such events on park resources. In addition, new and unforeseen stressors to park ecosystems can arise that will need to be accommodated, as feasible. Each of the protocols provides mechanisms for changes in the designs, as need to accommodate such changes in the park environment.

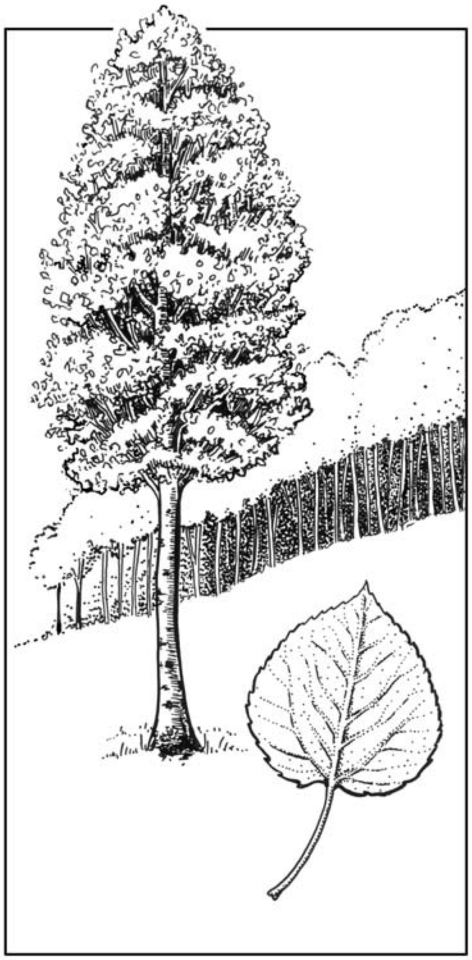
Chapter 5: Sampling Protocols

This chapter provides a summary of the justification and objectives of the protocols that will be used by the Klamath Network to monitor vital signs of ecosystem integrity. The protocol objectives nest under the main I&M goals of detecting status and trends in vital signs of ecosystem health, detecting abnormalities, and coming to a better understanding of dynamic park ecosystems through monitoring.

The Klamath Network is currently in the process of developing its sampling protocols, one of which has been submitted for peer review (as of September 2007). The protocols will be consistent with the National I&M guidelines described by Oakley et al. (2003). The guidelines explain how effective monitoring protocols must thoroughly define the monitoring questions, objectives, sampling designs, and statistical inferences that can be drawn. They must also determine ahead of time how monitoring data will be managed, analyzed, reported, and used (Oakley et al. 2003).

Although the Klamath Network's protocols are in development, a list of objectives and a rationale has been prepared for each. This listing was facilitated by the Network's decision to link potential vital signs with specific monitoring questions, which were ranked (Chapter 3). The monitoring objectives follow from the questions and define the specific parameters to sample over time. They are presented below in Table 5.1. This table also specifies which parks will be included in the monitoring of each vital sign and the justification for monitoring each vital sign. Protocol development summaries are presented separately in Appendix I; Appendix E has additional water quality sampling details. The fully documented protocols will be detailed, stand-alone documents that are supplemental to this monitoring plan. Drafts protocols submitted for peer-review and completed protocols will be posted in the NPS Protocol Databases located at: http://science.nature.nps.gov/im/monitor/protocoldb.cfm.

The development and implementation schedule for each protocol is presented in Chapter 9.



Aspen

Table 5.1. Protocols, the vital signs being monitored, the parks in which they will be monitored, a justification statement, and the specific monitoring objectives.

PROTOCOL NAME & IMPLMENTATION YEAR	VITAL SIGNS	PARKS	JUSTIFICATION	OBJECTIVES
Invasive Plants, Adaptive Sampling Early Detection Protocol for the Klamath Network. 2009.	Non-native, Invasive Species	CRLA, LAVO, ORCA, REDW, WHIS	Due to their ongoing impacts, non-native plants ranked as the top vital sign in the Klamath Network. Certain invasive species substantially alter the structure, function, and composition of ecosystems. Early detection is the key to preventing establishment or potentially controlling invasive species.	1. Develop and maintain a list of priority species with greatest potential for spread and impact to park resources for monitoring in each Network park, with revisions every five years, or more frequently as needed. 2. Use monitoring data collected early in the program to refine models of invasive species habitat requirements and of the most susceptible habitats. Adapt spatial sampling as knowledge of these high priority areas improves through monitoring. 3. Detect incipient populations and new occurrences of selected invasive non-native plants as efficiently and effectively as possible by sampling along roads and trails and in other select locations where introduction is most likely. Provide the information to park management on a timely basis to allow effective management responses.
Whitebark Pine (*Pinus albicaulis*) Vegetation Monitoring Protocol for the Klamath Network. 2009.	Whitebark Pine	CRLA, LAVO	Park populations of whitebark pines are keystone species being heavily impacted by a non-native species and disease. Changes resulting from non-natives are likely to have profound, ecosystem-wide effects in subalpine zones at Crater Lake and Lassen.	1. Determine status and trends in infection and death rates of whitebark pine from blister rust disease, mountain pine beetle, and other agents (fire, native diseases) over time. 2. Determine changes in plant species composition and cover associated with mortality of whitebark pine by collecting data compatible with other vegetation monitoring data.
Monitoring Vegetation Composition, Structure, Biomass, and Combustion Properties in the Klamath Network. 2009.	Terrestrial Vegetation	All	The development of the KLMN vital signs monitoring has emphasized the importance of documenting status and trends in the structure, function, and composition of ecosystems, which are largely defined by vegetation. Vegetation dominates biomass and energy pathways; and defines the habitat structure for many other forms of life. Vegetation ranked among the highest potential vital signs for monitoring in the Network's vital signs selection process.	1. Determine status and trends in vascular plant composition, diversity, and structure of predominant terrestrial vegetation and select special interest vegetation (e.g., sensitive high elevation, riparian, and wetland vegetation) across the parks of the Klamath Network. 2. Determine status and trends in tree recruitment and in tree mortality. 3. Determine status and trends in downed-woody fuel loadings and in height to bottom of live crowns of standing trees. 4. Determine status and trends in major forms of disturbance on vegetation-monitoring plots. Disturbances to be measured include fire, insect outbreaks, disease, and wind throw.

Table 5.1. Protocols, the vital signs being monitored, the parks in which they will be monitored, a justification statement, and the specific monitoring objectives (continued).

PROTOCOL NAME & IMPLMENTATION YEAR	VITAL SIGNS	PARKS	JUSTIFICATION	OBJECTIVES
Landbird Monitoring Protocol for the Klamath Network. 2008.	Landbird Communities	All	Bird communities were identified within the top 10 vital signs for the KLMN. Key reasons for monitoring landbirds are that 1) they come under the legal mandate related to the Endangered Species Act and Migratory Bird Treaty Act; 2) they are specifically identified in the parks' management objectives; 3) they are considered good indicators of the condition of park ecosystems because they respond quickly to changes in resource conditions; and 4) comparable regional and national datasets exist.	1. Determine status and trends in breeding-bird species richness and density in KLMN parks. 2. Determine status and trends in habitat characteristics through habitat surveys at locations where bird observations are recorded.
Intertidal Marine Resources of Redwood National Park. 2008.	Intertidal Communities	REDW	Intertidal communities consistently ranked among the top 10 potential vital signs evaluated by the KLMN. The only marine resources that the Network proposes to monitor are intertidal communities. Key reasons for monitoring intertidal communities are their unique species composition and diversity and their position at the land/sea interface, which results in particular sensitivity to ongoing changes in both marine and terrestrial realms (e.g., climate change and associated changes in sea temperatures, circulation patterns, and surface elevation). Intertidal communities are also highly vulnerable to anthropogenic stressors such as oil spills. Finally, the KLMN has put a premium on monitoring of keystone species. A classic example of a keystone species occurring in west coast intertidal systems is the sea star (*Pisaster ochraceous*).	1. Monitor the temporal dynamics of target invertebrate and algae species and surfgrasses across accessible, representative, and historically sampled sites at REDW that encompass the range of rocky intertidal habitats in the parks to: 1) Evaluate potential impacts of visitor use or other park-specific activities; and 2) Provide monitoring information to help assess level of impacts and changes outside normal limits of variation due to oil spills, non-point source pollution or other anthropogenic stressors that may come from outside the parks; 2. Determine status, trends, and effect sizes (as applies) through time for morphology (e.g., color ratios) and other key parameters describing population status (e.g., size structure) of selected intertidal organisms; 3. Integrate data with a network of monitoring groups spanning a broad geographic region in order to determine whether trends detected at Redwood are related to more widespread trends or are park specific; 4. Detect and document invasions, changes in species ranges, disease spread, and rates and scales of processes affecting the structure and function of rocky intertidal populations and communities to develop process knowledge of processes and normal limits of variation.

Table 5.1. Protocols, the vital signs being monitored, the parks in which they will be monitored, a justification statement, and the specific monitoring objectives (continued).

PROTOCOL NAME & IMPLMENTATION YEAR	VITAL SIGNS	PARKS	JUSTIFICATION	OBJECTIVES
Monitoring Water Quality and Aquatic Communities in the Klamath Network Parks. 2009.	Water Quality, Aquatic Communities (includes Aquatic Amphibians).	CRLA, LAVO, ORCA, REDW, WHIS	During the KLMN vital signs scoping process, water quality of the Network's aquatic resources was identified as an important element of the overall health of the Network's diverse ecosystems. Two of the 10 most important Network-wide vital signs identified by this process were water quality characteristics of surface waters and aquatic biota and communities. Aquatic ecosystem health was consistently a dominant theme during the identification of KLMN water quality issues.	1. Determine status and trends in the water quality (e.g., temperature, specific conductance, dissolved oxygen, pH, alkalinity, cations and anions, total nitrogen, ammonia, nitrate/ nitrite, total phosphorus, silica, total suspended solids, dissolved organic carbon, clarity, periphyton, and chlorophyll) of network ponds, lakes, and wadeable cold-streams. 2. Determine status and trends in the structure of aquatic communities in Network ponds, lakes, and wadeable cold-streams based on sampling the invertebrate (e.g. zooplankton and macroinvertebrates) and vertebrate (e.g., amphibians and fish) components of aquatic assemblages.
Integrated Cave Entrance Community and Cave Environment Monitoring for the Klamath Network. 2010.	Cave Entrance Communities & Cave Environmental Conditions	LABE, ORCA	Caves and cave entrance communities have unique biota, including a number of global endemics. There are 7-8 macroinvertebrate species and one subspecies known only from the main cave at Oregon Caves. Lava Beds has at least three troglobite species only known from their lava tube caves. At Lava Beds, there are also ferns and both vascular and non-vascular plants that are mostly or entirely restricted to cave entrances. The distinctive biodiversity and often spectacular geologic formations in caves depend on unique and specific environmental conditions. Despite their apparent stability, cave environments often show particular sensitivity to visitor impacts and ongoing changes in both atmospheric and terrestrial realms.	1. Determine status and trends in specific features and resources in managed and unmanaged caves along a gradient from cave entrance to cave. The following resources and parameters have been identified to monitor: Plants (measures of abundance —density, cover, frequency—at cave entrances); bats (harp trap counts, timed visual counts); macroinvertebrates (aggregate sample, use of attractants); microbes (cave sediment biological activity); air flow, relative humidity, and temperature using instrumentation; calcite slab for dissolution and deposition; ice features; impacts to cave formations: lint deposition; and surface polishing.
Land Cover Monitoring Protocol for the Klamath Network. 2010.	Land Cover	All	Landscape spatial structure resulting from natural processes, and its variation through time, underlies the diversity and integrity of ecosystems. The composition (types and amounts of different land-cover), configuration (spatial arrangement of land-cover types), and connectivity determine habitat availability, the movements of organisms, and energy and material flows on a landscape. Substantive changes in landscape structure occur in response to natural and anthropogenic processes.	1. Determine the status and trends in the composition and configuration of land cover types on park and adjacent lands at five-year intervals. 2. Determine the status and trends in the connectivity of land-cover types within parks and for park and adjacent lands combined at five-year intervals. 3. Determine the status and trends in cross-boundary (park vs. adjacent lands) contrasts in land-cover types at fire-year intervals. 4. Determine long-term changes in fire frequency and extent. 5. Determine long-term changes in the frequency and extent of insect and disease outbreaks.

Chapter 6: Data Management

6.1. Introduction

Information is the common currency of science, resource management, education, and policy. A data management system must provide efficient ways to enter, store, protect, and quickly disseminate accurate information to those who need it. Such a system draws little attention when working well, but can greatly limit the potential of a monitoring program when it is damaged or flawed. The Klamath Network has developed a Data Management Plan (Appendix J: available for download at http://www.nature.nps.gov/im/units/klmn/DM_Data_Management_Plan.cfm) that outlines the Network's strategy to support inventory and monitoring and to ensure that the program serves the parks and public. This chapter provides a general overview of this plan and its role in the Klamath Network's Inventory and Monitoring Program.

The Klamath Network will be monitoring a wide assortment of parameters through time and communicating our findings to diverse audiences for varied purposes. The complexity and expected longevity of the monitoring program creates complicated issues that need to be addressed. Long-term monitoring projects have the tendency to outlive the current staff. These programs are likely to adapt to changing knowledge, techniques, and equipment. They must account for shifting priorities and variable funding. In addition, they need to be developed for diverse and changing audiences. To efficiently and accurately provide for these needs, the Network has begun working on a data management strategy. Working with local, regional, and national NPS staff and with Southern Oregon University (SOU), we have developed an infrastructure that allows our data management system to grow while at the same time supply security, storage, and the ability to disseminate data and information. Through our Data Management Plan, we have outlined the methodologies we will use to manage data through time and ensure their integration in park science, management, and education activities.

6.2. Data Management Plan

The first step in implementing our data management strategy was to develop a detailed Data Management Plan. The plan outlines:

- The goals and objectives of the Klamath Network's Data Management Program.
- How Klamath Network personnel will prioritize time and funding towards data management activities based on information needs outlined in monitoring protocols and inventory study plans.
- The roles and responsibilities of each position in the Network to integrate proper data management skills into all aspects of the Network's business.
- Details of the infrastructure the Network will utilize to create, store, maintain, and disseminate data and information.
- The methods the Klamath Network will follow to manage data throughout all phases of a project's data life cycle.

In addition to the Data Management Plan, the Klamath Network has developed procedural documents to guide Network and project staff on many aspects of data management. Guideline documents provide detailed instructions that apply to all projects conducted or funded by the Network. Standard operating procedure (SOP) documents are similar to guideline documents except they are project-specific and will be created on an as-needed basis before implementing a project. Guideline documents are available at the Klamath Network internet website:

http://www.nature.nps.gov/im/units/klmn/DM_Data_Management_Plan.cfm.

These documents are also posted on the Klamath Network intranet website:

http://www1.nrintra.nps.gov/im/units/klmn/datamgmt/dm_index.cfm

The Data Management Plan and supporting procedural documents are all intended to be used in conjunction with each other to ensure that:

- Data are properly documented so they may be easily disseminated and utilized by a diverse group of users far beyond the lifespan of a project.
- Data are consistent and held to the highest quality possible by providing standards and methods that all employees working on a project will follow.
- Data and information are stored in a manner so they are secure, easily accessible, and protected from unauthorized use.
- The Network supports National I&M programs by providing data and information in a compatible format.

6.3. Types of Data and Information

In general, when conducting a natural resource project, field crews collect a set of quantitative and qualitative measures typically known as "raw data." These data are then processed, analyzed, and generalized to become "information" used to write reports, run analyses, create maps, and develop brochures. For the purposes of this document, we are describing "data" in their broadest sense. Data can mean anything ranging from raw data collected in the field to processed data used to create charts and statistical analyses. Data can also refer to the documentation that was developed based on the raw data and may include metadata, reports, presentations, and administrative records (Table 6.1).

6.4. Infrastructure

Our Network relies heavily on park, regional, national, and university information technology (IT) personnel and resources to maintain the overall data management infrastructure for the Klamath Network. Southern Oregon University IT staff is responsible for server maintenance, security, software updates, telecommunication networks, archiving, and routine backup for the Klamath Network administrative office. NPS IT staff are responsible for maintaining computer hardware, supplying software programs and updates, providing administrative functions, and administering security.

National I&M Program

The National I&M Program has played a key leadership role in data management by providing website support and several integrated databases that can be utilized to distribute data to a broad audience, including park staff, the research community, and the public. These databases include NatureBib, NPSpecies, Dataset Catalog, Natural Resource Database Template, and the NPS Data Store. Figure 6.1, provides a diagram of the natural resource data management framework.

Table 6.1. Data categories with examples of potential deliverables.

DATA CATEGORY	EXAMPLES
Raw data	Field forms and notebooks, photographs, digital data (sound/video recordings, GPS data, probe data, data loggers, telemetry data)
Derived data	Relational databases, GIS layers, maps, analyses
Documents	Protocols, data dictionaries, metadata, log books, project databases
Reports	Annual reports, synthesis and analysis reports, scientific publications
Administrative records	Contracts, agreements, study plans, permits and applications

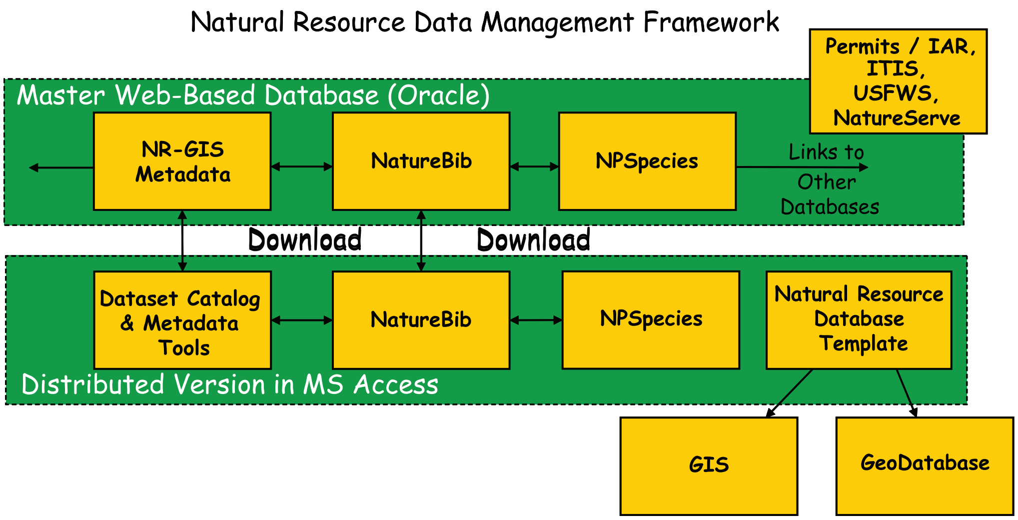


Figure 6.1. Model of the national-level application architecture for integrated natural resources databases.

