National Park Service
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Natural Resource Program Center

Upper Columbia Basin Network
Vital Signs Monitoring Plan

Natural Resource Report NPS/UCBN/NRR-2007/002

ON THE COVER

Seven of the 14 UCBN Vital Signs: Sagebrush-steppe, sage grouse, camas lily, aspen, invasive/exotic species, water quality, and bats.

NPS Photos.

Upper Columbia Basin Network
Vital Signs Monitoring Plan

Natural Resource Report NPS/UCBN/NRR—2007/002

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Executive Summary

THE MISSION of the National Park Service is "to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations" (NPS 1999). To uphold this goal, the Director of NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation's natural heritage through science, natural resource inventories and expanded resource monitoring (NPS 1999). Data obtained from a scientifically developed monitoring program will allow park resource staff to make better management decisions based on credible scientific information.

Through the Challenge, 270 parks in the national park system were placed into 32 inventory and monitoring networks. The parks of the Upper Columbia BAsin Network (UCBN) include Big Hole National Battlefield (BIHO), City of Rocks National Reserve (CIRO), Craters of the Moon National Monument and Preserve (CRMO), Hagerman Fossil Beds National Monument (HAFO), John Day Fossil Beds National Monument (JODA), Lake Roosevelt National Recreation Area (LARO), Minidoka Internment National Monument (MIIN), Nez Perce National Historical Park (NEPE), and Whitman Mission National Historic Site (WHMI).

Each network of parks that receives funding for monitoring is required to prepare a vital signs monitoring plan. Vital signs are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources. The purpose of this plan is to establish the vital signs, explain the approach used to develop sampling designs and protocols, and outline the administrative and budgetary framework of the Network. In addition, the report includes a data management plan that guides the long-term management of data essential to the monitoring program.

The UCBN vital signs monitoring plan was developed over the course of 4 years. Several initial steps were taken even before the network was formally funded, during the biological inventory process under the guidance of Dr. Gerald Wright of the University of Idaho. One essential step involved the use of conceptual ecological models. Conceptual models prepared by the UCBN explain the structure, function and interconnectedness of park ecosystems, enabling the identification of vital signs for assessing ecosystem health. In addition to conceptual modeling, the UCBN used scoping workshops, an internet-based questionnaire, and park-by-park ranking sessions using a Microsoft Access database to assist in prioritizing vital signs. Final ranking criteria used to develop the short list of priority vital signs included management significance, ecological significance, and legislative significance.

UCBN parks are situated in a complex ecological and managerial environment and this has made the identification of a prioritized list of vital signs challenging. It is impossible for any single monitoring program operating on a limited budget to develop a completely satisfactory picture of ecosystem health. The UCBN has identified 14 vital signs that represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales. Our intent has been to come up with a balanced and integrated "package" of vital signs that meets the needs of current park management, but will also be able to accommodate unanticipated environmental conditions in the future.

The UCBN vital signs monitoring plan identifies a suite of 14 vital signs chosen for monitoring implementation in the UCBN over the next 5 years. Water quality monitoring is fully integrated within the UCBN monitoring program. An integrated water quality monitoring protocol is in development that includes monitoring aquatic macroinvertebrates, surface water dynamics, and water chemistry vital signs.

The UCBN has also recognized a number of vital signs of importance that are identified for future projects, if funding and program capacity allows.

Network I&M staff and their cooperators will make hundreds of observations each year about water quality, plant, and animal populations, communities, and park envi-

Level 1– Landscapes	Level 2 – Landscape Dynamics	Level 3 – Vital Sign	Network Vital Sign Name
Geology and soils	Geomorphology	Stream/River Channel Characteristics	Stream/River Channel Characteristics
Water	Hydrology	Surface Water Dynamics	Surface Water Dynamics
	Water Quality	Water Chemistry	Water Chemistry
	Water Quality	Aquatic Macroinvertebrates	Aquatic Macroinvertebrates
Biological integrity	Invasive species	Invasive/Exotic Plants	Invasive/Exotic Plants
	Focal species or communities	Riparian Communities	Riparian Vegetation
	Focal species or communities	Shrubland Communities	Sagebrush-steppe Vegetation
	Focal species or communities	Forest/Woodland Communities	Aspen
	Focal species or communities	Forest/Woodland Communities	Limber Pine
	Focal species or communities	Birds	Osprey
	Focal species or communities	Birds	Sage Grouse
	Focal species or communities	Mammals	Bats
Human use	Cultural Landscapes	Cultural Landscapes	Camas Lily
Ecosystem pattern and processes	Land Dynamics	Land Cover and Use	Land Cover and Use

ronments. This requires a commitment to comprehensive data management in order to ensure that an accurate and complete record of those observations is maintained in perpetuity. The UCBN will follow procedures outlined in the Network Data Management Plan and summarized in Chapter 6 of this document to assure and maintain data integrity. Data management procedures follow five key steps: acquisition, verification, validation, analysis, and dissemination. In addition, storage, maintenance, and security issues apply to all stages of the data flow.

Reporting is the process through which we derive information from the underlying data through analysis and interpretation for use by park managers. Vital signs monitoring reports will include: 1) annual summaries written for park and network managers; 2) 5-year trend reports for park superintendents and natural resource managers; 3) internet websites for NPS staff and the general public; and 4) e-mail bulletins for park superintendents, natural resource managers, and the general public on-request. To promote efficient reporting, data management efforts during the summary and analysis phase focus on automation of routine reports. Summary analysis for annual reports of vital signs monitoring studies will include graphed results and descriptive statistics (mean, standard deviation) for all of the primary variables included in the project. Trend reports every 5-10 years will typically include correlation and trends analysis.

Administrative oversight for the program originates from the Board of Directors (BOD) and Network Science Advisory

Committee (SAC). The BOD, representing the superintendents of the nine parks, is charged with oversight of the network. The BOD comprises three superintendents that serve two year terms on a rotating basis. The SAC represents the natural resource managers of the nine parks and serves as the scientific and operational body of the network that develops recommendations on how monitoring is implemented. UCBN has its main office in Moscow, Idaho, and NEPE serves as the administrative park for the Network. The program coordinator is supervised by the Pacific West Regional (PWR) Coordinator with input from the BOD and the SAC. In turn, the program coordinator, or his/her subordinates, supervise all I&M staff.

The Network staffing structure reflects the intention of the Network to implement monitoring primarily through hiring of seasonal help to collect and input data. Cooperative agreements will be utilized to assist with status and trend analyses, database design, and other monitoring needs. Currently the UCBN employs three permanent and two temporary employees centrally located in Moscow, Idaho and on the Oregon State University/Central Oregon Community College Cascades Campus in Bend, Oregon. The I&M permanent and temporary staff includes project leaders who oversee implementation of particular vital signs monitoring projects; technical experts who provide support in GIS, data management, statistical analysis, and survey design; and administrative staff.

Several sources of funding are combined to support operations of the UCBN. The two principal sources are vital signs monitoring funds from the Natural Resource Challenge ($524,400) and ($48,300) funds from the Water Resources Division dedicated to water quality monitoring. All funds are managed by the program coordinator under the oversight of the BOD. An annual work plan is developed with input from the SAC and approved by the BOD that directs expenditure of funds to projects and parks. All I&M program funds must be strictly accounted for and disclosed in an Annual Administrative Report.

The UCBN will be subject to periodic reviews to ensure high program quality and accountability. Review of the draft network monitoring plan will be organized by the WASO monitoring leader and take place in January 2007. In 2012 and every fifth year thereafter, a comprehensive review of program operations will be conducted. Peer review of monitoring protocols will be conducted by the PWR I&M coordinator upon their completion and prior to implementation.

Acknowledgments

Many people contributed their ideas and hard work toward the development of the Upper Columbia Basin Network (UCBN) monitoring program and the preparation of this report. The resource managers of the Upper Columbia Basin parks understood the importance of establishing a long-term monitoring program before funding or positions were in place. They contributed their time and efforts, through the UCBN Science Advisory Committee (SAC), to lay the groundwork for the monitoring program. We thank John Apel, Timothy Fisher, Dan Foster, Fran Gruchy, Ken Hyde, Shirley Hoh, Wallace Keck, Jason Lyon, Roger Trick, Jodi Vincent, Jerald Weaver, and Paige Wolken for their contributions.

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We thank the UCBN Board of Directors (Debbie Bird, Terry Darby, Tami DeGrosky, Gary Somers, Jim Hammett, Wallace Keck, Doug Neighbor, Neil King, and Gary Somers) for their support, advice and advocacy. We trust that through their involvement, the program will grow to be integrated into park management and relevant to resource-related decisions.

We are indebted to all the Networks that have submitted reports before us, and particularly the Central Alaska Network, Cumberland Piedmont Network, Great Lakes Network, Heartland Network, Northern Colorado Plateau Network, Sonoran Desert Network, Southern Colorado Plateau Network, Greater Yellowstone Network, and the Southwest Alaska Network. We have extensively and liberally used their standardized wording and table formats, particularly with respective "best examples" chapters identified by Washington Office (WASO) leadership.

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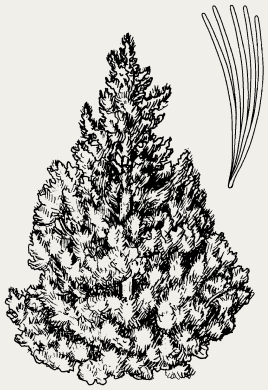
Chapter 1: Introduction and Background

Park Stewardship and Natural Resource Monitoring

KNOWING the condition of natural resources in parks is fundamental to the National Park Service's (NPS) ability to manage park resources "unimpaired for the enjoyment of future generations." NPS resource managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a foundation for making decisions and working with other agencies and the public for the benefit of park resources. Managers and scientists have long sought ways to characterize and determine trends in the condition of protected areas, assess the efficacy of management practices and restoration efforts, and provide early warning of impending threats. The challenge of protecting and managing park-wide natural resources requires a multi-agency, ecosystem approach because parks are open systems, with threats from air and water pollution, climate change, and invasive/exotic species originating outside park boundaries. An ecosystem approach is further needed because no single spatial or temporal scale is appropriate for all system components and processes; the appropriate scale for understanding and effectively managing a resource might be at the population, species, community, or landscape level, and in some cases may require a regional, national or international effort to understand and manage the resource. National parks are part of larger ecosystems and must be managed in that context.

Accordingly, the NPS launched the Natural Resource Challenge in 1999, a program designed to strengthen natural resource management in the Nation's national parks (NPS 1999). The single biggest undertaking of the Challenge was to augment ongoing park inventory and monitoring efforts into an ambitious comprehensive nationwide program. The Servicewide Inventory and Monitoring (I&M) program was introduced to 270 parks identified as having significant natural resources. Under this program, parks were organized into 32 networks based on similar geographic and natural resource characteristics, allowing for improved efficiency and sharing of staff and resources. The network organization facilitates collaboration, information sharing, and economies of scale in natural resource monitoring. Networks are guided by a Board of Directors who specifies desired outcomes, evaluates performance for the monitoring program, and promotes accountability. The Upper Columbia Basin Network (UCBN) was fully funded to conduct long-term vital signs monitoring in FY 2006. The level of funding available through the Natural Resource Challenge does not allow comprehensive monitoring in all UCBN parks, but does provide a significant foundation for initiating natural resource monitoring. From this foundation, the Network can increase its capacity to deliver monitoring information through collaboration and cost-sharing.

The UCBN Vital Signs Monitoring Plan was developed over a multi-year period following specific guidance from the NPS Washington Office (WASO) (NPS 2003a). This plan outlines the Network's monitoring program implementation strategy as well as the process by which the plan was developed, including the selection and prioritization of vital signs. Vital signs, as defined by the NPS I&M program, are a subset of physical, chemical, and biological elements and processes of park ecosystems selected



Vital signs are a subset of physical, chemical, and biological elements and processes of park ecosystems selected to represent the overall condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

NPS resource managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources…

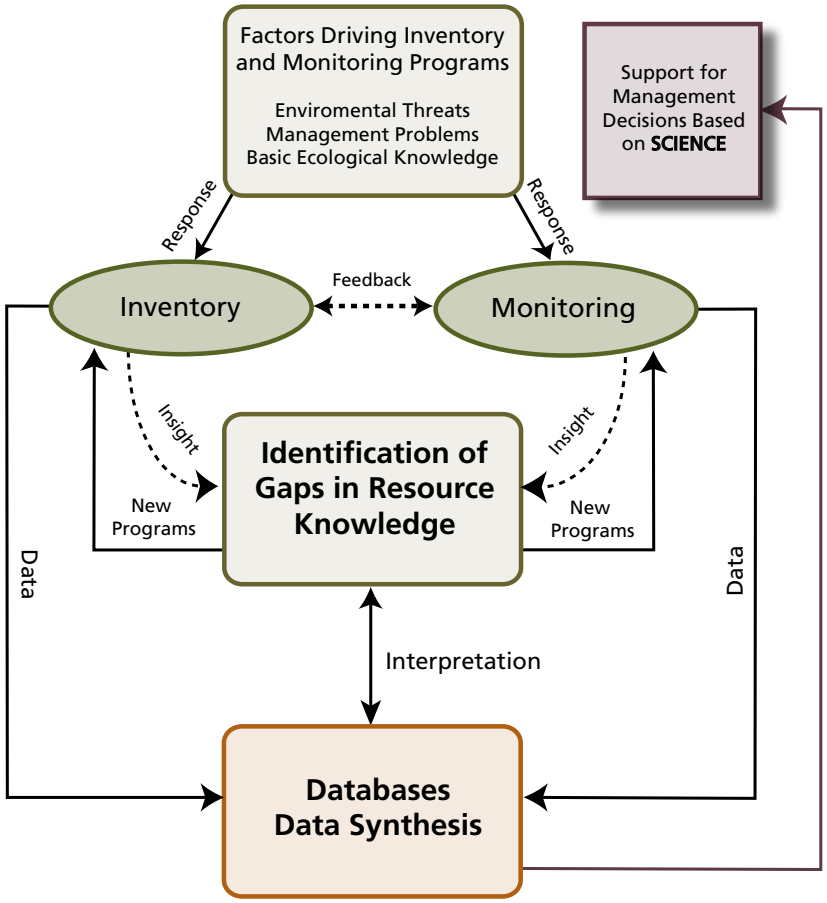


Figure 1.1. Stewardship of natural resources in national parks involves the interconnected activities of inventories and monitoring, synthesis of available information, and science-based adaptive management (modified from Wright 1993).

to represent the overall condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. Vital signs are part of the total suite of natural resources park managers are directed to preserve "unimpaired for future generations," including water, air, geologic resources, plants, and animals, and the various ecological, biological, and physical processes that act on these resources. In situations where natural areas have been so highly altered that natural physical and biological processes no longer operate (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers understand and develop effective approaches to restoration or, in cases where restoration is impossible, ecologically sound management. The broad-based, scientifically-credible information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promotion of public stewardship for the National Park System. As illustrated in Figure 1.1, monitoring is a central component of natural resource stewardship in the NPS, and in conjunction with natural resource inventories provides critical information needed for effective, science-based adaptive management and resource protection.

Parks in the Upper Columbia Basin

The UCBN consists of nine widely separated NPS units located in western Montana, Idaho, eastern Washington, and central Oregon (Figure 1.2) One unit of the Nez Perce National Historical Park (NEPE), Bear Paw Battlefield, is actually located outside the Network boundary in eastern Montana. This unit and one other park, Big Hole National Battlefield (BIHO), lie outside the Columbia River Basin, although administratively speaking they are part of the Network. UCBN parks vary in size from 30 ha (74 ac) to more than 188,197 ha (465,046 ac), and all but two are less than 6,000 ha (14,826 ac) (Table 1.1). These park units operate with limited budgets and few staff, and are not able to provide personnel and funds for many of the natural resource concerns they face. The resources available at the network level will greatly increase their capacity to meet increasingly complex resource management issues.

While the parks have been identified as having significant natural resources, the majority were actually established to protect cultural and paleontological resources (Table 1.1). The upper Columbia Basin holds a rich and fascinating cultural history, and several UCBN parks provide the nationally significant service of chronicling the pre-contact and contact cultures of the Nez Perce and Cayuse people, early pioneer and mission culture, and the tragic conflicts that arose between them. Two parks also protect and interpret globally significant fossil localities. Most also have some level of natural resource protection language included in enabling legislation or other guidance documents.

The enabling legislation of an individual park provides insight into the natural and cultural resources and resource values for which it was created to preserve. Along with national legislation, policy and guidance, a park's enabling legislation provides justification and, in some cases, specific guidance

for the direction and emphasis of resource management programs, including I&M.

National parks operate within a legal framework that applies to all units that make up the national park system. In addition, specific enabling legislation authorizes and defines each particular park. Lake Roosevelt National Recreation Area (LARO) does not have enabling legislation. Appendix A.3 presents information on the purpose of each park from various park documents, including general management plans, resource management plans, and strategic plans. This does not represent the comprehensive goals and objectives for each park but represents subsets most relevant to natural resource monitoring. Five categories encompass the Network perspective on the purpose of UCBN parks: 1) interpreting the culture and history of a place or people, such as the Nez Perce tribe, 2) preserving and protecting the uniqueness of an area, such as the geologic resources, the natural quiet, or the paleontological resources, 3) encouraging and supporting scientific research, 4) managing and protecting recreational resources, and 5) preserving and enhancing riparian and wetland areas.

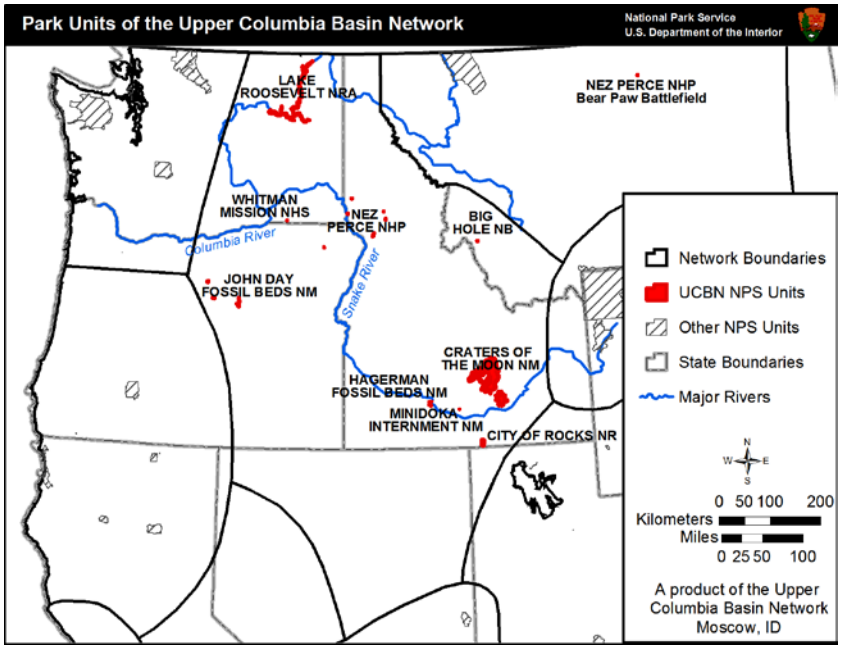


Figure 1.2. Map of UCBN park units.

Table 1.1. NPS Units in the UCBN.

Park	Park Code	State	Acres	Hectares	Originally Established For: Cultural Resources	Natural Resources	Recreation
Big Hole National Battlefield	BIHO	MT	655	265	X		
City Of Rocks National Reserve	CIRO	ID	14,107	5,708	X	X	X
Craters of the Moon National Monument and Preserve	CRMO	ID	465,046	188,197		X	
Hagerman Fossil Beds National Monument	HAFO	ID	4,351	1,760	X	X	
John Day Fossil Beds National Monument	JODA	OR	14,056	5,688	X	X	
Lake Roosevelt National Recreation Area	LARO	WA	100,390	40,625	X		X
Minidoka Internment National Monument	MIIN	ID	73	30	X		
Nez Perce National Historical Park	NEPE	ID	2,122	858	X		
Whitman Mission National Historic Site	WHMI	WA	98	40	X		

Legislation, Policy and Guidance for Natural Resource Monitoring

In establishing the first national park in 1872, Congress "dedicated and set apart (nearly 404,686 ha [1 million ac] of land) as a pleasuring ground for the benefit and enjoyment of the people" (16 U.S.C. 1 § 21). By 1900, a total of five national parks had been established, along with additional historic sites, scenic rivers, recreation areas, monuments, and other designated units. Each unit was to be administered according to its individual enabling legislation, but had been created with a common purpose of preserving the "precious" resources for people's benefit. Sixteen years later the passage of the National Park Service Organic Act of 1916 (16 U.S.C. 1 § 1) established and defined the mission of the NPS, and through it, Congress implied the need to monitor natural resources and guarantee unimpaired park resources:

> "*The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified . . . by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*."

Congress reaffirmed the declaration of the Organic Act in the General Authorities Act of 1970 (16 U.S.C. 1a-1a8) and effectively ensured that all park units be united into the 'National Park System' by a common purpose of preservation, regardless of title or designation. In 1978, the NPS's protective function was further strengthened when Congress again amended the Organic Act to state ". . .the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established. . ." thus further endorsing natural resource goals of each park. More than a decade later, park service management policy again reiterated the importance of this protective function of the NPS to "understand, maintain, restore, and protect the inherent integrity of the natural resources" (NPS 2001).

More recent and specific requirements for a program of inventory and monitoring park resources are found in the National Parks Omnibus Management Act of 1998 (P.L. 105-391). The intent of the Act is to create an I&M program that may be used "to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources." Subsequently, in 2001, NPS management updated previous policy and specifically directed the Service to inventory and monitor natural systems to inform park management decisions:

> "*Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions*" (NPS 2001).

In addition to the legislation directing formation and function of the NPS, there are several other pieces of legislation intended to not only protect natural resources within national parks and other federal lands, but address general concerns over the environmental quality of life in the United States (US). Many of these federal laws also require natural resource monitoring within national park units. As NPS units are among some of the most secure areas for numerous threatened, endangered or otherwise compromised natural resources in the country, the particular guidance offered by federal environmental legislation and policy is an important component to the development and administration of a natural resource I&M system.

Legislation, policy, and executive guidance have important and direct bearing on the development and implementation of natural resource monitoring in National Parks. Relevant federal legal mandates are therefore summarized in Appendix A.1. Of particular importance is the Government Performance and Results Act (GPRA) which is central to NPS operations, including the I&M program. The NPS has developed a national strategic plan identifying key goals to be met (NPS 2001). A list of the national GPRA goals relevant to UCBN parks is located in Table 1.2. In addition to the national

strategic goals, each park unit has a 5-year plan that includes specific park GPRA goals. Many of these park specific goals are directly related to natural resource monitoring needs.

Monitoring Goals and Objectives

The overarching mission of natural resource monitoring in parks is to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. More specifically, the program is guided by the five Servicewide goals presented in Table 1.3.

Working from the Servicewide goals, the UCBN has developed a set of monitoring objectives for each of its high-priority vital signs grouped into the following conceptual categories (Figure 1.3; Woodley 1993):

Table 1.2. Government Performance and Results Act (GPRA) goals specific to UCBN parks and relevant to the monitoring plan.

GPRA Goal	Goal #	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.	Category Ia	BIHO, CIRO, CRMO, HAFO, JODA, LARO, MIIN, NEPE, WHMI
Exotic vegetation contained	Ia1B	BIHO, CIRO, CRMO, HAFO, JODA, LARO, MIIN, NEPE, WHMI
Land health: wetland areas	1a1C	BIHO, JODA, NEPE
Land health: riparian areas condition	1a1D	BIHO, CIRO, JODA, LARO, NEPE
Land health: uplands (Desired Future Conditions and methodology to assess the status)	1e1E	BIHO, CRMO, JODA, NEPE
Threatened and endangered species	1a2A	BIHO, LARO, NEPE, WHMI (Spalding's Catchfly, Bull Trout, Bald Eagle, Steelhead)
Species of special concern (management plan with methodology to assess self-sustainability)	1a2B	CRMO, LARO
Surface water quality: rivers and streams	Ia4A	JODA, LARO
Cultural landscapes in good condition	Ia7	BIHO, JODA, NEPE , WHMI
The NPS 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.	Category Ib	BIHO, CIRO, CRMO, HAFO, JODA, LARO, MIIN, NEPE, WHMI
Park specific natural resource data sets (inventories)	Ib01	BIHO, CRMO, LARO, NEPE
Cultural landscapes inventory	1b2B	BIHO, MIIN, NEPE, MIIN, WHMI
Vital signs identified	1b3A	BIHO, CIRO, CRMO, HAFO, JODA, LARO, NEPE, WHMI
Vital signs monitoring implemented	Ib3B	BIHO, CIRO, CRMO, HAFO, JODA, LARO, NEPE, WHMI
Park partnerships: number of partners	IVb1A	BIHO, CIRO, HAFO, JODA, LARO, NEPE, WHMI

1. *Threat-specific Monitoring*. When sufficient understanding exists between potential effects and responses by park resources (Known Effects), monitoring of system drivers, stressors, and effected park resources is conducted.
2. *Focal Resource Monitoring*. A set of focal resources (including ecological processes) is monitored to address both known and unknown effects of system drivers and stressors on park resources.
3. *Ecosystem Status Monitoring*. Key properties and processes of ecosystem status and integrity are monitored to improve long-term understanding and potential early warning of undesirable changes in park resources.

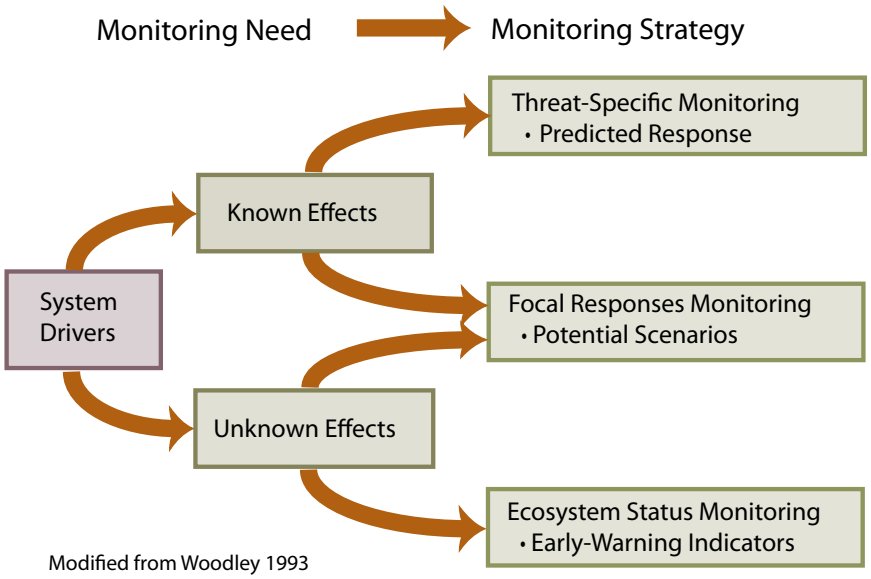
These categories provide a useful framework for organizing not only the selected vital signs, but also the thinking by which these vital signs were selected. The intent has been to ensure that at least some vital signs are selected from each category to ensure program integration, so that, when taken together, the UCBN program whole is greater than the sum of its parts. This approach is necessary simply because practical constraints such as budgets and staff size prevent the selection of all important vital signs. Selecting vital signs from each of these categories helps ensure a balanced and integrated program that can address the status and trends of ecological phenomena across a range of temporal and spatial scales, and for which effects are both known and unknown. This approach is discussed further in Chapter 2.

The UCBN selected vital signs for monitoring and developed corresponding monitoring objectives through a 2-year process that included soliciting input from scientists and park managers through regional workshops, online ranking surveys, and park-level workshops. Conceptual models and accompanying literature reviews were used extensively to visually explain linkages between drivers, stressors, and resources identified as important ecologically and of management significance. The process used to determine the "final list" of vital signs was

Table 1.3. NPS Servicewide vital signs monitoring goals.

1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
4. Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
5. Provide a means of measuring progress toward performance goals.

Figure 1.3. The conceptual framework for categorizing UCBN vital signs (adapted from Woodley 1993).



Modified from Woodley 1993

comprehensive and is detailed in Chapter 3. The 14 vital signs selected for monitoring, specific monitoring objectives developed for the vital signs, and conceptual models developed to illustrate key linkages are shown in Table 1.4.

Ecological Context

UCBN Natural Resources

To better understand the similarities and relationships among parks, the Network adopted ecoregions as a land classification system for supporting sustainable resource

Table 1.4. Selected Vital Signs for the UCBN with conceptual model(s) and monitoring objectives.

Vital Sign	Conceptual Model(s)	Objectives
Aquatic Macroinvertebrates	Lotic Submodel	Estimate status and trend in aquatic macroinvertebrate abundance, community composition, and functional feeding group composition in representative lotic UCBN waterbodies.
Aspen	Aspen Altered Fire Regime Submodel	Estimate status and trends in aspen abundance, conifer density, and regeneration of park aspen populations as well as individual stands within CIRO and CRMO.
Bats	Bat Community Submodel	Estimate trends in the occupancy dynamics of individual bat species in riparian areas of CIRO, CRMO, and JODA and in lava tubes of CRMO's north caves complex during summer pup-rearing.
Camas Lily	Cultural Landscape Model, Camas Lily Submodel	Estimate status and trend in total stem density and proportion of flowering plants for the camas lily population as well as frequency of targeted invasive plants in Weippe Prairie (NEPE) and within the targeted portion of BIHO
Invasive/Exotic Plants	Sagebrush Community Model/ Riparian Community Model, Cultural Landscape Model	Detect incipient populations and new occurrences of selected invasive nonnative plants before they become established and estimate the status and trend of established target invasive plant species frequency and abundance in UCBN parks.
Land Cover and Use	Land Cover/Land Use Model	Determine long-term trends in land cover distribution and patterns of relevant land cover types within and adjacent to UCBN park boundaries.
Limber Pine	Limber Pine Submodel	Detect new infections and estimate trends in the proportion, severity, and survivorship of limber pine trees infected with white pine blister rust in CRMO and CIRO.
Osprey	Osprey Submodel, Lotic and Lentic Submodels	Determine annual status and trend of nest occupancy and productivity (number of fledglings) for osprey in LARO.
Riparian Vegetation	Riparian Community Model, Bat Community Submodel, Lotic Submodel	Estimate trends in the abundance and composition of UCBN riparian plants species and communities, and targeted riparian-obligate vertebrate species of concern.
Sagebrush-steppe Vegetation	Sagebrush Community Model/ Sagebrush Altered Fire Regime Submodel	Estimate trends in the abundance in targeted plant species and horizontal strata and in diversity and species composition of UCBN sage-brush steppe communities.
Sage Grouse	Sagebrush Community Model, Sage Grouse Submodel	Cooperate with Idaho Department of Fish and Game to estimate trends in occupancy and abundance of male sage-grouse on lek sites in and adjacent to (within 2 miles of park boundaries) CIRO and CRMO and assess the status of grouse occupancy and abundance in park critical habitat areas.
Stream/River Channel Characteristics	Lotic Submodel	Estimate trends in streambank channel morphology of UCBN perennial wadeable rivers and streams.
Surface Water Dynamics	Lotic Submodel	Estimate trends in seasonal and annual flow regimes for (representative) lotic waterbodies within or near UCBN park units.
Water Chemistry	Lotic Submodel	Estimate status and trends in key water chemistry parameters for UCBN park water bodies.

management practices (Bailey 1995, 1998). Ecoregions effectively bring together the biological and physical worlds into a framework by which natural systems can be described, evaluated, and managed (Rowe 1992).The Columbia basin is in a transition-type climate zone and climate patterns are dominated by topographic features (Ferguson 1999; Quigley and Arbelbide 1997). Vegetation type and distribution varies depending on the soils, long-term precipitation patterns, and climate. Climate at park sites is influenced by three distinct air masses: 1) moist, marine air from the west that moderates seasonal temperatures; 2) continental air from the east and south, which is dry and cold in winter and hot with convective storms in summer; and 3) dry, arctic air from the north that brings cold air to the basin in winter and helps to cool the basin in summer (Ferguson 1999).