While the Klamath Network is currently utilizing the infrastructure described above, it is important to recognize that this system is currently in a state of transformation. The Natural Resource Program Center (NRPC) is in the process of transitioning data systems to a Service Oriented Architecture (SOA) and XML web services development approach for data management and delivery. The project called IRMA (Integrated Resource Management Applications) will initially integrate three NRPC data systems: NatureBib, NPS Data Store, and NPSpecies into a common web portal. Eventually, integration of these data systems with other NRPC applications is planned.

Host Park Support

The Klamath Network works closely with the staff at Redwood National and State Parks (REDW), the Network's host park, to provide administrative and information technology support. The staff at REDW provides support in the following areas:

- Purchasing
- Budget
- Personnel
- Time Keeping
- Records Management
- IT Support

Southern Oregon University

The NPS and SOU are both participants in the Pacific Northwest Cooperative Ecosystem Studies Unit, part of a nationwide network of similar units. They are organized around bio-geographical regions to provide high-quality scientific research, technical assistance, and education through the linking of participating agencies and university partnership. In 2004, the Klamath Network entered into a task agreement with SOU to establish an administrative office on the main campus, providing the program with access to the information technology, communication, and research capabilities of SOU. Within this agreement, SOU provides:

- A Principal Investigator to oversee all collaborative activities and to ensure that Klamath Network and SOU requirements are met.
- Facilities and infrastructure support, including offices, laboratories, libraries, computer-related services, equipment, supplies, telephone services, and meeting rooms.

In return for SOU's services, the Klamath Network provides:

- Financial assistance on a yearly basis for the amount approved in the Klamath Network's Annual Administrative Report and Work Plan.

- An Agreement Technical Representative (ATR) to collaborate with the University Principal Investigator.
- Involvement for faculty and students in research, internships, employment, and educational opportunities where appropriate and mutually beneficial.
- Staff to provide guidance and consultation with students and faculty as needed and appropriate with ongoing activities.

6.5. Roles and Responsibilities

The characteristics and qualifications of the personnel can be a major factor in the level of quality assurance assigned to the data the KLMN collects. The small number of core staff at the Klamath Network makes it necessary to have individuals participate in more than one role within the Network. As such, understanding the responsibilities associated with the various roles in the Network will be imperative. The KLMN will make every attempt to examine the skill sets of each employee and utilize his or her skills to help the Network reach our goals while at the same time providing the employee with valuable development opportunities. The Data Management Plan provides detailed descriptions of the roles and responsibility for each participant in a Network developed or funded project. Table 6.2 provides a list of the key roles along with some general responsibilities. In addition, we have listed the detailed responsibilities of some of the key core positions related to long-term monitoring and data management.

Data Manager

The Data Manager directs a complex program of data management activities within the Network. The person in this role has the overall responsibility for all data managed by the Network and must work closely with the Network Coordinator, Program Assistant, GIS Specialist, Network Contact, and each project manager to ensure data are meeting Network standards. It is the duty of the Data Manager to:

- Provide guidance and standards to everyone involved in data management.
- Make certain that infrastructure is sufficient to meet Network objectives.
- Provide coordination, training, technical assistance, and professional advice to meet the data management needs of the staff.
- Design, implement, support, and manage database systems for long-term monitoring projects, inventory projects, and various other I&M activities.
- Ensure there is constant communication between the Project Manager, Network Coordinator, GIS Specialist, Program Assistant, and Data Manager for all data management needs.

Project Manager

The Project Manager is responsible for all phases of an inventory or monitoring project. The person in this role works closely with the Network Coordinator, Data Manager, GIS Specialist, Network Contact, and project crew members to ensure data management protocols, SOPs, and guidelines are being followed. It is one of the Project Manager's core responsibilities to confirm that information collected in the field is accurate, complete, and correctly documented. Overall data management duties of the Project Manager are to:

- Select or develop, in close collaboration with the Network Contact, Network Coordinator, and Data Manager, the protocols, standard operating procedures, and sampling methodologies that will be implemented for each project.
- Supervise and certify all field operations including training, equipment handling, data collection and entry, quality assurance (QA)/quality control (QC) measures, verification, and validation.

- Transfer data to the Data Manager on a schedule determined during the planning phase of a project.
- Document field activities that relate to data management.
- Work with the Data Manager, Network Contact, and Network Coordinator to determine workload priorities, timelines, project deliverables such as summary and final reports, and deadlines.
- Serve as the point of contact for all data collection-related issues on the projects he or she manages.
- Develop summary reports, annual reports, analysis and synthesis reports, and scientific articles following the guidelines outlined in the Klamath Network Data Management Plan and in each Vital Sign Monitoring Protocol.

Network Contact

The Klamath Network monitoring program is designed to collect, analyze, and disseminate data from projects related to 10 vital signs that cover the various ecosystems of the Klamath region. It would be an almost impossible task to designate one person to be the Network Contact for all of these projects. To ensure that each project is well managed and has the support it needs to be efficient and productive, the Network has designated one person for each vital sign project not being conducted "in-house" to be the Network Contact when questions arise or tasks need to be completed. Some of the duties of the Network Contact include:

- Work closely with the Project Manager to ensure that all data management tasks outlined in the monitoring protocols or inventory study plans are being implemented.
- Act as the point of contact for issues related to conducting work in a national park such as permits, camp sites, designating park points of contact, vehicles, and administrative tasks.
- Make certain there is continuous communication between the project staff, Klamath Network employees, and the park's point of contact.
- Review and approve all project-generated reports prior to submitting the report to the Network staff.
- Ensure final products have been delivered to the Data Manager for posting, storage, and archiving at the end of each field season.

6.6. Data Management Process and Workflow

Understanding how data are developed allows us to easily communicate the overall objectives and importance of proper data management throughout each phase of a project. The Klamath Network's data management workflow follows the data management methodologies associated with a cyclic six phase approach known as the data life cycle (Figure 6.2). In planning a project, regardless of its length, it is necessary to follow the data life cycle. Each project will produce similar data (Table 6.1) that will need to be managed and made available to a diversity of users.

"The overall goal of our Data Management Program is to provide data and information that are of high quality containing minimal errors and biases."

Phase I - Planning

Planning is the first and one of the most important steps in the data life cycle. The planning phase can be a complex and arduous process. However, spending the time to meticulously plan all aspects of the project will save a considerable amount of time, effort, and money in the other phases of the project. During the planning phase:

- Goals and objectives of the project are determined and clearly stated.
- Ownership of the data and products is determined.
- A project record is created and populated in the project tracking database.
- Inventories of related information are reviewed and rated for usefulness.
- Proposals and budgets are created and funding sources are determined.
- Work plans are created.

Table 6.2. Roles and responsibilities of personnel working on a project funded or developed by the Klamath Network.

ROLE	DATA RESPONSIBILITIES
Project Crew Member	Collect, enter, and verify data. Document issues with data collection, data entry, and QA/QC process to Crew Leader.
Project Crew Leader	Organize and verify data. Report issues with data collection or documentation to Project Manager. Provide training on databases, data collection, and data entry.
Project Manager	Supervise project crews. Train Project Crew Leader on proper data management. Validate data. Provide data documentation. Convert data into information. Implement protocols and SOPs. Evaluate project-related data management methodologies.
Network Contact	Work with the Network Coordinator, Project Manager, and Data Manager to select or develop protocols and SOPs to implement. Act as the point of contact for issues related to conducting work in a national park such as permits, designating park points of contact, vehicles, and administrative tasks. Review and approve all project-generated reports and analysis. Ensure final products have been delivered to the Data Manager for posting, storage, and archiving.
Network Program Assistant	Work with the Data Manager, Project Manager, and Network Coordinator to keep the project records in the project database and national I&M databases current. Incorporate photographs and associated metadata into the KLMN Photograph Database. Ensure that documentation for databases, maps, and project information accompanies information posted on the KLMN internet and/or intranet websites.
GIS Specialist	Process, manage, and validate GPS and other spatial data. Make spatial data accessible and useable. Conduct spatial analyses. Work with the Data Manager to integrate spatial and tabular data. Train Project Manager on data management techniques as they relate to GIS/GPS.
Network Data Manager	Develop and support a KLMN data management system. Ensure KLMN-managed data are organized, documented, accessible, and safe. Train staff in proper data management methodology. Make certain data and information are properly archived. Provide guidance and standards for data sharing and access to sensitive data. Develop and maintain the Network websites.
Network Coordinator	Coordinate and oversee all KLMN activities. Review and approve all Network-generated reports and internal protocols and obtain policy review for all relevant KLMN documents. Work with the Data Manager to ensure data are collected, documented, and stored in a manner that supports the Network.
IT Specialist	Provide support for all hardware, software, and networking.
Park Curator	Oversee all aspects of specimen acquisition, preservation, and documentation. Manage the collections for parks in his/her jurisdiction.
Park Resource Managers	Provide technical assistance and advice for implementing KLMN goals and objectives. Integrate information provided by KLMN into park planning and management decisions.
Superintendents	Provide advice regarding the long-term goals and objectives of the Klamath Network data management process that will prove useful to park managers. Integrate information provided by KLMN into park planning and management decisions.
National Data Manager	Provide service-wide support.

- Contracts, agreements, and permits are obtained.
- Protocols, SOPs, and guidelines are selected or developed as needed.
- Attribute entities and rule sets are defined.
- Databases, datasheets, metadata, and data dictionaries are designed.
- Deliverables are identified and due dates are determined.
- Storage and dissemination methods are created.
- Timelines are determined.
- Equipment is purchased.

Phase II - Implementation

The implementation phase of the project is when the on-the-ground work begins. Field data collection is time-consuming, expensive, and, if not managed properly, provides ample opportunity to introduce errors. It is during this phase that we

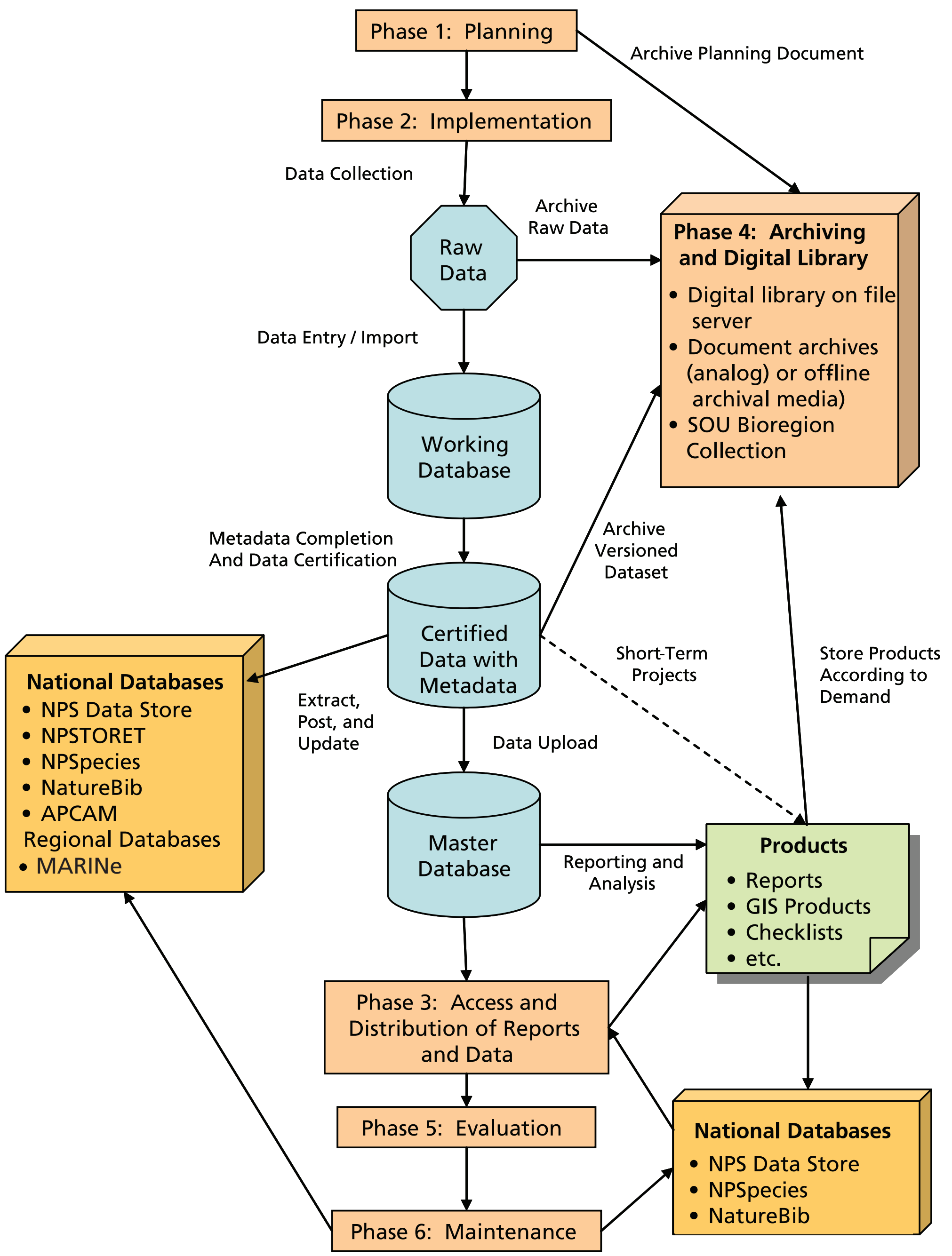


Figure 6.2. Diagram of the data life cycle, illustrating the major data management activities during the life of a project.

can begin to determine which data management methods are working, and which need to be adjusted and reassessed. During the implementation phase:

- Field crews, contractors, and additional personnel are hired and trained.
- Equipment is purchased and SOPs for equipment use and calibration are created.
- Data are collected and entered into databases. They undergo QA/QC processes and are certified, stored, and secured.
- Data are converted to information

through statistical and GIS analyses, map development, creation of dataset catalogs and metadata, and preparation of reports.
- Data management methods are tested and adjusted as needed.

Phase III - Access

One of the core goals of most KLMN projects is to create information that can be utilized by park staff, the public, and the scientific community, providing them with up-to-date information about natural resources occurring in and around the parks. To do this job efficiently, methodology must be in place to allow users easy access to tabular and spatial data, reports, and photographs collected during the project. In this phase:

- Products and data are distributed to a diversity of users, including park staff, KLMN employees, SOU personnel, national I&M databases, and the scientific community on a predetermined timeline.
- Data are stored in a manner that is secure but allows for timely distribution when needed.
- Information created from the project is posted to, or used to update, national databases, including NPSpecies, NatureBib, NPS Data Store, STORET, ANSC+, and NR-GIS Clearinghouse as needed.
- Klamath Network intranet and internet websites are updated with pertinent information.
- Reports and associated metadata are sent to SOU's Hannon Library for distribution.

Phase VI - Archiving

As stated in the 2006 NPS Management Policies, *"Information about natural resources that is collected and developed will be maintained for as long as it is possible to do so. All forms of information collected through inventorying, monitoring, research, assessment, traditional knowledge, and management actions will be managed to professional NPS archival and library standards."* In order to preserve the data for long-term use, archived data must:

- Be secure and easily accessible to meet future requests (e.g., FOIA, park staff, and the scientific community).
- Include all documentation needed to understand the archived datasets and GIS information. This includes administrative documents, reports, metadata, and data dictionaries.
- Be stored in their original format and in a comma-delimited, American Standard Code for Information Interchange (ASCII) text file. ASCII files will include the content of each file, relationships that may occur between tables, attribute definitions, and associated documentation.

The Network utilizes the knowledge and infrastructure provided by SOU and REDW to meet our archiving and storage needs. All Network information is backed up on a nightly, weekly, and quarterly basis. Weekly and quarterly backups are stored off-campus and managed by Record Masters of Southern Oregon. Weekly backups are stored for approximately two months while quarterly backups are archived for one year.

In addition, the Network is working with the SOU's Hannon Library to develop an archiving system for our digital reports and maps. This system will give the Klamath Network the opportunity to incorporate our reports and maps into a bioregional collection for the Klamath region, which will provide another medium for non-NPS employees to gain access to our reports.

Phase V - Maintenance

In order to maintain the highest quality useable data and the products created from the data (metadata, databases, reports, and the administrative records), a variety of evaluation, screening, and updating procedures are conducted at regular intervals (usually at the end of each field season). During this phase:

- Metadata, data catalogs, and data dictionaries will be evaluated to make sure they are up-to-date and meet all previously outlined standards.
- Seasonal data will be reviewed prior to integration with the master databases to verify that they are complete and meet data quality standards.
- Records in the project database will be updated.
- Data will be screened for sensitive information and protected from unauthorized use.
- Databases and datasheets will be updated to meet current objectives.
- Known users of the information will be informed of any revisions to the data or supporting documents.

Phase VI - Evaluation

The technology, methodology, and perspectives used to create and implement a project are dynamic and can change on a regular basis. It is important to constantly review all the aspects of a project to determine what is working, what needs to change, what needs to be added, and most importantly, what can be done better or more efficiently. Some informal evaluation should be conducted during all phases of a project. However, formal evaluation of the data management processes throughout the entire project should occur at the end of each field season. During this phase:

- Evaluation of the collection methodologies, protocols, SOPs, and guidelines is conducted to determine if they are still valid.
- Periodic evaluation of the data being collected takes place to determine if they are still needed and useful.
- Overall evaluation of the project is conducted to determine if the methodologies being used meet the goals and objectives of the project.
- Evaluation of the data management methodologies used to obtain, manage, disseminate, and archive the data is done to make sure they are still efficient.

Quality Assurance and Quality Control

Data collected for the purpose of detecting a change in natural resources over time must be of the highest quality with little or no bias. The quality of the data must address the objectivity, utility, and integrity of all data collected during a project. Applying proper QA/QC standards throughout the data life cycle, from the planning phase through the evaluation phase, will allow the Klamath Network to provide high quality, accurate data for scientific analysis and to support natural resources management. In this phase:

- Metadata files created during the planning phase of the project will be updated through every stage of the project.
- Validation and verification methodologies will be used to protect information being collected, recorded, and processed.
- Completeness and accuracy of data will be determined prior to distribution or incorporation of those data into the master database.
- Domain values, pick lists, and various other quality control methods will be incorporated into the databases prior to data entry.
- Monitoring projects will have data consistency checks conducted to make sure data collected over multiple years can be integrated.
- Data will be reviewed at multiple levels to correct errors and determine missing values.
- The Data Manager will monitor project folders to ensure that all data are available and located in their proper place.

"Information is the common currency of science, resource management, education, and policy."