Most precipitation accumulates during winter (20 to 40 cm [8 to 16 in]) in the central Columbia and Snake River Plateaus. The mountain snowpack acts as a natural reservoir and supplies the basin with most of its usable water. Summer precipitation through the basin ranges from about 20 to 50 cm (8 to 20 in). Trends in the last 50 to 100 years indicate a general decrease in winter precipitation and increase in summer precipitation (Ferguson 1999).

Temperatures are generally mild in the basin because of the periodic influxes of moderating Pacific moisture. Winter mean monthly temperatures range from -10 to -3°C (-50 to 27°F) and summer temperatures ranges from 10 to 15°C (50 to 59°F). Trends in the last 50 to 100 years indicate a slight increase in winter temperatures and slight decrease in summer temperatures (Ferguson 1999). Climate change scenarios identified by the US Global Change Research Program for the Rocky Mountain/Great Basin region, which includes the UCBN area, are complex but include a reduction in snowpack and an overall aridifaction of the region, with increased evapotranspiration negating the effects of potential increased summer precipitation (Wagner et al. 2003).

UCBN parks contain hundreds of soils that vary widely in their age and parent material, occur across a range of climatic conditions and topography, and support a wide variety of vegetation types. This variation results in a broad range of productivity. Soils descriptions are grouped by the province in which

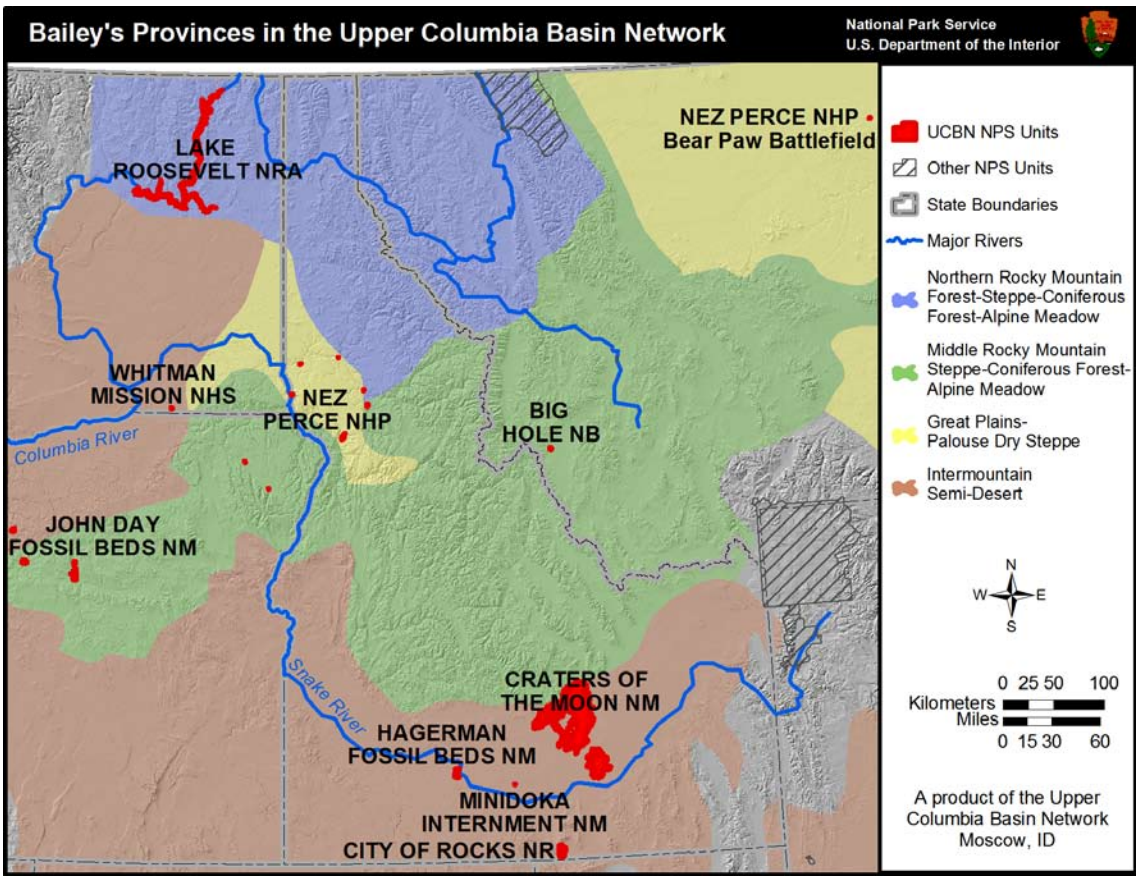


Figure 1.4. Bailey's Ecoregion Provinces in the UCBN.

a park occurs and can be found in Appendix B.3.

The Columbia Plateau is the most significant geologic province of the Network and its unique volcanic geology dominates much of the present day landscape. The plateau contains one of the world's largest accumulations of lava. Over 170,000 km^3 of basaltic lava, known as the Columbia River basalts, covers the western part of the province. Following this period of intense volcanism were repeat events of glaciation during the Pleistocene Epoch that reshaped much of the Columbia Plateau. Continental ice sheets reached as far south as the Spokane area in eastern Washington, and montane glaciers reached farther south down the Rocky Mountain and Cascade chains. Massive pluvial lakes and ice dams drove repeated flood events that continue to have a tremendous effect on modern day geomorphology as well as land use practices.

BIHO and the northern portion of LARO are considered within the Rocky Mountain geologic province. Both the Big Hole valley and the Okanagan Highlands of upper Lake Roosevelt have experienced extensive reshaping from Pleistocene glaciation. Beginning about 2.5 million years ago and lasting until about 10,000 years ago, lobes of continental and cordilleran ice sheets ground across the Northern Rockies and the northern edge of the Columbia Plateau. The Big Hole valley itself is a broad "U"-shaped valley carved by glaciers and the Okanagan Highlands were repeatedly smoothed over from periodic glacier movements (see Appendixes B.4 and B.5).

Shrub-steppe habitat is the most extensive vegetation type in UCBN parks (Table 1.5). However, forested vegetation is also widespread, especially in the north. Forest types present include ponderosa pine (See Appendix G.1 for all species scientific names) forest, pinyon-juniper woodlands, lodgepole pine forest, aspen communities, isolated stands of Douglas-fir, and limber pine woodland. Small amounts of wetland and riparian vegetation are also present in most parks. Descriptions of major vegetation types within the Network can be found in Appendix B.6 and are discussed at length in Appendix C.

Vertebrate communities associated with upper Columbia Basin habitats are well represented in UCBN parks. The fauna present vary widely from site to site due to presence or absence of refugia, type of vegetation communities, and the presence or absence of water. Over 300 terrestrial vertebrate species were identified during the 2000 to 2003 inventories, including 24 species of reptiles and amphibians, 76 species of mammals, and over 200 species of birds. Current estimates, based on existing information, indicate approximately 15 to 20 species of fish are also present in Network waters. The gray wolf, bald eagle, bull trout, and summer steelhead (Middle Columbia Evolutionary Significant Unit) are the only confirmed vertebrate species listed as threatened or endangered under the Endangered Species

Over 300 terrestrial vertebrate species were identified during the 2000 to 2003 inventories of UCBN parks.

Table 1.5. Percentage of UCBN park area in each land cover type as determined with the National Land Cover Dataset and the NPS digital park unit layer (NPS boundary).

Land Cover	BIHO	CIRO	CRMO	HAFO	JODA	LARO	MIIN	NEPE	WHMI
Open water	1%			1%	1%	75%		1%	6%
Urban			<1%			1%		<1%	
Bare rock/sand/clay			81%	<1%	1%	<1%			
Transitional	18%					<1%		4%	<1%
Deciduous forest	<1%	<1%			<1%	<1%		4%	2%
Evergreen forest	23%	4%		<1%	21%	11%		7%	
Mixed forest						<1%		<1%	
Shrubland	3%	71%	18%	53%	68%	6%	45%	17%	3%
Orchards/vineyards/other						<1%			5%
Grasslands/herbaceous	32%	23%	1%	41%	5%	4%	29%	51%	83%
Agriculture		3%	<1%	5%	5%	1%	26%	16%	
Woody wetlands	21%	<1%	<1%	<1%		<1%	<1%	<1%	
Emergent herbaceous wetlands	2%				<1%	<1%		<1%	

Act (see Appendix B.1). However, many vertebrates that occur in UCBN parks are listed as state and/or federal species of concern, and many are unique to the semi-arid habitats of the region. This list includes greater sage grouse, pygmy rabbit, spotted bat, Columbia spotted frog, and western toad. One of the last strongholds of the arctic grayling south of Canada and Alaska is in the upper reaches of the Big Hole and North Fork Big Hole Rivers (see also Appendix B.7).

The states of Idaho, Montana, Oregon, and Washington have identified species of greatest conservation need and are in the process of writing management plans for these species. The vertebrate species of greatest conservation need identified by the states is found in Appendix B.1.

Air Quality Monitoring

While air quality monitoring stations are located near several UCBN parks (Table 1.6), only CRMO has air quality monitoring onsite and is considered a Class I airshed under the Clean Air Act. This designation requires the highest level of air quality protection. Consequently, CRMO participates in the NPS's comprehensive air resources management program, designed to assess air pollution impacts and protect air quality related resources. The NPS operates monitoring instruments near the Monument's Visitor Center, which record concentrations of ozone, mercury, fine particles which affect visibility, and acid precipitation. These sites are part of national monitoring networks which record existing conditions, detect trends, and help in the development of predictive models for air quality used throughout the country. Air quality estimates for the UCBN parks can be found online in Air Atlas at http://www2.nature.nps.gov/air/Maps/AirAtlas/index.cfm (MIIN was not an NPS site when these estimates were made and was not included). Additional air quality information for the network can be found online in the Air Resources Information System (http://www2.nature.nps.gov/air/permits/aris/networks/index.cfm).

There are 15 National Atmospheric Deposition Program (NADP) sites within 300 km (186 mi) of UCBN parks. The purpose of the NADP network is to collect data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends. The precipitation at each station is collected weekly according to strict clean-handling procedures. It is then sent to the Central Analytical Laboratory where it is analyzed for hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations (such as calcium, magnesium, potassium and sodium). Table 1.6 lists only the closest NADP sites to each park. Further NADP data and information is available online at http://nadp.sws.uiuc.edu/.

The NPS and other federal land managers are required by the Clean Air Act to protect visibility at Class I areas, which include most national parks and wilderness areas. Twelve monitoring sites are operated by the Interagency Monitoring of Protected Visual Environments Program (IMPROVE) within 300 km (186 mi) of UCBN parks. The IMPROVE program includes characterization of haze by photography, measurement of optical extinction with transmissometers and nephelometers, and measurement of the composition and concentration of fine particles that produce the extinction and tracers that identify emission sources. Further IMPROVE data and information is available online at http://vista.cira.colostate.edu/improve/.

The NPS Gaseous Pollutant Monitoring Program (GPMP) monitors ozone at a number of parks, including CRMO, in order to evaluate air quality and determine compliance with the Clean Air Act, which has established a national standard for ozone to protect human health. The NPS Air Resources Division provides ozone data for parks at http://www2.nature.nps.gov/air/Monitoring/network.cfm. In addition, summary ozone data for CRMO and other ozone monitoring sites within 300 km (186 mi) of UCBN parks is available from EPA AirData at http://www.epa.gov/air/data/index.html.

The Air Resources Division (ARD) of the NPS released a detailed risk assessment report for parks in the UCBN (MIIN was not a NPS site at the time of this assessment and was not included) (Kohut 2005). This report describes the risk of foliar injury at each park and explains threshold values for ozone measurements. All parks in the UCBN, with the exception of CIRO were rated as low for ozone risk (Table 1.7). The risk of foliar ozone injury at CIRO is moderate. The risk of injury is greatest in years when the ambient level of ozone is high, and

soil moisture conditions favor uptake by plants. The assessment advised that quaking aspen and Scouler's willow could be used as bioindicator species to assess foliar injury.

Water Quality Monitoring

The Water Resources Division (WRD) of the NPS provides a separate source of funding each fiscal year (FY) to the UCBN to accomplish water quality monitoring. It was decided by the Network Board of Directors and Science Advisory Committee (SAC) that water quality monitoring for the Network will be accomplished as an integrated program with other monitoring. Vital signs related to water quality are discussed in more detail in Chapter 3. Aquatic resource vital signs include surface water dynamics, water chemistry, and aquatic macroinvertebrates.

Aquatic resources represent a very small percentage of total land cover in UCBN parks, except in the case of LARO (see Table 1.5). However, like riparian and wetland vegetation, aquatic environments are disproportionately important in terms of biodiversity, biological productivity, and many other ecosystem functions and values

Table 1.6. Distance (km) of National Atmospheric Deposition Program (NADP), Interagency Monitoring of Protected Visual Environments Program (IMPROVE), and Air Quality System monitoring stations from UCBN parks.

Type	SiteCode	BIHO	CIRO	CRMO	HAFO	JODA	LARO	MIIN	NEPE	WHMI
NADP	ID03		50-150	Onsite	50-150			50-150		
NADP	ID04								<50	
NADP	MT97	<50								
NADP	OR17					50-150				<50
NADP	OR18					50-150				
NADP	WA15						<50			
NADP	WA24								<50	
IMPROVE	CRMO			Onsite	50-150			50-150		
IMPROVE	CORI					50-150				
IMPROVE	HECA								<50	
IMPROVE	JARB		50-150					50-150		
IMPROVE	MONT									
IMPROVE	PASA						50-150			
IMPROVE	STAR					50-150				50-150
IMPROVE	SULA	<50								
Ozone	320	150-300	150-300	Onsite	50-150			50-150		
Ozone	938					50-150			150-300	150-300
Ozone	939									150-300
Ozone	944						<50		150-300	150-300

Table 1.7 Summary of ozone risk assessments for parks in the UCBN.

Park	Ozone Risk	O_3 Data Acquired
BIHO	Low	kriged
CIRO	Moderate	kriged
CRMO	Low	monitored onsite
HAFO	Low	kriged
JODA	Low	kriged
LARO	Low	kriged
NEPE	Low	kriged
WHMI	Low	kriged

The variability in climatic and geologic processes within the upper Columbia Basin has resulted in a complex diversity of aquatic habitats.

(Richardson 1994; Kauffman et al. 1997; McKinstry et al. 2004). Lotic (flowing water) environments in the UCBN include large rivers, perennial tributary creeks, irrigation ditches, and numerous seasonal and ephemeral streams, springs, and seeps. Lake Roosevelt, a large run-of-the-river reservoir in the Columbia River, and Lower Salmon Falls Reservoir in the Snake River adjacent to HAFO, function as lotic environments in the upper reaches of the reservoir and lentic environments near the dam. Impoundments on Columbia Basin rivers provide both lotic and lentic environments along longitudinal gradients. Other lentic environments include small lakes and ponds, as well as floodplain and depressional wetlands (Table 1.8)

The variability in climatic and geologic processes within the upper Columbia Basin has resulted in a complex diversity of aquatic habitats. Aquatic habitat heterogeneity is important to biological diversity in both terrestrial and aquatic environments (Gresswell et al 1994; Schlosser 1991). This is especially true in the semi-arid environment of the upper Columbia Basin, and aquatic environments, including the riparian/wetland vegetation "greenline" zone, provide three-dimensional connectivity between the atmosphere, uplands, and upstream/downstream reaches (Gregory et al. 1991). The maintenance of aquatic habitat complexity is critical for biodiversity within the context of increasing human-driven disturbances. Although climatic and geologic processes cannot be managed, human response to them can be planned, and in some cases, human disturbances might be modified to maintain desired habitat complexity in the context of natural disturbance regimes (Reeves et al. 1995).

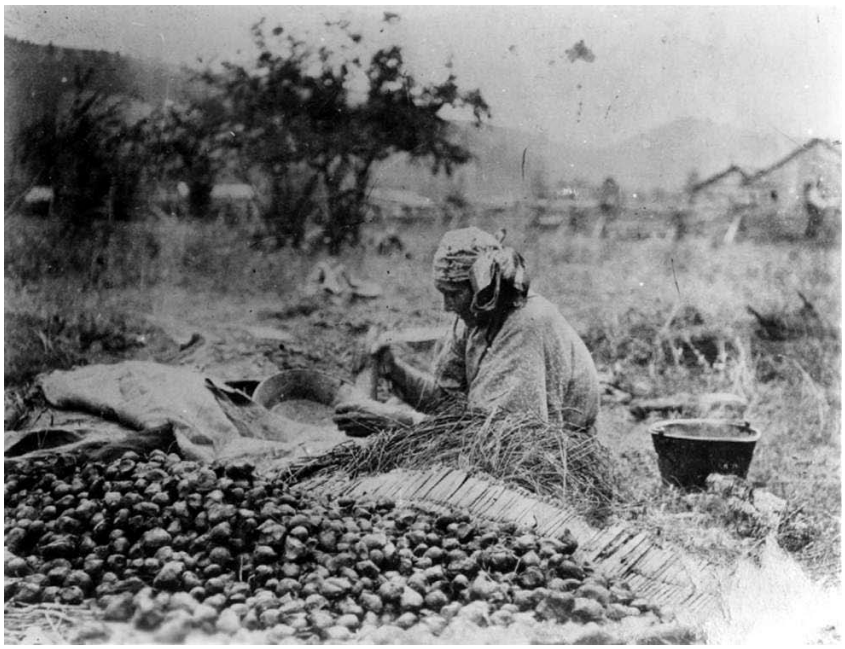
Activities throughout watersheds may affect ecosystem processes and water quality (Allan 2004), necessitating a watershed approach for effective management. However, individual watersheds typically contain a large number of owners, land uses and overlapping regulatory jurisdictions. Consequently, effective management of aquatic resources becomes increasingly complicated as the water body size and associated watershed increases. This is true within the UCBN park units, where waterbodies loosely fall into three general categories. Many waterbodies are small streams, seeps, or ponds with relatively small watersheds that may be partly or wholly contained with the park unit. These resources have no or few available data on water quality or aquatic biota. In contrast, three park units (JODA, NEPE, HAFO) include portions of free-flowing or impounded large rivers—the John Day, Clearwater, and Snake Rivers—that have watersheds extending thousands of square kilometers upstream of park units, and have or have had substantial aquatic resource monitoring. Lake Roosevelt is unique within the Network because the recreation area includes a large proportion of the reservoir shoreline. Impairments of aquatic resources by upstream inputs, particularly toxic pollutants from a lead-zinc smelter in Trail, British Columbia operated by Cominco, Inc. and past and current mining activities in the Coeur d'Alene drainage basin have had cascading effects on lake sediments and effects on human health are

Table 1.8. Aquatic Resources of UCBN Parks.

Park	Large Rivers (no.)	Small Rivers & Streams (no.)	Intermittent Streams (no.)	Irrigation Ditches (no.)	Ponds (no.)	Reservoir (no.)	Mapped Springs/ Seeps (no.)	Unmapped Springs/ Seeps (no.)
BIHO	1	1		2				
CIRO	5	5	numerous				5	1+
CRMO	1	1			1		9	numerous
HAFO				1		1	1+	numerous
JODA	1	2	1	2	1		8	6
LARO	1	5				1		
MIIN				1				
NEPE	2	1			1			
WHMI		2		1	1			

now being investigated. Lake Roosevelt is currently being considered for listing as an EPA "Superfund" site.

Our approach to water quality monitoring will reflect these differences. We propose to focus resources in the small waterbodies within the Network because these aquatic resources likely hold biotas which rely largely or completely on habitats within park units. In contrast to large river biota, the smaller water bodies and associated resources should respond more strongly to management and restoration action. These habitats will provide valuable monitoring sites for the detection of invasive/exotic species and help fill a water quality data gap compared to available data for large river systems and Lake Roosevelt.



Camas lily, a UCBN vital sign, has both an ecological and cultural significance. As shown, it was an important food source to the Nez Perce.

Cultural Landscapes

The upper Columbia Basin has a rich and fascinating cultural history. This is the land of a highly diverse human landscape, in which many linguistic and cultural traditions sprang up around the great salmon fisheries, wild root crops, and other natural resources of the region. The Nez Perce, Cayuse, Wasco, Yakima, Paiute, Shoshone, and their ancestors have lived in the region for thousands of years and have made an indelible imprint on the landscape. The Columbia Basin was also a central stage in the inexorable and tragic displacement of Native Americans by pioneering European Americans that occurred throughout the west during the 19th century. Beginning with the first encounter between Lewis and Clark's Corps of Discovery and the Nez Perce at Weippe Prairie in NEPE, this period of cultural schism is also remembered in the landscapes of Whitman Mission, Ft. Spokane at LARO, and the many battlefields of the Nez Perce Trail where the Wallowa Band was led on a 2,092 km (1,300 mi) exodus from Oregon to northcentral Montana under pursuit by the US Cavalry. Overlaid upon this historical period has been the formation of modern American cultural landscapes during the 20th century, such as the rural agricultural landscape of the Cant Ranch along the John Day River, the Minidoka Internment Center of World War II, and the creation of Franklin D. Roosevelt Lake behind the Grand Coulee Dam. Today thousands of visitors come to see and recreate in these landscapes, preserved and memorialized in UCBN parks.

Cultural landscapes are an important component of the parks of the UCBN. While cultural landscapes represent a relatively small proportion of total land area, they are disproportionately important to park mission and visitor experience. Cultural landscapes in the Network include historic sites, historic vernacular landscapes, and ethnographic landscapes (see Table 2.2 for definitions).

The UCBN monitoring program distinguishes cultural landscapes as distinct systems that exhibit unique and important ecosystem processes and interacts with surrounding ecosystems in profoundly important ways. It is within this context that the Network seeks to explicitly incorporate cultural landscapes into the vital signs monitoring program.

Summary of Key Resources and Natural Resource Threats and Issues

Key Resources and Management Concerns

Resource managers were asked to identify the most significant natural resources in their parks (Table 1.9). Cultural landscapes, fossil resources, kipukas (islands of vegetated lava located at CRMO), riparian vegetation communities, and aquatic resources

were identified as being the most significant resources in Network parks. Vertebrate and plant species of concern were also identified, including the Townsend's big-eared bat and sage grouse at CRMO, water birds at LARO, and sensitive plant communities at JODA (see Appendixes B.1 and D.4 for UCBN vertebrate and plant species of concern/conservation need).

Cultural landscapes are the most significant resource in at least five of the nine Network parks.

Cultural landscapes are the most significant resource in at least five of the nine Network parks. At BIHO, NEPE, and WHMI, the entire acreage contained within the park is considered a cultural landscape. Other parks, such as CIRO and LARO, encompass cultural landscapes that are central to park mission.

Two parks (HAFO and JODA) were designated as National Park sites due to their fossil resources. The Smithsonian Horse Quarry at HAFO and the numerous fossil beds of JODA are nationally and internationally significant. These beds include some of the world's richest fossil deposits from the Eocene, Oligocene, and Pliocene Epochs.

Riparian vegetation communities were also identified by several parks as being a significant resource. Riparian communities support unique plant and animal species and provide important ecological services. Throughout the Network these communities have been substantially altered by historic land use, invasive/exotic plants, development, and other impacts.

Natural Resource Threats and Issues

UCBN parks share many similar natural resource threats and issues. The most fundamental is the profound alteration and disturbance of their landscapes. Lands undisturbed by human activities are rare in the region and an even smaller proportion of the remaining undisturbed lands are formally protected. Land use change, habitat alteration, and fragmentation are some of most important agents of change and source of resource stress in UCBN parks. The scarcity of protected lands within these provinces was illustrated in a survey that assessed the degree to which units of the national park system contained a representation of all natural regions in the country (NPS 1972). This assessment found that various landscapes within the Columbia Plateau and Great Basin natural regions had the poorest representation within the national parks. Evidence of the lack of protection in these regions can also be found in the research of the Gap Analysis Program and by Wright et al. (2001) who has characterized the Snake River Plain and the Columbia Plateau - Palouse ecoregion as one of the least protected landscapes in North America. Conservation biologists have also characterized this region as an endangered ecosystem (Noss et al. 1995).

Table 1.9. Significant resources and management concerns in UCBN parks.

Park	Significant Resources	Management Concerns
BIHO	Cultural landscape	Invasive plants, hydrology
CIRO	California Trail, Indian Grove, riparian vegetation communities	Invasive plants, grazing, rock climbing impacts, dust dispersal and sedimentation, erosion
CRMO	Kipukas, class I airshed, lava tubes, volcanic geologic features, Sage grouse, Townsend's big-eared bats	Invasive plants, destruction of geologic features by collectors, illegal off-road vehicle use, regional haze impacts on visibility, development impacts on night sky, and white pine blister rust impacts on limber pine
HAFO	Fossils and the associated stratigraphy	Altered hydrologic regimes (high water tables, fluctuating reservoir levels, perched aquifers, irrigation) and wind/water erosion pose the biggest threats to slope stability and fossil resources, invasive/exotic plants
JODA	Fossil beds, Research Natural Areas, riparian vegetation, refugia for sensitive flora	Riparian area vegetation, changes in plant communities due to plant invasions, and reintroduction of fire
LARO	Aquatic resources, plant communities, raptors and water birds	Industrial pollution, residential development, and invasive/exotic plants
MIIN	Not included in survey	Not included in survey
NEPE	Cultural Landscape	Invasive plants
WHMI	Cultural Landscape	Invasive plants, quality of irrigation water coming into the park

Threats or stresses originating from outside park boundaries can, and are, significantly modifying biodiversity and other valued components of park ecosystems (NPCA 1979; Garratt 1984; Machlis and Tichnell 1985; Sinclair 1998). In 1980, greater than 50% of threats reported across the NPS system were from external sources, with development on adjacent lands, air pollution, urban encroachment and roads and railroads most frequently cited (NPS 1980). More recently, land use change (Hansen and Rotella 2002), fragmentation (Ambrose and Bratton 1990), and human population density (Newmark et al. 1994), have been documented as threats to individual parks. In addition, climate change is likely to exert a strong influence on biodiversity within parks. It has been hypothesized that only protected areas with adequate expanses of surrounding habitat and linkages to other protected areas will be able to support current levels of biodiversity into the future (Hansen et al. 2001).

An essential step in the process of selecting vital signs is the gathering of park specific information on natural resources and the significant management issues and concerns facing those resources. In order to narrow the focus, ensure relevance to Network parks, and increase efficiencies in the planning process, priorities must be established among focal resources and resource concerns. Network staff used several sources of information to summarize priority resources, stressors and resource concerns. Park planning documents were reviewed and summarized, resource managers were surveyed about the stressors affecting park resources, and information was compiled by questionnaire concerning threats to water quality (see Appendix B.8).

A survey of park resource managers confirmed that invasive/exotic plants had the highest negative impact on park resources. Other stressors with high negative impact rankings were agriculture practices on adjacent land, fire management practices, historic human impacts, NPS development, livestock grazing, recreational use, fire suppression, and landscape fragmentation.

The most common thread binding UCBN parks is that they are islands located in areas of highly fragmented and often highly disturbed habitat. Most resource problems arise from impacts caused by the mosaic of land uses around the parks and the legacy of historic land uses within existing park boundaries. Much less of a concern is the current land use and management activities within parks. The impact of current land use practices adjacent to park boundaries is compounded by the fact that all but one of the parks are small and lack external buffer zones that might mitigate impacts coming from lands external to the parks. The end result is parks are constantly beset by invasions of exotic plants and inputs from agricultural practices. They confront water and air quality problems due to agricultural and industrial activities on adjacent lands, and suffer from aesthetic impacts and intrusions, e.g., visual and noise pollution adjacent to the units. Along with these ecological problems, these factors disrupt the cultural setting many of the parks seek to portray. Viewsheds and soundscapes of cultural landscapes in the UCBN are at risk of degradation from outside land use changes.

Land use change, habitat alteration, and fragmentation are some of the most important agents of change and source of resource stress in UCBN parks.

A survey of park resource managers confirmed that invasive/exotic plants (such as spotted knapweed) had the highest negative impact on park resources.

Summary of Existing Monitoring and Partnership Opportunities

The UCBN staff is committed to complementing existing and fostering new regional collaborations that will benefit natural resource management within Network parks. Like many parks across the US, parks in the UCBN tend to be "islands" in a sea of multi-use lands. For eight of the nine park units, the greater part of land within 8 km (5 mi) of park boundaries is in private ownership.

Only CRMO is surrounded by a majority of public lands, primarily Bureau of Land Management (BLM). The BLM manages less than 20% of the lands around three additional parks in southern Idaho (MIIN, HAFO, and CIRO) and one park in Oregon (JODA). The US Forest Service (USFS) manages just over 40% of the land around BIHO and also has important land holdings around CIRO, LARO, and NEPE. Small, but valuable portions of state lands occur within 8 km (5 mi) of park units in all four states. Three of the parks (CIRO, JODA, and NEPE) are composed of multiple subunits. The most extreme case is NEPE, which consists of 38 subunits spread over all four states.