6.7. Water Quality Data

The water quality component of the Natural Resource Challenge (NRC) (Appendix E) requires that vital signs networks archive all physical, chemical, and biological water quality data collected with NRC water quality

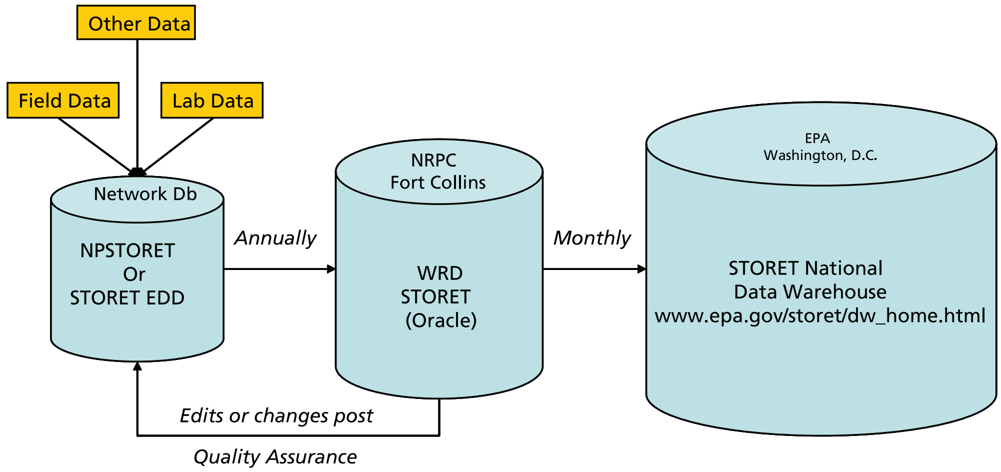


Figure 6.3. Simplified model of the Natural Resource Challenge vital signs water quality data flow.

funds (Appendix E) in the NPS Water Resources Division's (WRD) STORET database. To facilitate archiving data in the STORET database, the WRD has developed a series of Access-based templates (called NPSTORET), patterned after the NRDT, for networks to use to enter their water quality data in a STORET-compatible format. The Klamath Network will send our data from NPSTORET to the WRD on an annual basis for quality assurance and upload into the WRD's copy of STORET and the Environmental Protection Agency's (EPA) STORET National Data Warehouse (Figure 6.3).

6.8. Summary

The overall goal of our Data Management Program is to provide data and information that are of high quality containing minimal errors and biases. In order to provide park staff, the public, and the scientific community with accurate and reliable information in the most efficient manner possible, the Klamath Network is implementing a data management strategy that utilizes the Network's Data Management Plan, data guideline documents, and SOPs to instruct staff on the methods that need to be followed when collecting and managing data. The Network is confident that by following these processes, we will be able to provide sound scientific information to current and future generations of park and Network staff in an effort to help manage the park ecosystems and inform the public.

Chapter 7: Data Analysis and Reporting

7.1. Overview

In a successful monitoring program, data are analyzed, interpreted, and provided to managers, decision-makers, and interested parties at regular intervals in a reporting format appropriate for each of these audiences. Effective interpretation and timely reporting of monitoring data and key findings requires clear standards for data collection and management as described in Chapter 6, and consistent schedules for data summary and analysis. This chapter presents an overview of the Klamath Network's approach for data analysis and reporting. Ideally, the data analyses and reporting vehicles form an integrated whole and provide a strong platform to inform management and engage allied research. Figure 7.1 summarizes the major analysis approaches and reporting tools that will be pursued and how they interact with outside research to support the Network's programmatic goals.

7.2. Roles and Responsibilities for Data Analysis and Reporting

The data collected under the Klamath Network Vital Signs Monitoring Program are meant to be made available for collaborative use by the parks, network, regional and national I&M staff, and our research partners. In such collaborative ventures, it is critical to stipulate roles and responsibilities for data analyses and reporting at the outset. Table 7.1 discusses general analysis categories, the primary analytical questions, and the responsible parties. These individuals will be specified in each protocol. For each protocol, the Project Manager will be the lead person involved in all aspects of data analysis and reporting (Table 7.1).

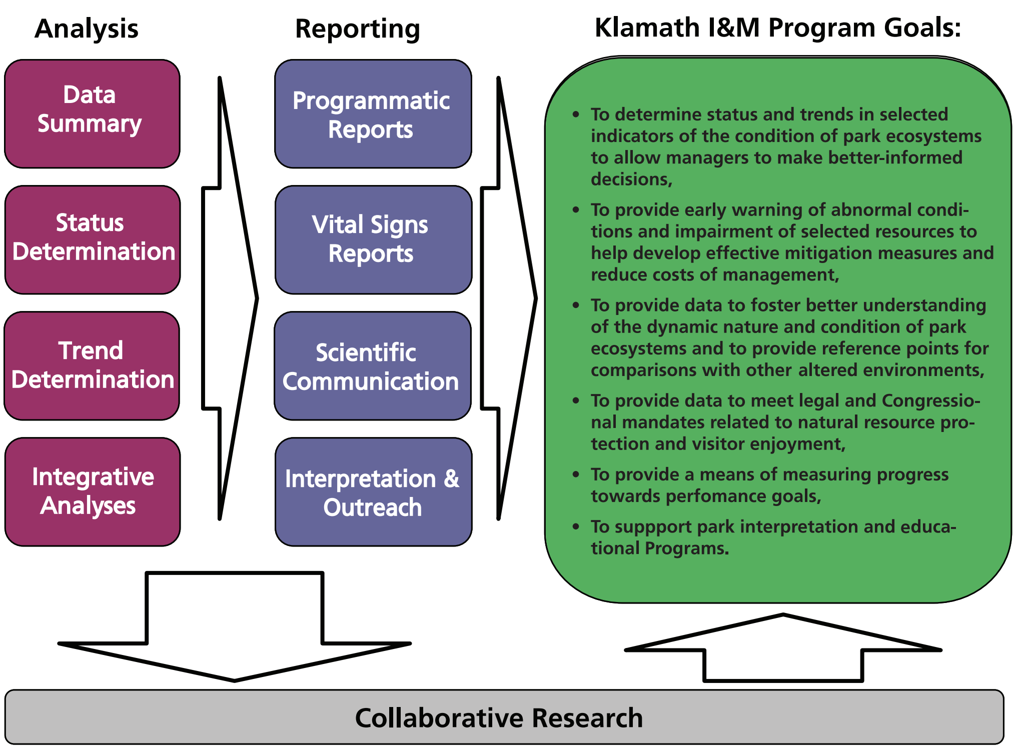


Figure 7.1. Relationships between analyses, reporting, research, and Klamath Network Inventory and Monitoring Program goals.

For all vital signs that will have a non-NPS Project Manager, a Network Contact has been designated. For data integration and synthesis, the Project Manager will work with the Network Contact. The Network Coordinator and Network Data Manager will play key support roles throughout the data analysis process. For a number of vital signs, data analysis support will also be provided by GIS specialists and other staff from the Network or parks. The specific analytical techniques that will be used are described in the following section. Descriptions of the major reporting tools and their intended purposes are provided in the reporting section. Report authorship is identified below in Table 7.2.

7.3. Data Analysis

The Klamath Network intends to use a variety of data analysis approaches to pursue the I&M monitoring goals outlined in Figure 7.1. The sampling designs and analyses are also based on the specific objectives for monitoring of each vital sign (Chapter 5). In this section, we discuss general analyses that will likely be used to pursue our vital signs monitoring goals. Detailed descriptions of data analysis and reporting procedures will be contained in the monitoring protocols for each vital sign.

Forms of Data and Assessment

Understanding status, trends, abnormal conditions, and ecosystem dynamics will require a broad, multifaceted program that analyzes both specific univariate and more integrative multivariate parameters to provide a comprehensive view of the ecosystems involved (Dale and Breyeler 2001). The Network's vital signs were selected to span this gradient from specific to integrative. We have also designed the system to allow synthesis across vital signs to provide a more comprehensive view of the major ecosystem domains in the Network. Individual parameters that are particularly important, such as numbers of tree seedlings, abundance of focal bird species, or pH of streams, will be analyzed and reported distinctly. There is increasing consensus, however, that single species or parameters do not adequately describe ecosystem level status, trends, or abnormalities (Barbour et al. 1995, Karr and Chu 1999, Dale and Beyeler 2001). We will be monitoring multiple parameters while in the field; therefore, multivariate data will be available for condition assessments and will compose a significant portion of our analyses.

The decisions made in the development of the sampling designs will affect the ease and suitability for specific data analyses. As mentioned in Chapter 4, nearly all our data will come from rigorous design-based sampling of the park environment in question, with peer-reviewed protocols and metadata available. This will ensure that inferences can be drawn defensibly from the parameter estimates provided.

Preliminary Data Summaries

After initial screening and quality control, data from all of our vital signs will undergo a similar suite of analyses to illustrate general descriptive patterns and to determine the suitability of the data for subsequent analyses. Standard techniques include data reduction, outlier detection, and analysis of parameter distributions (histograms, Q-Q plots, evaluations of spatial autocorrelation), and associated data transformations (Zar 1999, Legendre et al. 2002). In other cases, analyses will include relatively simple descriptive or graphical mapped data summaries that can inform reports or interpretive resources. For example, Figure 7.2 illustrates a bubble map for California myotis (Myotis californica) in Whiskeytown that demonstrates relative abundances at a number of inventory sites. Simple tabular or graphical summaries may also provide general information for evaluation of GPRA goals and other administrative review processes.

Table 7.1. Goals and general approaches for four levels of data analyses for monitoring data, with responsible parties.

LEVELS OF ANALYSIS	DESCRIPTION	ANALYSTS AND SUPPORTING INDIVIDUALS
Data Summary / Quality Control	Calculation of summary statistics and initial screening, including: • Measures of central tendency (mean, median) and variation (range, variance, standard error). • Identification of missing values and outliers (box-and-whisker plots, queries, QA/QC). • Graphical data summaries, visual inspection of parameter distributions. • Maps of parameter values. • Calculation of correlation and distance matrices. • Compilation of ancillary data and covariables. Evaluation of spatial autocorrelation patterns. • Review and compilation of related data in park, network, and surrounding lands, as appropriate.	Lead: Project Manager Support: Field Crew Leads, Network Coordinator, Network Data Manager, Network Vital Signs Contact, GIS Specialist, Park Staff
Status Determination	Analysis and interpretation of vital sign parameter values across target population to answer questions of concern: • Do observed values exceed regulatory standards or known ecological thresholds? • Are values within the range of historical or regional range of variability for a vital sign (if known)? • What is the precision and confidence in the status estimate? • What is the spatial distribution of observed values? • Is spatial variation stochastic or gradient-driven? • Do observed patterns in parameter values suggest relationships with unanticipated factors? • Do parameter values suggest status detection might be improved by model-assisted sampling? • What is the nature of the spatial autocorrelation (i.e., spatial dependence or directionality) in vital signs data? • What environmental factors function as covariates and influence the values of measurements?	Lead: Project Manager Support: Network Coordinator, Network Data Manager, Network Vital Signs Contact, GIS Specialist, Park Staff Consulting: University and Agency Scientists, Statisticians, Contract Specialists
Trend Evaluation	Evaluations of interannual trends will seek to address a number of temporal questions: • Is there continued directional change in indicator values over the period of measurement? • What is the estimated rate of change (and associated measure of uncertainty)? • Is there significant departure from the originally estimated (or simulated) power to detect trend? • Are there unforeseen correlations that suggest other factors should be incorporated as covariates in time or space? • Do parameter values show temporal variance in concert with known climatic or disturbance events during period? • Do trends in different target populations or sample frames (i.e., judgment, index, survey sites) show similar changes in magnitude and direction?	Lead: Project Manager Support: Network Coordinator, Network Data Manager, Network Vital Signs Contact, GIS Specialist, Park Staff Consulting: University and Agency Scientists, Statisticians, Contract Specialists.
Integration & Synthesis	Examination of patterns across vital signs within common sample frames; associations among indicators, stressors, and drivers; and tests of specific management-oriented questions, which will include: • Tests of hypothesized relationships, congruence among indicators, and covariate influences. • Development of analytical and predictive models. • Multimetric index development and application (indices of ecological integrity). • Evaluation of disturbance events. • Evaluation of effects of regional stressors (climate change). • Investigation of thresholds and transition phenomena. • Regional analyses, e.g., using marine data to examine how our intertidal dynamics relate to those coast-wide.	Leads: Network Coordinator, Network Vital Signs Contact, Project Managers, Support: Data Manager, GIS Specialist, Park Staff Consulting: University and Agency Scientists, Statisticians, Contract Specialists.

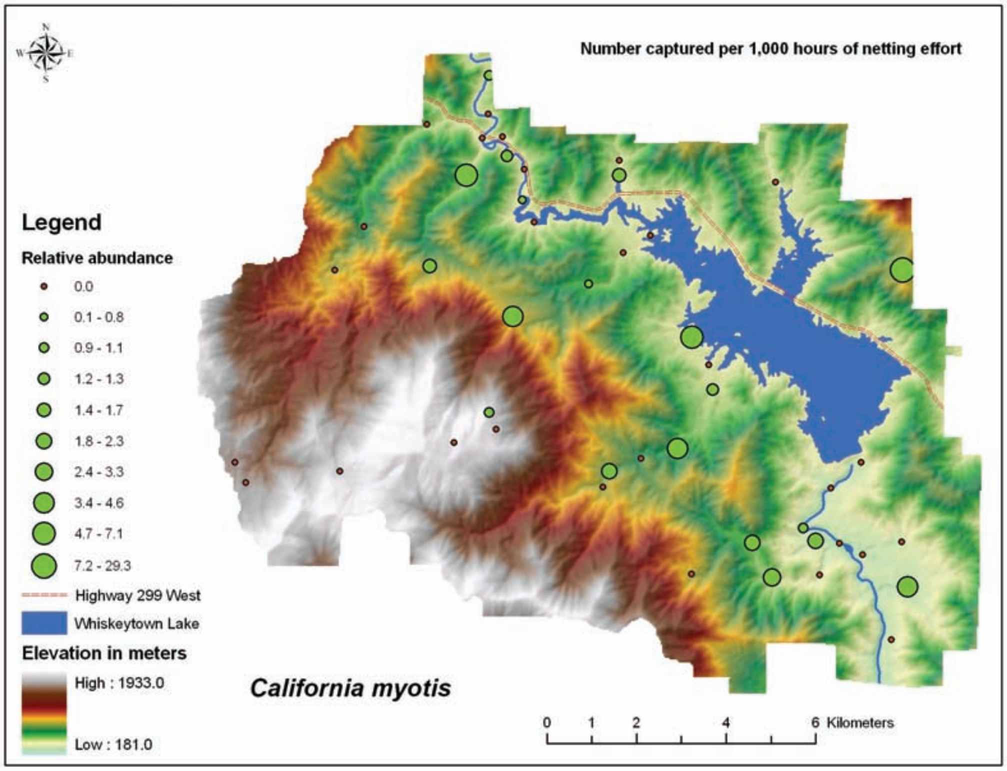


Figure 7.2. Bubble map of bat abundance at Whiskeytown National Recreation Area (from Morrell and Duff 2005).

Determination of Status and Trends in Park Vital Signs

The development of scientifically defensible estimates of the status and trends in park resources requires considerably more time and forethought than simple descriptive summaries. Moreover, estimates of the status and trends in park ecosystems will manifest themselves at different points in time and require distinctive analyses. The specific questions that will drive status and trends analyses are shown in Table 7.1. We discuss each category of analysis briefly below.

Status: In the early years of our program, we will be primarily concerned with evaluating the current status of the vital signs measured. Determination of status requires the development of statistically robust inference across the target population at a particular point in time. As mentioned in Chapter 4, sample designs for our vital signs have been selected to provide sufficient sample sizes at each field visit to obtain the most robust data within our budget and resource constraints. Consequently, vital signs such as invasive species, whitebark pine, vegetation, and birds cannot be sampled every year, nor can panels with water quality and aquatic community sites be sampled every year because this would unacceptably reduce the sample size and precision of status estimates. Sampling at two or three year intervals helps ensure that we can obtain more robust status information. Although each set of observations is only a “snap-shot” of the current level of the resource under study for a particular sampling season, robust inferences across the populations of interest can be of great use for understanding current baseline resource conditions and reporting them to park resource managers. A primary exception to our strategy of less frequent sampling with larger sample sizes will be for intertidal monitoring, which will involve sampling only three sites twice yearly.

However, the inclusion of the Redwood sites in the MARINe sampling frame will allow analyses to be conducted for the full array of over 80 core and biodiversity monitoring sites in California and Oregon, and over 40 sites within the more uniform Oregonian biogeographic province (Murray and Littler 1980).

For invasive species, whitebark pine, vegetation, bird communities, land cover, water quality (see Appendix E), and aquatic communities, we will develop spatial models that illustrate the mean abundances of target species, functional groups, and land cover classes or other parameters (e.g., stream pH) across the target population. Questions that will be addressed by the various data analysis methods are found in Table 7.1. For intertidal communities, specific summary charts and queries are available within the MARINe database and will be utilized to summarize and analyze the data. Preliminary spatial models to describe status of specific parameters across the target population for these vital signs will be developed using General Linear Models (GLMs). Such models will allow us to determine relationships between parameter estimates and measured environmental factors (Manly 2001). Where the sampled vital signs are continuous over space, such as landbird abundance, geostatistical models (e.g., kriging) will be developed to generate interpolated maps from point sampling data of the mean response variables and associated standard error terms (Maguire et al. 2005).

Summaries of community composition and structure (e.g., vegetation, birds, intertidal, cave entrance, and aquatic communities) will be developed using ordination and classification techniques to illustrate interrelationships among sites and parks (Gauch 1982, McCune and Grace 2002). A better understanding of the natural variation in species assemblages across the gradients in park ecosystems, including appropriate classifications of sites, will be highly valuable for distinguishing categorically different units and quantifying spatial variation. Along with these general community analyses, analyses of species variation within local replicates or across gradients and parks will be invaluable for distinguishing spatial from temporal variation in subsequent trend detection analyses (Philippi et al. 1998).

Multivariate indices of ecosystem condition, such as indices of biological or ecological integrity (IBIs, IEIs; Karr and Chu 1999) will also be explored. These have been most successfully applied in aquatic ecosystems, where disturbance or pollution effects have been well studied. For example, the Index of Biotic Integrity (Karr 1981), an early multivariate index, was developed to monitor the condition of streams using fish and macroinvertebrate data and was broadened to include stream channel and water quality parameters (Barbour et al. 1995, Karr and Chu 1999). More recently, indices have been developed and applied in riparian and wetland environments (Innis et al. 2000) and for terrestrial invertebrates (Kimberling et al. 2001) and bird communities (O'Connell et al. 2000). Although IEIs will be most useful for trend analyses, they will also be important for assessing the condition of local sites at specific points in time.