Monitoring efforts by agencies other than NPS may provide opportunities for partnership on natural resource projects aimed at wildlife, vegetation, air quality, water quality and weather conditions. Appendix E.3 summarizes the primary monitoring activities by adjacent land managers and/or other organizations that have been identified. In addition, numerous Geographic Information Systems (GIS) and remotely sensed data are available and will be invaluable for planning and conducting future monitoring (Appendix E.2).

Many of these surrounding land management agencies also designate areas for the long-term conservation of resources. At least 32 such conservation areas occur within 16 km (10 mi) of UCBN park units (Appendix B.2). Federal agencies manage 19, state agencies manage 10 and three are owned by The Nature Conservancy. Partnering with these entities as well as tribal and private landowners is essential for the long-term integrity of natural resources in UCBN parks (see Appendix D.3 for list of potential partners).

The lack of personnel to conduct monitoring in combination with the cultural resource focus of UCBN parks has limited the amount of natural resource monitoring currently occurring in Network parks. The resource management staff at LARO collects anecdotal data on wintering bald eagles for the US Fish and Wildlife Service. JODA and LARO have a fire effects monitoring plan that is coordinated and conducted by North Cascades National Park Complex. Groundwater dynamics monitoring is ongoing at HAFO, and WHMI is currently conducting a short-term soundscape monitoring project. Several parks participate in annual breeding bird surveys or Audubon Christmas bird counts but essentially none of the UCBN parks, except CRMO, conduct any formal natural resource monitoring.

We believe it is important to acknowledge the existing monitoring program at CRMO as we build an integrated network monitoring program. Appendix E.1 contains a current list of ongoing monitoring projects at CRMO. The existing monitoring program at CRMO is focused on air quality, wildlife, and vegetation. None of the monitoring projects at CRMO are conducted with peer-reviewed protocols that include a statistically sound sampling strategy. It was decided, through the vital sign prioritization process, to choose vital signs and corresponding protocols that had not been monitored in the past. The air quality monitoring protocols for wet deposition and ozone have been approved by the I&M office and can be found on the protocol database at http://science.nature.nps.gov/im/monitor/protocoldb.cfm. The visibility protocol is currently under development and several of the other listed projects have written protocols that have not been peer-reviewed or developed to meet the standards outlined by Oakley et al. (2003).

The lack of past monitoring activities in the Network serves to reinforce the importance of the I&M program to this group of parks. Natural resource information from which resource managers can base sound decisions upon is virtually non-existent.

Chapter 2: Conceptual Ecological Models

The inherent complexity of ecological systems presents a fundamental challenge to the development of a comprehensive and effective long-term ecological monitoring program. Long-term monitoring in the UCBN will help predict, identify, and understand change in selected park resources that reflect ecological condition. The monitoring program will also deliver information about ecological change into the hands of park managers and partner agencies in a timely and useful manner. In order to achieve this, it is necessary to reduce the complexity of the world in which we design the program into a manageable set of key components and processes.

Conceptual modeling has been widely used in monitoring programs to distill complex systems into key elements (Manley et al. 2000; Noon 2003). Conceptual modeling is not a goal in itself but is a tool to guide the thinking, communication, and organization that goes into identifying key ecosystem attributes and monitoring questions (Maddox et al. 1999). Conceptual models developed in concert with scoping sessions and other ground-level program development activities often directly point to measurable indicators (Maddox et al. 1999).

As an exercise, conceptual modeling can be effective in identifying gaps in knowledge as well as highlighting well understood ecosystem attributes (Roman and Barrett 1999). Conceptual models, as vehicles for communication and organization, reflect an iterative process and frequently remain in a dynamic "work in progress" condition rather than in a static "finished" state (Roman and Barrett 1999). They can play a central role in monitoring programs, evolving as new information is gained (Figure 2.1) (Maddox et al. 1999).

The UCBN began using conceptual models early in the process of building a vital signs monitoring program. In its first vital signs scoping workshop (April 2002) participants identified key ecosystem drivers, stressors, and ecosystem effects. A stressor-based model was developed during the course of the workshop that reflected the central management concerns (see Appendix D.2). This original model was refined during preparation for the second vital signs scoping workshop (March 2004) which resulted in a new set of models illustrating selected ecosystem and community dynamics and reflecting the Network's progress in developing vital signs and monitoring questions. These models were used in park-specific vital signs prioritization meetings (winter 2005) and were revised again following these meetings. These most recent models are presented in Appendix C.

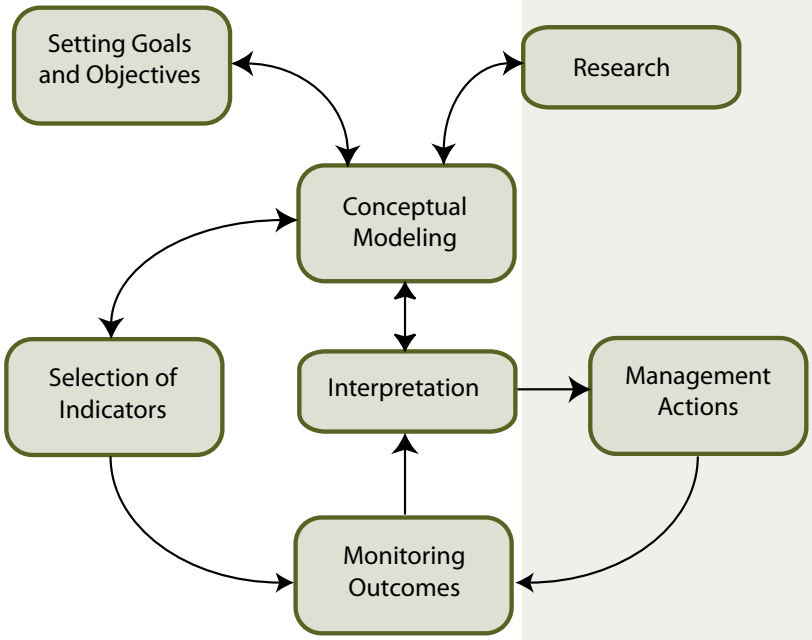
The UCBN Approach to Conceptual Modeling

> *"The problem of relating phenomena across scales is the central problem in biology and in all of science"* – Levin, 1992

A successful ecological monitoring program must be able to separate real change from inherent ecological variability. Temporal and spatial scale and the accompanying ecological organizational hierarchy act as lenses through which variability can become more or less focused. Patterns of variability may be apparent at one scale but not at another and meaningful detection of ecosystem change is dependent upon measurement at appropriate scales (Noss 1990; Morgan et al. 1994). Likewise, drivers, stressors, and effects may operate at different scales simultaneously within a nested hierarchy (O'Neill

A conceptual model is a visual or narrative summary that outlines the interconnections among ecosystem resources, the strength and direction of those links, and the attributes that characterize the state of the resource.

Figure 2.1. Central role of conceptual modeling in a dynamic monitoring program (adapted from Maddox et al. 1999).

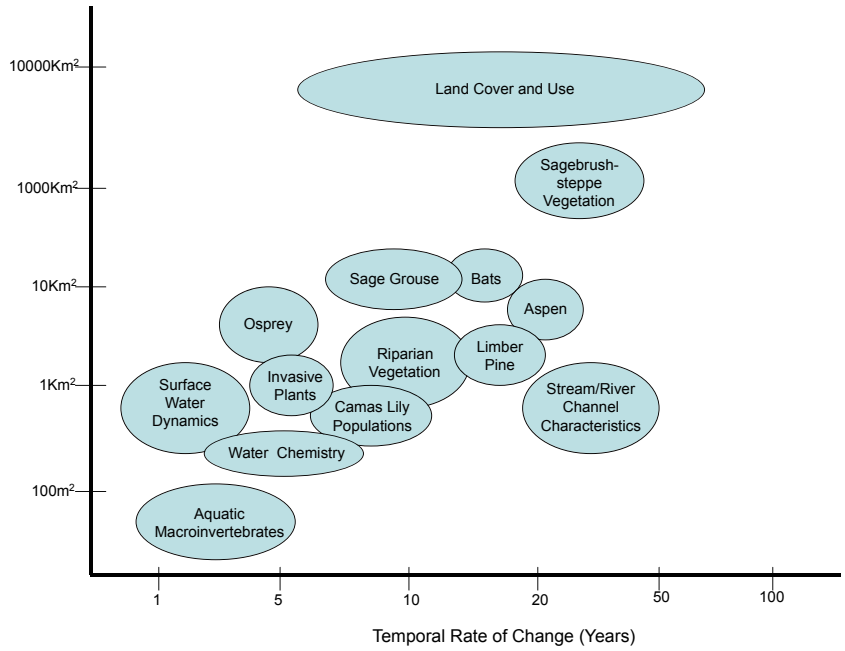


et al. 1986; Wu and David 2002). The NPS I&M program, following suggestions by O'Neill et al. (1986), Noss (1990) and others (e.g., King 1993; Woodley 1993), has identified integration of spatial, temporal, and ecological hierarchies as a key ingredient to monitoring efforts (NPS 2003c). Integration involves inclusion of hierarchical levels above and below the level of interest in conceptual models and monitoring designs.

Following an approach presented by Woodley (1993) and adapted by several other NPS I&M networks (e.g. Liebfreid et al. 2004; Mau-Crimmins et al. 2004), the UCBN has organized vital signs into three categories; threat-specific, focal resource, and ecosystem status (Figure 1.3). Selecting vital signs from each of these categories helps ensure a balanced and integrated program that can address the status and trends of ecological phenomena across a range of temporal and spatial scales, and for which effects are both known and unknown. The conceptual models developed by the Network reflect these categories, using both "stressor"-type and more mechanistic "control"-type models, and combining elements of both types in some models (Gross 2003). Stressor-effects relationships are widely represented (see Appendix C) because of the central role stressor-effects and threat-specific vital signs have taken to date. This central focus on threat-specific vital signs will lead to a program highly relevant to park management and will yield important information of more global significance as well. Park resource managers have consistently expressed concern over the impacts of a suite of approximately 6-10 anthropogenic stressors on park resources (Appendix D.5). Likewise, Dixon et al. (1997) and Olsen et al. (1997) have suggested focus on stressors and effects leads to more rich and interpretable results. This is consistent with the "issues orientation" promoted by Maddox et al. (1999) in which goals of management and threshold levels triggering management action are explicitly identified and incorporated into the monitoring program. Noon et al. (1999) have also promoted a stressor-oriented approach and have recognized the importance of establishing appropriate benchmarks with which to compare measured variability or change.

For many ecosystem attributes, however, effects of stressors are not well understood and threshold levels triggering management action are not easily articulated. A monitoring program based entirely on known stressor-effects relationships will fail in its ability to provide early-warning of new and emerging threats (Woodley 1993; Woodward et al. 1999; Vos et al. 2000). Ecosystem status vital signs help provide this early-warning capability and also, as independent explanatory covariates, provide greater interpretive power for observed changes and trends in threat-specific and focal resource vital signs (Bricker and Ruggiero 1998; Vos et al. 2000). Focal resource vital signs are those that by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or their indication of ecosystem condition. In this sense, focal resource vital signs address either known (or hypothesized) and unknown or unanticipated stressor-effects relationships. Focal resource vital signs add much in the way of management relevance and applicability to the UCBN monitoring program, as well as to the ecological relevance of the program. Figure 2.2 illustrates the range of spatial and temporal scales represented by the prioritized set of vital signs, and indicates that at least some measure of integration is being achieved in program planning. Recognizing that processes involved with each of these vital signs are operating

Figure 2.2. High priority vital signs organized according to the spatial extent and temporal rate of predicted or anticipated change in UCBN ecosystems.



across a range of spatial and temporal scales simultaneously, Figure 2.2 focuses on the primary scale of interest or observation for the UCBN. For example, the objective of the osprey vital sign is to monitor trends in nest use and fledging success in areas affected by recreation and water pollution. The focus will be on changes within the population of nest sites along the shore of Lake Roosevelt, which, after accounting for year-to-year variability, should become evident over a period of about 5 years.

UCBN developed a set of nested conceptual models that focus on key community dynamics, stressor-effects relationships, and individual park focal resources occurring over a range of spatio-temporal scales and ecological hierarchies. The primary goal of these models is to illustrate relationships of priority vital signs to ecosystem properties and processes and facilitate communication.

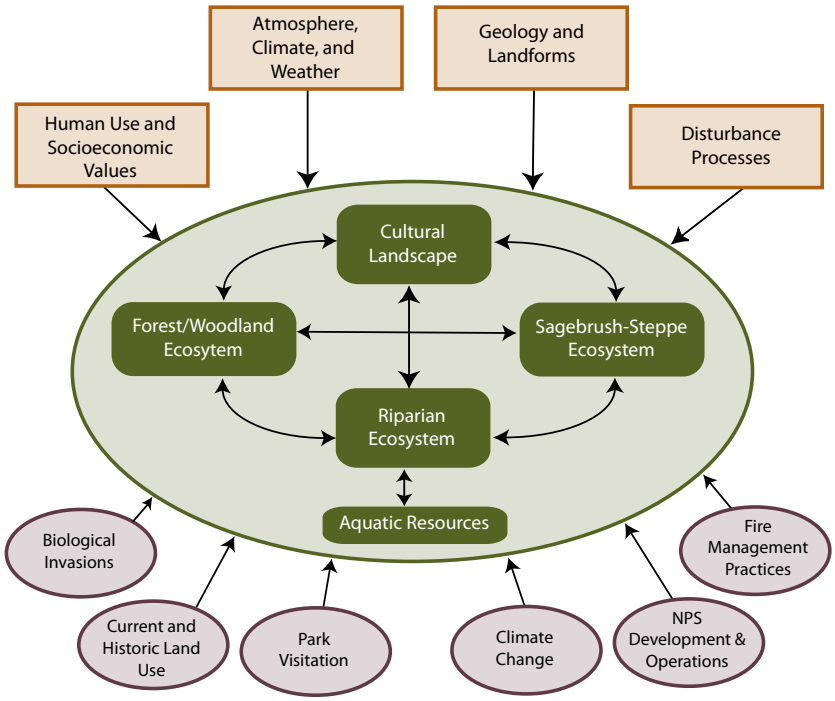


Figure 2.3. Five major focal systems in the UCBN and primary drivers and stressors that influence their distribution, structure, and function. Drivers are illustrated in orange boxes. Stressors are in the purple circles.

Focal Systems

The UCBN identified five focal systems upon which the monitoring program is based: cultural landscapes, sagebrush-steppe ecosystems, forest and woodland ecosystems, riparian ecosystems, and aquatic (lotic and lentic) ecosystems. These systems are defined primarily by land cover and encompass the suite of significant ecological resources of concern from which measurable information-rich indicators have been drawn. Figure 2.3 illustrates the interrelationships among these five systems, four global drivers that exert the strongest influence on the distribution of these systems across the region, and six broad stressor

Table 2.1. Conceptual models developed for the UCBN vital-signs monitoring program.

Focal Ecosystem	Conceptual Model	Appendix C, Figure and Page Number
Cultural landscape	Cultural landscape ecosystem control model	Fig. C.1, Pg. 57
	Camas lily submodel	Fig. C.2, Pg. 58
Sagebrush steppe ecosystems	Sagebrush-steppe ecosystem control model	Fig. C.4, Pg. 63
	Sagebrush-steppe altered fire regime submodel	Fig. C.5, Pg. 64
	Sage grouse population dynamics submodel	Fig. C.6, Pg. 65
Forest and woodland ecosystems	Forest and woodland ecosystem control model	Fig. C.9, Pg. 75
	Aspen community dynamics submodel	Fig. C.10, Pg. 76
	Limber pine community dynamics submodel	Fig. C.11, Pg. 77
Riparian ecosystems	Riparian ecosystem control model	Fig. C.14, Pg. 84
	Bat community dynamics submodel	Fig. C.15, Pg. 85
Aquatic ecosystems	Aquatic ecosystem control model	Fig. C.16, Pg. 91
	Lotic ecosystem submodel	Fig. C.17, Pg. 92
	Lentic ecosystem submodel	Fig. C.18, Pg. 93
	Osprey population stressors submodel	Fig. C.19, Pg. 94

categories that represent the greatest threats to ecosystem condition and are of greatest management concern. Conceptual models were built within this framework (Table 2.1) and accompanying narratives written to provide a review of relevant literature and an explanation of model properties (Appendix C). Ecosystem control models were designed to illustrate primary drivers and stressors controlling the distribution, composition, structure, and function of focal systems in the region. Submodels were developed to provide more detailed descriptions of specific community dynamics and stressor-effects relationships. It is within these submodels that specific relationships between system processes, vital signs, and measures are illustrated.

Cultural Landscapes

In contrast to Alaska, for example, where large, relatively pristine ecosystems still occur, the UCBN contains parks heavily influenced by historic and current human activities where only fragments of functioning "natural" ecosystems remain (USFS 1996; Bennett et al. 2003). In addition, many Network parks were established to preserve some type of historic cultural landscape or feature. As a result, the human "scene" has been explicitly incorporated into conceptual models not only as a key driver but also as a focal system with its own unique ecosystem attributes, processes, and approach to monitoring. Without this explicit consideration, entire parks (e.g., WHMI) would be greatly under-represented in conceptual models developed for other focal systems. Although humans constitute a major influence even in pristine systems, the unique historic and legislative context of the UCBN requires this be addressed in a very fundamental way.

In the United States, NPS has been a leader in defining and incorporating cultural landscapes into resource management, although the concept and utility of cultural landscapes in ecology has been much more widely exploited in Europe (La Pierre 1997; Taylor 2002). Birnbaum (1994), writing for the NPS, defines cultural landscapes as "a geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values." Interpreted broadly, this definition could be applied to most, perhaps all, landscapes in the Network. However, existing NPS definitions of cultural landscape types help narrow and clarify this somewhat. Four types of cultural landscapes are recognized: historic designed

Table 2.2. NPS definitions for the four types of cultural landscapes.

Historic designed landscape	A landscape that was consciously designed or laid out by a landscape architect, master gardener, architect, or horticulturist according to design principles, or an amateur gardener working in a recognized style or tradition. The landscape may be associated with a significant person(s), trend, or event in landscape architecture; or illustrate an important development in the theory and practice of landscape architecture. Aesthetic values play a significant role in designed landscapes. Examples include parks, campuses, and estates.
Historic vernacular landscape	A landscape that evolved through use by the people whose activities or occupancy shaped that landscape. Through social or cultural attitudes of an individual, family or a community, the landscape reflects the physical, biological, and cultural character of those everyday lives. Function plays a significant role in vernacular landscapes. They can be a single property such as a farm or a collection of properties such as a district of historic farms along a river valley. Examples include rural villages, industrial complexes, and agricultural landscapes.
Historic site	A landscape significant for its association with a historic event, activity, or person. Examples include battlefields and President's house properties.
Ethnographic landscape	A landscape containing a variety of natural and cultural resources that associated people define as heritage resources. Examples are contemporary settlements, religious sacred sites, and massive geologic structures. Small plant communities, animals, subsistence and ceremonial grounds are often components.

landscapes, historic vernacular landscapes, historic sites, and ethnographic landscapes (Table 2.2, Birnbaum 1994).

All four cultural landscape types are represented in the Network and seven of the nine parks contain at least one significant cultural landscape central to park enabling legislation (Table 2.3). A number of these landscapes have been inventoried and evaluated (Beckham and Lentz 2000; NPS 2003b) and a region-wide effort is ongoing to complete more inventories (Gilbert 1991). A number of other landscapes in the Network, especially those that meet the definition of ethnographic landscape type, remain outside formal designation but nonetheless are important and significant for the monitoring program.

Cultural Landscape or Feature	UCBN Park	Cultural Landscape Type
Ft. Spokane (incl. parade grounds)*	LARO	Historic Site
Whitman Mission (entire NHS)*	WHMI	Historic Site
Cant Ranch (incl. farm fields)	JODA	Historic Vernacular Landscape
Big Hole Battlefield	BIHO	Historic Site
Heart of the Monster*	NEPE	Ethnographic Landscape
White Bird Battlefield	NEPE	Historic Site
Spalding Mission (entire site)	NEPE	Historic Vernacular Landscape
Spalding Arboretum	NEPE	Historic Designed Landscape
Weippe Prairie	NEPE	Ethnographic Landscape
Buffalo Eddy	NEPE	Ethnographic Landscape
Old Chief Joseph Gravesite	NEPE	Historic Site
Bear Paw Battlefield	NEPE	Historic Site
Minidoka Internment Site	MIIN	Historic Site
Oregon Trail	HAFO	Ethnographic Landscape
Goodale's Cutoff	CRMO	Ethnographic Landscape
California Trail	CIRO	Ethnographic Landscape

Table 2.3. Landscapes and features representing the range of cultural landscapes within the UCBN. This list is not comprehensive and not all listed features are formally designated NPS cultural landscapes (* indicates formal designation).

Sagebrush-Steppe

The term sagebrush-steppe generally refers to a number of plant assemblages dominated by one or more of the big sagebrush species in association with perennial bunchgrasses and forbs (West and Young 2000; BLM 2002; Reid et al. 2002). The sagebrush-steppe ecosystem is often distinguished from sagebrush ecosystems of the Great Basin, in which the density of big sagebrush is much greater and perennial bunchgrass forms a relatively minor system component (Kuchler 1970; West and Young 2000). The climate of sagebrush-steppe is generally cooler and more mesic than the Great Basin sagebrush zone (BLM 2002). Sagebrush-steppe is widespread throughout the Columbia Plateau, Snake River Plain, and northern Great Basin (West and Young 2000), and overlaps with a significant portion of the UCBN.

The sagebrush-steppe ecosystem is the most widely distributed ecosystem type within Network parks and comprises over 50% of land cover in CIRO, HAFO, and JODA. At CRMO, where bare or sparsely vegetated lava rock comprises 81% of total land cover, sagebrush-steppe represents over 90% of the existing vegetation cover (see Table 1.5). In the remaining parks, sagebrush-steppe is present and significant at LARO, present as a transitional form in BIHO and occurs as minor relicts in MIIN, NEPE, and WHMI.

Forest and Woodlands

Forest and woodland ecosystems are the second most widespread ecosystem type, accounting for over 20% of the landscape in BIHO and JODA, and over 50% of terrestrial land cover in LARO. Forest and woodland ecosystems are also significant at CIRO, CRMO, and NEPE. Small woody riparian areas are present at HAFO and WHMI and no woodland is present at MIIN. Forest and woodland types that occur include mixed fir and pine forest, ponderosa pine forest, limber pine woodland, pinyon-juniper woodland, aspen groves, and riparian cottonwood galleries. Much like cultural landscapes, forest and woodland ecosystems tend to be disproportionately important and contribute significantly to biological diversity. This is particularly well illustrated at CRMO, where small stands of aspen, fir, and limber pine on the extreme north end of the monument contain a large number of vertebrates found nowhere else in the monument. Forests and woodlands also play key roles in ecological processes important to current park management, including conifer encroachment into cultural landscapes, juniper expansion into sagebrush steppe, fuel accumulation, and fire. Recent discovery of a pinyon Ips beetle outbreak and related pinyon pine mortality at CIRO and

The John Day River flows through JODA and is an example of a key riparian ecosystem within the Network.

whitepine blister rust at CRMO has focused attention on forest insect pathogens and disease as well.

Riparian Ecosystems

Riparian zones comprise less than 1% of total land cover in UCBN parks except at BIHO, where the floodplain of the meandering N. Fork Big Hole River supports extensive stands of willows and herbaceous wetland vegetation. As with forest, woodland, and aquatic areas, riparian zones are disproportionately important to biological diversity and ecological processes, such as water retention and nutrient cycling (Gregory et al. 1991; Kauffman et al. 1997). Typical of semi-arid environments, riparian areas are narrow zones surrounding open water and transition abruptly to upland areas. Riparian types are defined primarily by vegetation and soil characteristics and are represented by woody wetlands such as cottonwood and alder galleries, willow thickets, and stands of herbaceous vegetation such as reed canary-grass, sedges, and rushes.

Ecosystem drivers are major external driving forces…that have large scale influences on natural systems.

Aquatic Resources

Open water is relatively scarce in the UCBN, accounting for less than 1% of land cover, except at LARO, where Lake Roosevelt itself comprises 75% of total park area. Both lotic (running water) and lentic (lake and pond) aquatic habitats are represented and, like the riparian and wetland habitats they support, are very important to the overall structure and function of Network ecosystems. Most aquatic resources are lotic, and include large rivers, small creeks, and ephemeral springs and seeps. Lentic systems include large reservoirs on the Columbia and Snake Rivers, Lake Roosevelt and Salmon Falls Reservoir, several oxbow lakes, small artificial ponds, and numerous ephemeral vernal pools associated with geologic features at CIRO and CRMO.

Ecosystem Drivers

Ecosystem drivers are major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems. This section briefly introduces the major driving forces of UCBN ecosystems. These drivers, or specific elements of them, figure prominently in the conceptual models (Appendix C).

Atmosphere, Climate, and Weather

Local climate and weather patterns are created by the interaction of tremendously variable forces of topography, ocean temperature circulation, and circulation of the atmosphere. The latitudinal position of the UCBN receives insolation at an oblique angle, making it a relatively cool region. Interaction of latitude, prevailing westerly winds, and the Cascade Mountains to the west has created a cool, semi-arid climate subject to seasonal temperature extremes and highly variable seasonal precipitation

patterns. Variability in weather and climatic patterns in the region are driven by changes in ocean circulation (Pacific Decadal Oscillation), changes in atmospheric composition (primarily water vapor and CO_2), and elevation. This variability occurs across a broad range of spatiotemporal scales and, in concert with geology and landforms, exerts the most fundamental driving forces on the distribution, form, and function of UCBN ecosystems.

Geology and Landforms

Tectonic, volcanic, and surficial geomorphic processes drive contemporary ecosystems in the UCBN. These processes give rise to landforms, or topography, which, as stated previously, interact with the atmosphere and climate in fundamental ways. The effect of elevation on precipitation and aspect on evaporation, referred to as the topographic-moisture gradient, is the primary example of this, and largely explains the distribution of sagebrush-steppe, pinyon/juniper woodland, and coniferous forest across the region (Whittaker 1967; Peet 2000). Although elevational gradients are relatively low within park boundaries, largely due to their small size, gradients are quite steep in much of the surrounding landscapes and in the region as a whole. Geologic and geomorphic processes also provide parent material for soil development. Again, with interaction from atmospheric and climatic forces, weathering and soil development is tightly bound to network ecosystems and soil type is a fundamental driver of vegetation distribution and composition.

Human Use and Socioeconomic Values

Humans have been a profound source of ecosystem change in the Columbia Basin (USFS 1996; Marquet and Bradshaw 2003) and the long-term ecological trajectories of UCBN ecosystems and landscapes are heavily influenced by historic land use and disturbance regimes as well as societal values (Rapport et al. 1998; Foster 2002). The fundamental role of humans in shaping and controlling ecosystems is represented in Figure 2.3 as a global driver and a cultural landscape focal system. Anthropogenic influences are primary ecosystem stressors and understanding and modeling both historic and contemporary human impacts is an important ingredient in the monitoring program. Human use and manipulation of regional ecosystems have ranged from prehistoric use of prescribed fire, to rerouting of streams for irrigation and flood control, to creation of entirely artificial ecosystems, such as some of the cultural landscapes.

This spatter cone at CRMO was formed by volcanic processes.

Disturbance Processes

A disturbance can be defined as a relatively discrete event that disrupts structure of a

At CRMO and other UCBN parks, fires in sagebrush communities are burning more frequently and at higher intensities, greatly impacting the ecosystem and often allowing for cheatgrass invasion.

community, population, or ecosystem and changes resource availability or the physical environment (White and Pickett 1985). Disturbances vary in space and time and are described in terms of frequency, intensity, and size. These characteristics determine the ecological impact of a disturbance event or regime. Disturbances can become stressors when frequency, intensity, or size exceeds limits of natural variability. In the UCBN, fire is an important disturbance driver and most vegetation communities are adapted, or resilient, to fire. Depending on the plant community, historic fire regimes in the region range from frequent, low-intensity fires to infrequent, high-intensity fires (Agee 1993). Fire suppression and establishment of non-native invasive vegetation has significantly altered historic fire regimes and contributed to profound changes in ecosystem structure and function (D'Antonio and Vitousek 1992). Other important disturbance agents in the UCBN include floods, landslides, and forest insect outbreaks.

Invasive species have been called the "single most formidable threat of natural disaster of the 21st century." (Schanse et al. 2002)

Ecosystem Stressors and Effects

Ecosystem stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive (or deficient) level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution. This section introduces major stressors influencing UCBN ecosystems, all of which are anthropogenic or, in the case of accelerated climate change, hypothesized as anthropogenic.

Biological Invasions

Non-indigenous invasive species are a major threat to native species diversity and ecosystem function, causing economic impacts within the US estimated at more than $100 billion annually (Pimentel et al. 1999). In addition to competing with and displacing native species, establishment of introduced species leads to a positive feedback loop and alters conditions to promote the establishment and spread of other non-native species. This is particularly evident in the upper Columbia Basin and other arid environments in which non-native annual grasses alter fire regimes, in turn creating conditions favorable to further plant invasion (Mack and D'Antonio 1998, Bunting et al. 2002). Invasive species have been called the "single most formidable threat of natural disaster of the 21st century" (Schnase et al. 2002). Non-native plant invasion is the most difficult and pressing management concern in the UCBN with 36 different species affecting at least one Network park (Appendix D.4). Invasive animals are also of significant concern, most notably the bullfrog and various non-native gamefish, which have contributed to the extirpation of several species of native amphibians.

Current and Historic Land Use

The Columbia Basin has been occupied and manipulated by humans for millenia (USFS 1996). However, as a source of ecosystem stress, land use practices introduced during the settlement era in the latter 19th century are most relevant (Mack 1981; Yensen 1981; Todd and Elmore 1997; West and Young 2000; Reid et al. 2002). There are very few, if any, areas within UCBN parks not subjected to some form of historic anthropogenic stress. Even in remote portions of CRMO, evidence of historic mining and historic invasive plant introductions are evident. A recent study of vegetation in remote kipukas in CRMO found some relatively free of invasive plants (Huntley and Pedersen, Idaho State University, unpublished data), and these areas represent the most pristine ecosystems in the Network. Intensive livestock grazing, non-native plant introductions, agricultural conversion, irrigation and flood control related manipulations, and fire suppression represent the most ecologically significant and pervasive historic human stressors in the region.