"Because major compositional changes involve parallel changes in a number of species or ecological parameters, they can provide compelling evidence that a meaningful ecological event has occurred or an ecological threshold has been exceeded"

Trend: Determination of significant trends in vital signs will require considerably more time than status, depending on the degree of variance and magnitude of change in each vital sign. Our primary questions with trend analyses are listed in Table 7.1.

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). Analyses of covariance (ANCOVA) procedures

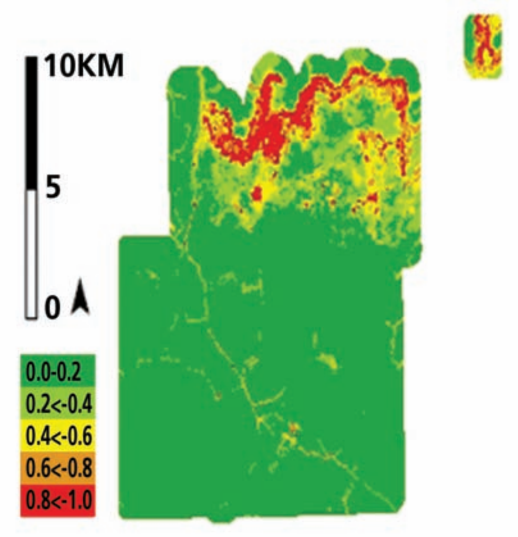


Figure 7.3. Predictive model of invasive plant *(Verbascum thapsus)* probability of presence at Lava Beds National Monument based on Random Forests analysis of pilot monitoring data (Edwards et al. 2007).

will be used to assess seasonal and temporal patterns of abundance for each of the target species at permanent intertidal monitoring sites (Miner et al. 2005). Geostatistical-temporal modeling (Kyriakidis and Journel 1999) will also be used to identify whether or not the spatial patterns in mean responses are changing over time (e.g., to compare "maps" of mean values developed from different field seasons). For vital signs that are concerned with investigating invasion processes, such as the invasive species and whitebark pine protocols, trends in spatial and temporal patterns of abundance will be valuable for predicting invasive spread (Higgins and Richardson 1996, With 2002). Invasive plant species and pathogen data will also be subject to modeling analyses to estimate spatial patterns in abundance as well as areas of most rapid spread. Unlike most analyses, these models will aim to predict beyond the current range of data to new sites in the parks. Such models will most likely be developed in partnership with outside scientists and will likely include some combination of spatial or mechanistic models, including, but not limited to, general linear or logistic regression, regression tree or random forest, reaction-diffusion, or metapopulation models (Higgins and Richardson 1996, With 2002, Edwards et al. 2007). An example of this modeling method is shown in Figure 7.3.

As with the determination of status, much of the information and insight about temporal change will be contained in multivariate datasets for each vital sign. Although detecting trends in multivariate data is more challenging than for univariate parameters, multivariate analyses can be particularly valuable when data for individual species are highly variable or are confined to presence or absence information (e.g., species richness in vegetation plots). 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). In other cases, we will want to track and evaluate cumulative changes in composition over time, such as with analysis using time dependent techniques of polar ordination (Beals 1984, Philippi et al. 1998). Figure 7.4 illustrates an ordination diagram that shows a clear trend in progressive change in species composition for a site over successive sampling intervals. Such site-specific analyses of ecological change can either be conducted for single sites (e.g., judgment sites) or for a sample of index sites.

Although we expect to see change over time in many if not all our sites, we are particularly interested in changes associated with human impacts. We believe that multivariate IEIs will be valuable tools to track such human-caused changes in our ecosystems through time. The most likely candidates for IEIs are those systems where ecological responses to impacts are well understood, such as in streams (Karr and

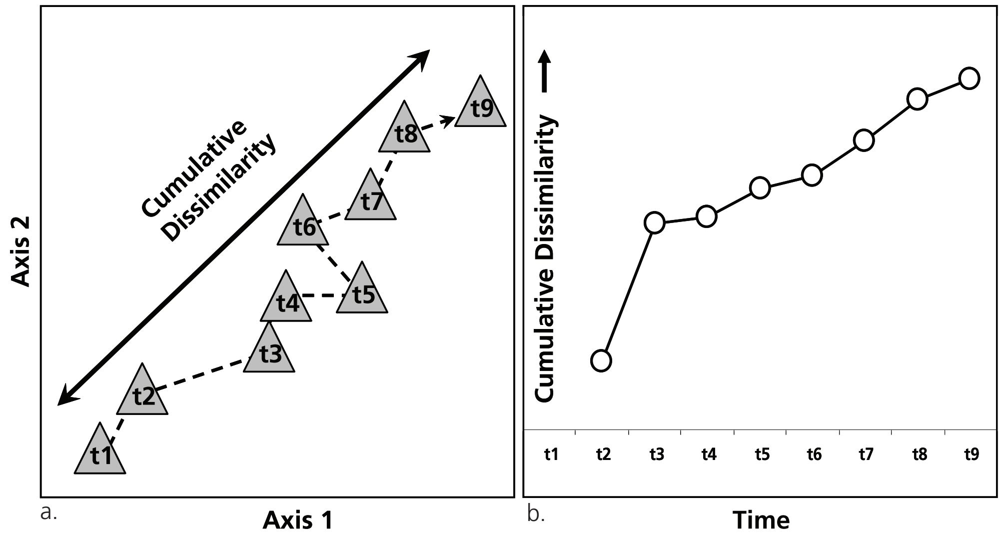


Figure 7.4 a and b. Cumulative change in species composition over nine sampling seasons.

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.

Chu 1999). However, we may be able to develop a broader suite of IEIs during our program. We anticipate that IEIs can be adopted or developed for our aquatic, intertidal, landbird, vegetation, and cave entrance community vital signs.

Ecological Dynamics and the Detection of Abnormalities: To provide early warning of abnormal conditions and impairment of selected resources, we will need to develop a quantitative understanding of what is "normal" at different locations in the terrestrial, freshwater, marine, and subterranean ecosystem domains. This may be one of the most challenging analysis problems we face. Exceptionally low or high values in most ecological parameters may be part of the natural range of variation and may be expected. For example, acorn masting events are an important reproductive strategy in native oaks. Even with pooled transect data, intertidal community monitoring of acorn barnacles at Redwood shows considerable variation within a short period of time (Figure 7.5). More broadly speaking, all ecosystems are dynamic, characterized by natural disturbance regimes (Pickett and White 1985, Wu and Loucks 1995, Poff et al. 1997) and long-term fluctuations in climate and biogeography (Whitlock and Bartlein 1997, Mohr et al. 2000, Weisberg and Swanson 2003). Relatively infrequent, extreme events are important parts of the disturbance regime in most natural ecosystems (Benda and Dunne 1997, Moritz 1997). Disturbance-mediated variation is important for biodiversity (Sousa 1979, Spies and Turner 1999, Odion and Sarr 2007), yet the dynamics are often highly nonlinear and vary with scale (Sarr et al. 2005a). When sampling time series are short, it is likely that any estimates of the range in "normal" conditions will be premature (Willis and Birks 2006). Therefore, we must proceed with caution in evaluating monitoring data for signs of abnormality.

To meet our monitoring goal of understanding long-term dynamics,

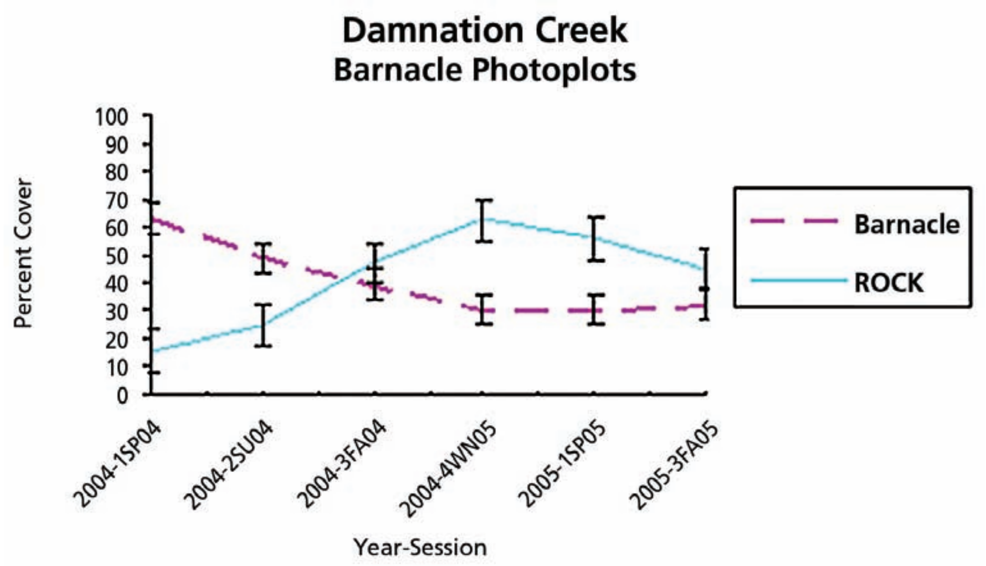
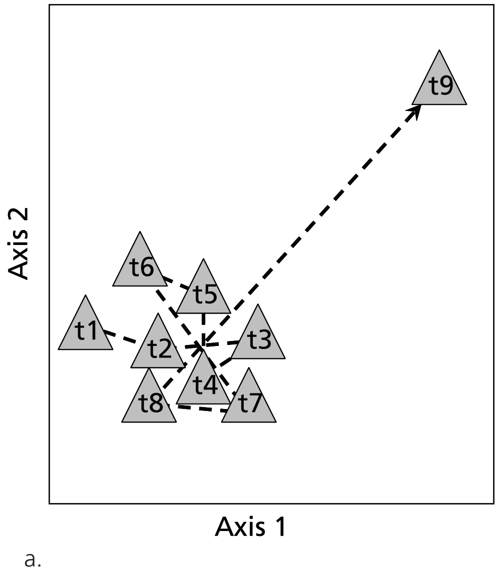


Figure 7.5. Example graph from two years of percent cover data for acorn barnacles *Chthamalus dalli, C. fissus*, and *Balanus glandula* and bare rock at Damnation Creek, REDW.

we will need to look for directional and cyclical phenomena across park landscapes and to interpret interrelationships among our vital signs. Initially, natural dynamics may appear as "noise" in our status and trend determinations. However, we expect that our understanding of such variations will evolve iteratively through cumulative observations of directional changes in species composition or other parameters following "natural experiments" such as fire, floods, and other disturbances, measurements of non-native and sensitive species abundances over time, close evaluation of spatial patterns (i.e., space for time observations), and joint analysis of climatic and disturbance, recruitment, or mortality events (Turner 1990, Allen and Breshears 1998, Veblen et al. 2000). Observations of cyclical phenomena in monitoring time series will be noted and covariance with other vital signs or environmental variables (e.g., weather) will be analyzed (McBean and Rovers 1998). To fully appreciate the frequency, magnitude, and ecological importance of natural dynamics will require synthetic analyses that span multiple vital signs and may also require inclusion of data from outside the parks. We will also need to be opportunistic and adaptive in our analyses to respond to changes we observe over time (Walters and Holling 1990, Gunderson and Holling 2001).

As the monitoring time series matures for each of our vital signs, the estimated mean, variance, and distributional forms will become increasingly robust and allow us to use traditional methods for detecting extreme values. These include outlier determination and control chart development (McBean and Rovers 1998, Anderson and Thompson 2004). Figure 7.6 illustrates the value of multivariate ordination and dissimilarity analyses for detecting "normal" and "abnormal" values from multivariate datasets over time. We expect to develop quantitative estimates for all our community vital signs that will allow such explorations. Major compositional changes involve parallel changes in a number of species or ecological parameters, they can provide compelling evidence that a meaningful ecological event has occurred or an ecological threshold has been exceeded (Anderson and Thompson 2004).



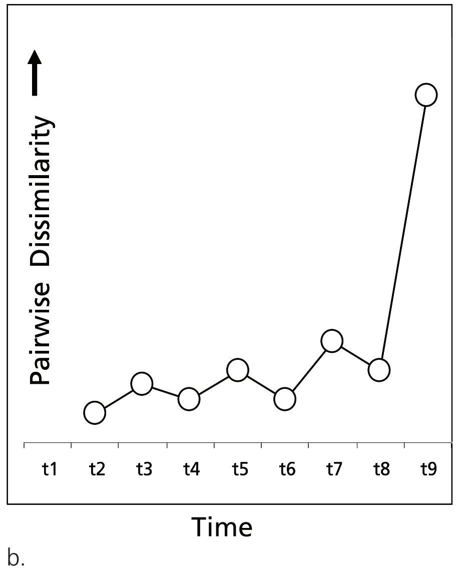


Figure 7.6 a and b. Year-to-year change in species composition over nine sampling seasons, with a major change at year nine.

a.) An idealized two-dimensional ordination diagram illustrating the compositional position of a site at time one through nine where Euclidean distances between each pair of years (i.e., time steps t1, t2...t9) are proportional to pairwise species dissimilarity. The dashed arrow follows the year-to-year change in composition. b.) A graph of pairwise dissimilarity between each pair of successive time steps from years one to nine. Note that the composition is similar, but slightly variable in years one to eight, with a major change in year nine.

Risk Assessment: For some vital signs, such as air and water quality, where stressors are known and critical thresholds established by state and federal regulations, such as sections 305(b) and 303(d) of the Clean Water Act, risk assessment principles and techniques will be employed (EPA 1992, Johnson 1998). Specific analyses will include development of Cumulative Sum (CUSUM) analyses (Manly 2001) for key water-quality parameters (e.g., air and water pollutants and stream water temperature) and tabulation of values approaching (within 20%) and exceeding air and water quality standards for Oregon and California. Such risk and condition assessment will conform to established analysis and reporting guidelines, such as a requirement to determine percent of stream kilometers impaired and to provide data that are compatible with EPA's STORET database. For other vital signs that indicate direct impacts to park ecosystems (e.g., non-native invasive species abundance, blister rust infection of whitebark pines), we will need to develop or adapt thresholds for determining ecological change and for triggering management actions (Wright 1999, Bestelmeyer 2006), recognizing that it may be challenging (Groffman et al. 2006).

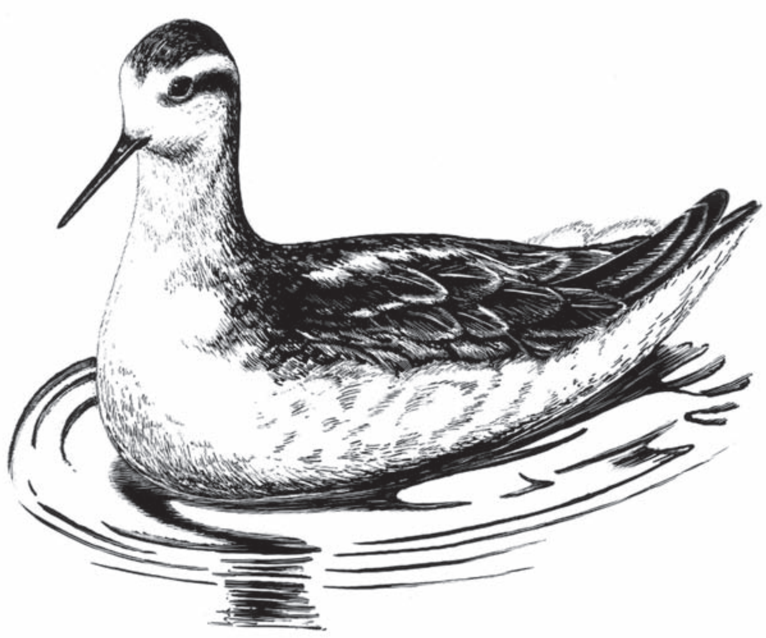
Integration and Synthesis

The Klamath Network vital signs are designed to function as self-sufficient monitoring programs for questions specific to the target populations of concern. The data collected will include individual parameters as well as more integrative multivariate information to provide context. To increase their value for park managers, we will also perform periodic syntheses of information across related vital signs to provide a more comprehensive view of environmental conditions across entire ecosystem domains. For instance, evidence for climate change will likely be detected in direct climate monitoring

"Determining how monitoring should inform management will also require knowledge about the scientific values and attributes of each vital sign, as well as their values for managers and the public."

and also through directional changes in the composition of vegetation, landbird, aquatic, and intertidal communities. Fire effects are likely also to be captured by shifts in a number of vital signs (e.g., vegetation, landbird communities, and water quality). Synthetic analyses (e.g., meta-analysis, Fisher 1970, Osenberg et al. 1999) that allow a weight-of-evidence approach to analysis will be particularly important for improving our understanding of such synoptic scale changes in park ecosystems that have wide-ranging effects.

Examples of synthetic analyses include tests of hypothesized relationships between drivers or stressors and vital signs, evaluation of congruence among indicators in response to far-field stressors (e.g., climate change), and development of predictive models. Comparisons of park or Network patterns with those reported in the literature or on adjacent lands will also be important. O'Connor et al. (2000) provided several useful recommendations and techniques for synthesizing data from multiple taxa to evaluate ecological conditions that would be appropriate for synthetic analysis of our vital signs data. They include covariate control to separate human and natural sources of variation, metric re-scaling to make different metrics statistically comparable, standardizing of the signs of taxa responses to disturbance to allow additive analyses, and dimensional reduction to constrain the numbers of input variables to a tractable level. Synthetic analyses will also require close interaction with academic and agency researchers, to ensure that findings from individual vital signs contribute to and are fully informed by outside research and monitoring. We anticipate that the program will make substantial contributions to general ecological knowledge that will be published in national and international level journals and related outlets.



Red-necked Phalarope

7.4. Reporting

Following the guidelines of the National Inventory and Monitoring Program, the Klamath Network has developed reporting requirements to ensure that we are meeting our objectives programmatically and for each vital sign. This section includes information about the following reporting tools:

Programmatic Reports

Annual Administrative Report and Work Plan
Program Reviews

Vital Signs Reports

Annual Vital Signs Reports
Analysis and Synthesis Reports
Comprehensive Synthesis Reports
Protocol Review Reports

Scientific Communication

Technical Bulletins, Journal Articles, and Book Chapters
Symposia, Workshops, and Conferences

Interpretation and Outreach

Klamath Kaleidoscope/Featured Creatures
Klamath Network Technical Briefs
Inter- Intranet Websites

Information about the target audience, reporting frequency, author(s), and review process for each reporting tool is provided in Table 7.2. In Chapter 9, we discuss how these reports fit into the larger schedule of Network activities.

Format

Each report type will be formatted to maximize its clarity and utility for the target audience(s). Generally, programmatic and vital signs reports will follow a specified format provided by the National I&M Program to ensure that our efforts can contribute to national level knowledge and agency reporting goals. All vital signs reports will conform to formatting guidelines specified at the NPS Natural Resource Publications Management website (http://nature.nps.gov/publications/nrpm/). Where feasible, those publications expected to gain wide distributions will aspire to the "best" formatting option described at the site. General scientific communications will follow the formatting and editorial guidelines specified by the appropriate journal, book, or symposium proceedings editor. Interpretation and outreach vehicles will be formatted following Klamath Network guidelines, except for the intra- and internet sites, which will conform to National I&M guidelines.