Over the past century, land use dynamics in the rural western US have shifted from livestock grazing, agriculture and mining to suburban and ex-urban development (Johnson 1998; Rudzitis 1999; Hansen et al. 2002). Although this process is occurring at variable rates within the region, ex-urban development is evolving as a major force in land conversion and is certain to have considerable impacts on biodiversity in parks

and neighboring ecosystems (Hansen et al. 2002). Livestock grazing, hay and vegetable crop production, and other agricultural land use activities also continue to be widespread in lands surrounding UCBN parks. Habitat fragmentation, resulting from both ex-urban and agricultural land use change diminishes habitat quality and quantity and alters the pattern and distribution of habitat, further altering the movement of organisms and across the landscape (Ambrose and Bratton 1990; Harrison and Fahrig 1995; Trombulak and Frissell 2000). Adjacent land use practices influence the spread of invasive species into parks, as well as water and airborne contaminants such as agricultural chemicals and excessive nutrients. Upstream water withdrawals affect aquatic and riparian ecosystems in several UCBN parks.

Fire Management Practices

Both fire suppression and use of prescribed fire are employed by land managers within UCBN parks and on surrounding lands. Thinning of trees for fuel reduction, a widespread practice throughout forest lands in the region and practiced at LARO, is done for both suppression and to facilitate use of prescribed fire. While fire management objectives often aim to increase ecological condition, effects of these practices are controversial and a cause of (unintended) reduced ecological integrity in many cases (Tiedemann et al. 2000; Keane et al. 2002; Bunting et al. 2002). Of particular concern is the unresolved question of historic fire regimes and historic forest and rangeland structure and composition (Simberloff 1999; Tiedemann et al. 2000; Baker and Ehle 2001; and Soulé et al. 2004). In many sagebrush-steppe ecosystems, the risk of increasing non-native plant invasion through prescribed burning is high (D'Antonio and Vitousek 1992; D'Antonio 2000; Bunting et al. 2002). Effects of fire management practices on primary productivity, nutrient cycling, and biological communities are not well understood but represent a potentially very significant ecosystem stressor.

NPS Park Development and Operations

Growth in regional populations and associated rise in visitation increases demand on existing park resources and leads to new expansion in infrastructure and operations. For instance, park roads may need to be resurfaced or extended, parking lots may need to be expanded, visitor and interpretive centers, campgrounds, and other facilities may need to be built or upgraded. These developments have potential to become significant ecosystem stressors. Ongoing park operations related to park mission, including permitted grazing and maintenance of historic agricultural landscapes, are additional sources of ecosystem stress. In addition to fire management practices, weed control efforts and other resource management practices can be significant stressors.

There are very few, if any, areas within UCBN parks not subjected to some form of historic anthropogenic stress.

In 2005, LARO attracted over 1 million visitors primarily for its recreational opportunities leading to growing concerns of park managers about the impacts of these uses.

Park Visitation and Recreation

Estimates of annual park visitation in the UCBN from 1992 to 2002 have remained relatively constant with a Network average of approximately 250,000 visitors, but range from 12,000 at HAFO to over 1 million in LARO (NPS Public Use Statistics Office http://www2.nature.nps.gov/stats/). However, several parks are concerned about increasing visitor use and are responding to heavy, albeit localized, visitor impacts at current levels of use. Visitor use creates demands for continued park development, or upgrade of existing development, particularly trails, which fragment wildlife habitat, bring people into sensitive areas, and contribute to off-trail use in these sensitive areas (NPS 1997). Recreational uses in these parks have potential to impact park resources through trampling, disturbance to aquatic resources, behavioral disturbances to wildlife, and damage to cultural resources. In addition, the introduction and spread of exotic/invasive plant species by visitors

poses a significant challenge to ecosystem management. The actual level of impacts depends on variables such as patterns of visitor concentration and the intensity of specific activities (i.e., rock climbing at CIRO and boating and fishing at LARO).

Climate Change

Warming of the Earth's atmosphere results from the interaction of solar radiation with accumulated greenhouse gases (e.g., carbon dioxide, methane, chlorofluorocarbons, and water vapor). This warming effect has been enhanced over the past century by increased contributions of these gases, particularly carbon dioxide, from anthropogenic sources (NAST 2001). Climate models suggest that the Great Basin and Columbia Basin may get warmer and wetter over the next 100 years (Wagner et al. 2003). Predicting effects of global warming are complicated by interactions with global precipitation patterns (most notably for the upper Columbia Basin is the El Nino-Southern Oscillation). Altered precipitation patterns may lead to reduced snowpack and increased summer rain, although a net drying effect, rather than a more mesic summer climate, seems more likely (Melack et al 1997; Wagner et al. 2003). Increases in mean annual temperature and increased temperature extremes may occur, as well as elevated levels of CO_2. Possible ecosystem effects include increased fire frequency and intensity, increased rates of plant invasions, and increased rates and extents of plant pest outbreaks (D'Antonio 2000; Smith et al. 2000; Logan and Powell 2001; Whitlock et al. 2003; McKenzie et al. 2004).

Climate models suggest that the Great Basin and Columbia Basin may get warmer and wetter over the next 100 years.

Chapter 3: Vital Signs

The term vital sign is defined in the UCBN monitoring program as "a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values" (http://science.nature.nps.gov/im/monitor/). In this chapter, we describe the vital signs for the UCBN and the process used to select and prioritize these vital signs.

Practical constraints such as budgets and staff size prevent the selection of all important vital signs. The UCBN has identified 14 vital signs that represent monitoring objectives that characterize threat-specific monitoring, focal resource monitoring, and ecosystem status monitoring. These categories provide a useful framework for organizing not only the selected vital signs, but also the thinking by which these vital signs were selected. Selecting vital signs from each of these categories helps ensure a balanced and integrated program that can address the status and trends of ecological phenomena across a range of temporal and spatial scales, and for which effects are both known and unknown.

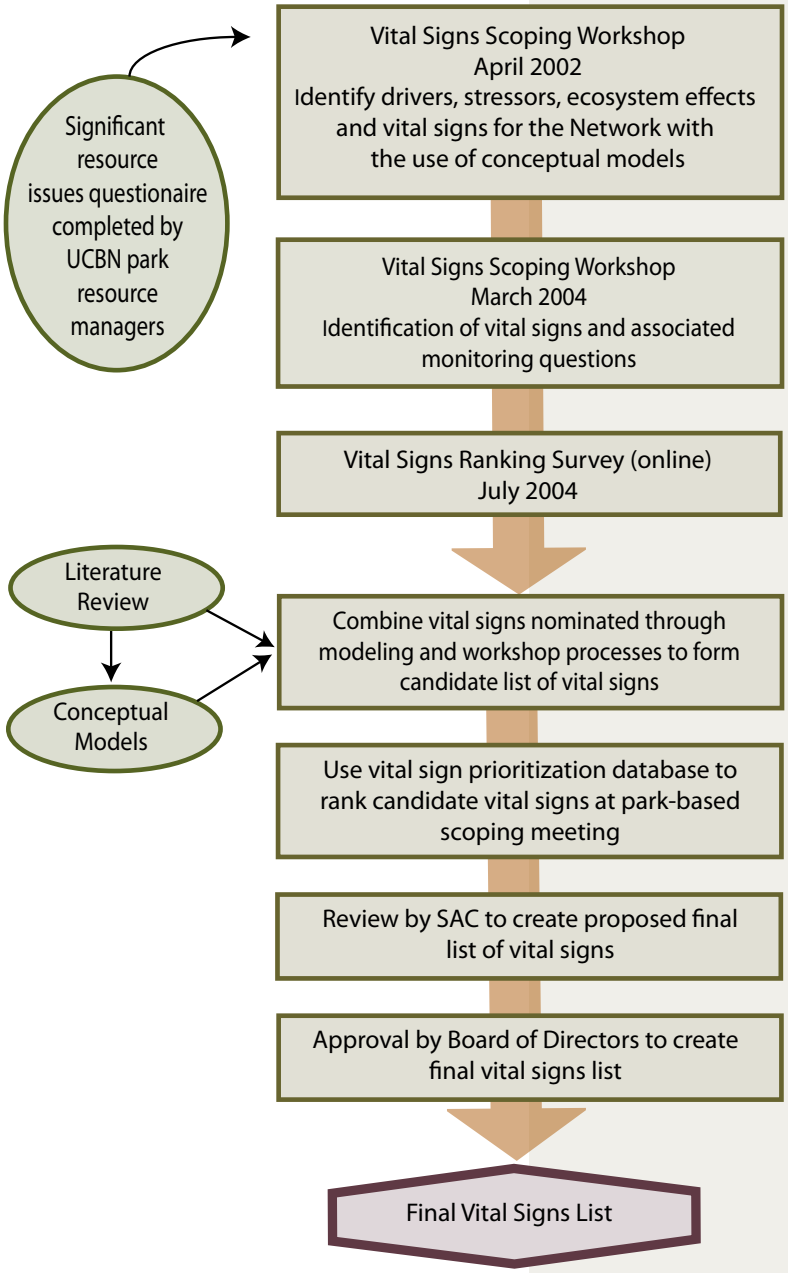
Overview of the Vital Sign Selection Process

The UCBN vital signs prioritization process involved multiple steps including the use of conceptual models and formal criteria-based team decisions (Figure 3.1). The primary purpose was to provide objective identification and ranking of ecosystem vital signs that would be the focus of long-term monitoring. Explicitly, our processes first identified vital signs suitable for monitoring, then ranked or prioritized them.

Our process was based on team discussion and analysis of conceptual models that summarize diverse abiotic and biotic components and functional aspects of ecosystems. The conceptual sub models served to focus team attention on discrete ecosystem variables (see Chapter 2 and Appendix C). Another key feature of the ranking process was the use of selection criteria, together with a defined numerical scoring system, to quantify each vital sign ranking (see Appendix D.8 for ranking criteria). This strategy permitted impartiality in the selection process, lending greater credence to the overall process, increasing our confidence in the outcome, and enhancing overall validity.

An essential implementation component was the use of a team discussion format. This format emphasized open discussion of models, vital signs, issues and concerns, and application of criteria and scoring in a consensus-based manner that sought ac-

Figure 3.1. Model depicting elements of the UCBN vital signs prioritization and selection processes.



Concerns with issues such as white pine blister rust infection of limber pine at CRMO and CIRO led to its consideration as a UCBN vital sign.

tive contribution from all team participants. Team discussion and consensus-building also enhanced objectivity while supporting real consideration of diverse perspectives, expertise, and interests of park managers and the contributing "outside experts." The following sections explain the UCBN vital sign selection and prioritization process in more detail.

Regional Workshops

Regional workshops were held in 2002 and 2004 at the University of Idaho in Moscow, Idaho, and provided a forum for scientists from various disciplines to brainstorm on potential vital signs and monitoring questions that would assist in monitoring the ecological condition of UCBN parks (see http://www1.nature.nps.gov/im/units/ucbn/ReportTable2.htm#Monitoring for reports). The first regional workshop (April 2002) was organized to identify and validate vital signs common to each park site, substantiate the premises of the conceptual model, further develop the monitoring focus, and identify preliminary measures and methods. In preparation for the first workshop, the UCBN staff completed a computerized resource database documenting all natural resource studies pertaining to each park, species lists for each park and information on existing natural resource data. A simple, straightforward conceptual model was developed before the workshop, providing a starting point and framework for addressing and evaluating vital signs and monitoring strategies at the Network level. Prior to the workshop, resource managers were sent a questionnaire examining the significant natural resources and threats for Network parks. Resource managers responded to the questionnaire in writing and a summary of their responses is contained in Appendix D.1. Park summaries were prepared for this workshop that contained information on the size of the park, designation date, park history and purpose, location, elevation, climate, fauna, flora, unique features, species of special concern and resource management concerns.

A second workshop was held in March 2004 to solicit additional input from park managers and regional scientists on potential vital signs and associated monitoring questions. Heavy emphasis was placed on development of monitoring questions, since it was becoming clear that vital signs were of limited value without an associated set of status-and-trend type questions. The outcomes from this workshop included: 1) creation of a network of stakeholders (Appendix D.3), 2) review of technical information developed by the Science Advisory Committee, and 3) development of a list of vital signs and associated monitoring questions.

A primary emphasis of UCBN efforts in 2004 was to define the most significant resources, resource concerns and stressors within parks. Information from questionnaires sent to resource managers before the workshop was presented to workshop participants. This information included a

list of invasive plant species of special concern (Appendix D.4) and a list of prioritized stressors affecting park natural resources (Appendix D.6).

Online Vital Sign Ranking Survey

Following the March 2004 workshop, a vital signs ranking survey was developed for the Network by the University of Idaho and placed online for a period of 45 days. Workshop participants and other stakeholders were solicited by email to complete individual ranking exercises for the list of vital signs and associated monitoring questions developed during the workshop.

In this survey, each participant was asked to rank the list of vital signs and candidate monitoring questions for its importance and value as an indicator of ecosystem condition and significance to management. Questions were organized around the five resource categories used as workgroups in the workshop – vegetation, wildlife, soils/geology, water/riparian, and air/climate/land use. Ranking was completed by 34 stakeholders for each vital sign and associated monitoring question and new questions were offered by some participants. The UCBN staff conducted a review of survey results and further refined the preliminary list to 57 high priority vital signs with associated monitoring questions (Appendix D.6).

Park-level Scoping Workshops and Vital Sign Prioritization

The final step in vital sign ranking for UCBN parks focused on prioritizing the 57 candidate vital signs (see Appendix D.7) using a Microsoft ACCESS database. Adopting this database approach in park-focused workshops gave participants the opportunity to:

- Review vital sign objectives, existing protocols, and partnership opportunities.
- Review threats and management concerns and complete a prioritization of vital signs by park.
- Interact with each other to ensure the list of vital signs for individual park units reflected the consensus view of the resource management staff at the park level.
- View the Network list of vital signs after park-level vital signs were prioritized.

The ranking process considered a vital sign's ecological significance, park management significance and legal mandate (Appendix D.8). Each of these categories was weighted with ecological significance (40%), park management (40%), and legal mandate (20%) of the total. The weighting could be modified if a park desired to place more emphasis on one criterion over another. Database contents were projected on a screen so workshop participants could experience interactively how changes in the management significance, ecological significance, or legal mandate rankings could ultimately change the prioritization of vital signs for their park.

Table 3.1. Park prioritization workshops.

Date	Parks	Participants
February 1, 2005	WHMI	Superintendent, Chief of Interpretation and Resources Management, Education Specialist, Park Ranger Interpreter, Network Coordinator, Network Data Manager/Spatial Ecologist, Network Ecologist
February 3, 2005	NEPE	Superintendent, Cultural Resource Specialist, Network Coordinator, Network Data Manager/Spatial Ecologist
February 23, 2005	BIHO	Superintendent (NEPE), Superintendent (BIHO), Cultural Resource Specialist, Park Ranger, Network Coordinator, Network Data Manager/Spatial Ecologist
February 24, 2005	LARO	Superintendent, Chief of Compliance and Natural Resource Management, Law Enforcement, Maintenance, Chief of Interpretation, Network Coordinator, Network Data Manager/Spatial Ecologist
March 1, 2005	HAFO/MIIN	Superintendent, IT Specialist, Chief of Administration, Visitor Center employee, Chief of Operations, Natural Resource Specialist, Education Specialist, Paleontologist/Curator, Maintenance, Natural Resource Specialist – hydrologist, Network Coordinator, Network Data Manager/Spatial Ecologist
March 2, 2005	CIRO	Superintendent, Resource Ranger, Network Coordinator, Network Data Manager/Spatial Ecologist
March 3, 2005	CRMO	Superintendent, Interpretive Staff, Integrated Resource Program Manager, Ecologist (Botanist), Network Coordinator, Network Data Manager/Spatial Ecologist
March 30, 2005	JODA	Superintendent, Resource Manager, Network Coordinator, Network Data Manager/Spatial Ecologist, Network Ecologist, Interpretive Staff

(Monitoring) techniques which are easy to implement will facilitate collection, analysis, and interpretation of data...

Eight workshops were held from February through March 2005 (Table 3.1). The vital sign ranking team for each park varied but at a minimum included the Network Coordinator, Network Data Manager, Park Resource Manager, and Superintendent. The role of the vital sign team was to present conceptual models and review their connection to park-specific management issues, to define terms, and to provide discussion for ecological concepts during the ranking process. The top 10 vital signs were numerically ranked for each park (Appendix D.9).

Final Selection - "Short List" of UCBN Vital Signs

The overall goal of the UCBN vital signs selection process is to develop a comprehensive monitoring program such that it will yield information "greater than the sum of its parts". We recognize, however, that no monitoring program can monitor everything and that monitoring is less expensive, easier, and ultimately more successful when techniques are simple to use and focus on specific components of the ecosystem. Techniques which are easy to implement will facilitate collection, analysis, and interpretation of data, and lessen the problems associated with handing over program responsibility to subordinates (Wright 1993). The latter point is important in parks because, as a long-term exercise, monitoring frequently involves many different people, each possibly for only a few years (Usher 1991). The UCBN believes an emphasis in parsimony is critical to development of a successful long-term monitoring program and undertook vital signs selection within this context.

For a monitoring program based on simple, discrete indicators, objectives, and measures to be truly comprehensive, it must be well integrated both ecologically and programmatically. Following recommendations by Noss (1990) and others, the UCBN aimed to develop an ecologically integrated program by selecting vital signs that span a range of spatial and temporal scales and multiple levels of ecological hierarchy (Figure 2.2). Programmatic integration will require consideration of other programs and projects ongoing within UCBN parks as well as other NPS networks and partnering agencies.

A major challenge of the vital sign prioritization process was assembling a suite of vital signs that reflected park-level management concerns, would lead to a broader understanding of ecosystem condition, and were shared across all parks in the Network. The UCBN parks share some similarities (e.g., sagebrush-steppe habitat in seven of nine parks) but are also markedly different in size, enabling legislation, and ecological context. The Network was open to including vital signs that were considered important by small as well as large parks and cultural focused parks as well as natural resource focused parks. By defining these differences and similarities early on in the planning process the resulting list of selected vital signs demonstrate the Network-wide perspective together with specific park-level monitoring.

After completion of park-level workshops the UCBN Science Advisory Committee and Board of Directors decided on the "final" list of vital signs (Table 3.2). Protocols are being written for monitoring the 14 vital signs and these protocols will be implemented in the next 3-5 years. The selected vital signs represent Level I categories that include geology and soils, water, biological integrity, human use, and ecosystem patterns and processes.

Candidate Vital Signs Selected for Future Projects

In keeping with our "do fewer things better" program philosophy, it was understood that selected vital signs should be few in number and, ideally, functionally coherent and interconnected. Therefore, several candidate vital signs were ranked lower for a variety of reasons (see Table 3.3). Some lower ranked vital signs, not selected for initial monitoring, but considered for future projects include:

- *Air Contaminants:* One park (CRMO) is classified as a Class I airshed and currently has air quality monitoring. The feasibility and cost to include additional parks in a similar program was not currently considered cost-effective with a limited monitoring budget.
- *Insect Pests:* The presence of the pinyon *Ips* beetle in red-topped and dead pinyon pine has been confirmed at

Table 3.2. UCBN vital signs and measures in the Vital Signs framework developed by the NPS Vital Signs Monitoring Program.

Level 1 - Landscapes	Level 2 – Landscape Dynamics	Level 3 - Vital Sign	Network Vital Sign Name	Measures Collected	BIHO	CIRO	CRMO	HAFO	JODA	LARO	MIIN	NEPE	WHMI
Geology and soils	Geomorphology	Stream/river channel characteristics	Stream/river channel characteristics	Bankfull width and depth, substrate composition, bank angle, undercut depth, pool depth, and sinuosity.	X	X	X		X			X	X
Water	Hydrology	Surface water dynamics	Surface water dynamics	Flow rate and annual water level fluctuation.	X	X		X	X	X		X	X
	Water quality	Water chemistry	Water chemistry	Daily, seasonal and annual values for core parameters.	X	X	X	X	X	X		X	X
		Aquatic macroinvertebrates	Aquatic macroinvertebrates	Species and functional group composition and abundance (counts).	X	X	X	X	X			X	X
Biological integrity	Invasive species	Invasive/exotic plants	Invasive/exotic plants	Frequency (presence/absence), distribution, abundance (cover), detection of new species, and incipient invasions	X	X	X	X	X	X		X	X
	Focal species or communities	Riparian communities	Riparian vegetation	Abundance (cover) of target genera and species and strata, and composition of communities and community types.	X	X	X	X	X	X		X	X
		Shrubland communities	Sagebrush-steppe vegetation	Abundance (cover) of target species and genera and strata, tree density, composition, and diversity.		X	X	X	X	X			
		Forest/woodland communities	Aspen	Abundance (aspen stem density, conifer density), and tree size class.		X	X						

Table 3.2. UCBN vital signs and measures in the Vital Signs framework developed by the NPS Vital Signs Monitoring Program (continued).

Level 1 - Landscapes	Level 2 – Landscape Dynamics	Level 3 - Vital Sign	Network Vital Sign Name	Measures Collected	BIHO	CIRO	CRMO	HAFO	JODA	LARO	MIIN	NEPE	WHMI
Biological integrity	Focal species or communities	Forest/woodland Communities	Limber pine	Frequency of trees infected, distribution of infection in parks, number and location of cankers and rate of survival after blister rust infection		X	X						
		Birds	Osprey	Nest occupancy (proportion occupied), productivity (fledglings per nest)						X			
		Birds	Sage grouse	Lek occupancy, abundance, distribution and amount of critical habitat, occupancy and abundance in critical habitat		X	X						
		Mammals	Bats	Riparian occupancy, cave occupancy and abundance, local extinction rates		X	X		X				
Human use	Cultural landscapes	Cultural landscapes	Camas lily	Abundance (density), flowering rate, frequency of target invasive plants	X							X	
Ecosystem pattern and processes	Land dynamics	Land cover and use	Land cover and use	Proportion of area in different cover types, patch metrics, perimeter and core area metrics, and measures of landscape connectivity	X	X	X	X	X	X	X	X	X

CIRO. This bark beetle species is probably the cause of much observed mortality in pinyon pine within the reserve. Dr. Steve Cook, University of Idaho researcher, recommended a systematic survey of pinyon mortality be conducted. Insect pests have been identified by park management as a vital sign but a significant lack of information exists and targeted research is needed.

- *Sagebrush-steppe Birds:* The UCBN recognizes that monitoring birds could be an important component of a biodiversity monitoring program. However, the use of birds as ecological indicators has been questioned because determining the effect of environmental changes on bird populations is very difficult given the myriad of factors that can cause population changes (Morrison 1986; Temple and Wiens 1989). In addition there is the added cost of using the double-observer variable circular plot method and additional expertise necessary to accurately identify bird species. It was decided that vegetation community monitoring took precedence because data from vegetation monitoring would better address identified monitoring questions.
- *Peripheral/Relict Species:* The area in and around CIRO coincides with a unique biogeographic setting where the pinyon-juniper woodland reaches its northern distributional limit, occurs in conjunction with large granite cliffs, and supports a diverse but poorly described mammalian fauna associated with these features, including several rare species also at their northern distributional limit and found nowhere else in Idaho. Park management is addressing this knowledge gap with an integrated sampling effort involving several techniques to provide new information on the distribution, abundance, and habitat association of the ringtail, cliff chipmunk, pinyon mouse, and canyon mouse. When this inventory information becomes available, a monitoring project could be initiated, if funding is available.

Birds that occupy sagebrush-steppe communities, such as the Brewer's sparrow, were not initially selected as a vital sign but will be considered for future projects.

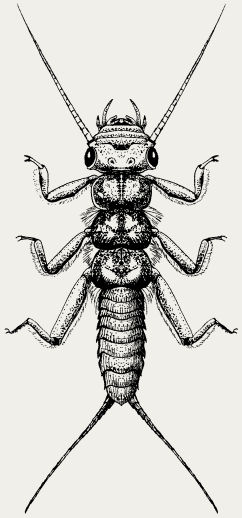
- *Freshwater Shrimp:* Three new species of fairy shrimp have been documented in Idaho since 1996. Six species of fairy shrimp are known to reside in Idaho. The shrimp are small crustaceans. The shrimp eggs can lay dormant for up to 10 years before a heavy rain event, with flooding or rapid snowmelt will cause a big enough change in the pH to trigger a hatch. Insects, birds and amphibians prey on fairy shrimp. More inventory and research information is necessary before protocols for freshwater shrimp could be developed due to the complexity of evaluating data about this little known organism.

The cliff chipmunk has been identified as an Idaho Species of Greatest Conservation Need and further research regarding its distribution, abundance, and habitat association in the pinyon-juniper woodlands of CIRO may lead to its monitoring by the UCBN.

Table 3.3 UCBN vital signs not selected for monitoring but identified as possible future projects.

Parks	Vital Sign	Reason for Lower Priority Ranking
CIRO	Ozone	Low score – limited to one park
Network	Air contaminants	Feasibility and cost
HAFO	Soil erosion	Feasibility and cost
CIRO, CRMO	Insect pests	Research needed
CIRO, JODA	Springs/seeps	Lack of inventory data
CIRO, CRMO	Pinyon-juniper woodland	Objectives not clearly understood
LARO	Forest structure	Objectives not clearly understood
Five parks	Sagebrush-steppe birds	Feasibility and cost
Network	Riparian birds	Feasibility and cost
CIRO, CRMO, HAFO	Raptors	Low score
CIRO	Peripheral/relict species	Lack of inventory data/research needed
CIRO	Cliff swallows	Limited to one park
CIRO, CRMO, HAFO	Pygmy rabbits	Presence not documented in parks
CIRO, CRMO	Freshwater shrimp	Lack of inventory data
JODA, NEPE, WHMI	Amphibians and reptiles	Low score
JODA, NEPE	Terrestrial invertebrates	Inventory and research needed
Five parks	Rare plants	Low score - research needed
CIRO, JODA, LARO	Visitor usage	Objectives not clearly understood
BIHO	Forest structure (cultural landscape)	Limited to one park
CRMO	Pika	Inventory and research needs

Chapter 4: Sampling Design



Sampling designs describe the series of decisions that dictate where, when, and how often to measure a vital sign component (e.g., nitrate as a component of water quality monitoring). The ultimate purpose is to ensure adequate scope of inference and collection of representative samples to support defensible conclusions about a population of interest. Sampling design decisions are often difficult to make, require cost-benefit trade-offs, and ultimately represent a balance between idealized objectives and practical constraints of cost, time, logistics, safety, and technology.

These decisions involve the determination of target populations and sampling frames, allocation and arrangement of samples (*membership design*), frequency of sampling occasions (*revisit design*), measurements to be taken at sampling locations (*response design*), and the number of samples required to meet stated objectives (*sample size*) (italicized terms are described later in this Chapter). This chapter presents an overview of general approaches taken by the UCBN for its suite of vital signs scheduled to be implemented during the next 5 years. Strategies for integrating sampling designs for groups of vital signs are also presented and basic design decisions summarized (Table 4.1). Specific design details and decision justifications are included in individual protocols and protocol development summaries (Chapter 5 and Appendix F).

An overview of basic concepts and terminology is followed by specific UCBN design strategies organized in two broad categories: terrestrial resources, which include those in riparian zones, and water resources.

Basic Concepts and Terminology

The UCBN has adopted several principles as fundamental to a successful long-term monitoring program. First, sampling design development must be driven by clear and concise monitoring objectives. Practically speaking, this is an iterative process and objectives continue to be refined as insight is gained into particular vital signs and park management needs. Second, sampling designs must be flexible. Because the intent is to develop a robust monitoring program that can meet the needs of NPS managers well into the future, designs must be able to accommodate changes in management and funding priorities, as well as unanticipated environmental change. This means that monitoring objectives must be written to balance specific needs of current park managers with a more general need for long-term status and trend information that can be utilized by future generations of managers facing new and emerging challenges. Finally, sampling designs must be appropriately simple and accessible. Overly complex designs increase information management and analysis challenges and are, by their very nature, more at risk of failure over the projected life of the program. Complex designs may also reduce accessibility by key constituents (park managers and superintendents) many of whom are not well versed in statistics and sampling design theory.

The UCBN is somewhat unique within the I&M program, being composed of small and widely separated parks and having a relatively small staff and budget. This, coupled with a radically altered matrix of surrounding lands, has resulted in the emphasis on a practical and straightforward approach to monitoring, an approach oriented toward management needs rather than toward broader concerns for ecosystem structure and function. With only few exceptions, UCBN parks do not support the large, relatively intact ecosystems found in the Nation's large wilderness parks, and this monitoring program is necessarily going to look and feel different, and typically simpler, than those networks with large parks. The UCBN monitoring program is built from a position of simplicity, with complexity added conservatively and only as necessary to achieve objectives.

Sampling designs must be:

- Driven by clear and concise monitoring objectives
- Flexible
- Appropriately simple and accessible

As presented in Chapters 1 and 3, monitoring objectives call for the estimation of status, trend, or both. Use of the two terms is intentional and follows definitions reviewed by Urquhart et al. (1998) and McDonald (2003). *Status* is a measure of a current attribute, condition, or state, and is typically measured with a population parameter es-

Table 4.1. Proposed sampling design components for UCBN vital signs scheduled for protocol development and implementation within the first 5 years of monitoring. Vital signs with multiple objectives requiring different design strategies are separated by semicolons. TBD abbreviates "To be developed." Spatially-balanced random samples refer to the generalized random tessellation stratified (GRTS) random sampling procedures described by Stevens and Olsen (2003, 2004). The co-location/co-visitation protocols column identifies physically integrated protocols that pertain to individual vital signs. These protocols are described in Chapter 5.

Vital Sign	Target Population	Membership Design	Revisit Design	Co-location/ Co-visitation Protocols
Aquatic Macroinvertebrates	Macroinvertebrate community in representative UCBN aquatic sampling sites	Subset of sample sites drawn from full spatially-balanced random sample of stream networks for integrated riparian protocol	Rotating Panel [1-2], 2 samples/yr/panel	Integrated Water Quality; Integrated Riparian
Aspen	Aspen population of CIRO and CRMO	Two-stage design: Exhaustive sample of all aspen stands > 0.2 ha (primary units), systematic random sample within stands	Rotating Panel [1-5], Multiple panels for CIRO, single panel for CRMO	None
Bats	Bat species using riparian areas of CIRO, CRMO, and JODA; Townsend's big-eared bat colonies in CRMO North Caves Complex	Subset of sample sites drawn from full spatially-balanced random sample of stream networks for integrated riparian protocol; Non-random index sites for caves (judgment sample)	Rotating Panel [1-2], 1 panel/park; for CRMO caves, single panel [1-2] coordinated with riparian bat monitoring	Integrated Riparian
Camas Lily	Camas populations within Weippe Pr. (NEPE) and core camas population of BIHO	Simple random sample drawn from discrete populations in each park	Annual, 1 panel per year per park population ([1-n]; never revisit)	None; Contributes to invasive plants
Invasive/Exotic Plants	Targeted vegetated areas of UCBN Parks	Probabilistic sample determined by other vegetation protocol designs; Comprehensive survey (for small parks) or probabilistic survey of target areas for early detection	TBD	Integrated Riparian, Sagebrush-steppe, Camas Lily
Land Cover and Use	All parks and surrounding areas (distance from park boundary TBD)	Complete survey of parks and park buffer area (TBD)	TBD	None; Ground-truthing accomplished with vegetation protocols

Table 4.1. Proposed sampling design components for UCBN vital signs scheduled for protocol development and implementation within the first 5 years of monitoring (continued).