7.5. Linking Monitoring Science and Park Management

The intent of all the analyses and reporting strategies in this chapter and strategic planning efforts throughout this document is to provide scientifically-defensible information about the status and trends in the park resources measured. While this information will be vital to park managers, it is important to recognize that it comes with uncertainty. In many cases it will be necessary to conduct additional research and experimentation to test hypotheses about causal factors driving changes, and what should be done about them. It may be possible for managers to undertake this work within the context of adaptive management treatments. Determining how monitoring should inform management will also require knowledge about the scientific values and attributes of each vital sign, as well as their values for managers and the public. Bennetts et al. (2007) discuss the value of setting assessment points for levels of vital signs parameters. This may be a very valuable effort for the Network to pursue in the coming years of the program. For particular vital signs, such as water quality of lakes and streams, where likely stressors and responses are well-known, regulatory concepts of maximum or critical loads, provide rather clear guidance to development of management assessment points. For most of our ecosystems, however, critical ecological thresholds are not known at this time. Development of linkages between vital signs measurements and park management through identification of management assessment points may be a collaborative goal that will strengthen linkages between monitoring science and park management in the Network.

Table 7.2. Major report types, with purpose, target audience, frequency, authors, and review process.

REPORT TYPE	PURPOSE	TARGET AUDIENCE	FREQUENCY	AUTHOR(S)	REVIEW PROCESS
Programmatic Reports					
Annual Administrative Reports and Work Plans	• Account for funds and FTEs expended over the fiscal year. • Plan yearly work flow. • Describe objectives, tasks, accomplishments, products of the monitoring effort. • Improve communication within park, network, and region. • Report annual Network summary to Congress.	Superintendents, SAC, KLMN staff, Regional Coordinators, Service-wide program managers	Annual	KLMN I&M staff	Reviewed and approved by PWR Regional Coordinator and Service-wide program manager.
Program Reviews	• Perform periodic formal reviews of operations and results (at 5-year intervals). • Undertake the quality assurance and peer review process.	Superintendents, resource managers, KLMN staff, Service-wide program managers, external scientists, partners	5-year intervals	Network Coordinator, PWR I&M Coordinator, National Program Manager	Results of external, blind peer review with at least five subject-matter experts, including one statistician and one monitoring program manager.
Vital Signs Reports					
Annual Vital Signs Reports	• Summarize annual data and document monitoring activities for the year. • Describe current condition of the resource (determine status). • Document changes in monitoring protocols. • Increase communication between the parks and KLMN.	Superintendents, resource managers, KLMN staff, Service-wide program managers, external scientists, partners	Prepared each sampling season for each vital sign	Network Contacts, Project Managers,	Peer reviewed at the Network level.
Analysis and Synthesis Reports	• Determine patterns/trends in condition of resources being monitored. • Discover new characteristics of resources and correlations among resources being monitored. • Analyze data to determine amount of change that can be detected by the type and level of sampling. • Recommend changes to management of resources (feedback for adaptive management).	Superintendents, resource managers, KLMN staff, external scientists	3-5 year intervals	Network Contacts, Project Managers, consulting scientists	Peer reviewed at the Network level.
Comprehensive Synthesis Reports	• Determine patterns/trends in condition of resources across multiple vital signs. • Develop integrative indices (IEIs) to assess condition of ecosystem domains. • Place data for the park within a multi-park, regional or national context. • Recommend changes to management of resources (feedback for adaptive management).	Superintendents, resource managers, interpreters, public, scientific community	Usually after 3-5 sampling cycles (6-15 years)	Network Contacts, Project Managers, consulting scientists	Peer reviewed at the Network level.
Protocol Review Reports	• Review protocol design and products to determine whether changes are needed. • Perform quality assurance and peer review.	Superintendents, resource managers, KLMN staff, Service-wide program managers	5-year intervals	Network Contacts, Project Managers	Peer reviewed at regional and/or national level, KLMN Board of Directors, Technical Committee.

Table 7.2. Major report types, with purpose, target audience, frequency, authors, and review process (continued).

REPORT TYPE	PURPOSE	TARGET AUDIENCE	FREQUENCY	AUTHOR(S)	REVIEW PROCESS
Science Communications					
Technical Bulletins, Journal Articles, and Book Chapters	• Expose I&M activities to larger scientific community. • Subject I&M activities and approaches to unbiased peer review. • Make scientific contributions to ecological and monitoring science. • Elevate scientific standing and authority of program.	KLMN staff, resource managers, external scientists	Variable	KLMN staff, Program Managers, consulting scientists	Peer reviews directed by Regional or National I&M Program, journal, or book editor.
Symposia, Workshops, and Conferences	• Expose I&M activities to regional or national scientific community. • Elevate scientific standing and authority of program. • Communicate to scientists or managers.	Resource managers of federal and state agencies, scientific community	Variable	KLMN staff, Program Managers, consulting scientists	May be peer reviewed by editor if written papers are published.
Interpretation and Outreach					
Klamath Kaleidoscope / Featured Creatures	• Distill scientific findings into non-technical articles. • Provide forum for frequent communication with parks and interested public. • Provide information to interpretation programs. • Showcase the unique biodiversity of the KLMN.	Park staff, agency partners, cooperators, interpreters, public	Biannual by email and on KLMN website	KLMN staff with contributions from NPS and outside scientists	Peer reviewed at Network level.
Klamath Network Technical Briefs	• Condense summary of key findings from inventory and monitoring activities. • Introduce topics explored in further depth in technical reports and scientific manuscripts.	Park resource managers, KLMN staff, external scientists	Occasional, linked to publication of major technical reports or other key findings	KLMN staff, Project Managers	Peer reviewed at Network level.
Inter- Intranet Websites	• Create web-presence for Network. • Provide access point for reports and resources. • Serve as internal hub for NPS-specific documents.	Superintendents, resource managers, KLMN staff, Service-wide program managers, external scientists, public	As reports are finalized	KLMN staff	Only reviewed, finalized products without sensitive information will be posted to the internet. NPS specific or sensitive material may be posted to the intranet.

Chapter 8: Administration/Implementation of the Monitoring Program

8.1. Overview

This chapter describes the Klamath Network's plan for administering the monitoring program. The Network has developed a five-year (FY 2008-2012) plan under which we will develop and implement monitoring protocols for our core vital signs. In this chapter, we describe the governing bodies that will guide the Network and the staff that will implement the monitoring. We also explain how the Network and park operations will be integrated and in-house fieldwork carried out. We conclude by describing partnership opportunities and the periodic review process for the program.

8.2. Administration

Governing Structure

The governance of the Klamath Network Inventory and Monitoring Program is directed by a charter that defines permanent and ad hoc advisory and decision-making bodies. These groups are composed of senior administrative and natural resource staff in each park of the Network, with periodic participation by USGS and university scientists.

Klamath Network Charter: The KLMN charter describes the process used to plan, manage, and evaluate the monitoring program within the Network in accordance with the intent and purpose of the National Park Service Natural Resource Challenge. It stipulates the governance structure of the Klamath Network I&M Program and provides a schedule for participation by Superintendents and Natural Resource Chiefs of each park, as well as selected Pacific West Regional representatives. Three executive and advisory bodies play important roles in the governance, administration, and scientific guidance of the KLMN I&M Program: the Board of Directors, the Technical Advisory Committee, and the Scientific Advisory Committee.

Board of Directors: Overall direction for the Klamath Network is provided by a Board of Directors. The Board is composed of all six Park Superintendents, the Deputy Regional Director for the Pacific West Region, two rotating Natural Resource Chiefs, and the Regional and Network Inventory and Monitoring Coordinators. The Board meets each year in early winter after the fall Technical Advisory Committee meeting to facilitate action on any recommendations for the fiscal year. Final authority on the overall program rests with the Board of Directors.

Technical and Science Advisory Committees: The Network has an eight-member Technical Advisory Committee, composed of Natural Resource Chiefs from each of the six parks, the Network Coordinator, who serves as chair, and the Network Data Manager. The Technical Committee meets once per year, usually in September, to discuss and make decisions on the technical aspects of designing and implementing the program for the coming fiscal year, and to find ways to integrate inventory and monitoring with other research or management efforts. For decisions on permanent hiring of staff, significant allocations of funds, or the overall direction of the program, the committee makes recommendations to the Board of Directors. A Science Advisory Committee composed of the Technical Advisory Committee and additional NPS, USGS, and university scientists meets on an ad-hoc basis to provide scientific reviews, comments, and advice to the program.

"The Klamath Network Board of Directors and Technical Advisory Committee meet each year to ensure that I&M activities are integrated within the larger context of park management."

Staffing Plan

The formal staffing requirements for the program have been developed by the Network to provide adequate capacity to implement the monitoring program while retaining flexibility for future adjustments. Generally, a core staff will provide day-to-day management and oversight of the program, with supplemental staffing from the parks, universities, nonprofit partners, volunteers, and other agencies.

Core Network Staff: Four positions compose the "core staff" of the KLMN, including three technical professionals, the Network Coordinator, Data Manager, and Aquatic Ecologist, and the Program Assistant, who provides support for them. The technical professionals share responsibility for vital signs planning and, together with affiliated park staff and cooperators, will implement the program. The professional staffing structure has been designed with the expertise required to design, execute, evaluate, and report findings about a vital signs monitoring program encompassing terrestrial, subterranean, freshwater, and marine ecosystems. The Network Coordinator and Data Manager positions are permanent; the Aquatic Ecologist and Program Assistant positions are temporary, with the possibility of conversion to permanent in the future. The core staff is duty stationed at the Klamath Network I&M Office in Ashland, Oregon.

Supplemental Staffing: In addition to the Network's core staff, we expect to hire a number of seasonal employees to implement the fieldwork required by the program. They will be supervised by the core staff or by designated leads in each park, hereafter park leads. In addition, outside entities will have an important role in implementing the program. During the three-phase monitoring plan and protocol development process, Southern Oregon University provided the Network with a Technical Writer/ Ecologist and GIS Specialist, while USGS provided an Aquatic Ecologist. We expect that the continued services of these positions will be required during the first years of program implementation. In addition, we are utilizing staff from the University of California, Santa Cruz for monitoring of intertidal communities, and from the Klamath Bird Observatory to conduct landbird monitoring. Figure 8.1 illustrates the expected staffing structure at full program implementation (FY 2009 and beyond). The roles, responsibilities, affiliations, durations, and duty stations of all supplemental staff will depend on the requirements described in the monitoring protocols. Interagency agreements, cooperative agreements, and contracts are used to obtain supplemental staff.

Roles and Responsibilities: The program integrity depends upon rigorous design and implementation at all stages, therefore all employees and partners will need to be aware of the standards and time required to accomplish monitoring objectives. The Network's core staff will develop and update protocols and standard operating procedures for each vital sign to ensure that all employees are aware of programmatic expectations. Decisions to use park-based positions as project managers and/or crew members on monitoring teams will only be exercised when the following requirements can be met: 1) capable staff already exist at the park and are available to conduct monitoring; 2) the park can provide work space; 3) there are mechanisms in place to assure that the work can be completed following the guidelines in the monitoring protocol, data management plan, and the schedule established in the annual work plan; and 4) the employee's supervisor has approved of the activity and ensured the KLMN Board of Directors that the park can allocate the employee adequate time and logistical support to fulfill the obligation to the I&M Program; 5) I&M duties will be included in the employees yearly performance evaluation. Managing individual performance and seeing that park employees carry out their assigned duties according to established protocols is the responsibility of their park supervisor. Communication is especially important when a park employee is assigned to the responsibility of collecting data for the Network. In these instances, it is essential that the primary supervisor interact with the Network Contact to develop and evaluate employee performance, as established in the annual employee performance plan.

If the core staff of the Network is not directly supervising any aspect of a vital sign monitoring project, the Network Coordinator will designate one technical professional as the Network Contact for that project. It is the Network Contact's responsibility to ensure protocols and SOPs are being properly implemented, review all reports and publications, act as a point of contact for the parks and the Project Manager, and be familiar with all activities of that particular project.

Training and Professional Development: All dedicated staff charged with executing the I&M Program will be expected to possess or obtain adequate field, planning, data management, writing, and statistical skills necessary to complete their duties. Professional development through personalized training programs, workshops, and study curricula will be made available to all program staff and will be reviewed and updated in annual personal development plans. Where possible, the Network will arrange workshops that allow for the efficient training of core and supplemental staff.

Administrative Structure

Administrative Support and Office Location: The Network receives its base administrative support from its host park, Redwood National and State Parks. This support includes personnel functions such as: 1) position classification, recruitment, human resources functions, and development; 2) budget management and contracting; 3) information technology support, and 4) property management and inventory. The Program Assistant works closely with all park-based or university-

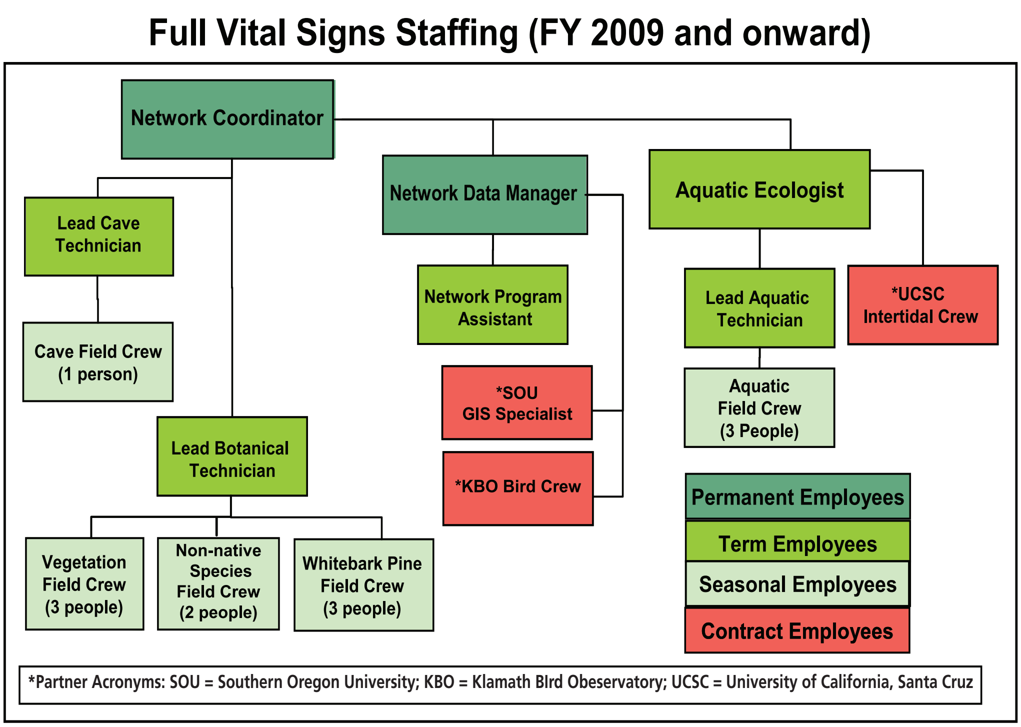


Figure 8.1. Staffing structure for the Klamath Network at full program implementation (FY 2009 and onward).

based administrative personnel and provides local administrative support needs in the network office. Most cooperative agreements are coordinated and processed directly through the Cooperative Ecosystem Studies Unit Offices, with some administrative assistance provided by the Pacific West Regional Office. The Klamath Network provides funding through one such agreement to pay for electronic infrastructure to maintain an administrative office on the campus of Southern Oregon University.

Supervision: The Network Coordinator is supervised by the Pacific West Regional I&M Coordinator, with yearly review and input by the KLMN Board of Directors. The Network Coordinator supervises the other NPS employees in the program, who supervise seasonal employees operating under each vital sign subprogram (Fig. 8.1).

8.3. Operations

The NPS I&M Program is intended to be a well-designed system that provides adequate resources for planning, data collection, management, analysis, reporting, and periodic program review and refinement. As such, the operational details of the program must begin with the mastery, by every Project Manager, of the monitoring objectives and schedule for the vital signs. In addition, they need to have a detailed knowledge of the staffing resources, schedule, sampling locations, and logistical needs for each phase of sampling. In a given year, several phases of activities will be required, from pre-field preparations through data entry and validation. (See Appendix E for supplemental water quality information.)

Pre-Field Preparations

For each year that sampling is scheduled, the Project Manager for a given vital sign will need to review the expected timing and locations for field visits within the parks; evaluate staffing, housing, and vehicle requirements; and obtain and check necessary field equipment. By early winter, the Project Manager should contact resource and administration staff in each park to inform them of the field schedule and any logistical needs. Before start of the field season, staff will need to be hired, vehicles procured, equipment, maps, and field forms prepared, and any necessary training scheduled.

Field Sampling

Safety of field personnel is the first concern that needs to be recognized in all phases of the planning and implementation process. Not all safety concerns are self-evident. Numerous safety concerns may arise as field personnel have potential to contact waterborne pathogens, chemicals, and potentially hazardous plants and animals. Weather conditions can be extreme. Fieldwork requires an awareness of potential hazards and knowledge of basic safety procedures. It is the responsibility of the Project Manager to ensure that field crews are familiar with all relevant safety procedures, to provide for safety checklists, and to ensure that employees are referred to Chapter A9 of the USGS National Field Manual for recommended safety procedures. In addition, employees are instructed to contact local park safety officers for current information regarding local problems or issues such as disease, wildlife, fire, or avalanche hazards.

Training

Because it is likely that the program will endure considerable turnover in staff through time, particularly for seasonal employees, effort will need to be placed on training new staff and on refreshing permanent or returning seasonal staff each year. Well-trained employees are essential for continuity and maintenance of a successful quality assurance program. The development of standard operating procedures alone does not guarantee that high-quality data will be collected. Training programs will assist field and laboratory staff in obtaining a clearer understanding of planned data collection procedures; the programs should include a documented trainee certification process. When applicable, a training manual should be developed to provide guidance about the training process. The Project Manager will see that employees engaged in monitoring have adequate skills and experience to conduct monitoring.

Field Equipment

The I&M Program will provide the equipment and supplies necessary to conduct monitoring of each vital sign being implemented by NPS staff. Property and equipment will be managed according to NPS property management guidelines. Sensitive property (e.g., cameras, computers, radios, and binoculars) will be managed as accountable. The purchase of equipment likely to depreciate will be scheduled to reduce the impact of replacing substantial amounts of equipment in any given year. Calibration of equipment will follow manufacturer directions and will be included as part of an appendix or an SOP to the relevant monitoring protocol. Vehicles will normally be leased through General Services Administration, unless the KLMN Board of Directors decides to purchase one or more field vehicles in the future. For projects implemented by non-NPS organizations, it is the organization's responsibility to provide all necessary equipment.