Vital Sign	Target Population	Membership Design	Revisit Design	Co-location/ Co-visitation Protocols
Limber Pine	Limber pine population within CIRO and CRMO	Two-stage design: Simple random sample of primary units (limber pine stands) and systematic random sample of secondary units within stands	TBD	None
Osprey	Lake Roosevelt osprey population nesting along the NPS-owned shore of Lake Roosevelt	Census of known nests. Periodic targeted searches to add new nests to census	Rotating Panel [1-2]	None
Riparian Vegetation	Riparian communities adjacent to lotic waterbodies in and adjacent to UCBN parks.	Spatially-balanced random sample of stream networks	Rotating Panel [TBD]	Integrated Riparian; Integrated Water Quality; Contributes to invasive plants, Bats
Sagebrush-steppe Vegetation	Steppe vegetation of UCBN Parks	Two-stage design: Simple random sample of primary units (100 x 100 m grid cells) and simple random placement of transects within cells (secondary units)	Split-panel with permanent and temporary plots, [1-0,1-n]	None; Contributes to invasive plants
Sage Grouse	Male sage grouse on leks; Seasonal grouse populations in CRMO and CIRO critical habitat areas	Census of known leks; Probabilistic sample (TBD) in park critical habitat areas. Periodic targeted searches to add new/moved leks to census	Annual lek counts; TBD for critical habitat areas	None
Stream/River Channel Characteristics	Wadeable perennial lotic waterbodies in and adjacent to UCBN parks	Spatially-balanced random sample of stream networks	Rotating Panel [TBD]	Integrated Riparian; Integrated Water Quality
Surface Water Dynamics	Representative UCBN waterbodies	Non-random index sites (judgment sample)	Annual Compilation	Integrated Water Quality

Status refers to specific points in time, whereas trend pertains to measurements across multiple time periods.

timate such as a mean or proportion. *Trend* is a measure of directional change over time and can occur in some population parameter, such as the mean (*net trend*), or in an individual member or unit of a population (*gross trend*). Status applies to specific points in time, whereas trend pertains to measurements across multiple time periods. Status typically is served best by a spatially extensive sample size, while trend is less reliant on large samples for each sampling occasion, but does require adequately frequent sampling through time. This sets up the first cost-benefit decision, as described above, and is one that must be addressed through a careful consideration of program objectives.

The next important step when developing a sampling design is to define the collection of animals, plants, natural resources, or environmental attributes of interest within a specified study area. This quantity is referred to as the *target population*, a statistical population that may or may not refer to a biological population. A target population consists of *elements* which are the measured items or attributes, such as individual animals or plants. The target population consists of all elements for which information is wanted. Attempts to quantify the target population use a *sampling frame*, which consists of *sampling units*. Sampling units are non-overlapping collections of elements, although some may not contain any elements (e.g., an empty sample). Common examples of sampling units in the UCBN monitoring program include plots, quadrats, and pixels on a digital map. Sampling units also include discrete phenomena such as stream segments, ponds, and individual raptor nests. A sample is a chosen subset of units from the target population for which a response is observed and recorded for each unit. The response of interest could be a count or some other form of measurement (Cochran 1977). This is in contrast to a *census*, in which a response is obtained from every element in the population. If the subset of units is chosen using a procedure that allows for calculation of the probability of selecting that sample from the population, the sample is said to be a *probability sample*. Whenever possible, a probability sample has been used to monitor UCBN vital signs. Probabilistic sampling designs are desirable because they permit valid inference to the sampled population, whereas non-random judgment sampling allows inference only to individual sampling units. Judgmental sampling is frequently used to collect information about a specific location of management concern, or in cases where other monetary or logistic constraints prevent probabilistic sampling. In such cases, index sites may be selected using clearly defined, logical criteria, usually with the aim of providing the "best-bang-for-the-buck." While scientifically robust, probabilistic designs require relatively large sample sizes. If only a few (<3-5) samples can be taken because of logistical or monetary constraints, strategic judgmental sampling will usually provide more useful information because locations selected using probabilistic criteria (e.g., randomly selected locations) will probably not provide enough statistical power to make useful inferences to other locations. For example if only two locations can be sampled, sampling where a stream enters and leaves the park provides pre- and post-information about water quality. Index sites are also quite useful in determining trend, despite the limited spatial scope of inference. Index sites can be particularly informative for small parks, and this strategy will be employed for several UCBN vital signs.

Once the target population and sampling frame have been determined, it becomes important to identify a strategy for drawing samples, allocating them appropriately across the sampling frame, and timing visits to collect samples. Most sample designs proposed for the UCBN 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 time period (Urquhart and Kincaid 1999; McDonald 2003). The way in which units in the population become members of a panel is called the *membership design* (McDonald 2003). The membership design specifies the procedure for drawing a probability sample. One familiar membership design strategy is *simple random sampling*, which involves selecting units from a population at random with equal probability, and where each possible sample of *n* units has the same probability of selection (Thompson 2002). Although frequently adequate, this also can fail to produce an ideal spatial sample in ecological settings because of uneven spatial patterns inherent to any particular simple random draw and concordant environmental spatial patterns.

An alternative, and one that the UCBN is proposing to use for sampling along linear stream networks, is a *spatially-balanced random sample* following methods described by Stevens and Olsen (GRTS method; 2003, 2004). This approach allows for a spatially-balanced random draw of samples with variable inclusion probabilities and an ordered list of samples that can support additions and deletions of samples while maintaining spatial balance. These features provide considerable flexibility and efficiency to the UCBN program, particularly when co-location of sampling units for two or more vital signs is desired. Another sampling design strategy common to several UCBN vital signs is the *two-stage sampling design*, in which a probability sample of primary units is taken, for example of limber pine stands at CRMO, and then another probability sample (stage 2) is taken of the area within the pine stands (Elzinga et al. 1998; Thompson 2002).

Once samples are drawn, they must be assigned to variously constructed panels and scheduled for revisits over time. In the case of some small and closely located parks (e.g., WHMI and NEPE), a panel may consist of samples from more than one park. In the largest park, CRMO, multiple panels may be required. The temporal scheduling of sampling, particularly when multiple panels are being used, requires a *revisit design* (Urquhart and Kincaid 1999; McDonald 2003). The UCBN 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, the second 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 (Figure 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 6 years. A common split-panel design employed by the UCBN will be [1-0, 1-*n*] which allows for a set of permanent plots or units to be re-measured every occasion, and an additional new panel of non-permanent units to be sampled simultaneously. This supports the competing demands of status and trend objectives, in which spatially-extensive and temporally intensive samples are desired.

Figure 4.1. Examples of different revisit designs, beginning with the simplest, in which a single panel is visited on every sampling occasion, and ending with a split-panel design in which the first panel is sampled on every occasion and each additional panel is sampled only once.

	Sample Occasion									
Panel	1	2	3	4	5	6	7	8	9	10
Design [1-0]										
1	X	X	X	X	X	X	X	X	X	X
Design [1-n]										
1	X									
2		X								
3			X							
4				X						
5					X					
6						X				
7							X			
8								X		
9									X	
10										X
Design [1-2]										
1	X			X			X			X
2		X			X			X		
3			X			X			X	
4				X			X			X
5					X			X		
Design [2-3]										
1	X	X				X	X			
2		X	X				X	X		
3			X	X				X	X	
4				X	X				X	X
5					X	X				X
Design [1-0,1-n]										
1	X	X	X	X	X	X	X	X	X	X
2	X									
3		X								
4			X							
5				X						
6					X					
7						X				
8							X			
9								X		
10									X	

Response design (measurements taken at sampling locations) and *sample size* (the number of samples required to meet stated monitoring objectives) are two essential components of any sampling design and are detailed in monitoring protocols (see Chapter 5). In brief, response design and sample size components are developed after basic decisions regarding target and sampling population, spatial allocation and membership, and revisit strategies have been made. In addition, a response design is usually necessary before sample size can be estimated appropriately. This is particularly true when response decisions, such as plot shape and size, strongly influence the variability of population estimates. However, sample size decisions must be made to finalize decisions about membership and revisit, and in practice, sampling designs arise out of an iterative process. As with the design decisions described above, sample size determination is primarily an exercise in cost-benefit trade-offs, and must be determined through careful consideration of program objectives.

Further, a *sampling objective* is necessary to establish a desired level of statistical power and, thus, the ability to detect a real change or trend, a minimum detectable change or effect size, and acceptable levels of both false-change (α or Type I) and missed-change (β or Type II) error probabilities (Elzinga et al. 1998). Sample size is a function of these components, and decreasing sample size, a desirable goal from a programmatic perspective (e.g., reducing costs), will often force acceptance of higher error and lower power. These trade-offs are mitigated by reducing variance estimates, either through modifications in response design or some other component (e.g., revisit design), or by accepting a higher minimum effect size (Steidl et al. 1997). Nonsampling errors, such as those related to detectability of cryptic organisms, missing data, and measurement errors, can greatly affect variance estimation, and therefore sample size and power (Thompson 2002). These can be minimized with appropriate sampling designs and rigorous quality assurance and control routines, as described in Chapters 5 and 6.

In general, sample size should be large enough to give a high probability of detecting any changes of management or conservation importance, but not unnecessarily large (Manly 2001a). Scientists traditionally seek to reduce the probability of Type I errors, and accordingly prefer small α levels (Shrader-Frechette and McCoy 1992). In a monitoring program with a strong resource-conservation mandate, however, it is preferable to employ an early-warning philosophy by tolerating a higher α, but consequently increasing the power to detect differences or trends (Shrader-Frechette and McCoy 1992; Sokal and Rohlf 1995; Roback and Askins 2005). This approach is inherently conservative, reduces the "conservationist risk" rather than "polluter's risk" and is an appropriate approach for the NPS (Irwin 2006). Accordingly, the UCBN has conservatively adopted minimum standards of $\alpha = 0.10$ and $1-\beta$ (power) = 0.80, to detect desired magnitudes of change (minimum detectable change), in agreement with national NPS I&M approaches.

For the initial set of protocols, *a priori* power analyses will be conducted to determine approximate sample size needed to detect meaningful (greater than or equal to 20%) levels of change. Given specifications of α, desired power, and effect size, combined with information on the variance of the response variable in question (obtained from available data or comparable analogous data), it is possible to calculate the sample size required to achieve these results. Statistical power analysis (Gerrodette 1987; Elzinga et al. 1998; Thompson 2002; Lewis 2006) is the typical approach to estimating sampling sizes for monitoring population trends. Existing programs (e.g., TRENDS; Gerrodette 1993) and simple equations (Elzinga et al. 1998; Manly 2001a; Thompson, 2002; Irwin 2006) are used for approximating sample sizes while more powerful command-driven programs such as the UnifyPow macro with SAS software (SAS Institute, Inc.), and R (http://www.r-project.org/) are used for more sophisticated power analyses based on simulations (Manly 1992, 2001b, Lewis 2006). Periodically, power analyses will be recalculated for individual vital signs as improved variance estimates become available to refine and revise sampling designs and ensure objectives are being met.

Overview of UCBN Sampling Designs

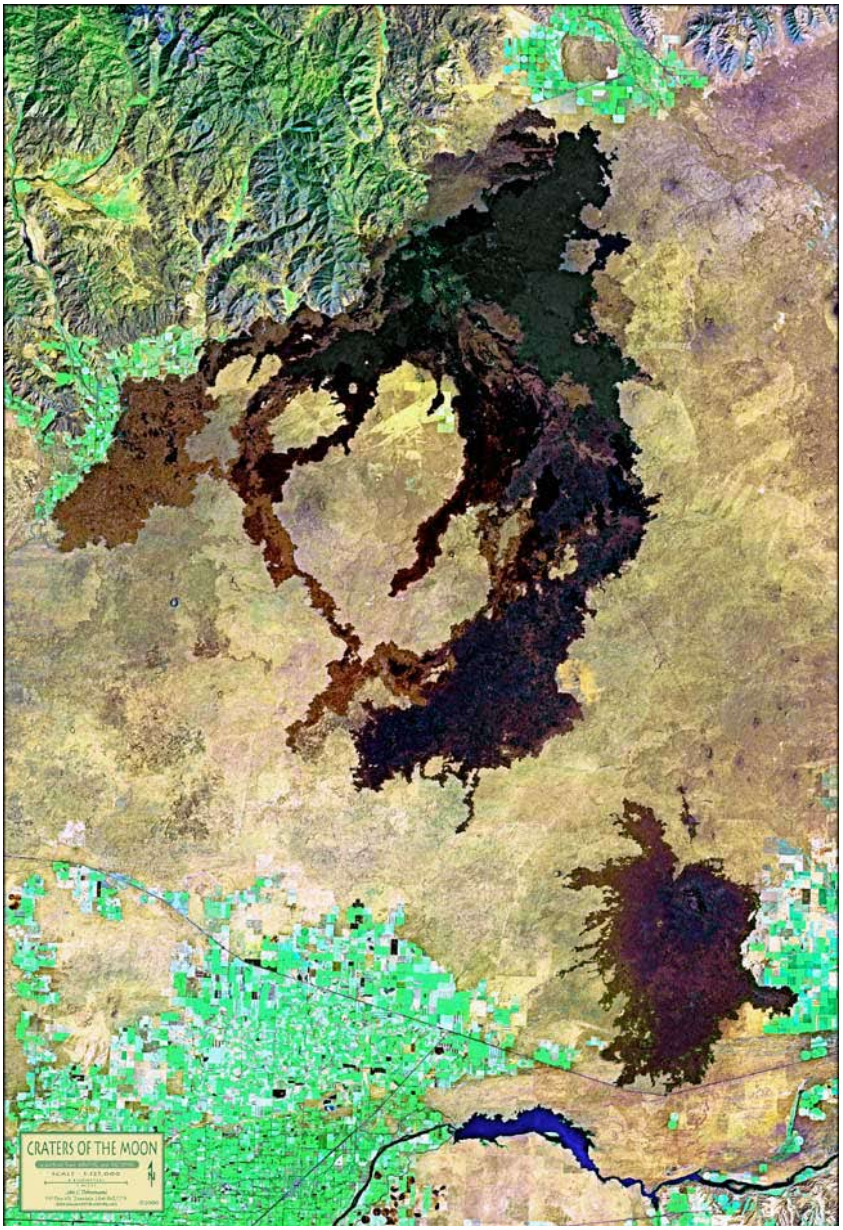
The following overview of UCBN sampling designs presents current anticipated approaches. There are no pre-existing monitoring programs for any of the 14 priority vital signs being implemented over the next 5 years and new protocols are being developed or adapted from other NPS networks or outside agencies. Accordingly, the sampling design details presented below should be considered preliminary. Protocol development for several vital signs has been initiated and protocols and protocol development summaries containing more specific details are located in Appendix F.

Terrestrial Systems

Aspen: Aspen populations will be monitored in CIRO and CRMO. Inference is desired to entire park aspen populations and a raster-based sampling frame will be developed that will permit a comprehensive survey of all aspen stands >0.2 ha in size. Aspen primarily reproduces vegetatively as a clone, and therefore the likelihood of new stands developing over the course of the monitoring program that are not included in the original sampling frame is low. The sampling frame will be based on current stand delineations. No modifications in sampling frame boundaries are anticipated. Changes in the areal extent of aspen stands will be monitored remotely through the land cover and use protocol. Within stands, a systematic random sample of transects will be established and temporary and permanent circular plots will be placed along these transects. Maps have been constructed with delineated aspen stands that will support this approach. A rotating split panel design with 5-year sampling intervals will be developed. Available aspen monitoring protocols, particularly those from the Wyoming Department of Fish and Game and from David Burton at the USDA Forest Service Pacific Southwest Research Station, will be modified for implementation in the UCBN.

Bats: Bat monitoring will incorporate two different methodologies to meet UCBN objectives of estimating trends in 1) individual species occupancy and use patterns and dynamics in riparian zones and 2) Townsend's big-eared bat occupancy patterns of lava tubes at CRMO. Acoustic methods involving deployment of automated echolocation call detection units (ANABAT system, Titley Electronics, NSW Australia) will be used along riparian areas and at lava tube caves. Manual and instrument-aided roost exit count methods involving direct counting of bats will also be used at lava tube cave entrances. Target populations for these two objectives include the riparian zones of three target parks (JODA, CIRO, CRMO) and the lava tube caves in the CRMO North Caves Complex. An integrated raster-based sampling frame will be used to draw a spatially-balanced random sample from park linear stream networks in conjunction with riparian vegetation and stream/river channel characteristics vital signs designs (Figure 4.2). Monitoring of CRMO caves will follow a non-random judgment sample of index cave sites. Historic data available from early studies in the park as well as more recent vertebrate inventory efforts indicate that approximately 3-5 caves in the park's North Caves Complex are important maternity and hibernacula roost sites. Difficult travel through extensive broken "aa" lava fields, safety concerns, and limited availability of acoustic detection equipment precludes any probabilistic sampling of CRMO caves. Revisit designs will involve a rotating panel design that will allow acoustic monitoring equipment to be shared by each park. The response design will be based on employment of passive acoustic monitoring stations and will allow for continuous sampling during targeted temporal windows coinciding with approximations of pre-volant pup-rearing from late May to late July. Supplemental manual roost exit counts will also be made at caves.

Camas Lily: The target population for camas lily monitoring includes the entire NPS-owned portion of the Weippe Prairie and the "core" camas prairie at BIHO. In the case of Weippe Prairie, a raster-based sampling frame is being used that excludes a 10 m buffer around the park boundary and creek. The Weippe Prairie sampling frame has been further subdivided into 4 discrete sections that approximate four different biologically and statistically meaningful populations of camas lily. These populations are bounded by roads, a stream channel, and a drainage ditch, and each have been subjected to different land use histories. At BIHO,



Satellite image with land cover information for CRMO.

the sampling frame excludes some "core" camas prairie for cultural and historical reasons. A simple random sample of non-permanent sampling units will be drawn for each population each year, with a [1-n] "never revisit" strategy involving a new panel of units sampled each occasion. This will enable spatially-extensive estimates suitable for site status determination as well as an ability to estimate net trend over time. Historic and cultural concerns, as well as practical concerns (e.g. trampling, monumenting), preclude the use of permanent sampling locations. The response design involves the use of long, narrow quadrats with dimensions 15 cm by 400 cm (5.9 by 157.5 in) (see Elzinga et al. 1998 for a discussion on benefits of this shape). Measures will include camas density and proportion of flowering camas (counts), graminoid thatch depth, and frequency of target invasive species (presence/absence).

Invasive/Exotic Plants: Monitoring of invasive plants in the UCBN will involve two approaches. The first will involve periodic rapid assessments of weed-free or other high priority areas for early-detection of incipient invasions. In this case the sampling frame will be based on predictive models or other tools that will support a targeted probabilistic sampling effort in high-priority areas. The second approach will involve status and trend estimation for targeted, established, invasive plant species. Both approaches will require an *a priori* determination of targeted species. Current efforts are underway within the NPS I&M program to develop guidelines and protocol templates for networks to begin early-detection invasive species monitoring (Geissler and Welch *in prep*). Monitoring of established species will be conducted primarily through other vegetation monitoring protocols. The inclusion of presence and cover measures for targeted invasive species in camas lily, sagebrush-steppe, and riparian vegetation protocols will facilitate the estimation of status and trends in frequency and abundance of established weeds.

Land Cover and Use: Several national and regional NPS efforts are underway to develop land cover change protocols. The UCBN will adopt and adapt as necessary pre-existing protocols. We are currently assessing the utility of the approach presented by Townsend et al. (2006) for the National Capital Region Network, a network similar to the UCBN in its makeup of many disparate and small parks. This same development team is also working with the Appalachian Highlands Network to develop a similar protocol. Land cover and use will be monitored in all UCBN parks, and will use park-wide sampling frames with buffer widths beyond park boundaries to be determined.

Limber Pine: The UCBN will adopt and modify as necessary the white pine blister rust monitoring protocol currently under development for limber pine by the Whitebark Pine Ecosystem Foundation. This will follow closely the draft whitebark pine pro-

tocol already developed by the foundation, and currently in review for implementation by the NPS Greater Yellowstone Network (GRYN; Tomback et al. 2004). Target populations include all limber pine within CIRO and CRMO, although sampling will be restricted to a rasterized sampling frame of mapped limber pine stands, which will be incomplete in some instances, particularly in CIRO, where limber pine sometimes occurs within stands of pinyon-juniper vegetation. A two-stage sampling design will be used, involving a simple random sample of limber pine stands and a secondary systematic sample for placement of transects within limber pine stands. The current draft protocol for the GRYN indicates only limber pine stands greater than or equal to 2.5 ha (6.2 acres) will be included in the sample, but this may not work for the unique distribution of limber pine in CIRO and CRMO. Secondary sample units will consist of 10 m x 50 m (33 by 164 ft) belt transects.

Osprey: The target population for monitoring osprey will be the nesting osprey population along the NPS-owned shoreline of Lake Roosevelt in LARO. The lake will be divided into upper, middle, and lower sections and each lake section will be considered a panel for the purposes of sampling. Aircraft will be used to survey for initial locations of nests at the beginning of the monitoring program and periodically throughout the monitoring program at intervals to be determined. Each nest site will be assigned to one of three panels and will be visited once every three years (i.e. a [1-2] panel design). Nest occupancy will be evaluated each sampling period and occupied sites will be monitored by foot or boat to determine productivity, as measured by the number of fledglings per nest.

Riparian Vegetation: Riparian vegetation will be monitored in all parks except MIIN and possibly LARO. The size of LARO precludes monitoring all areas and priority riparian areas have not been determined yet. Target populations include riparian zones along lotic (flowing) waterbodies. Sampling frames will be constructed from rasterized stream GIS coverages, so that spatially-balanced samples can be drawn using available GRTS algorithms (http://www.epa.gov/nheerl/arm/designing/design_intro.htm) implemented in the R language and environment, facilitating co-location and co-visitation with stream/river channel characteristics, integrated water quality, and vertebrate monitoring efforts. Transect-based vegetation sampling methods will be adopted and modified as necessary from regional riparian condition protocols in development by the USFS PacFish/InFish Biological Opinion Effectiveness Monitoring Team (PIBO) and by the Pacific Northwest Aquatic Monitoring Program (PNAMP; www.pnamp.org).

Sagebrush-steppe Vegetation: Sagebrush-steppe vegetation monitoring will occur in CIRO, CRMO, HAFO, JODA, and LARO. The target population includes all sagebrush-steppe vegetation in these parks, including pinyon-juniper woodlands in JODA and CIRO. Exclusion zones will be developed for dangerous and inaccessible areas of parks with > 30° slope, which will exclude most of the fossil-bearing badlands of JODA and HAFO. Land cover maps will be used to exclude remaining portions of these off-limits areas, as well as large portions of inaccessible barren lava in CRMO. Riparian zones will be excluded with a 10 m buffer around waterbodies. A two-stage sampling design will be developed with a grid-based sampling frame constructed for all parks (primary sampling unit cell size TBD, currently 100m^2), and secondary (stage 2) sampling units consisting of 100 m transects. Park-wide panels of simple random samples of grid cell primary units will be constructed for each park. CRMO may require multiple panels. An annual split-panel design will be developed for each park that will include one panel that is always revisited (1-0) and remaining panels never revisited (although individual sample units may be revisited in a new panel for a "with replacement" approach between years). The response design will follow recommendations by Herrick et al. (2005) and Miller et al. (2006) and will be based on line-intercept methods for estimating abundance of target species, including both native and invasive non-native plants. Community dominance and diversity relationships will also be measured. Sample size will be allocated, at least initially, as "probability-proportional-to-size (park area)" sampling described by Thompson (2002), although minimum sample sizes for small park units (e.g., Clarno Unit of JODA) will be used, regardless of area proportions.

Sage Grouse: Sage grouse lek occupancy,

Osprey nesting and productivity will be monitored at LARO once every three years.

relative abundance of lekking males, and seasonal use of critical habitat will be monitored in and adjacent to CIRO and CRMO, in cooperation with Idaho Department of Fish and Game. Lek monitoring will be conducted under the direction of Idaho Department of Fish and Game, and will follow a protocol developed by the Idaho Sage Grouse Advisory Committee. Scope of inference will be limited to the population of known active and inactive leks within 3.2 km (2 mi) of park boundaries, although UCBN data will contribute to a statewide monitoring program with regional inference. Periodic surveys will be conducted to update the list of known lek sites following Advisory Committee recommendations. Monitoring of seasonal use of critical habitat areas will follow a probabilistic design, based on a GIS-based spatial sampling frame, targeted at all critical habitat areas within CIRO and CRMO.

Stream/River Channel Characteristics: Stream/River channel characteristics will be monitored in all parks except HAFO, LARO, and MIIN. Target populations include all wadeable perennial streams. Sampling frames will be constructed from rasterized stream GIS coverages, so that spatially-balanced samples can be drawn using the GRTS algorithm as described previously for riparian vegetation, facilitating co-location and co-visitation with riparian, bats, and water quality vital signs monitoring efforts. Quantitative channel profile methods will be adopted and modified as necessary from regional riparian condition protocols in development by the USFS PIBO and by the Pacific Northwest Aquatic Monitoring Program (PNAMP; www.pnamp.org).

Aquatic Systems

Aquatic Macroinvertebrates: Aquatic macroinvertebrate monitoring will occur in non-randomly selected index streams in each UCBN park except LARO and MIIN. Table 4.2 lists priority waterbodies selected for monitoring macroinvertebrates. While a full census or spatially balanced probabilistic sampling design would be desirable so inferences to all UCBN waterbodies could be made, the limited number and diverse nature of the water bodies within the UCBN and very limited sampling resources do not allow a full census or a robust probabilistic design. Rather, we have selected a target population consisting primarily of representative streams selected following several criteria detailed in the Integrated Water Quality protocol. Site prioritization and index site selection was based on 1) preference for larger streams or rivers, 2) preferences and perceived need from park resource managers, and 3) available monitoring resources. Importantly, the index sites identified in Table 4.2 represent the majority of major streams and ponds in UCBN parks.

Within each stream, site selection will be made using a spatially-balanced design. Current resources permit sampling at 5-6 sites randomly selected from the GRTS list drawn for integrated riparian vegetation. Water chemistry sampling will be also be co-located at the most downstream of the macroinvertebrate sites to maximize sample co-location. Within each sampling location, the specific location of macroinvertebrate samples will be randomly selected using established protocols (e.g., USEPA EMAP protocols). Each macroinvertebrate site will be sampled twice each year on a 3-year rotating panel. The power to detect changes in macroinvertebrate assemblages between sampling periods will be only moderate, though statistical power could be substantially improved with investment of modest additional resources should these become available in the future.

Surface Water Dynamics: Monitoring of stream flow and lake water levels will be accomplished through compilation of data from available USGS gauges in and near UCBN parks. Sampling locations are non-randomly located index sites previously established by USGS. Compilations and reporting will be conducted on an annual basis and made available to parks accordingly.

Water Chemistry: Water chemistry, including core parameters and temperature, will be monitored by 1) comprehensive monitoring and compilation of available appropriate EPA and state Department of Environmental Quality (DEQ) data outside park boundaries and 2) using continuous multiparameter water quality monitoring probes ("multiprobes"). Data compilation will be conducted for all available streams, while multiprobe monitoring will be co-located with macroinvertebrates and riparian vegetation at selected water bodies (Table 4.2).

Core water quality parameters (temperature, dissolved oxygen, specific conductance, pH, and turbidity) will be estimated at the most downstream site of those selected for macroinvertebrate sampling using the assumption that water quality parameters at the downstream site reflect those upstream for some distance within the park. Core water quality parameters will be sampled by rotating two multiprobes among UCBN sites. Parameter values will be estimated on hourly time scales for 2-week periods at each index stream, 4 times/year. Specific locations of water quality multiprobes within each site will be partially judgmental in nature because logistics of deploying the equipment will probably constrain final site selection. The Integrated Water Quality protocol will contain a QA/QC protocol for establishing that index sites are spatially representative and are not located at unusual features such as locations with large groundwater input.

Sampling Integration of UCBN Vital Signs

Physical integration of vital signs is fundamental to successful program implementation and persistence because the UCBN consists of primarily small and widely separated parks, operates within a relatively small annual budget, and is constrained with a small staff. This integration will occur in two ways. First, several protocols will be designed to simultaneously measure numerous response variables and covariates for more than one vital sign, such that they will be sampled at the same place (co-location) and time (co-sampling). In Table 4.1, the protocols designated to facilitate physical integration have been identified. For example, under the terrestrial vegetation vital signs (sagebrush-steppe, riparian vegetation, and camas lily) we expect to meet the objective for trend monitoring of established target invasive weeds as well. By including presence and cover of targeted invasive species in the response design, trends in frequency and abundance can be estimated, and park weed management will be able to respond quickly to these recorded locations. In Table 4.1, this integration is indicated in the last column by noting which protocols (described in Chapter 5) will be used to accomplish integration for respective vital signs. The most involved integration opportunity is with the riparian condition and water quality vital signs. Three vital signs, bats, riparian vegetation, and stream/river channel characteristics, are being co-located and co-visited through an integrated riparian condition monitoring protocol. The integrated water quality monitoring protocol, which includes aquatic macroinvertebrates, water chemistry, and surface water dynamics vital signs, will also be nested within the same riparian condition sampling design. Figure 4.2 illustrates how this will be accomplished in JODA, using a spatially-balanced sampling design implemented using the GRTS algorithm. Anticipating a scenario in which the sampling intensity of vital signs differ, subsets of sampling locations can be randomly selected from the ordered GRTS list of samples for comprehensive sampling (3 [or more] vital signs) or for reduced sampling (1

Aquatic macroinvertebrates will be sampled in non-randomly selected streams within the UCBN twice a year on a 3-year rotating panel.

Table 4.2. UCBN priority waterbodies selected for macroinvertebrate (MI) and water chemistry monitoring (WC). Additional park waterbodies will be added to this list as budgets permit.

Park	Waterbodies	Monitoring	USGS HUC
BIHO	N. Fork Big Hole River and slough areas	MI, WC	10020004
CIRO	Circle Creek	MI, WC	17040210
CRMO	Little Cottonwood Creek	MI	17040209
HAFO	Yahoo Creek	MI	17040212
JODA	John Day River	MI, WC	17070201 17070204
JODA-Sheeprock	Rock Creek	MI, WC	17070201
JODA-Painted Hills	Bridge Creek	MI, WC	17070204
NEPE-Whitebird Battlefield	Schwartz Pond	MI	17060209
NEPE-Weippe Prairie	Jim Ford Creek	MI, WC	17060306
NEPE-Spalding	Lapwai Creek	MI, WC	17060306
WHMI	Mill Creek	MI, WC	17070102
WHMI	Doan Creek	MI, WC	17070102

or 2 vital signs only), while still maintaining spatial balance and flexibility to increase or reduce sampling for individual vital signs as needed. This approach is not only cost-effective and practical, it will provide for a much more information-rich understanding of park riparian ecosystems. In this example, riparian vegetation and stream/channel characteristics might be monitored at all sites (red, orange, and yellow), bats at only orange and yellow sites, macroinvertebrates at only yellow sites, and the water chemistry index sites at only the northernmost yellow site where the river exits the park.

The second approach to physically integrating UCBN vital signs monitoring will involve partnership, data sharing, compilation, and reporting with other national and regional monitoring programs. Water chemistry, for example, will be monitored so that statistically robust results are obtained for each park, yet the data are comparable with other national and regional (North American Aquatic Monitoring Partnership) programs. Some of these programs have accumulated more than 20 years of data at more than 1,000 sites around the Columbia Basin, and include sites near UCBN parks. This level of integration will provide a regional context for many Network vital signs. Surface water dynamics will involve the compilation of data from existing USGS stream gauges in or near parks. Osprey may be monitored through a partnership between NPS and the Confederated Tribes of the Colville Reservation, in which nests on the north side of the lake are surveyed by tribal staff, nests on the south side by NPS staff, and data pooled to complete a lake-wide monitoring program. Similarly, sage grouse monitoring will be a partnership with Idaho Department of Fish and Game to monitor leks both on and off NPS land, share data, and increase the efficiency and information content for both agencies.

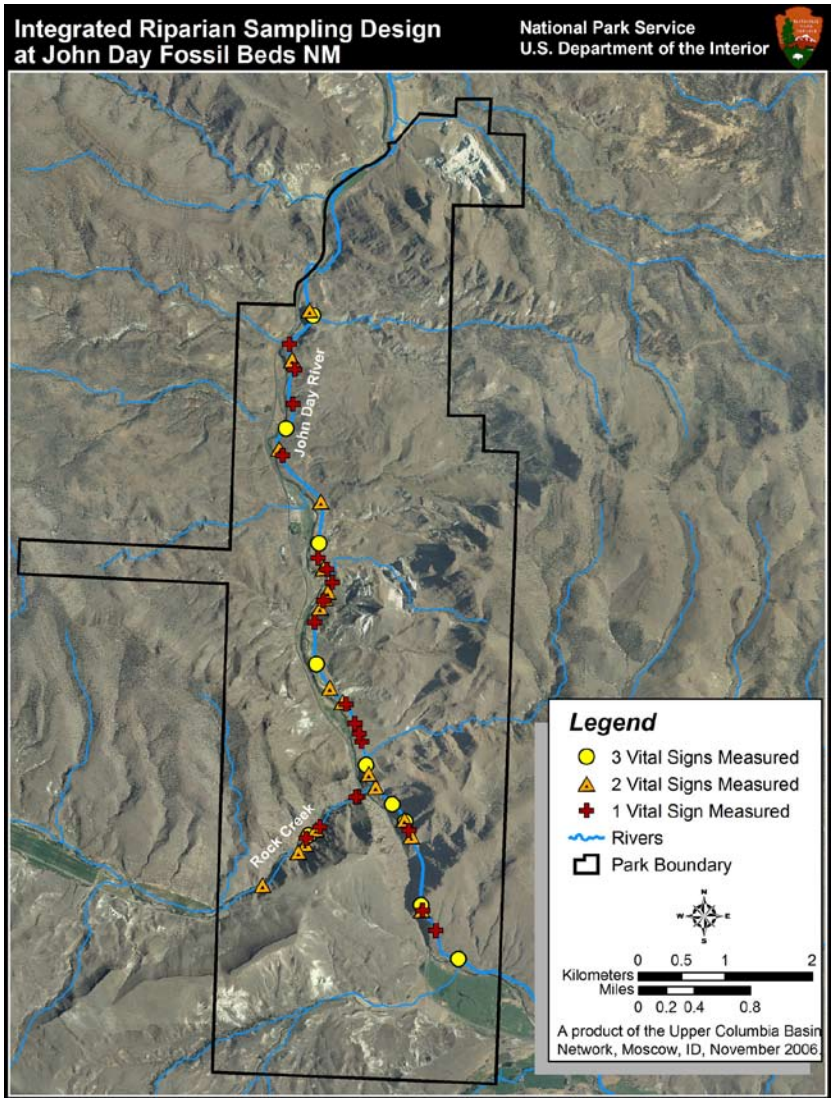
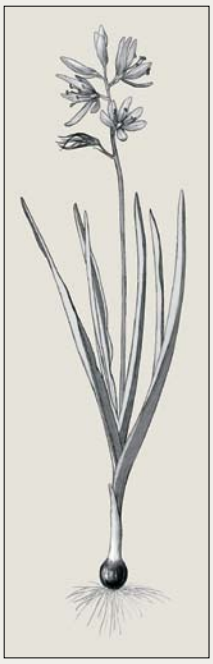


Figure 4.2. An integrated spatially-balanced sampling design drawn with the GRTS algorithm for co-locating and co-visiting riparian vegetation, stream/river channel characteristics, bats, and water quality vital signs in the Sheep Rock Unit of JODA and where each of the vital signs have different sample size requirements.

While at least some degree of sampling integration is planned across most vital signs, several are not well suited for co-location and co-visitation because they do not exhibit spatial or temporal overlap with others. For example, osprey will be monitored along the shore of Lake Roosevelt, but no other vital signs will be monitored in that same vicinity. Both aspen and limber pine are park specific vital signs that do not overlap with other vital signs, and the anticipated response design is not conducive to the collection of invasive plant data.

In most cases, integration has been achieved by integrating the response designs. As was described previously, estimating trends in target invasive plants will be achieved by measuring frequency and abundance of those species in plots sampled for other vegetation vital signs (e.g., camas lily, sagebrush-steppe, and riparian vegetation). This same approach will be employed for water quality index sites, where aquatic macroinvertebrates will be sampled at the same time and place as water chemistry, and these index sites will be part of the probabilistic sample for riparian condition. The first set of 11 core UCBN protocols will also guide future integration. Those developing new protocols will have, as a first option, a set of probabilistically chosen sites or plots to use. The choice of whether to adopt these sites will depend on ecological and statistical considerations.

Chapter 5: Monitoring Protocols



Monitoring protocols are detailed study plans that explain how data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs. Protocols are necessary to be certain that changes detected by monitoring actually are occurring in nature and not simply a result of measurements being taken by different people or in slightly different ways. . . . A good monitoring protocol will include extensive testing and evaluation of the effectiveness of the procedures before they are accepted for long-term monitoring. Peer review of protocols and revisions are essential for their credibility. The documentation should include reviewers' comments and authors' responses. (Oakley et al. 2003)

The monitoring protocol is the fundamental document required to implement a monitoring program. Each UCBN vital sign will be addressed in a stand-alone peer-reviewed monitoring protocol that serves as a detailed study plan with step-by-step instructions for all participants involved in monitoring, from field technicians to data analysts and project leaders. A well-written and thorough protocol is key to the long-term success of the monitoring program. It ensures monitoring persists in a consistent manner through generations of I&M program staff, providing *de facto* institutional memory. It also ensures changes detected by monitoring actually are occurring in nature and do not stem from measurement variability introduced when different people or methods are used (Oakley et al. 2003). The NPS I&M program has placed a premium on developing and utilizing rigorous and practical monitoring protocols. The review by Oakley et al. (2003) has been adopted as the standard and the UCBN will closely follow their recommendations and outline for each protocol developed or adopted.

Following Oakley et al. (2003), each monitoring protocol will include a narrative providing the rationale for vital sign selection, an overview of the monitoring protocol components, and a history of protocol development. The narrative will detail protocol sampling objectives, sampling design (including location and time of sample collection), field methods, data analysis and reporting, staffing requirements, training procedures, and operational requirements. Specific measurable objectives must be identified in the objective section of the narrative. Narratives also summarize the design phase of a protocol development and any relevant decision-making, including all design component details (see Chapter 4). Documenting the history of a protocol during its development phase helps ensure future refinement continues to improve and is not a mere repetition of previous trials or comparisons (Oakley et al. 2003). Narratives also provide a listing and brief summary of all standard operating procedures (SOPs), which are developed in detail as independent sections.

SOPs carefully and thoroughly explain in a step-by-step manner how each procedure identified in the protocol narrative will be accomplished. At a minimum, SOPs address pre-sampling training requirements, data to be collected, equipment operations, data collection techniques, data management, data analysis, reporting, and any activities required at the end of a field season (i.e., equipment storage). One SOP identifies when and how revisions to the protocol are undertaken. As stand alone documents, SOPs are easily updated compared to revising an entire monitoring protocol and changes are identified in a revision log.

Finally, monitoring protocols identify supporting materials critical to development and implementation of the protocol (Oakley et al. 2003). Examples of this material may include databases, reports, maps, geospatial information, species lists, species guilds, analysis tools tested, and any decisions resulting from these exploratory analyses. Material not easily formatted for inclusion in the monitoring protocol can also be included in this section as well as comments received from peer reviewers.

Protocol Development Schedule

The UCBN protocol development schedule was established based on the prioritization of vital signs (see Chapter 3) with 14 identified for development over the next 5 years. Several water quality vital signs will

A monitoring protocol for bats, such as this spotted bat, and other UCBN vital signs will be developed over the next few years.

be simultaneously developed and incorporated into one protocol. Similarly, much of the invasive/exotic plants monitoring will also be accomplished within other vegetation monitoring protocols, although an early-detection invasive plant protocol will be required. An integrated riparian condition protocol will be developed to address the riparian vegetation and stream/river channel characteristics vital signs. A bat monitoring protocol will be integrated with the riparian condition sampling design in order to facilitate co-location and co-visitation of each of these sampling efforts. A total of 11 protocols addressing the 14 vital signs are scheduled for completion by September 2012 (Table 5.1). At least one complete, peer-reviewed protocol ready for implementation will be included with the final draft of this monitoring plan to be submitted no later than September 2007. The camas lily protocol is complete, has been peer-reviewed, and has been accepted for implementation. Three other protocols are in development and will be submitted for peer review as soon as possible and no later than December of 2007. Five "Phase 2" protocols will be initiated as current protocols are nearing completion, and development of the remaining "Phase 3" protocols will follow accordingly. The early detection invasive plants protocol, currently being developed by the national I&M program, will be adapted and adopted when it becomes available. Protocol development summaries have been developed following standardized NPS format and content requirements to serve as placeholders until protocols become available, and are located in Appendix F. Abbreviated summary information is found in Table 5.2.

Concerns over aspen declines throughout the west prompted its listing as a UCBN vital sign.

Table 5.1. Development phase of 11 protocols addressing the 14 UCBN vital signs.

Vital Sign	Protocol	Development Phase
Aquatic Macroinvertebrates	Integrated Water Quality	In development
Aspen	Aspen	In development
Bats	Bats	Phase 2
Camas Lily	Camas Lily	Complete; Peer-reviewed
Invasive/Exotic Plants	Invasive/Exotic Plants	Phase 3 (National)
Land Cover and Use	Land Cover and Use	Phase 3
Limber Pine	Limber Pine	Phase 2
Osprey	Osprey	Phase 2
Riparian Vegetation	Integrated Riparian	Phase 2
Sagebrush-Steppe Vegetation	Sagebrush-steppe Vegetation	In development
Sage Grouse	Sage Grouse	Phase 3
Stream/River Channel Characteristics	Integrated Riparian	Phase 2
Surface Water Dynamics	Integrated Water Quality	In development
Water Chemistry	Integrated Water Quality	In development

Table 5.2. Key information from each protocol at its current state of development, including applicable parks, specific monitoring objectives, measures, justification, and projected management applications.

Protocol (Vital Sign)	Parks	Monitoring Objectives	Measures	Justification	Management Applications
Aspen (Aspen)	CIRO, CRMO	1) Estimate status and trend in aspen abundance, as measured by stem density of live and dead trees, within CIRO and CRMO aspen stands. 2) Estimate status and trend in conifer density within CIRO and CRMO aspen stands. 3) Estimate status and trend in regeneration of park aspen populations as well as individual stands within CIRO and CRMO.	Abundance (aspen stem density, conifer density)	Quaking aspen is declining rapidly in the western US with an estimated loss of 61% in Idaho; Aspen communities are one of the most biologically rich areas in the intermountain west; Aspen decline cascades into losses of vertebrate species and vascular plants as well as invertebrates and nonvascular organisms; Visitors come to many parks in the fall to view the aspen coloration.	Inform regional assessment of aspen community status; Trigger management actions including mechanical removal of invasive conifer trees, use of prescribed fires, and management of grazing allotments.
Bats (Bats)	CIRO, CRMO, JODA	1) Estimate trends in the occupancy dynamics of individual bat species during summer pup-rearing in riparian areas of CIRO, CRMO, and JODA. 2) Estimate trends in Townsend's big-eared bat occupancy and abundance in lava tubes of CRMO's north caves complex during summer pup-rearing.	Riparian occupancy and detectability (ψ and ρ), local extinction and colonization rates (ε and γ), cave occupancy and abundance (roost exit counts)	Riparian corridors provide critical foraging and commuting habitat for all 14 bat species in the UCBN and as many as half of these species are listed as federal and or state species of concern; Changes in bat species presence and activity patterns at monitoring sites will serve as good indicators of environmental change and riparian/aquatic focal system integrity.	Identify critical seasonal use patterns to inform management prescriptions for visitor use; Inform regional assessments of sensitive species status; Identify priority riparian restoration areas; Part of an integrated suite of information for understanding park aquatic and riparian health.

Table 5.2. Key information from each protocol at its current state of development, including applicable parks, specific monitoring objectives, measures, justification, and projected management applications (continued).

Protocol (Vital Sign)	Parks	Monitoring Objectives	Measures	Justification	Management Applications
Camas Lily (Camas Lily)	BIHO, NEPE	1) Estimate the mean for stem and flowering stem densities (status) in the camas lily populations of Weippe Prairie and within the targeted portion of BIHO. 2) Determine trends (net trend) in the densities of camas lily in Weippe Prairie and BIHO. 3) Determine trends in the proportion of flowering to non-flowering camas plants in Weippe Prairie and BIHO. 4) Determine trends in frequency of occurrence of targeted invasive plant species. 5) Determine the magnitude and direction of camas density response to measurable explanatory variables such as monthly mean precipitation, graminoid thatch depth, and specific management activities.	Stem density, flowering plant proportion, and frequency of target invasive plants.	Camas lily is a key cultural focal resource as well as an important ecological component of herbaceous wetland communities and has historical importance in Weippe Prairie (NEPE) and BIHO; These wetland prairie ecosystem types have experienced significant regional declines due to agricultural conversion, exotic plant invasion, and altered hydrology.	Provide benchmarks for evaluating site management strategies, including effectiveness of grazing and weed control; Inform park assessment of cultural resource status; As a facultative wetland species, help assess progress toward wetland land health goal (or upland, depending on park reporting approach).
Integrated Riparian (Riparian Vegetation)	BIHO, CIRO, CRMO, HAFO, JODA, NEPE, WHMI	1) Estimate trends in the abundance of targeted plant species and horizontal strata (i.e., trees, graminoids, etc.) and species and community composition in UCBN riparian zones. 2) Estimate trends in vertebrate community composition and the occupancy dynamics of targeted riparian-obligate species in the UCBN riparian areas.	Presence (occupancy) and abundance (cover) of target genera and species (e.g., Willow, aspen) and strata (e.g., tree, graminoid) and composition of species and community types (similarity indices, richness and dominance).	UCBN riparian zones are disproportionately important to park ecosystems, complex, and inextricably linked to aquatic and upland ecological processes; Abundance and composition of species and communities are fundamental and directly measurable attributes, and also specifically address objectives related to the invasive plants vital sign.	Inform management prescriptions for weed control and restoration; Provide benchmarks for evaluating restoration and other management actions; Help assess progress towards riparian health goal.

Table 5.2. Key information from each protocol at its current state of development, including applicable parks, specific monitoring objectives, measures, justification, and projected management applications (continued).

Protocol (Vital Sign)	Parks	Monitoring Objectives	Measures	Justification	Management Applications
Integrated Riparian (Stream/River Channel Characteristics)	BIHO, CIRO, CRMO, JODA, NEPE, WHMI	1) Estimate trends in streambank channel morphology, including sinuosity, bank stability, and substrate composition, of UCBN perennial wadeable rivers and streams.	Bankfull width and depth, substrate composition, bank angle, undercut depth, pool depth, and sinuosity.	UCBN riparian zones are disproportionately important to park ecosystems, complex, and inextricably linked to aquatic and upland ecological processes; Streambank channel morphology, stability, and composition are fundamental and directly measurable attributes of lotic systems that directly affect riparian vegetation, water quality, and aquatic fauna, particularly macroinvertebrates and fish.	Identify critical areas for streambank restoration and other management actions; Increase understanding of riparian vegetation and bat occupancy trends.
Integrated Water Quality (Aquatic Macroinvertebrates)	BIHO, CIRO, CRMO, HAFO, JODA, NEPE, WHMI	1) Estimate status and trend in aquatic macroinvertebrate abundance, community composition, and functional feeding group composition in representative lotic UCBN waterbodies.	Species and functional group composition and abundance (counts).	Aquatic environments are disproportionately important in terms of biodiversity, biological productivity, and other ecosystem values; All UCBN waters are on 303(d) lists for impairment of at least one parameter; Aquatic macroinvertebrates are good indicators of ecosystem condition because they occur in all waterbodies, integrate point, nonpoint, pulse, and press disturbances, are trophically diverse, are less mobile than fishes, and are affected both by conditions in local stream reaches and those within the watershed.	Identify priority riparian restoration areas; Effects of transient (and difficult to sample) events such as floods or chemical pulses on aquatic community structure and ecosystem processes may be detected with infrequent sampling; A key measure of water quality; Connected to riparian vegetation and overall riparian health.

Table 5.2. Key information from each protocol at its current state of development, including applicable parks, specific monitoring objectives, measures, justification, and projected management applications (continued).

Protocol (Vital Sign)	Parks	Monitoring Objectives	Measures	Justification	Management Applications
Integrated Water Quality (Surface Water Dynamics)	BIHO, CIRO, HAFO, JODA, LARO, NEPE, WHMI	1) Estimate trends in seasonal and annual flow regimes for (representative) lotic waterbodies within or near UCBN park units.	Flow rate and annual water level fluctuation.	Aquatic environments are disproportionately important in terms of biodiversity, biological productivity, and other ecosystem values; All UCBN waters are on 303(d) lists for impairment of at least one parameter; Water quantity and flow regime have overriding influence on stream channel morphology and stream and riparian biota; The strong alteration of flow regimes by human activity and climate frequently alters biotic communities and ecosystem processes.	Critical to understanding streambank morphology and riparian vegetation dynamics, as well as water chemistry. Restoration goals and success benchmarks, including WHMI Doan Cr., informed by an understanding of streamflow and system energy, particularly timing, duration, and intensity of floods.
Integrated Water Quality (Water Chemistry)	BIHO, CIRO, CRMO, HAFO, JODA, LARO, NEPE, WHMI	1) Estimate seasonal and annual means (status) in key water chemistry parameters for water bodies within and near UCBN park units. 2) Estimate interannual trends in key water chemistry parameters using historical and current data. 3) Estimate status and trends in seasonal and annual temperature profiles of (representative) UCBN waterbodies.	Daily, seasonal and annual values for core parameters (include water temperature, dissolved gas, pH, conductivity, and turbidity).	Aquatic environments are disproportionately important in terms of biodiversity, biological productivity, and other ecosystem values; All UCBN waters are on 303(d) lists for impairment of at least one parameter; Human alteration of stream water chemistry and temperature is associated with changes in biotic communities and ecosystem processes; Monitoring these parameters has increased due to concerns over cold-water fish habitat, recognized influences of land- and water-use on stream thermal regime, and the need for baseline information to monitor climate change effects.	Key measure of water quality. Is part of integrated suite of information for understanding park aquatic and riparian health. Will help assess progress toward water quality GPRA goal.
Invasive/Exotic Plants (Invasive/Exotic Plants)	BIHO, CIRO, CRMO, HAFO, JODA, LARO, NEPE, WHMI	1) Detect incipient populations and new occurrences of selected invasive nonnative plants before they become established. 2) Estimate the status and trend of established target invasive plant species frequency and abundance in UCBN parks.	Frequency (presence/ absence) distribution, abundance (cover), and detection of new species and incipient invasions.	The management and control of invasive non-native species has been identified as a high priority issue within the NPS and is an accountable goal under the GPRA of 1993; Invasive plants are one of the greatest threats to natural and cultural resources in all UCBN parks.	Identify high priority areas for treatment; Provide trigger points for management action; Direct early detection and intervention efforts; Help assess progress toward several land health goals.

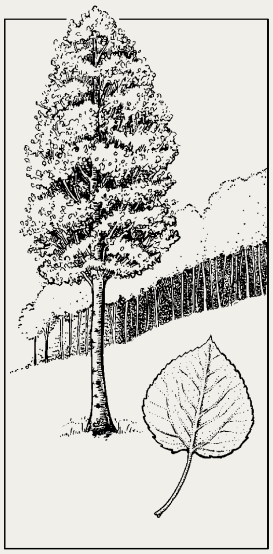
Table 5.2. Key information from each protocol at its current state of development, including applicable parks, specific monitoring objectives, measures, justification, and projected management applications (continued).

Protocol (Vital Sign)	Parks	Monitoring Objectives	Measures	Justification	Management Applications
Land Cover and Use (Land Cover and Use)	All	1) Determine long-term trends in land cover distribution within and adjacent to UCBN park boundaries. 2) Determine patterns of relevant land cover types within and adjacent to UCBN park boundaries.	Proportion of area in different cover types, patch metrics (patch number, density, mean patch size), perimeter and core area metrics, and measures of landscape connectivity (nearest neighbor metrics)	Land cover distribution is a critical description of a park landscape; Changes in land cover can dramatically influence a host of biological, physical and chemical resources within that park; Maps of land cover distribution and changes in those distributions are a central component to assessing changes in other resources.	Essential quantitative information for managers to understand the changing context in which their park resides. This will inform all aspects of park management and increase understanding of park resource challenges and suggest possible sources of ecological change.
Limber Pine	CIRO, CRMO	1) Conduct early detection status surveys for limber pine blister rust infection at CRMO and CIRO. 2) Estimate trends in the proportion, severity, and survivorship of limber pine trees infected with white pine blister rust stands in CRMO and CIRO.	Frequency of trees infected, distribution of infection in parks, number and location of cankers, and rate of survival after blister rust infection.	Limber pine is suffering extensive, heavy mortality throughout the West due to the invasive exotic fungal disease white-pine blister rust; Blister rust causes cankers which often results in cessation of cone production and in some cases, death of the tree; Limber Pine contributes significantly to the biodiversity of CIRO and CRMO, directly as a unique tree species, and indirectly as habitat for associated plants and animals and is essential to the CRMO landscape. Blister rust infection was first documented in CRMO in 2006 (not yet documented in CIRO).	Provide early detection and trigger early management intervention; Determine vulnerability of trees according to location; Identify resistant trees for genetic analysis.
Osprey	LARO	1) Determine status and trends of nest occupancy for osprey in LARO. 2) Determine status and trends of productivity (number of fledglings) for osprey in LARO.	Nest occupancy (proportion occupied) and productivity (fledglings per nest).	Osprey populations are rebounding after a drastic decline (1950-60's) due to organochlorine contamination; Their sensitivity to contaminants and other human disturbances and their role as a top predator in a complex food chain, makes osprey useful indicators of environmental change; Lake Roosevelt has high levels of environmental contaminants and increasingly high levels of boater-oriented recreation; Though the lake supports an apparently stable summer breeding population, little information has been collected on osprey in the area.	Inform regional/statewide assessment of species status; Identify critical areas for increased protection from adverse boating impacts. Will indicate broader systemic effects of LARO pollution, if present.

Table 5.2. Key information from each protocol at its current state of development, including applicable parks, specific monitoring objectives, measures, justification, and projected management applications (continued).

Protocol (Vital Sign)	Parks	Monitoring Objectives	Measures	Justification	Management Applications
Sagebrush-steppe Vegetation	CIRO, CRMO, HAFO, JODA, LARO	1) Estimate status and trends in the abundance of targeted plant species, groups (e.g. *Artemisia spp*.) and horizontal strata (e.g., perennial grass, shrub, etc.) in UCBN sagebrush-steppe communities. 2) Estimate status and trends in species composition and diversity of UCBN sagebrush-steppe communities.	Abundance (cover) of target species and genera (e.g., *Artemisia*) and strata (e.g., shrubs, forbs), tree density, composition (e.g., proportion legumes), and diversity (richness and dominance).	Sagebrush-steppe is the most abundant vegetation type in the UCBN; Significant portions of the sagebrush steppe have since been converted to agriculture and heavily grazed rangeland and much of what remains has been degraded through altered fire regimes and invasion of introduced plants; These changes have resulted in native flora and fauna declines, decreased soil stability, and reduced hydrologic function; Land use practices both within and adjacent to the UCBN parks continue to fragment and alter steppe ecosystems; Predicted climate change scenarios will likely intensify these stressors.	Help assess progress toward land health goal for upland communities; Inform management actions concerning grazing allotments, fire management, and western juniper reduction; Inform trend estimates for established invasive plants.
Sage Grouse	CIRO, CRMO	1) Cooperate with Idaho Department of Fish and Game to estimate trends in occupancy and abundance of male sage-grouse through annual lek counts in and adjacent to (within 2 miles of park boundaries) CIRO and CRMO. 2) Identify potential critical sage-grouse habitat areas within the parks and conduct periodic status surveys to estimate occupancy and abundance.	Lek occupancy, abundance (lek counts), distribution and amount of critical habitat, and occupancy and abundance in critical habitat.	The greater sage-grouse has been decreasing in numbers and range throughout much of the western US; It has unique seasonal habitat requirements and the loss or conversion of these habitats is believed to be a primary cause the declines; The sage grouse is a sagebrush obligate species and is considered an umbrella species for other species of fauna and flora; Lek counts are the most common way to monitor sage-grouse populations and are currently being conducted in Idaho.	Inform regional assessment of species status; Identify critical habitat areas within parks for increased protection from visitors or other adverse impacts

Chapter 6: Data Management



Information is the common currency among the activities and staff involved in the stewardship of natural resources for the NPS. This chapter summarizes the data management strategy for the UCBN using material drawn from the network Data Management Plan (DMP). The DMP, as a companion document to this UCBN Monitoring Plan, serves as a guide for UCBN staff and for current and future UCBN project leaders to ensure the continuity and documentation of data management methods and procedures over time. The DMP, in turn, refers to other guidance documents and standard operating procedures which convey the specific standards and steps for achieving the Network's data management goals.

The data management mission of the UCBN is to provide data and information resources that are organized, available, useful, compliant, and secure. The data management strategy described in the DMP focuses on the processes used to:

- Acquire, store, manage and archive data
- Ensure data quality
- Document and disseminate data
- Ensure the long-term access to and utility of data

Data Management Goals

The data management goals articulated in the DMP are framed around the service-wide I&M Program goal of identifying, cataloging, organizing, archiving, and making available relevant natural resource information (http://science.nature.nps.gov/im/monitor/DataManagement.cfm). These data management goals and their associated objectives are as follows:

- **Goal 1 -** Ensure the high quality and long-term availability of the ecological data and related analyses produced from the network's inventory and monitoring work
  - Objective - Outline the procedures and work practices that support effective data management
  - Objective - Establish an organizational schema for UCBN program data and information so that they are retrievable by staff, cooperators, and the public
  - Objective - Establish standards for data, data distribution, and data archiving to ensure the long-term integrity of data, associated metadata, and any supporting information
- **Goal 2** - Integrate data management activities with all aspects and at all stages of network business
  - Objective - Encourage effective data management practices as an integral part of project management so all data are available and usable for park management decisions, research, and education, now and into the future
  - Objective - Establish quality control and quality assurance standards
- **Goal 3** - Specify data stewardship responsibilities for all personnel
  - Objective - Guide current and future staff of the UCBN to ensure that sound data management practices are followed
  - Objective - Establish data management roles and responsibilities of UCBN staff
- **Goal 4** - Work within and outside the Network, as appropriate, to improve the quality and availability of legacy NPS datasets and data from outside sources
  - Objective – As time and resources permit, migrate high-priority legacy datasets into modern formats and improve the quality and documentation of these datasets or other data originating from outside the Inventory and Monitoring Program
  - Objective – Work with partner agencies and institutions to promote the sharing and development of data, software applications, and analyses

The UCBN data management strategy is more fully presented in the DMP, which serves as the overarching strategy for achieving the goals and objectives noted above, and supports service-wide I&M Program goals by ensuring that network data are documented, secure, and remain accessible and useful indefinitely.

Data Management Priorities

The priorities for network data management efforts are to:

- Produce and curate high-quality, well-documented data originating with the I&M Program
- Assist with data management for current projects, legacy data, and data originating outside the I&M Program that complement program objectives
- Help ensure good data management practices for park-based natural resource projects that are just beginning to be developed and implemented

The range of data products coordinated or managed by UCBN fall into four general categories: data, documentation, reports, and administrative records (Table 6.1). Documentation, in the form of protocols, data dictionaries, database user guides, standard operating procedures (SOPs), and metadata, provides the long-term value of data by setting the context of how and why the data were collected, analyzed, and reported.

Table 6.1. Categories and examples of data products addressed in the Data Management Plan.