Laboratory Analysis

Where laboratory analyses are required, such as for water quality and aquatic community monitoring samples, consistent processing standards will be stipulated in the protocol for inclusion in any cooperative agreements or contracts with universities or private laboratories. Field crews will be trained in relevant SOPs for specimen collection to ensure that samples and vouchers are properly obtained and archived.

8.4. Integration and Partnerships

The Klamath Network Board of Directors and Technical Advisory Committee meet each year to ensure that I&M activities are integrated within the larger context of park management. Either at the annual Board of Directors Meeting or soon thereafter, the Board Chair and Network Coordinator meet with the Chiefs of Interpretation from all six parks to discuss collaborative opportunities for outreach and education. In addition, the Network Coordinator and other I&M staff maintain ongoing communication with technical leads from the Fire Program, the Crater Lake Science and Learning Center, and the Exotic Plant Management Teams to share details of the Network's operations and potential collaborative opportunities. The Network Coordinator also participates in the preliminary review of network-related research proposals, to help keep abreast of research needs, share technical advice, and clarify relationships between I&M activities and park information needs.

"Active partnerships will help us bring the best possible science to the service of the parks and ensure that our efforts contribute to regional science, conservation, and education."

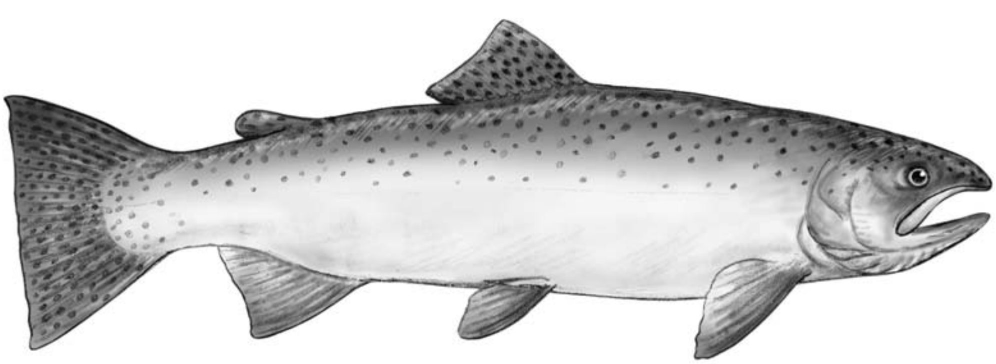
The KLMN I&M Program has established and proven partnerships with a variety of federal and nonfederal partners. A primary partner is the US Geological Survey, Biological Resource Division. The Klamath Network actively works with scientists at both the Forest and Rangeland Ecosystem Science Center and the Western Ecological Research Center. The Network is an active participant in the Pacific Northwest and California Cooperative Ecosystem Studies Units, through which we have active task agreements with Southern Oregon University, Oregon State University, University of California, and University of Idaho. The Network is also in the process of completing a cooperative agreement with the Klamath Bird Observatory for bird monitoring and associated research. We intend to maintain and expand our array of partnerships and collaborations in all stages of our program, from scoping and project planning to collaborative field research and scientific publication. Active partnerships will help us bring the best possible science to the service of the parks and ensure that our efforts contribute to regional science, conservation, and education.

8.5. Periodic Program Review

A schedule for periodic review of the monitoring program will be added to the Network's charter to encourage continuous improvement and modification of the program. Presently, the first program review is planned for FY 2010. Additional reviews will be conducted at five-year intervals thereafter, and may also be initiated by the Network Coordinator. Each program review will consist of an external, blind peer-review with at least five subject-matter experts, including one statistician and one monitoring program manager. Reviews will focus on scientific rigor, implementation of the program, and achievement of programmatic goals and specific monitoring objectives. After each review, the KLMN Technical Advisory Committee will evaluate which program review recommendations to implement and how and when to implement them. The evaluation will be presented to the KLMN Board of Directors for review and approval before work commences.

Periodic protocol reviews will be the chief means to assess and adjust individual elements of the monitoring program. Protocol reviews will commence after 3-5 years when the first Analysis and Synthesis Report (Chapter 7) is issued for a given vital sign. Depending upon the vital sign, the review process may involve outside scientists with specific knowledge of the subject material and no obvious conflicts of interest with respect to the topic. Alternatively, a workshop panel may be convened to review the protocol. After each review, the Technical Advisory Committee will prepare a list of actions to meet the peer review recommendations.

Additional formal and informal peer review will occur during the scientific publication process, presentations at scientific meetings, and discussions with other monitoring program staff. All input that might improve the I&M Program will be presented to the Technical Advisory Committee for further discussion, and possible consideration by the Board of Directors.



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Chapter 9: Schedule

9.1. Overview

In the first few years of the program, we must move from conceptual and logistical planning to protocol development and peer-review to monitoring implementation. This chapter describes the schedule for implementing the Klamath Network Vital Signs Monitoring Program and for conducting field sampling.

9.2. Implementation and Sampling Schedules

The planning process for most of the vital signs is already underway. General goals and monitoring objectives have been prepared in Protocol Development Summaries for all the core vital signs (Appendix I; water quality and aquatic communities also detailed in Appendix E.). In Table 9.1, we describe the implementation timeline for each of our vital signs protocols. Similar to the phased process each network takes to develop a monitoring plan, the Klamath Network is taking a phased approach to the implementation of vital signs monitoring. At present, we anticipate that the protocols will be implemented in three phases, the first starting in FY 2008, the second in FY 2009, and the final in FY 2010. Two additional vital signs elements are being considered for implementation after FY 2010, but pursuit of these elements will depend upon the outcome of current research (for aspen stands), cost-effective collaborative monitoring opportunities (for terrestrial amphibians), and the availability of sufficient funding. The Klamath Network will conduct periodic data analyses for the unfunded Air Quality and Climate Vital Signs in correlation with the analysis and synthesis reports that will be completed every 3-5 years (Chapter 7). Data for these analyses will be collected from a variety of established organizations, including the Western Regional Climate Center, the National Climatic Data Center, and the NPS Air Resources Division. In assigning a target year for protocol implementation, we have estimated the time required to resolve remaining informational or logistical needs through pilot studies, database development, plot installation, equipment purchase and calibration, and hiring and training of staff.

Table 9.1. Schedule for protocol development steps, review, revision, and implementation, calendar year 2007-2012; depicts the implementation schedules and expected sampling years for the 10 core vital signs. The implementation schedules vary somewhat depending upon the availability of existing data or protocols.

	2007				2008				2009				2110				2111				2112			
	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL
Non-native, Invasive Species Early Detection																								
Park Scoping Meeting	■																							
Protocol Development	■	■	■																					
Pilot Study			■	■																				
Protocol Refinement				■	■																			
Peer Review						■	■																	
Protocol Revision & Approval								■	■															
Implementation (1-0, alternate yr sampling)										■	■	■						■	■	■				
Whitebark Pine																								
Park Scoping Meeting				■																				
Protocol Development				■	■	■																		
Pilot Study							■																	
Protocol Refinement								■	■															
Peer Review									■	■														
Protocol Revision & Approval										■														
Implementation (1-2, Each site revisited every 3rd yr)										■	■	■		■	■	■						■	■	■
Terrestrial Vegetation																								
Park Scoping Meeting	■																							
Protocol Development		■	■	■	■	■																		
Pilot Study							■	■																
Protocol Refinement								■	■	■														
Peer Review									■	■														
Protocol Revision & Approval										■														
Implementation (1-2, Each site revisited every 3rd yr)										■	■	■		■	■	■		■	■	■		■	■	■
Landbird Monitoring																								
Park Scoping Meetings	■		■																					
Protocol Development	■	■	■																					
Pilot Study (Pilot Inventories 2002-2006)	■	■	■																					
Peer Review				■	■																			
Protocol Revision & Approval					■	■																		
Implementation (1-1, Each site revisited every other yr)						■	■			■	■			■	■			■	■			■	■	

Table 9.1. Schedule for protocol development steps, review, revision, and implementation, calendar year 2007-2012; depicts the implementation schedules and expected sampling years for the 10 core vital signs. The implementation schedules vary somewhat depending upon the availability of existing data or protocols. (continued).

	2007				2008				2009				2110				2111				2112			
	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL
Intertidal Protocol																								
Park Scoping Meeting	■																							
Protocol Development	■	■																						
Pilot Study	■	■																						
Protocol Refinement		■																						
Peer Review		■	■																					
Revision & Approval				■	■																			
Implementation (1-0, sampling two times/year)						■		■		■		■		■		■		■		■		■		■
Integrated Aquatic Protocol																								
Park Scoping Meeting	■																							
Protocol Development		■	■	■	■																			
Pilot Study						■	■																	
Protocol Refinement							■																	
Peer Review								■	■															
Revision & Approval									■	■														
Implementation (1-2, Each site revisited every 3rd yr)										■	■			■	■			■	■			■	■	
Land Cover, Use, Pattern Protocol																								
Park Scoping Meeting				■																				
Protocol Development				■	■	■	■																	
Pilot Study								■																
Protocol Refinement									■															
Peer Review										■	■													
Revision & Approval												■												
Implementation (1-2, Each site revisited every 3rd yr)														■	■									
Integrated Cave Monitoring Protocol																								
Park Scoping Meeting					■																			
Protocol Development																								
Pilot Study										■	■													
Protocol Refinement											■													
Peer Review												■	■											
Revision & Approval													■	■										
Implementation (1-1, Each site revisited every other yr)														■	■							■	■	

Table 9.2. Type, seasonal timing, and intensity of sampling for the eight monitoring protocols and two unfunded vital signs; illustrates the type, seasonal timing, and intensity of sampling for each of the protocols during a given sampling year. Most of our field sampling will occur in the summer season, with non-summer activities consisting of primarily data collection from automated instrumentation. This approach will allow data analysis, synthesis, and reporting activities for most vital signs to occur each winter.

VITAL SIGN	SAMPLE TYPE	MONTH											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Non-Native, Invasive Species	FS				////	////	////	////	////	////			
Whitebark Pine	FS						/ /	////	////	/ /			
Vegetation Communities	FS				////	////	////	////	////	////			
Landbird Communities	FS					////	////	/ /	/ /	/ /			
Intertidal Communities	FS, AS				*		/ /				*		/ /
Integrated Aquatic	FS, AS				*		/ /	////	////	/ /	*		
Land Cover, Use, Pattern	RS	/ /	/ /	/ /									/ /
Integrated Cave	FS, AS				*		/ /	////	////	/ /	*		
[U] Air Quality	DS	/ /	/ /	/ /									/ /
[U] Climate	DS	/ /	/ /	/ /									/ /

//// = Full-time
/ / = Part-time
* = Single Park Visit
(data download from automated instrumentation).

FS = Field Sampling
AS = Automated Sampling
RS = Remote Sensing
DS= Data Summary
U= Unfunded Vital Sign

Chapter 10: Budget

10.1. Budget Overview

In this chapter, we present a five-year budget for the Klamath Network monitoring program. Two primary sources of funding support the Klamath Network I&M Program. They are the vital signs monitoring funds from the Natural Resource Challenge ($796,200 / year), and $76,000 / year for water quality monitoring provided by the NPS Water Resources Division.

Natural Resource Challenge funds for the program are held in Washington Office base accounts and transferred annually through the Pacific West Regional Office to Redwood National and State Parks, the Network's host park. All funds are managed by the Klamath Network Coordinator under the auspices of the Board of Directors with assistance from the Budget Officer at Redwood. The Board approves the Annual Work Plan, with input from the Technical Advisory Committee. The work plan directs expenditure of funds to projects, parks, and offices.

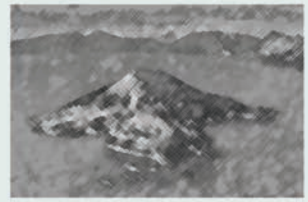
10.2. Implementing the Vital Signs Program

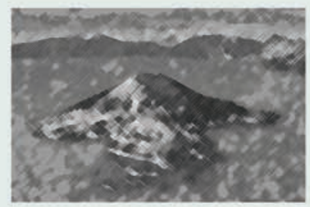
Here we provide a view of the program budget during the first five years of operation after review/approval of our plan. We anticipate that this period will begin in FY 2008. By showing a five-year period, we can illustrate the phasing in of our vital signs monitoring, as well as the variation in allocations across years. All of our vital signs will be monitored at five year or shorter revisit intervals (Chapter 4), so a complete monitoring cycle for all vital signs is included. Table 10.1 shows the Network budget using the same expense categories networks use when preparing the Annual Administrative Reports and Work Plans that are submitted to Congress. We anticipate that the annual vital signs and water quality appropriations will be fixed, with the exception of cost of living adjustments for federal employees. During our first five years of implementation, we anticipate allocating 46-64% of the budget annually to personnel. This personnel expenditure includes permanent staff, term staff, and seasonal help for field sampling.

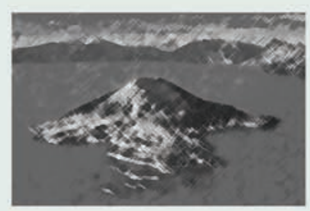
Cooperative agreements are used to obtain staffing for several of our vital signs and for maintaining the Network infrastructure at Southern Oregon University. Expenditures on agreements will range between 13-20% of the annual budget during the five-year period. We intend to purchase major equipment for all vital signs in the program in 2008, when approximately 20% of the total funding will go to operations/equipment. Thereafter, we expect operations/equipment to range between 10-15% of the annual budget. Travel is expected to consume 3-6%, and miscellaneous and contingency expenses between <1% and 9% of the annual budget. Some variation in miscellaneous and contingency expenses occurs due to alternating sampling intensities for different years and changes in staffing costs through time.

The Klamath Network has explored a variety of implementation schedules for the vital signs program. It was clear under all scenarios we considered that costs will increase through time and the amount available for vital signs implementation will decrease proportionately. It was equally apparent that what seems feasible in the first several years of the program may prove untenable in the future unless flexibility is maintained. Consequently, we have chosen to develop a fiscally conservative program that will ensure that the program can accomplish its goal of monitoring vital signs through time with the appropriation provided. We used the following considerations in the preparation of the program budget:

- All vital signs must remain within 10% of projected funding levels at 10 years into the program.







- Costs of permanent and term employees will increase at 5% per year.
- Seasonal salaries and all other expenses will increase at 3% per year.
- Agreements will not adjust annually, but will be renegotiated at 5-year intervals to reflect inflation rates.
- All vital signs monitoring can be conducted with Natural Resource Challenge and Water Resources Division funds.
- All vital signs measurements can be conducted by network-funded field crews or partners. Augmentation of network crews with park-based staff will be conducted where they can be made available for sufficient time to contribute materially to the project sampling season.
- Funds for miscellaneous and contingency expenses will be maintained at approximately 5% of the annual budget to address periodic and nonrecurring expenses, such as protocol and program review, equipment replacement or repair, and to obtain outside assistance with development or review of Analysis and Synthesis Reports.

Partnerships and additional funding will be pursued wherever feasible to augment the vital signs measurements

Initial projections have shown that full implementation of all 10 vital signs monitoring protocols each year will be impossible with the fiscal resources available. As a result, the Network has discussed the implications of different sampling frequencies for each vital sign. For all vital signs except intertidal monitoring, annual sampling was not considered essential to meeting our data analysis and reporting goals (Chapter 7). However, annual field visits will be necessary for those vital signs that will use large sample sizes in extensive panel designs (i.e., vegetation, landbirds, aquatic communities, and water quality). For the remaining vital signs, we expect to conduct fieldwork in alternate years or to alternate sampling intensity by year to increase affordability and logistical efficiency. Figure 10.1 shows the costs of core staffing and fixed infrastructure and outreach costs and the annual allocation toward each vital sign from FY 2008-2012.

10.3. Budgeting for Data and Information Management

A fundamental theme in the NPS I&M Program is the allocation of detailed planning and resources for data and information management (Appendix J). The Klamath Network has explicitly planned for this in the staffing structure, allocation of duties for each core staff member, and in our collaborations and partnerships. Table 10.2 displays the projected allocations to information management in FY 2008. Generally, within-NPS expenditures to information management are 20-50%, depending upon the staff member's primary duties. Financial allocations within cooperative agreements are comparable. For non-NPS Project Managers, we provide detailed guidance for appropriate data management procedures and expected financial contributions to information management activities throughout the life cycle of any NPS-funded project.

10.4. Program Development

To augment the modest budgets that the program allows for each vital sign, we will actively pursue additional funding and collaborative relationships with the parks, other NPS programs, and outside partners wherever feasible and appropriate. In many cases, supplemental staffing and funding relationships will be short-term in nature, with specific research, inventory, or monitoring objectives that supplement our vital signs goals. When sources of permanent funding or staffing can be located, they will be incorporated into the vital signs budget in future amendments to the monitoring plan. All changes to the monitoring plan will undergo review by the Klamath Network Technical Advisory Committee and ratification by the Klamath Network Board of Directors.

Table 10.1. Annual budget for the Klamath Network I&M Program with income and major expenses, 2008-2012. All values are in $1000s.