Category	Description	Examples
Data		
• Raw Data	Data obtained from the environment and that has not been subjected to any quality assurance or control beyond those applied during field work.	• Field data sheets • Specimens • Remotely sensed data • Data gathered electronically on field computers • GPS rover files • Photographic imagery
• Verified and Validated Data	Data that have been evaluated for completeness, correctness, and conformance/compliance of a specific data set against the standard operating procedure (verified), as well as reviewed for specific analytic quality (validated).	• Relational databases • Tabular data files • Laboratory results • GIS layers • Maps
• Analyzed Data	Data that have been subjected to analytical routines after validation (may includes statistical operations for arriving at a measure of the given ecological parameter) or a compilation of analyzed data from different sources or time periods to derive new information.	• Summarized reports, data, and maps from statistical or query operations
Documentation	Documentation provides the information required to understand the context of the data.	• Data collection protocols • Data processing/analysis protocols • Record of protocol changes • Data dictionary • FGDC metadata • Database design documents • QA/QC reports • Catalogs
Reports	Reports provide a means of presenting and publishing the methods and the results of analysis in the context of which it was intended.	• Annual progress reports • Final reports • Trend analysis reports • Publications
Administrative Records	Administrative records supplement the context of a project and should be considered part of the projects deliverables.	• Contracts and agreements • Study and work plans • Research permits • Critical administrative correspondence

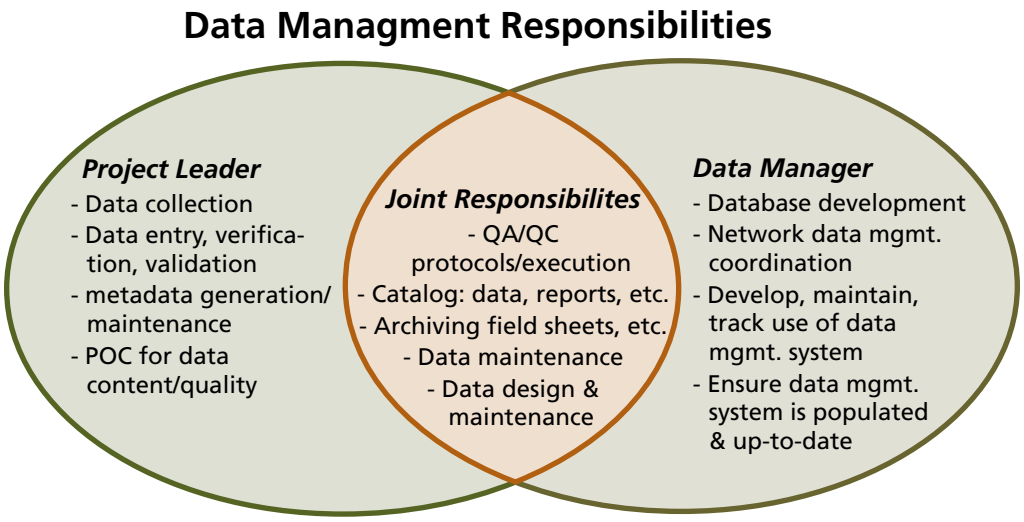


Figure 6.1. Core data management responsibilities for a project leader and the data manager.

Data Stewardship Roles and Responsibilities

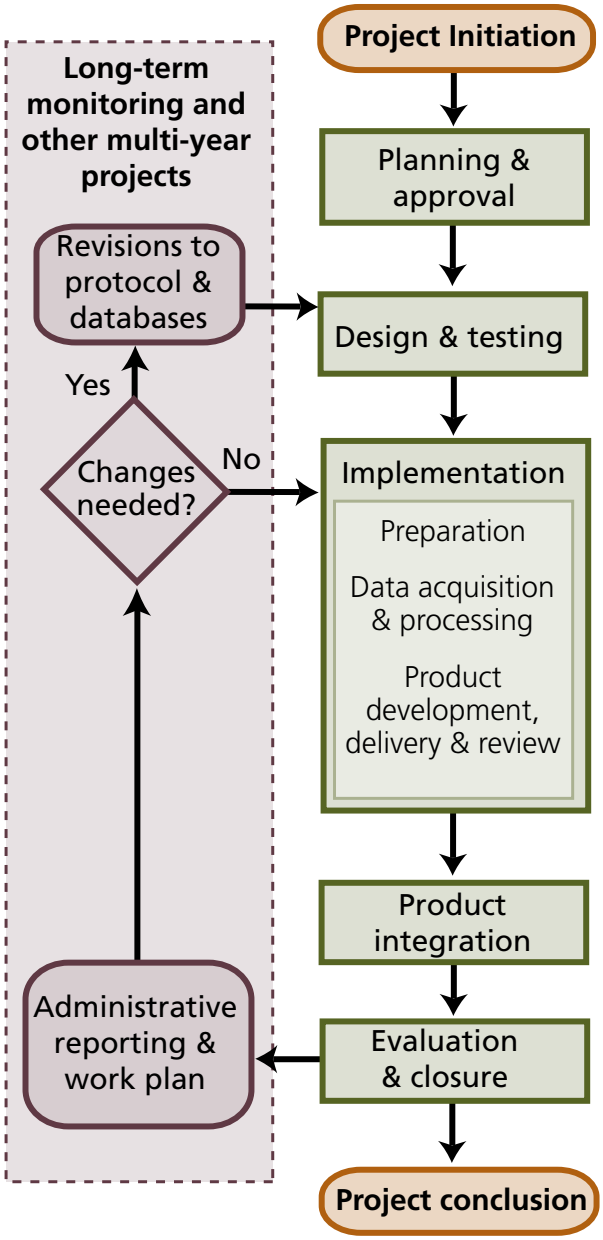
Every individual involved in the I&M Program is required to understand and perform data stewardship responsibilities in the production, analysis, management, and end use of the data as described in the DMP and the specific vital sign monitoring protocols. Network coordinators, project leaders, and data managers comprise the central data management team for inventory and monitoring projects. Each is responsible for certain aspects of project data and all share responsibility for some overlapping tasks (Figure 6.1). Because of the collaborative nature of project data management, good communication among these personnel is essential to meeting program goals.

Stewardship of data and information assets requires that knowledgeable individuals from scientific, administrative, and technological disciplines work in concert to ensure that data are collected using appropriate methods, and that resulting datasets, reports, maps, models, and other derived products are well managed. Datasets and the presentations of these data must be credible, representative, and available for current and future needs. Stewardship responsibilities apply to all personnel who handle, view, or manage data (Table 6.2). Vital sign monitoring protocols will describe more detailed, project-specific data stewardship roles and responsibilities.

Table 6.2. Programmatic roles and responsibilities for data stewardship.

Role	Data Stewardship Responsibilities
Project Crew Member	Collect, record, and verify data
Project Leader/Principal Investigator	Direct project operations. Communicate data management requirements and protocols to project staff and data manager. Responsible for data verification, validation, and documentation, and for submission of products and deliverables.
Data/GIS Manager (Project)	Develop and manage GIS data and metadata in standard file formats
Statistician/Biometrician (Project or Network)	Analyze data and/or consult on analysis
Park Research Coordinator (Park)	Facilitate data acquisition by external researchers; communicate NPS requirements to permit holders
Park Resource Specialist	Validate and make decisions about data
Curator (Park or Region)	Oversee all aspects of specimen acquisition, documentation, and preservation; manage park collections
Network Data Manager	Ensure inventory and monitoring data are organized, useful, compliant, secure, and available
Network Ecologist	Integrate science in park and network activities
Network Coordinator	Coordinate and oversee all network activities
GIS Manager (Region)	Support park management objectives with GIS and resource information management
Information Technology Specialist (Region)	Provide IT support for hardware, software, networking
I&M Data Manager (National)	Provide Service-wide database availability and support
End Users (managers, scientists, interpreters, public)	Inform the scope and direction of science information needs and activities; interpret information and apply to decisions

Figure 6.2. Project work flow, with the five primary project stages shown in green boxes.



Data and Information Workflow

Understanding the life cycle of data throughout a project will help to manage the staffing resources necessary to complete and support quality data. UCBN projects include short-term data collection, analysis, and reporting efforts, such as inventories, and long-term efforts such as vital sign monitoring, as well as efforts external to the I&M Program that generate data of interest to UCBN. Short- and long-term projects share workflow characteristics and both generate products that must be managed and made available. The workflow of project management can be divided into five primary stages (Figure 6.2), each of which entails a set of project management and data management tasks

Descriptions of the data management related activities associated with each of the five project stages depicted in Figure 6.2 are as follows:

1. Planning and approval- In this stage, many of the preliminary decisions are made regarding project scope and objectives. In addition, funding sources, permits, and compliance are addressed. Primary responsibility rests with project leaders and program administrators. It is important that data managers remain informed of projects in this stage, especially as timelines for deliverables are finalized. Contracts, agreements, and permits should include standard descriptions for formats, specifications, and timelines for project deliverables.
2. Design and testing- During the design stage, details are worked out regarding data acquisition, processing, analysis, reporting, and availability. Applicable SOPs, guidance documents, and training materials are collected and/or developed. The project leader is responsible for development and testing of methods, sampling design, field forms, database design requirements, and SOPs for data collection and processing. Regular communication between the project leader and the network data manager will establish good data management throughout the project. An important part of such collaboration is the development of the data models and data dictionaries, which define in detail the parameters to be collected and allow the project leader and data man-

ager to construct the project database application(s).

3. Implementation- During the implementation stage, data are acquired, processed, error-checked, and documented. This stage is also when products such as reports, maps, GIS themes, and other products are developed and delivered. The project leader oversees all aspects of implementation from logistics planning to data acquisition, report preparation, and final delivery. Throughout this stage, data management staff fills a facilitation role by providing training and support for database applications, GIS, GPS, and other data processing applications; facilitating data summarization, validation, and analysis; and assisting with the technical aspects of documentation and product development.
4. Product integration- During this stage, data products and other deliverables are integrated into national and network databases, metadata records are finalized and posted in clearinghouses, and products are distributed or made available to intended audiences. Another aspect of integration is merging data from a working database to a master database maintained on the network server. This step occurs only after the annual working dataset has been validated and certified by the project leader. Certain projects may also have additional integration needs, such as when working jointly with other agencies sharing a common database.
5. Evaluation and closure- Upon project closure, network records and project-tracking tools are updated to reflect the status of the project and its associated deliverables. For long-term monitoring and other cyclic projects, this stage occurs at the end of each field season, and leads to an annual review of the project. For non-cyclic projects, this stage represents project completion. Program administrators, project leaders, and data managers will work together to assess how well the project met its objectives, and determine possible improvements in methodology, implementation, and formatting of the resulting information. For monitoring protocols, careful documentation of all changes is required. Changes to methods, SOPs, and other procedures are maintained in a tracking table associated with each document. Major revisions may require additional peer review.

During a project's five stages, project data take different forms and are maintained in different places as they are acquired, processed, documented, and archived. This data life cycle can be modeled as a sequence of events and tasks (Figure 6.3), which involves interaction with the following objects:

- *Raw data* – Analog data recorded by hand on hard-copy forms and digital files from handheld computers, GPS receivers, telemetry data loggers, etc.
- *Working database* – A project-specific database for entering and processing data for the current season (or other logical time period); this may be the only database for short-term projects with no need to distinguish current season data from the full set of validated data
- *Certified data and metadata* – Completed data and documentation for short-term projects, or one season of completed data for long-term monitoring projects; certification is a confirmation by the project leader that the data have passed all quality assurance requirements and are complete and ready for distribution; metadata records include the detailed information about project data needed for its proper use and interpretation
- *Master database* – Project-specific database for storing the full set of validated project data; current season data from working database(s) must pass all quality assurance steps prior to upload into this master project database
- *Reports and data products* – Information that is derived from certified project data
- *Edit log* – A means of tracking changes to certified data
- *National databases and repositories* – Applications and repositories maintained at the national level, primarily for the purpose of integration among NPS units and for sharing information among NPS staff, cooperators, and the public

- *Digital libraries and archiving* – All certified digital files associated with a project are stored on file servers at the network level, including data backups; archiving of all project hard-copy items is accomplished at the park level by cultural resources staff, with coordination from both the project leader and UCBN staff

For long-term projects, this sequence of data life cycle events occurs in an iterative fashion, repeating at the end of each field season or other logical data collection and reporting period. Conversely, this sequence is followed only once for short-term projects. UCBN uses a project tracking database (see DMP) to document and track project status, changes to protocols, and archiving and distribution of product deliverables.

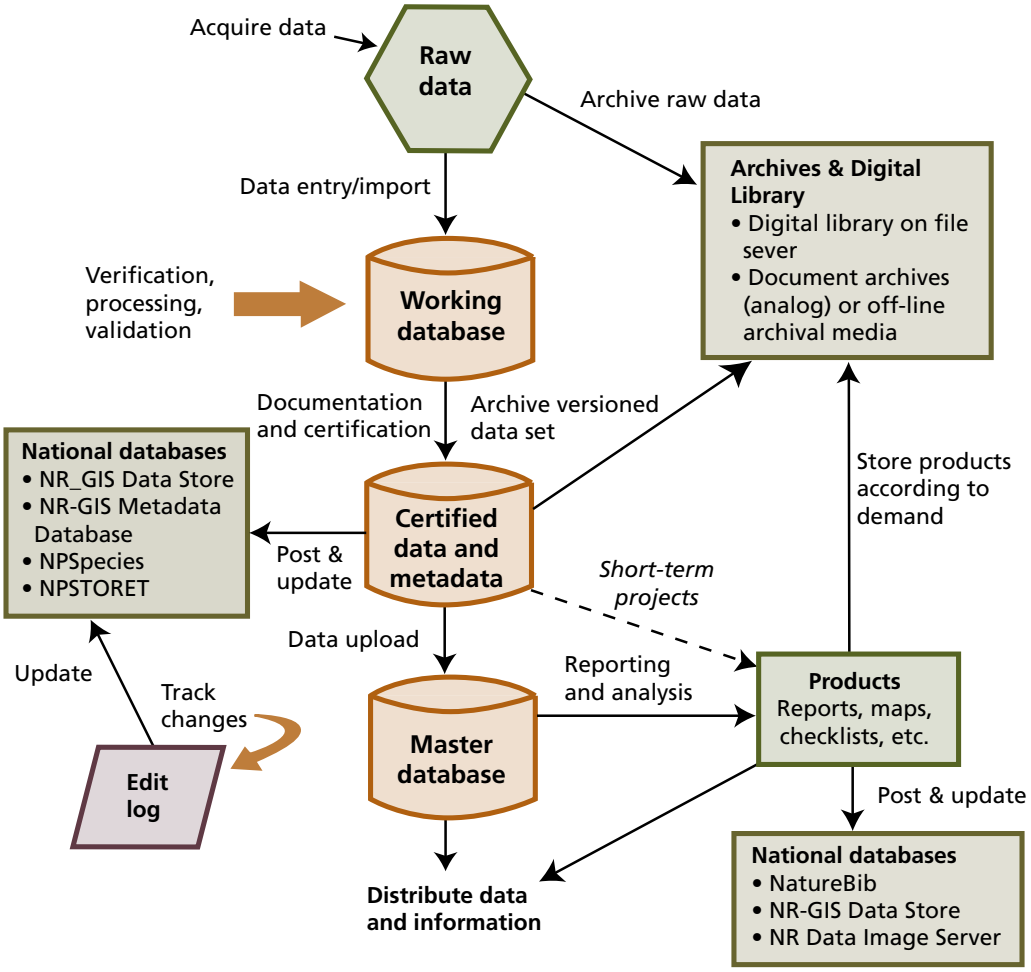
Infrastructure and System Architecture

Infrastructure refers to the network of computers and servers that our information systems are built upon. UCBN relies heavily on the national, regional, and park information technology (IT) personnel and resources to maintain its computer infrastructure. This includes computers, servers, and other related hardware, backups of server data, software installation and support, email administration, security updates, virus-protection, telecommunications, and computer networking.

The infrastructure supports these required functions:

- Provides a central repository for master datasets
- Provides a controlled subsets of data for local computing

Figure 6.3. Diagram of project data life cycle.



- Provides a means for uploading and downloading data for both NPS and the public
- Supports desktop and internet applications
- Provides security, stability, and backups of digital data products

UCBN offices are located in Moscow, Idaho, and the UCBN information system architecture takes advantage of file and database servers maintained at the national level and at the regional wide area network (WAN) level. In addition, a local area network (LAN), linking network workstations and a Network Attached Storage (NAS) unit, is maintained at the network office level (Figure 6.4). This system allows for UCBN staff sharing of working files, archiving of products and metadata, and posting of products and metadata to national clearinghouses. Sharing of data files with park staff typically requires use of FTP sites and/or distributed external hard drives. Secure data backups are accomplished at the network office level, employing a rotating external hard drive schedule in order to copy and store NAS file content off-site from the network office.

Database Design Strategies

For UCBN inventory projects and vital sign monitoring projects, the project leader and the data manager will work together to develop conceptual and logical data models to:

1. Understand the data life cycle flow of the data collection process; identify the starting point of data collection (e.g., a visit to a site) and the steps involved in data processing
2. Determine the data relationships for database development (e.g., one site visited on multiple dates with numerous categories of data collected)
3. Determine how the information will be organized for efficient retrieval and presentation

Each database must ultimately meet the needs of the project leaders and network staff. Considerations for these needs may include ease of use, maintenance, integration (with other programs or agencies), and customization. Data management elements or principles common to more than one vital sign protocol will, to the greatest extent practical, be standardized so as to enhance overall data integrity and the comparability of data across the network.

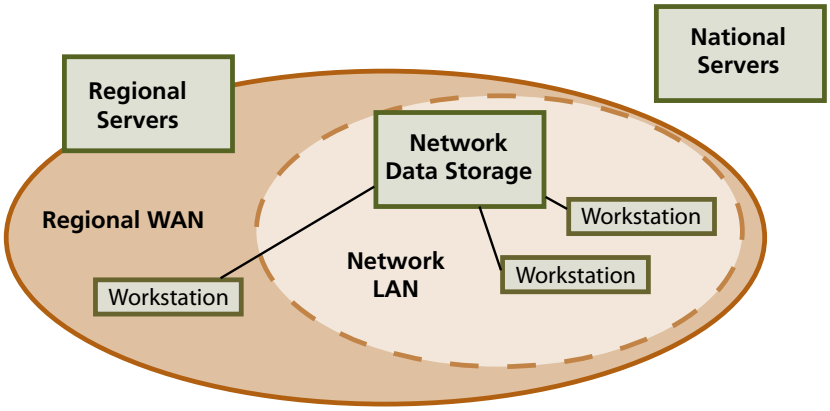


Figure 6.4. Schematic representing the layout and connectivity of IT resources. Most of the UCBN natural resource information system is maintained on the national servers and network storage unit.

Acquiring and Processing Data

The types of data handled by the I&M Program fall into three general categories:

- Program data – produced by projects that are initiated (funded) by and/or involve the I&M Program (e.g., natural resource inventories and vital signs monitoring projects)
- Non-program legacy/existing data – produced by NPS entities without the involvement of the I&M Program (e.g., park or regional projects)
- Non-program external data – produced by agencies or institutions other than the NPS (e.g., weather and water quality data)

Data acquisition steps outlined in the DMP are data discovery, data harvesting, and data collection for projects (including remote sensing), as well as data compilation, processing, and integration. Most data acquired by the network will be collected as field data (inventories and long-term monitoring) or discovered through data mining initiatives (legacy/existing data). Methods of field data collection, such as paper field data forms, field computers, automated data loggers, and GPS units, will be specified in individual monitoring protocols and study plans. Field crew members must closely follow the established standard operating procedures (SOPs) in the project protocol. Data acquired through non-program sources, such as data downloaded from other agencies, will also be specified in individual monitoring protocols.

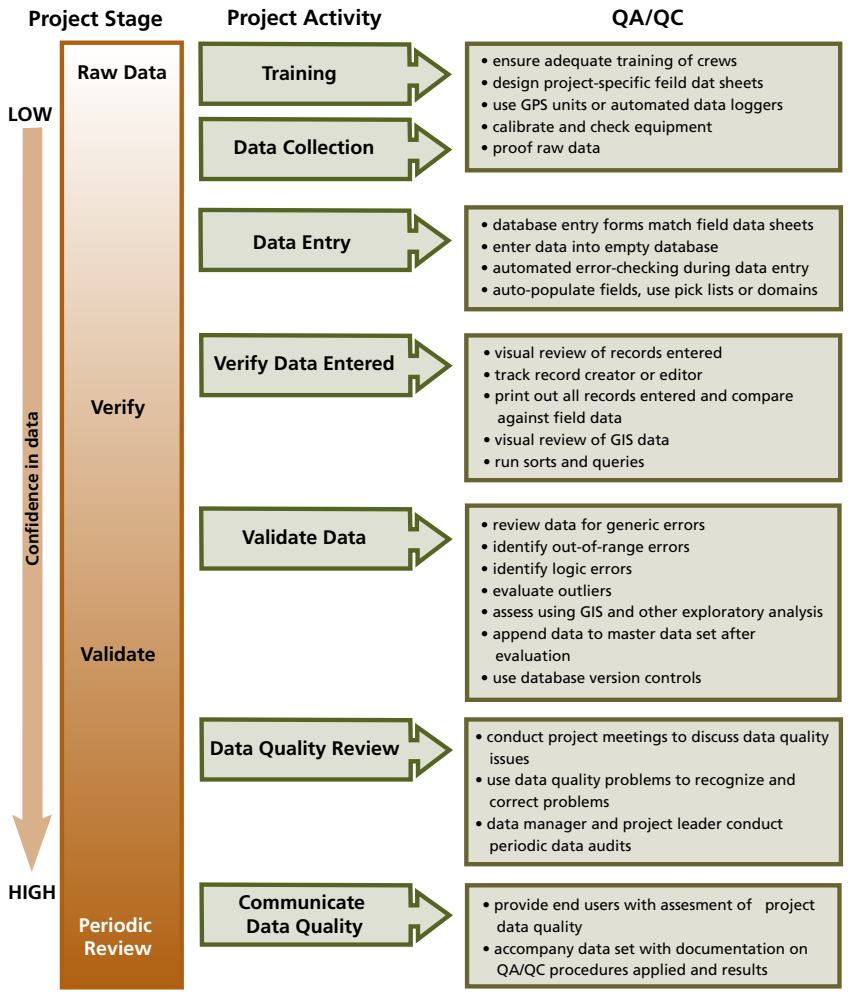


Figure 6.5. Schematic of the Quality Assurance/Quality Control procedures to be carried out during the project stages associated with the typical data life cycle.

Ensuring Data Quality

High quality data and information are vital to the credibility and success of the I&M Program and everyone plays a part in ensuring products conform to data quality standards.

Although many quality assurance/quality control (QA/QC) procedures depend upon the individual vital sign being monitored, some general concepts apply to all. Specific procedures to ensure data quality must be included in the protocols for each vital sign. It is critical that each member of the team work to ensure data quality. Examples of QA/QC practices include:

- Field crew training
- Standardized field data sheets with descriptive data dictionaries
- Use of handheld computers and data loggers
- Equipment maintenance and calibration
- Procedures for handling data in the field
- Database features to minimize transcription errors, including imports from data loggers, range limit, pick lists, etc.
- Verification and validation, including automated error-checking database routines

Quality assurance methods must be in place at the inception of any project and continue through all project stages to final archiving of the dataset (Figure 6.5). The final step in project quality assurance is the preparation of summary documentation that assesses the overall data quality. A statement of data quality will be composed by the project leader and incorporated into formal metadata. Metadata for each dataset will provide information on the specific quality assurance procedures applied and the results of the review, and these procedures will be documented in the protocol and SOPs.

Data Documentation

Documenting datasets, data sources, and methodology by which the data were acquired establishes the basis for interpreting and appropriately using data. At a minimum, all data managed by the network will require the following elements of documentation:

- Project documentation
- Formal metadata compliant with Federal Geographic Data Committee (FGDC) standards
- Data dictionaries and Entity Relationship Diagrams (ERDs) for all tabular databases

Data documentation will be available and searchable in conjunction with related data and reports via the UCBN website as well as the NPS Data Store, a searchable online application for managing and sharing natural resource and GIS metadata and data generated by the NPS.

Data Analysis and Reporting

Providing meaningful results from data summary and analysis is a cornerstone of the I&M Program and characterizes the network's data management mission to provide

useful information for managers and scientists. Each monitoring protocol establishes requirements for on-demand and scheduled data analysis and reporting. Based on these requirements, the associated databases for the protocols include functions to summarize and report directly from the database as well as for import to other analysis software programs. In addition to tabular and charted summaries, the network provides maps of natural resource data and GIS analysis products to communicate spatial locations, relationships, and geospatial model results. Chapter 7 of the UCBN Monitoring Plan provides more details regarding the network's analysis and reporting schedule and procedures.

Data Dissemination

The UCBN data dissemination strategy aims to ensure that:

- Data are easily discoverable and obtainable
- Only data subjected to complete quality control are released, unless necessary in response to a Freedom of Information Act (FOIA) request
- Distributed data are accompanied by appropriate documentation
- Sensitive data are identified and protected from unauthorized access and inappropriate use

Access to UCBN data products will be facilitated by a variety of means that allow users to browse, search, and acquire network data and supporting documents (Table 6.3). These means include, but are not limited to:

- Links to public data products from UCBN public website
- NPS Data Store, an online application for managing and sharing natural resource and GIS metadata and data (distribution instructions for each dataset will be provided in the respective metadata)
- Service-wide databases, such as NPSTORET for water quality data, NPSpecies for species biodiversity data, and NatureBib for bibliographic data
- National or Regional data servers for providing datasets in a read-only format
- External repositories such as the University of Idaho, Washington State Uni-

Table 6.3. Primary repositories for UCBN information and associated specimens.

Item		Repository
Reports (public)	digital	NPS Focus, NPS Data Store, UCBN website
	hard copy	Park and network libraries, park archives
	bibliography	NatureBib
Network-generated digital datasets and data products (public, non-sensitive) • certified data and data products (including photos) • metadata		NPS Data Store, UCBN website, NPSpecies, NPSTORET
Network-generated digital datasets and data products (NPS staff, sensitive) • raw, validated, and analyzed data • metadata • submitted reports • digital photos • digital presentations		UCBN intranet website; selected vital sign data may be housed externally with an established Memorandum of Understanding
Project product materials • specimen vouchers • photograph film		Park archives, or other curation facility (according to project protocol)
Project administrative records or miscellaneous items (hard copy)		UCBN office

versity, US Geological Survey, US Forest Service, Western Regional Climatic Center, and many others

- FTP sites, CDs, DVDs, or hard drives, as appropriate

Information will be made available to two primary audiences: public and NPS employees, as determined by data sensitivity and development status. Only fully documented, certified, non-sensitive data and data products will be released to the public.

Ownership, FOIA, and Sensitive Data

UCBN products are considered property of the NPS. However the Freedom of Information Act (FOIA) establishes access by any person to federal agency records that are not protected from disclosure by exemption or by special law enforcement record exclusions. The NPS is directed to protect information about the nature and location of sensitive park resources under one Executive Order and four resource confidentiality laws:

- Executive Order No. 13007: Indian Sacred Sites
- National Parks Omnibus Management Act (NPOMA; 16 U.S.C. 5937)
- National Historic Preservation Act (16 U.S.C. 470w-3)
- Federal Cave Resources Protection Act (16 U.S.C. 4304)
- Archaeological Resources Protection Act (16 U.S.C. 470hh)

When any of these regulations are applicable, public access to data can be restricted. If disclosure could result in harm to natural resources, the records may be classified as 'protected' or 'sensitive'. The NPS recognizes the following resources as sensitive:

- Endangered, threatened, rare, or commercially valuable NPS resources
- Mineral or paleontological sites
- Objects of cultural patrimony
- Significant caves

The UCBN will comply with all FOIA restrictions regarding the release of data and information, as instructed in NPS Director's Order #66 and accompanying Reference Manuals 66A and 66B (currently in development). Managing natural resource information that is sensitive or protected requires the following steps:

- Identification of potentially sensitive resources
- Compilation of all records relating to those resources
- Determination of which data must not be released in a public forum
- Management and archive of those records to avoid their unintentional release

Classification of sensitive data will be the responsibility of Network staff, park superintendents, and project leaders. Network staff will classify sensitive data on a case-by-case, project-by-project basis and will work closely with project leaders and park staff to ensure that potentially sensitive park resources are identified, that information about these resources is tracked throughout the project, and that potentially sensitive information is removed from documents and products that will be released outside the network.

Digital Data Maintenance, Storage, and Archiving

UCBN data maintenance, storage, and archiving procedures aim to ensure that digital data and related metadata documentation are:

- Kept up-to-date with regards to content and format such that the data are easily accessed and their heritage and quality easily learned
- Physically secure against environmental hazards, catastrophe, and human malice

Primary data maintenance occurs on UCBN workstations and NAS unit, and on service-wide servers maintained by NPS staff and cooperators at the Washington Area Support Office in Fort Collins, Colorado. UCBN staff are responsible for keeping data and information current on the network NAS unit and on service-wide servers, and depend on national and regional IT staff for backups of data housed on national and regional servers. UCBN staff will ensure that the latest versions of primary data are available in conventional formats reflecting common data usages in the resource management community.

Project data are electronically archived as stand-alone products that include:

- Project documentation
- Data in raw, verified, and analyzed conditions
- Respective metadata
- Supporting files, such as photographs, maps, etc.
- All associated reports

Non-Digital Data Archiving and Records Management

In most instances, administrative documents, natural history specimens, photographs, audio tapes, and other materials are essential companions to the digital data. Direction for managing many of these materials (as well as digital materials) is provided in NPS Director's Order 19: Records Management (2001) and its appendix, NPS Records Disposition Schedule (NPS-19 Appendix B, revised 5-2003). NPS-19 states that all records of natural and cultural resources and their management are considered mission-critical records; that is, they are necessary for fulfillment of the NPS mission and must be permanently archived.

The UCBN data management strategy includes assisting project leaders in complying with archival directives. Whenever necessary, physical items considered project products such as reports, maps, photographs, or notebooks will be cataloged and archived by the park(s) involved with the project. When this is not possible, an alternative storage strategy and location, such as a university or the network office, will be found and fully described in the project documentation. Physical specimens, such as plants and animals, will be accessioned and housed at the appropriate archival institution (typically a park archival facility, but may also be a university or other partner institution).