INCOME AND EXPENDITURES (X $1000)					
CATEGORY	2008	2009	2010	2011	2012
Income					
Vital Signs Monitoring	796	796	796	796	796
Water Quality	76	76	76	76	76
Projected Cost of Living Adjustments	0	12	30	49	69
Total Income	872	884	903	921	941
Personnel					
Permanent Positions					
Network Coordinator (GS-12)	94	99	104	109	115
Data Manager (GS-11)	79	83	87	92	96
Term Positions					
Aquatic Ecologist (GS-11)	77	81	85	89	94
Program Assistant (GS-7)	58	61	64	67	70
Lead Biotech (GS-7; 0.75 FTE)	30	46	48	51	53
Temporary Positions					
Field Sampling Crews	66	174	168	139	178
Total Staff Costs	405	544	556	546	606
Agreements					
Network Office Infrastructure	23	24	24	25	26
Bird Monitoring (Klamath Bird Obs.)	70	30	70	30	70
Land Use and Land Cover Change	30				
Intertidal Monitoring (UC Santa Cruz)	30	30	30	30	30
Network Outreach (SOU)	30	31			
Total Agreement Costs	183	115	124	85	126
Operations/Equipment	175	108	104	112	110
Travel	31	54	49	54	52
Miscellaneous and Contingencies	78	63	69	123	47
Total Expenditures	872	884	903	921	941

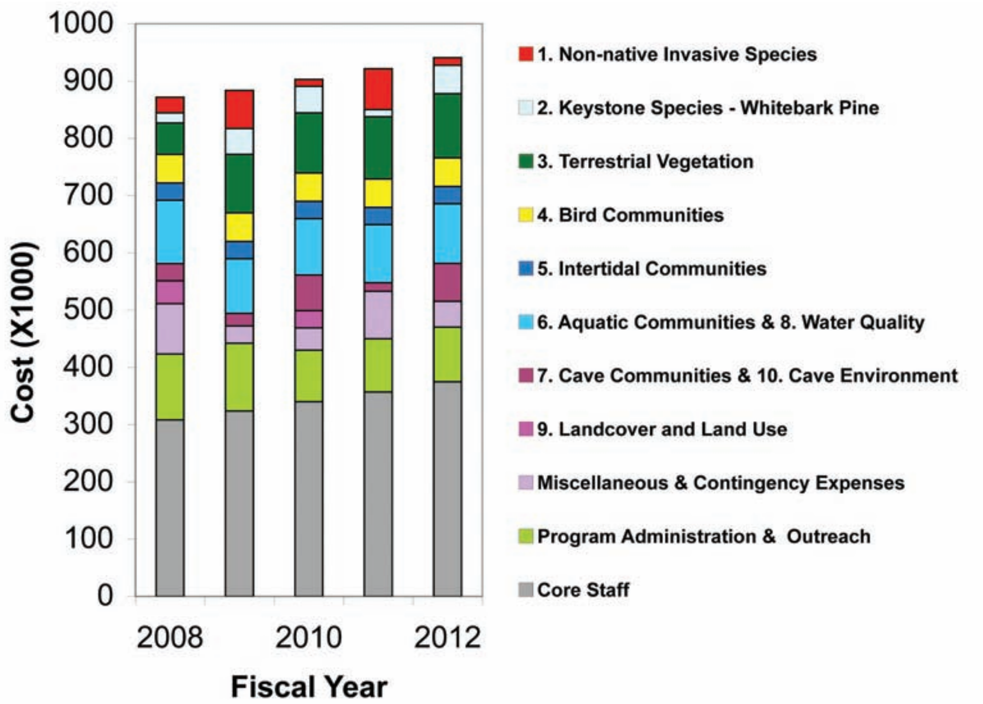
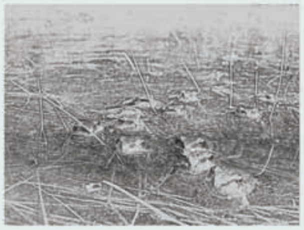


Figure 10.1. Annual project budgets for each of the top 10 vital signs (grouped by protocol), as well as fixed costs (core staff, program administration, and outreach) and miscellaneous and contingency expenses from FY 2008-2012. Vital signs ranks are given in the legend. Integrated vital signs are presented together with the ranks of both vital signs included.

Waxmyrtle

Table 10.2. Projected budget allocations for information management, FY 2008.

EXPENSE CATEGORY	BUDGETED AMOUNT	DATA & INFORMATION MANAGEMENT ALLOCATION	% OF BUDGETED EXPENSE
		Expenditures (X $1000)	
Personnel			
Permanent Positions			
Network Coordinator (GS-12)	94.0	18.8	20.0
Data Manager (GS-11)	79.0	67.2	85.0
Term Positions			
Aquatic Ecologist (GS-11)	77.0	15.4	20.0
Program Assistant (GS-7)	58.0	29.0	50.0
Lead Biotech (GS-7; 0.75 FTE)	30.0	15.0	50.0
Temporary Positions			
Field Sampling Crews	66.0	19.8	30.0
Total Staff Costs	405.0	165.2	40.8
Agreements			
Network Office Infrastructure	23.0	4.6	20.0
Bird Monitoring (Klamath Bird Obs.)	50.0	15.0	30.0
Land Use and Land Cover Change	40.0	24.0	60.0
Intertidal Monitoring (UC Santa Cruz)	30.0	9.0	30.0
Network Outreach (SOU)	30.0	12.0	40.0
Total Agreement Costs	183.0	65.9	36.0
Operations/Equipment	175.0	70.0	40.0
Travel	31.0	4.7	15.0
Miscellaneous and Contingencies	78.0	11.7	15.0
Total Expenditures	872.0	317.4	36.4



Acker, S., M. Brock, K. Fuhrmann, J. Gibson, T. Hofstra, L. Johnson, J. Roth, D. Sarr, and E. Starkey. 2002. A study plan to inventory vascular plants and vertebrates. Unpublished report on file. U.S. Department of the Interior, National Park Service, Klamath Inventory and Monitoring Network, Ashland, OR.

Allen, C. D., and D. D. Breshears. 1998. Drought-induced shift of a forest-woodland ecotone: Rapid landscape response to climate variation. Proceedings of the National Academy of Sciences 95:14839-14842.

Anderson, M., and A. Thompson. 2004. Multivariate control charts for ecological and environmental monitoring. Ecological Applications 14:1921-1935.

Angermeier, P. L., and J. R. Karr. 1994. Biological integrity versus biological diversity as policy directives: Protecting biotic resources. BioScience 44:690-697.

Arnold, J., Wildlife Biologist, Lassen Volcanic National Park. Personal communication. 28 July 2004.

Atzet, T., D. E. White, L. A. McCrimmon, P. A. Martinez, P. R. Fong, and V. D. Randall. 1996. Field guide to the forested plant associations of southwestern Oregon. R6-NR-ECOL-TP-17-96. U.S. Department of Agriculture, U.S. Forest Service, Pacific Northwest Region, Portland, OR.

Bakker, E. 1971. An island called California: An ecological introduction to its natural communities, 2nd edition. University of California Press, Berkeley, CA.

Barbour, M. G., and J. Major. 1977. Terrestrial vegetation of California. John Wiley and Sons, New York, NY.

Barbour, M. J., B. Stribling, and J. R. Karr. 1995. Multimetric approach for establishing biocriteria and measuring biological function. Pages 63-77 in W. Davis and T. Simon, editors. Biologial assessment and criteria: Tools for water resource planning and decision making. Lewis Publishers, Boca Raton, FL.

Beals, E. W. 1984. Bray-Curtis ordination: An effective strategy for analysis of multivariate ecological data. Advances in Ecological Research 14:1-55.

Benda, L., and T. Dunne. 1997. Stochastic forcing of sediment supply to channel networks from landsliding and debris flow. Water Resources Research 33:2849-2863.

Bennett, A. J., K. C. Oakley, and D. C. Mortenson. 2003. Phase I report-vital signs monitoring plan: Southwest Alaska Network. Unpublished report on file. U.S. Department of the Interior, National Park Service, Southwest Alaska Inventory and Monitoring Network, Anchorage, AK.

Bennetts, R., J. E. Gross, K. Cahill, C. McIntire, B. Bingham, A. Hubbard, L. Cameron, and S. L. Carter. 2007. Linking monitoring to management and planning: Assessment points as a generalized approach. George Wright Forum 24:59-77.

Bestelmeyer, B. T. 2006. Threshold concepts and their use in rangeland management and restoration: The good, the bad, and the insidious. Restoration Ecology 14:325-329.

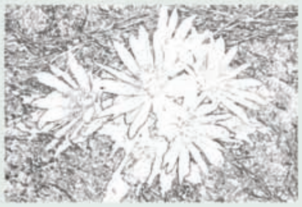
Bestelmeyer, B. T., J. R. Miller, and J. A. Wiens. 2003. Applying species diversity theory to land management. Ecological Applications 13:1750-1761.

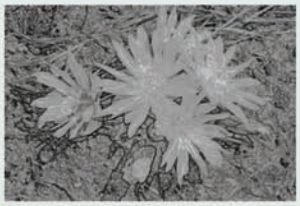
Bond, W. J., and B. W. van Wilgen. 1996. Fire and plants. Chapman and Hall, London, UK.

Bossard, C. R., J. M. Randall, and M. C. Hoshovsky. 2000. Invasive plants of California's wildlands. University of California Press, Berkeley, CA.

Box, G., and G. Jenkins. 1976. Time series analysis: Forecasting and control. Holden-Day, San Francisco, CA.

Burgess, S. S. O., and Dawson, T. E. 2004. The contribution of fog to the water relations of Sequoia sempervirens (D. Don): Foliar uptake and prevention of dehydration. Plant, Cell & Environment 27:1023-1034.





Bury, R. B., and C. A. Pearl. 1999. Klamath-Siskiyou herpetofauna: Biogeographic patterns and conservation strategies. Natural Areas Journal 19:341-350.

Busch, D. E., and J. C. Trexler, editors. 2003. Monitoring ecosystems: Interdisciplinary approaches for evaluating ecoregional initiatives. Island Press, Covelo, CA.

California Department of Fish and Game. 2001. Species and natural communities monitoring and assessment program. Online. (http://www.dfg.ca.gov/habitats/rap/pdf/resassessprogram.pdf). Accessed 17 August 2007.

Ceres. 2004. California nearshore waters and open ocean. California Coastal Commission's California coastal resource guide. Online. (http://ceres.ca.gov/ceres/calweb/coastal/waters.html). Accessed 17 August 2007.

Clements, F. E. 1936. Nature and structure of the climax. Journal of Ecology 24:252-284.

Cochran, W. G. 1977. Sampling techniques, 3rd edition. John Wiley, New York, NY.

Coleman, R. G., and A. R. Kruckeberg. 1999. Geology and plant life of the Klamath-Siskiyou mountain region. Natural Areas Journal 19:320-340.

Collier R., J. Dymond, J. McManus, and J. Lupton. 1990. Chemical and physical properties of the water column at Crater Lake, Oregon. Pages 69-102 in E. T. Drake, G. L. Larson, J. Dymond, and R. Collier, editors. Crater Lake - an ecosystem study. American Association for the Advancement of Science, San Francisco, CA.

Connell, J. H. 1978. Diversity in tropical forests and coral reefs. Science 199:1302-1309.

Costanza, R., H. Daly, C. Folke, P. Hawken, C. S. Holling, A. J. McMichael, D. Pimentel, and D. Rapport. 2000. Managing our environmental portfolio. Bioscience 50:149-155.

Cox, K., and C. McGary. 2006. Marine resources of Redwood National and State Parks: Comprehensive report (2004-2005) for Humboldt and Del Norte County, California. NPS Report REDW-00008. Unpublished report on file. U.S. Department of the Interior, National Park Service, Klamath Inventory and Monitoring Network, Ashland, OR.

Currie, D. J. 1991. Energy and large scale patterns of animal - and plant - species richness. American Naturalist 137:27-49.

Dale, V. H., and S. C. Breyeler. 2001. Challenges in the development and use of ecological indicators. Ecological Indicators 1:3-10.

De Leo, G. A., and S. Levin. 1997. The multifaceted aspects of ecological integrity. Conservation Ecology 1:3. Online. (http://www.consecol.org/vol1/iss1/art3/). Accessed 17 August 2007.

DeFerrari, C. M., and R. J. Naiman. 1994. A multi-scale assessment of the occurrence of exotic plants on the Olympic Peninsula, Washington. Journal Vegetation Science 5:247-258.

DellaSala, D. A., S. T. Reid, T. J. Frest, J. R. Strittholt, and D. M. Olson. 1999. A global perspective on the biodiversity of the Klamath-Siskiyou ecoregion. Natural Areas Journal 19:300-319.

Drake, E. T., G. L. Larson, J. Dymond, and R. Collier, editors. 1990. Crater Lake: An ecosystem study. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA.

Edwards, T. C., Jr., D. R. Cutler, K. H. Beard, and J. Gibson. 2007. Predicting invasive plant species occurrences in national parks: A process for prioritizing prevention. Final Project Report No. 2007-1. USGS Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, UT.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. Technical Reference 1730-1. U.S.

Department of the Interior, Bureau of Land Management, Denver, CO.

Elzinga, C. L., D. W. Salzer, J. W. Willoughby, and J. P. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Science, Inc., Malden, MA.

Environmental Protection Agency. 1992. Framework for ecological risk assessment. EPA/630/R-92/001. Office of Research and Development, Washington, D.C.

Erickson, J. L., and S. D. West. 2002. The influence of regional climate and nightly weather patterns of insectivorous bats. Acta Chiropterologica 4:17-24.

Fisher, R. A. 1970. Statistical methods for research workers, 14th edition. Oliver and Boyd, Edinburgh, UK.

Fleishman, E., G. T. Austin, and A. D. Weiss. 1998. An empirical test of Rapoport's rule: Elevational gradients in montane butterfly communities. Ecology 79:2482-2493.

Fleishman, E., D. D. Murphy, and P. F. Brussard. 2000. A new method for selection of umbrella species for conservation planning. Ecological Applications 10:569-579.

Franklin, J. F., and C. T. Dyrness. 1988. Natural vegetation of Oregon and Washington. Oregon State University Press, Corvallis, OR.

Franklin, J. F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. General Technical Report PNW-118. U.S. Department of Agriculture, U.S. Forest Service, Pacific Northwest Station, Portland, OR.

Fryer, S., Physical Scientist, Lava Beds National Monument. Personal communication. 7 August 2007.

Fujimora, T. 1977. Stem biomass and structure of a mature Sequoia sempervirens stand on the Pacific coast of northern California. Journal of the Japanese Forestry Society 59:435-441.

Gates, D. M. 1980. Biophysical ecology. Dover Publications, Mineola, NY.

Gauch, H. G. 1982. Multivariate analysis in community ecology. Cambridge Press, Cambridge, UK.

Giorgi, F., B. Hewitson, J. Christensen, M. Hulme, H. Von Storch, P. Whetton, R. Jones, L. Mearns, and C. Fu. 2001. Regional climate information: Evaluation and projections. in Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. A. Johnson, editors. Climate change 2001: The scientific basis. Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK.

Gleason, H. A. 1926. The individualistic concept of the plant association. Bulletin of the Torrey Botanical Club 53:1-20.

Groffman, P. M., J. S. Baron, T. Blett, A. J. Gold, I. Goodman, L. H. Gunderson, B. M. Levinson, M. A. Palmer, H. W. Paerl, G. D. Peterson, and others. 2006. Ecological thresholds: The key to successful environmental management or an important concept with no practical application? Ecosystems 9:1-13.

Gross, J. G. 2003. Developing conceptual models for monitoring programs. Unpublished report on file. U.S. Department of the Interior, National Park Service, Inventory and Monitoring Program Office, Fort Collins, CO.

Groves, C., and J. Meiman. 2005. Flooding. Pages 251-254 in W. B. White and D. C. Culver, editors. Encyclopedia of caves. Elsevier Academic Press, Burlington, MA.

Gunderson, L. H., and C. S. Holling. 2001. Panarchy: Understanding transformations in systems of humans and nature. Island Press, Covelo, CA.

Hansen, A. J., and J. J. Rotella. 1999. Abiotic factors. Pages 161-209 in M. Hunter, editor. Maintaining biodiversity in forest ecosystems. Cambridge University Press, Cambridge, U.K.

Hansen, A. J., and J. J. Rotella. 2002. Biophysical factors, land use, and species viability in and around nature reserves. Conservation Biology 16:1-12.

Herman, J. S. 2005. Water chemistry in caves. Pages 609-614 in W. B. White and D. C. Culver, editors. Encyclopedia of caves. Elsevier Academic Press, Burlington, MA.

Higgins, S. I., and D. M. Richardson. 1996. A review of models of alien plant spread. Ecological Modeling 87:249-265.

Hobbs, R. J. 1991. Disturbance a precursor to weed invasion in native vegetation. Plant Protection Quarterly. 6:99-104.

Hobbs III, H. H. 2005. Diversity patterns in the United States. Pages 170-183 in W. B. White and D. C. Culver, editors. Encyclopedia of caves. Elsevier Academic Press, Burlington, MA.

Holling, C. S., and G. K. Meffe. 1996. Command and control and the pathology of natural resource management. Conservation Biology 10:328-337.

Holling, C. S. 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. Ecological Monographs 62:447-502.

Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. A. Johnson, editors. 2001. Climate change 2001: The scientific basis. Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK.

Huston, M. A. 1979. A general hypothesis of species diversity. American Naturalist 113:81-101.

Huston, M. A. 1994. Biological diversity: The coexistence of species on changing landscapes. Cambridge University Press, Cambridge, UK.

Innis, S. A., R. J. Naiman, and S. R. Elliot. 2000. Indicators and assessment methods for measuring the ecological integrity of semi-aquatic terrestrial environments. Hydrobiologia 422:111-131.

Iwatsubo, R. T., and R. C. Averett. 1981. Aquatic biology of the Redwood Creek and Mill Creek drainage basins, Redwood National Park, Humboldt and Del Norte Counties, California. Geologic Society Open-File Report 81-143. U.S. Department of the Interior, U.S. Geologic Society, Arcata, CA.

Johnson, D. H., and T. A. O'Neil. 2001. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR.

Johnson, R. K. 1998. Spatiotemporal variability of lake macroinvertebrate communities: Detection of impact. Ecological Applications 8:61-70.

Jones, C. G., J. H. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. Oikos 69:373-386.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21-27.

Karr, J. R. 1991. Biological integrity: A long neglected aspect of water resource management. Ecological Applications 1:66-84.

Karr, J. R., Chu, E. W. 1999. Restoring life in running waters: Better biological monitoring. Island Press, Washington, D.C.

Kimberling, D. N., J. R. Karr, and L. S. Fore. 2001. Measuring human disturbance using terrestrial invertebrates in the shrub-steppe of eastern Washington (USA). Ecological Indicators 1:63-81.

Kozloff, E. N. 1973. Seashore life of the northern Pacific Coast: An illustrated guide to northern California, Oregon, Washington, and British Columbia. University of Washington Press, Seattle, WA.

Kyriakidis, P., and A. Journel. 1999. Geostatistical space-time models: A review. Mathematical Geology 31:651-684.

Lamberti, G. A., S. V. Gregory, L. R. Ashkenas, R. C. Wildman, and K. M. S. Moore. 1991. Stream ecosystem recovery following a catastrophic debris flow. Canadian Journal of Fisheries and Aquatic Sciences 48:196-208.

Landres, P. B., P. Morgan, and F. J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications 9:1179-1188.

Landres, P. B., J. Verner, and J. W. Thomas. 1988. Ecological uses of vertebrate indicator species: A critique. Conservation Biology 2:316-328.

Larson, G., R. Collier, and M. Buktenica. 2007. Long-term ecological research and monitoring at Crater Lake, Oregon. Hydrobiologia 574:1-11.

Legendre, P., M. Dale, M. J. Fortin, J. Gurevitch, M. Hohn, and D. Myers. 2002. The consequences of spatial structure for the design and analysis of ecological field surveys. Ecography 25:601-615.

Leung, L. R., Y. Qian, X. Bian, W. M. Washington, J. Han, and J. O. Roads. 2004. Mid-century ensemble regional climate change scenarios for the western United States. Climatic Change 62:75-113.

Levine, L., M. Bacca, and K. O. Fulgham. 2002. Plant zonation in a salt spring supporting the only known population of Puccinellia howellii (Poaceae). Madroño 49(3):178-185.

Lindenmayer, D. B., A. D. Manning, P. L. Smith, H. P. Possingham, J. Fischer, I. Oliver, and M. A. McCarthy. 2002. The focal-species approach and landscape restoration: A critique. Conservation Biology 16:338-345.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. A. Bazzaz. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. Technical Report. Ecological Society of America, Issues in Ecology. Ecological Applications 10:689-670.

Maguire, D., M. Batty, and M. Goodchild. 2005. GIS, spatial analysis, and modeling. ESRI Press, Redlands, CA.

Manley, P. N., W. J. Zielinski, M. D. Schlesinger, and S. R. Mori. 2004. Evaluation of a multiple species approach to monitoring species at the ecoregional scale. Ecological Applications 14:296-310.

Manly, B. 2001. Statistics for environmental science and management. Chapman and Hall, Boca Raton, FL.

May, C. L., and R. E. Gresswell. 2003. Processes and rates of sediment and wood accumulation in headwater streams of the Oregon Coast Range, USA. Earth Surface Processes and Landforms 28:409-424.

McBean, E, and F. Rovers. 1998. Statistical procedures for analysis of ecological monitoring data and risk assessment. Prentice Hall PTR, Upper Saddle River, NJ.

McCune, B., and J. B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, OR.

McDonald, T. L. 2003. Environmental trend detection: A review. Environmental Monitoring and Assessment, 85:277-292.

McDonald, T., and P. Geissler. 2004. Systematic and stratified sampling designs in long-term ecological monitoring studies. USGS and West, Inc. Online. (http://science.nature.nps.gov/im/monitor/docs/SampleDesigns.doc). Accessed 17 August 2007.

McLaughlin, S. P. 1989. Natural floristic areas of the western United States. Journal of Biogeography 16:239-248.

Merriam, C. H., and L. Steineger. 1890. Results of a biological survey of the San Francisco Mountain region and desert of the Little Colorado in Arizona. North American Fauna 3:1-136.

Miner, M., P. T. Raimondi, R. F. Ambrose, J. M. Engle, S. N. Murray. 2005. Monitoring of rocky intertidal resources along the central and southern California mainland: Comprehensive 100 report (1992-2003) for San Luis Obispo, Santa Barbara, and Orange Counties. OCS Study, MMS 05-071. U.S. Department of the Interior, U.S. Minerals Management Service, Pacific OCS Region, Camarillo, CA.

Mitchell, V. L. 1976. The regionalization of climate in the western United States. Journal of Applied Meteorology 15:920-926.

Mitsch, W. J., and J. G. Gosselink. 2000. Wetlands. John Wiley and Sons, Inc. New York, NY.

Mohr, J., A. Mohr, C. Whitlock, and C. N. Skinner. 2000. Postglacial vegetation and fire history, eastern Klamath Mountains, California, USA. The Holocene 10:587-601.

Montgomery, D. R. 1999. Process domains and the river continuum. Journal of the American Water Resources Association 35:397-410.

Moritz, M. A. 1997. Analyzing extreme disturbance events: Fire in Los Padres National Forest. Ecological Applications 7:1252-1262.

Moyle, P. B. 2002. Inland fishes of California. University of California Press, Berkeley, CA.

Murray, S. N., and M. M. Littler. 1980. Biogeographical analysis of intertidal macrophyte floras of southern California. Journal of Biogeography 8:339-351.

Murray, S. W., and T. H. Kunz. 2005. Bats. Pages 39-45 in W. B. White and D. C. Culver, editors. Encyclopedia of caves. Elsevier Academic Press, Burlington, MA.

Naiman, R. J., T. J. Beechie, L. E. Benda, D. R. Berg, P. A. Bisson, L. H. MacDonald, M. D. O'Connor, P. L. Olson, and E. A. Steel. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion. Pages 127-188 in R. J. Naiman, editor. Watershed management: Balancing sustainability and environmental change. Springer-Verlag, New York, NY.

National Academy of Sciences. 1992. Science and the national parks. Unpublished report on file. Committee on improving the science and technology programs of the National Park Service. National Academy Press, Washington, D.C.

National Park Service Air Resources Division. 2002. Air quality in the national parks, 2nd edition. Lakewood, CO. Online. (http://www2.nature.nps.gov/air/Pubs/pdf/aqNps/aqnps.pdf). Accessed 17 August 2007.

National Park Service. 2006. Chapter 4: Natural resources in Management Policies. U.S. Department of the Interior, National Park Service, Washington, D.C. Online. (http://www.nps.gov/policy/MP2006.pdf). Accessed 18 August 2007.

National Park Service. 1988. Management policies. U.S. Department of the Interior, National Park Service, Washington, D.C.

National Park Service. 2004a. Invasive species monitoring resource website. Online. (http://www1.nature.nps.gov/biology/invasivespecies/). Accessed 17 August 2007.

National Park Service. 2004b. Outline for vital signs monitoring plans. Online. (http://science.nature.nps.gov/im/monitor/docs/monplan.doc). Accessed 17 August 2007.

Neilson, R. P., and L. H. Wullstein. 1983. Biogeography of two southwest American oaks in relation to atmospheric dynamics. Journal of Biogeography 10:275-297.

Niemi, G. J., J. M. Hanowski, A. R. Lima, T. Nicholls, and N. Weiland. 1997. A critical analysis on the use of indicator species in management. Journal of Wildlife Management 61:1240-1252.

Niemi, G. J., and M. E. McDonald. 2004. Application of ecological indicators.

Annual Review of Ecology and Systematics 35:89-111.

Nilsson C., G. Grelsson, M. Johansson, and U. Sperens. 1989. Patterns of plant species richness along riverbanks. Ecology 70:77-84.

Noon, B. R., T. A. Spies, and M. G. Raphael. 1999. Conceptual basis for designing an effectiveness monitoring program. in B. S. Mulder, B. R. Noon, T. A. Spies., M. G. Raphael, C. J. Palmer, A. R. Olsen, G. H. Reeves, and H. H. Welsh Jr., editors. The strategy and designing of the effectiveness program for the Northwest Forest Plan. General Technical Report PNW-GTR-437. U.S. Department of Agriculture, U.S. Forest Service, Pacific Northwest Station, Portland, OR.

Norris, R. M., and R. W. Webb. 1990. Geology of California, 2nd edition. John Wiley and Sons, Inc., New York, NY.

Noss, R. 1990. Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology 4:355-364.

O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 2000. Birds as indicators of ecological condition in the central Appalachians. Ecological Applications 10:1706-1721.

O'Connor R. J., T. E. Walls, and R. M. Hughes. 2000. Using multiple taxonomic groups to index the ecological condition of lakes. Environmental Monitoring and Assessment 61:207-228.

Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin 31:1000-1003.

Odion, D. C., E. J. Frost, and R. Sweeney. 2004. Summary of current information on fire regimes in the Klamath region. (cross-listed as Appendix D in the Klamath Network Phase II Monitoring Report) Online. (http://www1.nature.nps.gov/im/units/klmn/MON_Phase_II.cfm#phase2). Accessed 17 August 2007.

Odion, D., D. Sarr, B. Truitt, A. Duff, S. Smith, W. Bunn, E. Beever, S. Shafer, S. Smith, J. Rocchio, and others. 2005. Vital signs monitoring plan for the Klamath Network: Phase II report. U.S. Department of the Interior, National Park Service, Klamath Inventory and Monitoring Network, Ashland, OR. Online. (http://www1.nature.nps.gov/im/units/klmn/Documents/Phase_Reports/PhaseII/KLMN_Phase_II_Monitoring_Report.doc). Accessed 17 August 2007.

Odion, D., and D. Sarr. 2007. Managing disturbance regimes to maintain biodiversity: A new conceptual model. Forest Ecology and Management 246:57-65.

Ohmann, J. L., and T. A. Spies. 1998. Regional gradient analysis and spatial pattern of woody plant communities of Oregon forests. Ecological Monographs 68:151-182.

Osenberg, C. W., O. Sarnelle, S. D. Cooper, and S. D. Holt. 1999. Resolving ecological questions through meta-analysis: Goals, metrics, and models. Ecology 80:1105-1117.

Orr, W. N., and E. L. Orr. 1999. Geology of Oregon, 5th edition. Kendall Hunt Publishing Company. Dubuque, IA.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics 37:637-669.

Parmesan, C., and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421:37-42.

Parrish, J. D., D. P. Braun, and R. S. Unnash. 2003. Are we conserving what we say we are: Measuring ecological integrity within protected areas. BioScience 53:851-860.

Philippi, T. E., P. M. Dixon, and B. E. Taylor. 1998. Detecting trends in species composition. Ecological Applications 8:300-308.

Pickett, S. T. A., and P. S. White. 1985. The ecology of natural disturbance and patch dynamics. Academic Press, Orlando, FL.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime: A paradigm for river conservation and restoration. BioScience 47:769-784.

Pyle, R. M. 2002. The butterflies of Cascadia: A guide to all the species of Washington, Oregon, and surrounding territories. Seattle Audubon Society, Seattle, WA.

Redmond, K. T. 1990. Crater Lake climate and lake level variability. Pages 127-142 in E. T. Drake, G. L Larson, J. Dymond, and C. Robert, editors. Crater Lake - an ecosystem study. American Association for the Advancement of Science, San Francisco, CA.

Reeves, G. H., L. E. Benda, K. M. Burnett, P. A. Bisson, and J. R. Sedell. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium 17:334-349.

Rejmanek, M. 1989. Invasibility of plant communities. Pages 369-388 in J. A. Drake, H. A. Mooney, F. DiCastri, R. H. Groves, F. J. Kruger, M. Rejmanek, and M. Williamson, editors. Biological invasions: A global perspective. Wiley, Chichester, UK.

Ricketts, E. F., and J. Calvin. 1939. Between Pacific tides, 4th edition. Stanford University Press, Stanford, CA.

Root, T. 1988. Energy constraints on avian distributions and abundances. Ecology 69:330-339.

Roth, J. L. 2000. Why so many Siskiyou plants? Crater Lake Nature Notes 31:17-31.

Royo, A. R. 2004. Desert USA, Caves of the North American Deserts. Online. (http://www.desertusa.com/mag99/feb/stories/caves.html). Accessed 17 August 2007.

Runkle, J. R. 1985. Disturbance regimes in temperate forests. Pages 17-34 in S. T. A. Pickett, and P. S. White, editors. The ecology of natural disturbance and patch dynamics. Academic Press, New York, NY.

Sarr, D., M. Wing, and S. Shafer. 2004. A geographic information system-based spatial sampling framework for the Klamath Network parks. Unpublished report on file. U.S. Department of the Interior, National Park Service, Klamath Inventory and Monitoring Network, Ashland, OR.

Sarr, D. A., D. E. Hibbs, and M. A. Huston. 2005a. A hierarchical perspective of plant diversity. Quarterly Review of Biology 80:187-212.

Sarr, D. A., D. C. Odion, D. E. Hibbs, J. Weikel, R. E. Gresswell, R. B. Bury, N. M. Czarnomski, R. J. Pabst, J. Shatford, and A. R. Moldenke. 2005b. Riparian zone forest management and the protection of biodiversity: A problem analysis. Technical Bulletin No. 908. National Center for Air and Stream Improvement, Research Triangle Park, NC.

Sawyer, J. O., S. C. Sillett, J. H. Popenoe, A. LaBanca, T. Sholars, D. L. Largent, F. Euphrat, R. F. Noss, and R. Van Pelt. 2000. Characteristics of redwood forests. Pages 39-79 in R. F. Noss, editor. The redwood forest. Island Press, Washington, D.C.

Scott, C. T. 1998. Sampling methods for estimating change in forest resources. Ecological Applications 8:228-233.

Sellars, R. W. 1997. Preserving nature in the national parks: A history. Yale University Press, New Haven, CT.

Shine, R., E. G. Barrott, and M. J. Elphick. 2002. Some like it hot: Effects of forest clearing on nest temperatures of montane reptiles. Ecology 83:2808-2815.

Simberloff, D. 1998. Flagships, umbrellas, and keystones: Is single-species management passé in the landscape era? Biological Conservation 83:247-257.

Smartt, P. F. M., and J. E. A. Grainger. 1974. Sampling for vegetation survey: Some aspects of the behaviour of unrestricted, restricted, and stratified techniques. Journal of Biogeography 1:193-206.

Smith, S., and S. Jessup. In preparation. A flora of Lava Beds National Monument. Thesis. Southern Oregon University, Ashland, OR.

Smith, J. P., and J. O. Sawyer, Jr. 1988. Endemic vascular plants of northwestern California and southwest Oregon. Madroño 35:54-69.

Snyder, M. A., L. C. Sloan, N. S. Diffenbaugh, and J. L. Bell. 2003. Future climate change and upwelling in the California current. Geophysical Research Letters 30:1823-1826.

Sousa, W. P. 1979. Disturbance in marine intertidal boulder fields: The nonequilibrium maintenance of species diversity. Ecology 60:1225-1239.

Spies, T. A., J. F. Franklin, and M. Klopsch. 1990. Canopy gaps in Douglas-fir forests of the Cascade Mountains. Canadian Journal of Forest Research 20:649-658.

Spies, T. P., and M. G. Turner. 1999. Dynamic forest mosaics. Pages 95-160 in M. L. Hunter Jr., editor. Maintaining biodiversity in forest ecosystems. Cambridge University Press, New York, NY.

Stebbins, G. L., and J. Major. 1965. Endemism and speciation in the California flora. Ecological Monographs 35:1-35.

Stevens, D. L., and A. R. Olsen. 2003. Variance estimation for spatially-balanced samples of environmental resources. Environmetrics 14:593-610.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

Stewart, I. T., D. R. Cayan, M. D. Dettinger. 2004. Changes in snowmelt runoff timing in western North America under a 'business as usual' climate change scenario. Climatic Change 62:217-232.

Stinton, D. S., J. A. Jones, J. L. Ohmann, and F. J. Swanson. 2000. Windthrow disturbance, forest composition, and structure in the Bull Run Basin, Oregon. Ecology 81:2539-2556.

Stone, F. D., F. G. Howarth, H. Hoch, and M. Asche. 2005. Root communities in lava tubes. Pages 477-484 in W. B. White and D. C. Culver, editors. Encyclopedia of caves. Elsevier Academic Press, Burlington, MA.

Strong, D. H. 1973. Footprints in time: A history of Lassen Volcanic National Park. W. L. Walker, Red Bluff, CA.

Strong, P. I. V. 1990. The suitability of the common loon as an indicator species. Wildlife Society Bulletin 18:257-261.

Sullivan, T. J., D. L. Peterson, C. L. Blanchard, and S. J. Tanenbaum. 2001. Assessment of air quality and air pollution impacts in class I national parks of California. Cooperative agreement number 400-7-9002 between NPS and University of Virginia. U.S. Department of the Interior, National Park Service, National Inventory and Monitoring Program, Fort Collins, CO. Online. (http://www2.nature.nps.gov/air/Pubs/all.cfm). Accessed 18 August 2007.

Sutherland, W. J. 1996. Ecological census techniques: A handbook. Cambridge University Press, Cambridge, MA.

Swanson, B. J. 1998. Autocorrelated rates of change in animal populations and their relationships to precipitation. Conservation Biology 12:801-808.

Turner, M. 1990. Spatial and temporal analysis of landscape patterns. Landscape Ecology 4:21-30.

Urquhart, N. S., and T. M. Kincaid. 1999. Designs for detecting trend from repeated surveys of ecological resources. Journal of Agricultural and Biological Environmental Statistics 4: 404-414.

Urquhart, N. S., S. G. Paulsen, and D. P. Larsen. Monitoring for policy-related regional trends over time. Ecological Applications 8:246-257.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E.

Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Veblen, T. T., T. Kitzberger, and J. Donnegan. 2000. Climatic and human influences on fire regimes in ponderosa pine forests in the Colorado Front Range. Ecological Applications 10:1178-1195.

Vitousek, P. M., and H. A. Mooney. 1997. Human domination of Earth's ecosystems. Science 277:494-500.

Walker, R. B. 1954. The ecology of serpentine soils. Ecology 35:259-266.

Wallace, D. R. 1983. The Klamath knot. Sierra Club Books, San Francisco, CA.

Walter, H. 1973. Vegetation of the earth in relation to the eco-physiological conditions. Springer-Verlag, New York, NY.

Walters, C. J., and C. S. Holling. 1990. Large-scale management experiments and learning by doing. Ecology 71:2060-2068.

Weisberg, P. J., and F. J. Swanson. 2003. Regional synchroneity in fire regimes of western Oregon and Washington, USA. Forest Ecology and Management 172:17-28.

Western, D. 1987. Africa's elephants and rhinos: Flagships in crisis. Tree 2:343-346.

Wetzel, R. G. 1983. Limnology, 2nd edition. Saunders College Publishing, Philadelphia, PA.

White, W. B., and D. C. Culver. 2005. Cave, definition of. Pages 81-85 in W. B. White and D. C. Culver, editors. Encyclopedia of caves. Elsevier Academic Press, Burlington, MA.

Whitlock, C., and P. J. Bartlein. 1997. Vegetation and climate change in Northwest America during the past 125k yr. Nature 388:59-61.

Whittaker, R. H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs. 26:1-80.

Whittaker, R. H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30:279-338.

Whittaker, R. H. 1961. Vegetation history of the Pacific coast states and the central significance of the Klamath region. Madroño 16:5-23.

Whittaker, R. H. 1965. Dominance and diversity in land plant communities. Science 147:250-259.

Whittaker, R. H. 1967. Gradient analysis of vegetation. Biological Review 42:207-264.

Whittaker, R. J., K. J. Willis, and R. Field. 2001. Scale and species richness: Towards a general, hierarchical theory of species diversity. Journal of Biogeography 28:453-470.

Willis, K. S., and H. J. B. Birks. 2006. What is natural? The need for a long-term perspective in biodiversity conservation. Science 314:1261-1265.

With, K. 2002. The landscape ecology of invasive spread. Conservation Biology 16:1192-1203.

Woodward, F. I. 1987. Climate and plant distribution. Cambridge University Press, London, UK.

Wright, R. G. 1999. Wildlife management in the national parks: Questions in search of answers. Ecological Applications 9:30-36.

Wu, J., and O. L. Loucks. 1995. From balance of nature to hierarchical patch dynamics: A paradigm shift in ecology. Quarterly Review of Biology 70:439-466.

York, F. F., and D. Deur. 2002. Huckleberry Mountain traditional-use study. Unpublished report on file. U.S. Department of the Interior, National Park Service, Crater Lake National Park, Crater Lake, OR.

Zar, J. A. 1999. Biostatistical analysis, 4th edition. Prentice Hall, Upper Saddle River, NJ.

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