Water Quality Data

All water quality data collected by the UCBN will be managed according to guidelines from the NPS Water Resources Division (WRD). This includes facilitating the transfer of park and network water quality into suitable NPSTORET format, as dictated by WRD. UCBN data management staff will transfer all network water quality data, in an NPSTORET-compatible format, at least annually to WRD for upload to the STORET database (Figure 6.6). Although WRD's data dissemination needs dictate a monthly schedule for uploads to their data warehouse, UCBN data collection and summation activities will likely be on an annual schedule requiring data uploads to the master WRD database only once a year.

Implementation

The Data Management Plan (DMP) contains practices that may be new to staff and principal investigators. With a few exceptions, however, the DMP does not include any requirements that are new. Almost every requirement comes from law, Director's Orders, or the I&M Program. The DMP helps to put these requirements into context and in sequence, and provides operational guidance for achieving these requirements. Good data management practices will take time. Some vital sign collection procedures and data management practices are already in use and may require minimal revisions. Others may involve several iterations of procedures and databases before reaching their acceptable and functional data reporting formats.

Vital signs monitoring protocols will be the primary focus of UCBN data management efforts. Integration of data management guidance and standards among these monitoring protocols and associated SOPs is an overarching goal of the UCBN data management strategy, and will contribute significantly to the long-term usefulness of the I&M Program and its data products.

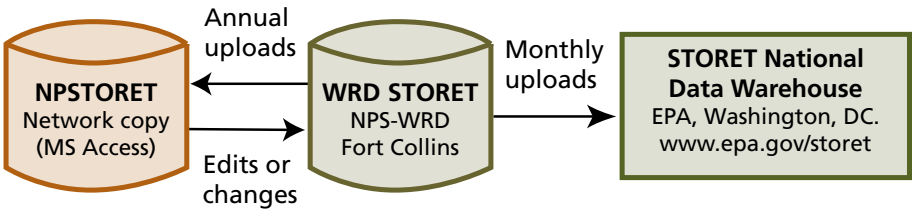


Figure 6.6. Data flow diagram for water quality data.

Chapter 7: Data Analysis and Reporting

The UCBN monitoring program is fundamentally an information system in which I&M data are analyzed, interpreted, and communicated to a diverse audience consisting of park managers and superintendents, peer scientists, and the lay public. Recognizing this fact, and following national I&M program guidance, a minimum of one-third of the Network's resources are committed toward the management, analysis, and timely reporting of I&M information. Success of this program depends on the ability to deliver meaningful information to parks regarding the status and trend of park vital signs, and this is the key link in completing the adaptive management cycle (Figure 7.1).

The UCBN strategy for completing analyses and reporting in an effective and efficient manner is described below. This includes a description of basic approaches to data analysis and identification of staff and cooperators with primary analytical responsibility. The various reports and other products of the monitoring effort, their content, intended audience, frequency and format of products, and the reporting roles and responsibilities of UCBN staff and cooperators are also described.

Data Analysis

Successful data analysis depends upon well-articulated questions and objectives and appropriate sampling designs. As described in Chapter 4, simple and flexible sampling designs are emphasized in the Network, partly to facilitate data analysis. These typically are "unstructured" designs with a minimum of stratification, known and typically equal sample selection probabilities, and simple panel membership designs. Straightforward and flexible designs in turn facilitate direct and interpretable analytical approaches. By emphasizing a design-based approach to monitoring, inferences can be drawn directly from designs and can minimize reliance on assumptions (Edwards 1998; Manly 2001a). This will be particularly true for estimation of status, where classical sampling theory for finite populations is well-developed and provides design-unbiased estimators of population parameters such as the population mean and variance (Thompson 2002). Sampling designs chosen also support, and often require, the use of model-assisted or model-based approaches. This is particularly true for trend estimation, and to address sampling and nonsampling errors (year, site, and residual random effects), missing data, and important auxiliary variables (Urquhart and Kincaid 1999; Thompson 2002). This, of course, requires assumptions and, since model-based inference is only as good as the model used, an ability to evaluate the model (e.g., Akaike's Information Criterion (AIC); Burnham and Anderson 2002). Appropriate models can often provide more precise parameter estimates, can be used to generate and test hypotheses about the ecological processes at work underlying the observed patterns in trend, and at best, can be used to predict future scenarios. This is an essential step in delivering meaningful information to park managers, for it is not sufficient to simply report on a trend, but is also necessary to provide some interpretation of the trend.

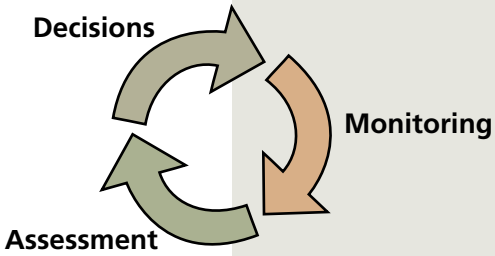


Figure 7.1. Conceptual diagram of adaptive management illustrating the iterative cycle of monitoring, assessment and decisions.

Selection of specific analytical tools for interpreting monitoring data is a function of monitoring objectives, assumptions regarding the target population, and the level of confidence desired or practical given natural and sampling variability. Each monitoring protocol (Chapter 5) will contain detailed information on analytical tools and approaches for data analysis and interpretation, including rationales for a particular approach, advantages and limitations of each procedure, and SOPs for each prescribed analysis. It is just as important to document which analyses were considered but rejected during protocol development, and the reasoning behind these decisions. This information will be captured in the Protocol Development Narratives (Chapter 5) for each vital sign.

…a minimum of 1/3 of the Network's resources are committed toward the management, analysis, and timely reporting of I&M information.

Four general categories of analysis for UCBN vital signs and the primary analyst responsible for each are summarized (Table 7.1). The primary analyst ensures data are analyzed and interpreted within protocol and program guidelines, but may not actu-

Table 7.1. Four approaches to analyzing monitoring data and the "core staff" responsible for analyses.

Levels of Analysis	Description	Primary Analyst
Data Summarization/ Characterization	Calculation of basic statistics of interest and initial screening, including: • Measures of central tendency [mean, median] • Measures of variability and distribution [range, variance, standard error] • Identification of missing values and outliers [box-and-whisker plots, queries, QA/QC] • Visual inspection of data Summarization encompasses both measured and derived variables mentioned in the monitoring protocols, as well as creation of data matrices for community analyses.	The Project Leader for each monitoring protocol, working with the data management staff will produce data summaries and prepare data for further analysis. Procedures for data summarization are specified in the monitoring protocols.
Status Determination	Analysis and interpretation of vital sign status to answer: • Do observed values exceed a regulatory standard or a known ecological threshold? • How do observed values compare with the range of historical variability for a vital sign? • What is the precision (i.e., variability) and confidence in the status estimate? • What is the spatial distribution (park, Network, ecoregion) of observed values at evaluation time? • Do these patterns suggest relationships with other factors not accounted for in the design? Design-unbiased population estimators (e.g. Horvitz-Thompson) will be used for status determination.	The Project Leader for each monitoring protocol is the primary analyst for status determination, though cooperators or other Network staff may conduct analyses and assist with interpreting results. Consultation with regulatory and subject matter experts will provide support.
Trend Evaluation	Evaluations of interannual trends will seek to address: • 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)? • How does this rate compare with rates observed from historical data, other indicators from the same area, or other comparable monitoring in the region? • 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? [correlations, regression analyses] Analysis of trends will initially employ graphic portrayals (Cumulative Sum (CUSUM) and control charts), then repeated-measures and time-series using mixed linear models.	The Project Leader for each monitoring protocol is the primary analyst for trends evaluation, though cooperators or other network staff may conduct analyses and assist with interpreting results. Consultation with regulatory and subject matter experts will provide support.
Synthesis	Examination of patterns across vital signs; 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 influence • Model selection • Integrative approaches [ordination of community data, multiple regression, diversity and conservation-value indices, Bayesian hierarchical and graphical models] • Evaluation of competing *a priori*-specified models that explain dynamics in indicator; model averaging, variable weights, and prediction Synthetic analyses require close interaction with academic and agency researchers, and may employ myriad approaches as new indicators and questions are included. Integration with existing results from other monitoring and research is critical.	The Network Ecologist is the primary analyst for synthesis, though cooperators or other Network staff may conduct analyses and assist with interpreting results. Consultation with regulatory and subject matter experts and integration of outside research results will support meaningful syntheses

ally perform the analyses or interpret the results. The primary analyst for monitoring protocols will be the Project Leader, although this individual may rely on non-NPS cooperators to provide analysis services. The UCBN is currently employing the services of statisticians at Oregon State University and University of Idaho through a cooperative agreement. This arrangement, or something similar, will provide high level analytical support in the future.

Communications and Reporting

As part of the NPS effort to "improve park management through greater reliance on scientific knowledge", data analysis and reporting are cornerstones of the I&M Program. Therefore, developing and implementing effective communication tools for a wide audience is vital to the long-term success of the Network. The primary audience for many I&M products is at the park level, providing park managers with information needed to make better-informed decisions. However, certain products are intended for other key audiences including park planners, interpreters, Congress, the President's Office of Management and Budget, external scientists and the general public.

The following section summarizes general UCBN reporting strategies, primary methods for reaching specific audiences and outreach activities. Additional specific data summary, analysis and reporting requirements and procedures will be discussed in each project protocol.

The overall UCBN reporting goals are to:

- Prepare monitoring reports that are understandable and useful to park resource managers (the primary audience)
- Prepare reports promptly
- Ensure all reports are readily available.

General Reporting Strategies

For monitoring information to be effective, analysis and interpretation need to be provided at regular intervals and in formats specific to intended audiences. This implies that, to effectively share information with Network parks, external scientists, cooperators, adjacent land managers and other potential collaborators, the same information needs to be packaged and distributed in different formats. General UCBN reporting mechanisms (Table 7.2) are based on national guidance, modified to fit Network needs, and summarized below.

Administrative Reports: The Annual Administrative Report and Work Plan (Table 7.2 A.) is necessary to satisfy national reporting requirements. This report addresses aspects of program implementation including objectives, tasks, accomplishments, and budgeting.

Program and Protocol Review Reports: An important component of the overall quality assurance and peer review process is assessment of monitoring procedure efficacy and overall program effectiveness. Protocol reviews will be conducted coincident with the corresponding Analysis and Synthesis Report and documented in Protocol Review Reports (Table 7.2 E). Protocol reviews will emphasize three features:

- Implementation – what is feasible to implement compared to what was specified
- Effectiveness – minimum change detection levels compared to expected levels
- Information Management – compliance with standards for data entry, QA/QC, retrieval and archiving

The Program Review Report (Table 7.2.E) documents both program operations (e.g., adherence to schedule and budget, meeting reporting requirements, etc.) and effectiveness (e.g., how well monitoring results are communicated to target audiences).

Annual Protocol Reports and Comprehensive Analysis and Synthesis Reports: Two types of reports document the collection, analyses, and interpretation of monitoring data: Annual Protocol Reports (Table 7.2 B) and Comprehensive Trend Analysis and Synthesis Reports (Table 7.2 D). Annual protocol reports document monitoring activities for the year, including any changes to the protocols, and describe the current status of monitored resources. The trend reports are completed every 3-5 years and report results of detailed trend analyses and syntheses within multiple spatial contexts. These reports are detailed, thorough and intended primarily for resource managers

Table 7.2. Summary of UCBN reporting mechanisms.

Type of Report	Purpose of Report	Primary Audience	Frequency	Review Process
A. Annual Administrative Report & Work Plan	• Account for funds and FTEs expended. • Describe objectives, tasks, accomplishments, products of the monitoring effort. • Improve communication within park, network, and region.	Superintendents, SAC, UCBN staff, regional coordinators, and Servicewide program managers; Used for annual report to Congress.	Annual	Reviewed and approved by IMR Regional Coordinator and Servicewide Program manager
B. Annual Reports for each Protocol or Project	• Document monitoring activities for the year • Describe status of the resource and provide alert if data are outside bounds of known variation • Document changes in monitoring protocols or provide recommendations for necessary changes • Communicate monitoring efforts	Superintendents, park resource managers, UCBN staff, Servicewide Program managers, external scientists and partners.	Annual	Peer reviewed at Network level
C. Comprehensive Trend Analysis and Synthesis Reports	• Determine patterns/trends in resource condition • Discover new characteristics of resources and correlations among resources • Interpret data within park, multi-park, network, and regional contexts • Recommend changes to management (feedback for adaptive management)	Superintendents, park resource managers, UCBN staff, external scientists	3-5 year intervals for resources sampled annually	Peer reviewed at the Network level
D. Summary of Trend Reports	• Summarize Comprehensive Trend Analysis and Synthesis Reports to highlight key findings and recommendations.	Superintendents, park resource managers, interpreters, general public	Commensurate with frequency of Comprehensive Reports	Peer reviewed at the Network level
E. Program and Protocol Review Report	• Formally review operations and results • Review protocol design and products to determine necessary changes • Ensure peer-review and quality assurance	Superintendents, park resource managers, UCBN staff, Servicewide Program managers	5-year intervals	Peer reviewed at regional and/or national level, UCBN Board of Directors, Technical Committee
F. Scientific journal articles and book chapters	• Document and communicate advances in knowledge. • Ensure peer-review and quality assurance	External scientists, park resource managers, UCBN staff	Variable	Peer reviewed by journal or book editor

Table 7.2. Summary of UCBN reporting mechanisms (continued).

Type of Report	Purpose of Report	Primary Audience	Frequency	Review Process
G. Symposia, workshops, and conferences	• Review and summarize information on a specific topic or subject area. • Communicate latest findings to peers. • Identify emerging issues and generate new ideas.	Resource managers of NPS and other federal and state agencies, UCBN staff, external scientists	Variable	May be peer reviewed by editor if written papers are published
H. UCBN Newsletter	• Review and summarize network activities and findings of general interest. • Describe the role and purpose of the network to non-technical audiences.	Park staff, agency partners and cooperators, interpreters, general public	Biannual by email and on UCBN website	Peer reviewed at Network level
I. UCBN Annual Science Meeting	• Review and summarize information on UCBN vital signs • Identify emerging issues and generate new ideas • Facilitate interactions among park resource managers and external scientists	Park resource managers, UCBN staff, external scientists	Annual	Peer reviewed at Network level
J. Internet Website	• Centralized repository of all final reports to ensure products are easily accessible in commonly-used electronic formats	Superintendents, park resource managers, UCBN staff, Servicewide program managers, external scientists, general public	As reports are finalized	Only reviewed, finalized products without sensitive information will be posted

… it is the broader public that will decide the fate of these resources." – National Park Advisory Board 2001.

and scientists. On a more frequent basis, the biannual UCBN Newsletter (Table 7.2 H) will summarize network activities and findings of general interest.

Scientific Publications and Presentations: Scientific publications (Table 7.2 F) and presentations (Table 7.2 G) communicate advances in knowledge and are an important means of QA/QC. Scrutiny of the scientific peer-review process is one of the best methods for ensuring scientific rigor in the program's methods, analyses, results and conclusions. As the opportunity arises, Network staff will submit manuscripts and present findings at professional symposia, conferences and workshops.

Additionally, the UCBN hosts an Annual Science Meeting (Table 7.2 I) intended primarily for park resource managers and external scientists. This meeting facilitates interactions among resource managers and external scientists, allows for review of UCBN vital signs, identifies emerging issues and generates new ideas.

Internet Website: Websites are important for promoting communication, coordination, and collaboration among various entities. The UCBN internet website serves as a centralized repository for all finalized, reviewed reports and summaries which do not contain sensitive information (Table 7.2.J, L). The Network website ensures non-restricted products are easily accessible in commonly-used formats.

Outreach and Education

The National Park Advisory Board (2001) emphasized the need for communicating knowledge about resources and their condition to the general public because "…it is the broader public that will decide the fate of these resources." Thus, outreach and education are integral to the UCBN's vision of a long-term monitoring strategy. Volunteers have played, and will continue to play, a key role. For example, the Oregon Museum of Science and Industry has provided both student and staff volunteers as well as housing in exchange for Network-staffed educational programs.

In addition, the UCBN currently works with the Cooperative Ecosystems Studies Units (CESU; Great Basin, Rocky Mountain, and Pacific Northwest), AmeriCorps, Palouse-Clearwater Environmental Institute, Oregon Museum of Science and Industry, University of Idaho and park interpreters to more effectively interpret I&M results to the parks and the public. Park interpreters are invited to participate in all stages of the I&M program (from protocol development through data collection efforts and reporting) to increase communication and promote integration among programs.

Chapter 8: Administration/Implementation of the Monitoring Plan

Administration

The UCBN Charter, originally written in 2002, describes the process used to plan, manage, and evaluate the Network monitoring program in accordance with the intent and purpose of the NPS Natural Resource Challenge. The Board of Directors, hereafter referred to as the "Board," represents Superintendents from the nine UCBN parks, a representative from the SAC, the Pacific West Region (PWR) I&M Coordinator, the Deputy Regional Director and UCBN liaison, and the UCBN Coordinator (Table 8.1). The Board is charged with oversight of the Network's vital signs monitoring program and makes all significant management and budgeting decisions. The Board receives technical assistance and advice from the SAC (see below) as well as program quality assurance, oversight, and technical assistance as requested from the NPS PWR. This management structure is designed to foster development of a monitoring program which is responsive to the unique set of long-term resource issues and threats within the Network parks.

Annual Board membership includes representative Superintendents from three parks. Any superintendent can participate at all times but these three representative superintendents are charged with "official" oversight on an annual basis. Superintendents shall serve a term of 3 years with the term of one superintendent expiring annually (see Network Charter, Appendix A.4). The park representative from the SAC to the Board will serve a term of 2 years and the terms are also shown in the Network Charter.

The major responsibilities of the Board shall be to:

- Promote accountability and effectiveness by reviewing organizational and administrative development of the UCBN I&M Program.
- Provide review of the design and implementation of vital signs monitoring to ensure the program is relevant to natural resource management issues within the parks, as well as the comprehensive Servicewide I&M Program requirements.
- Recommend strategies for leveraging funds and personnel to best accomplish the monitoring objectives.
- Provide review of monitoring plans, network budgets, and personnel selections.

The SAC, comprised of natural resource managers and subject matter experts both within and outside the NPS, provides technical assistance and advice to the Board and Network parks (Table 8.2). Currently, Dr. Gerald Wright, emeritus professor from the University of Idaho, serves as an advisor. In the future, it is anticipated that additional scientists with knowledge of sampling procedures, monitoring techniques, statistical methods, and monitoring strategies will be asked to also serve as advisors.

The SAC organizes an Annual Science Day at the end of each field season to review monitoring results and attend presentations by researchers who have been working in their respective parks. This gives park staff an opportunity to interact with scientists developing protocols and/or analyzing monitoring results.

Responsibilities of the SAC include:

- Advising Network parks in the development of the Network Monitoring Plan and identification of monitoring objectives by:

The Board of Directors is charged with oversight of the Network's vital signs monitoring program and makes all significant management and budgeting decisions.

Table 8.1. Composition of the 2007 UCBN Board of Directors.

Directors	Title	Park(s)
Apel, John (2007)	Resource Manager	CRMO
Bird, Debbie	Superintendent	LARO
Darby, Terry (2007)	Superintendent	WHMI
DeGrosky, Tami	Superintendent	BIHO
Garrett, Lisa (2007)	UCBN Coordinator	Network
Hammett, Jim	Superintendent	JODA
Keck, Wallace (2007)	Superintendent	CIRO
King, Neil	Superintendent	HAFO/MIIN
Latham, Penny (2007)	PWR I&M Coordinator	PWR
Neighbor, Doug	Superintendent	CRMO
Somers, Gary (2007)	Superintendent	NEPE
Westburg, Rory (2007)	Deputy Regional Director (PWR liaison)	PWR

Table 8.2. Composition of the 2007 UCBN SAC.

Committee Members	Title	Park(s)
Apel, John (Board Representative)	Resource Manager	CRMO
Garrett, Lisa	UCBN Coordinator	Network
Gruchy, Fran	Chief of Operations	HAFO
Hoh, Shirley	Resource Manager	JODA
Lyon, Jason	Integrated Resource Manager	NEPE
Rodhouse, Tom	Ecologist	Network
Dicus, Gordon	Data Manager	Network
Trick, Roger	Chief of Interpretation and Resource Management	WHMI
West, Robert	Park Ranger	BIHO
Bennett, Tim	Chief of Natural Resources	CIRO
Weaver, Jerald	Chief of Compliance and Natural Resource Management	LARO
Wright, R. Gerald	Emeritus Professor UIdaho, USGS Scientist	
Wolken, Paige	Vegetation Ecologist	CRMO

The Science Advisory Committee provides technical assistance and advice to the Board of Directors and Network parks.

- Compiling and summarizing existing information about park resources and the findings and recommendations of any scoping workshops.
- Development of a Network monitoring strategy.
- Selection of vital signs such as indicator species, communities, and processes.
- Evaluating initial sampling designs, methods and protocols to assure they are scientifically credible.

- Reviewing annual data reports and interpretation as well as participating in preparation of the Annual Work Plan and Annual Report.
- Developing materials for and facilitating the 5-Year Program Review.

Products and recommendations of the SAC will be presented to the Board for discussion, modification, and final approval. The Board may form a standing Information and Education Committee comprised of interpretation, education, and public affairs staff at a later date.

To be most effective, Board members will need to maintain a close working relationship with their representative on the SAC, the PWR I&M Coordinator and the Network I&M Coordinator. Board members are encouraged to participate in and/or keep informed with respect to the work of the SAC. The Network I&M Coordinator is expected to provide regular briefings (by memoranda, electronic mail or telephone conference) to the Board.

The UCBN has an agreement in place with NEPE to provide budget and procurement assistance. Computer support, along with connectivity to the NPS network, is cooperatively provided by the PWRO-Seattle, NEPE IT support staff, and the IT staff at the University of Idaho in Moscow, Idaho. Office space as well as limited IT and library research support is provided through a task agreement with the University of Idaho, the local affiliate of the Pacific Northwest CESU.

Staffing Plan

In accordance with national I&M goals, and UCBN park priorities, Network activities revolve around five broad program functions (Table 8.3).

The Network staffing plan is designed to support these functions, and to provide park managers with the professional expertise needed to implement a scientifically credible I&M program addressing the parks' most critical long-term resource issues. These issues, reflected in the Network vital signs, are centered around aquatic resources, invasive plants, and vegetation communities, but also include aspen (CIRO, CRMO), bats (CRMO, JODA), camas lily (BIHO, NEPE), limber pine (CIRO, CRMO), osprey (LARO), and sage grouse (CIRO, CRMO). To meet the Network's need for broad subject matter expertise in these areas, institutionalize professional information management practices, meet the need for qualified field personnel, and properly administer the I&M program, the Network has created a staffing plan made up of a Coordinator, a professional Ecologist, a Data Manager, a quarter-time Aquatic Ecologist, a part-time Data Technician, and five Biological Technicians serving for approximately 4 months each (Table 8.4, Figure 8.1). Short descriptions of these positions and their primary functions follow.

Coordinator: The Coordinator provides overall direction for the UCBN I&M program. The Coordinator works with the Network parks, SAC, Board of Directors, and PWR I&M Coordinator to develop

I&M strategies and recommend implementation schedules for funding and staffing consideration. This position coordinates project-specific data analysis and reporting, and ensures information is provided to park managers in useful formats. The Coordinator supervises the UCBN professional level positions and provides general oversight and accountability for the program.

Data Manager: The Data Manager has a central role in ensuring project data conforms with program standards, designing project databases, disseminating data, and ensuring long-term data integrity, security, and availability. To maintain high data quality standards and promote ready use of project data the Data Manager collaborates with the project manager to develop data entry forms, QA/QC procedures, and automated reports. The UCBN Data Manager maintains spatial data themes associated with Network I&M projects, and incorporates spatial data into the Network GIS. The Data Manager maintains standards for this data and the associated metadata, and develops procedures for sharing and disseminating GIS data to Network parks and partners.

Ecologist: The Ecologist serves as the primary Network subject matter expert for terrestrial resource issues. The Ecologist coordinates all aspects of terrestrial I&M projects including protocol design and pilot testing; data collection, whether it is oriented toward field data collection or gathering existing data from other sources; data quality during all phases of a project; creation of project documentation and metadata; and preparation and dissemination of project analyses and reports. The Network Ecologist also provides oversight and supervision for biological technicians working on UCBN projects. In addition, this position serves as the primary Network technical contact for potential partners working on terrestrial resource issues.

Aquatic Ecologist: The Aquatic Ecologist serves as the primary Network subject matter expert for aquatic resource issues. The Aquatic Ecologist coordinates all aspects of aquatic I&M projects including protocol design and pilot testing; data collection, whether it is oriented toward field data collection or gathering existing data from other sources; data QA/QC during all phases of a project; creation of project documentation and metadata; and preparation and dissemination of project analyses and reports. The Network Aquatic Ecologist also provides oversight and supervision for biological technicians and serves as the primary Network technical contact for potential partners working on aquatic resource issues.The Aquatic Ecologist is a quarter time position and is presently working under a cooperative agreement between the University of Idaho and the UCBN. The UCBN will continue this cooperation working with Research Scientist support staff at the University of Idaho.

Biological/Data Technicians: These are seasonal positions, working under the Network Ecologists and Data Manager. Their primary duties include data collection, whether it involves field data collection or gathering data from existing sources, and data verification. The biotechnicians follow existing protocols to gather data, record, verify and correct data values, and to perform regular

Table 8.3 Five broad programmatic areas encompassing UCBN activities.

Conducting baseline inventories of natural resources in the parks, including those currently underway (rare plants, vascular plant and vertebrate surveys, vegetation mapping), as well as other critical inventory needs of Network parks.
Developing data management and decision support systems (including GIS and other tools) to aid park managers in identifying, implementing, and evaluating management options.
Developing an integrated, scientifically credible, long-term ecological monitoring program to efficiently and effectively monitor status and trends of selected vital signs.
Integrating I&M programs with park planning, maintenance, interpretation and visitor protection activities to help the parks in their efforts to make natural resource interpretation and protection even more of an integral part of overall park management.
Cooperating with other agencies and organizations to share resources, achieve common goals, and avoid unnecessary duplication of effort and expense.

Table 8.4. UCBN staff positions and their primary duties (cost in approx. FY2007 dollars).

Position	Primary Duties	% of Time	Total FTE	Total Cost (k)
Coordinator	Provides direction, and manages overall planning and implementation of the Network I&M program	35%	0.35	32.7
	Coordinates project-specific data analysis, summary, and reporting	30 %	0.30	28.0*
	Ensures information is provided to parks and partners in useful formats	15%	0.15	14.0
	Coordinates I&M partnerships	10%	0.10	9.4
	Provides program oversight and supervision	10%	0.10	9.4
Data Manager	Conducts data archiving and dissemination, database development, overall QA/QC	50%	0.5	38.3*
	Works with ecologists to ensure information is provided to parks and partners in useful formats	20%	0.2	15.4*
	Implements data management partnerships	20%	0.2	15.4*
	Provides oversight and supervision for data management activities	10%	0.1	7.6*
Ecologist	Provides guidance, oversight and management of terrestrial projects	25%	0.25	18.5
	Conducts project-specific data analysis, summary and reporting, data validation and verification	35%	0.35	25.9*
	Works with program professionals to provide information to parks and partners in useful formats	20%	0.2	14.8
	Coordinates partnerships	10%	0.1	7.4
	Provides supervision for terrestrial projects	10%	0.1	7.4
Aquatic Ecologist (1/4 time)	Provides guidance, oversight and management of aquatic projects	25%	0.0625	4.5
	Conducts project-specific data analysis, summary and reporting, data validation and verification	35%	0.0875	6.3*
	Works with program professionals to provide information to parks and partners in useful formats	20%	0.05	3.6
	Coordinates partnerships	10%	0.025	1.8
	Provides supervision for aquatic projects	10%	0.025	1.8
Biological Technicians (5 seasonals)	Work with program ecologists to collect field data, and document methods, procedures and anomalies	70%	1.225	35.0
	Conduct data entry and verification	30%	0.525	15.0*
Data Technician (8 mos.)	Work with data manager to conduct data entry and verification	100%	.66	20.0*
TOTAL			**5.66**	**332.2**

*- denotes staff time devoted to data management activities (total = $171,900 or 30% of the UCBN annual operating budget of $572,700.

data transfer and backup. These positions also assist with dataset and procedural documentation and are responsible for documenting any deviations from protocols.

Field crew members will likely be recruited during job fairs held at the University of Idaho and Washington State University during the winter months preceding summer field season. The data technician may work during the school year to help fulfill information management needs.

All Network permanent positions are duty-stationed in Moscow, Idaho. The Network Ecologist teleworks from an office in Bend, Oregon, to work closely with JODA staff and facilitate partnerships with Oregon State University and Oregon Museum of Science and Industry.

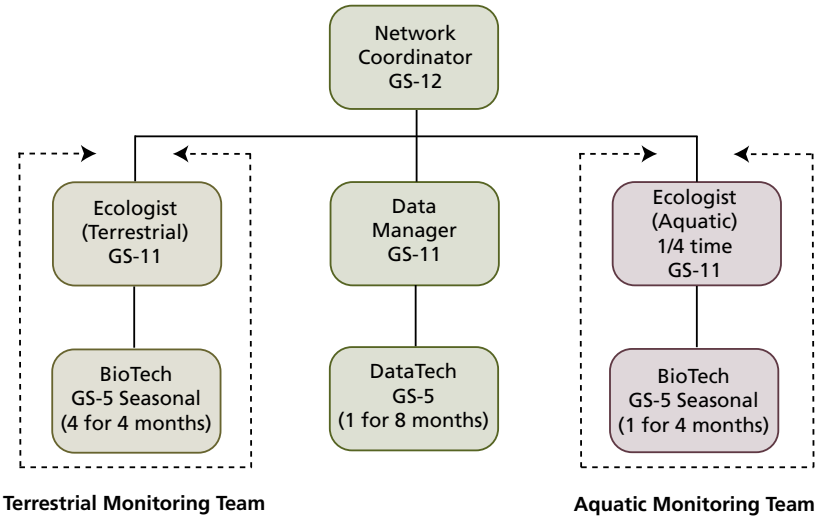


Figure 8.1. Organizational structure of the UCBN.

Program Integration

I&M data will be available to all other park operations including interpretation, law enforcement and maintenance. Interpretation is particularly important, being the major conduit of natural resource information from parks to the public. UCBN staff work with park interpreters to convey information in an interesting and understandable fashion to various audiences. Articles on I&M activities have been prepared for park newspapers, presentations given at park all-employees meetings, and funding provided for seasonal positions to assist interpretative staff in preparing meaningful interpretative materials on the monitoring program. I&M information should also be helpful to maintenance and planning divisions, with compliance reviews of proposed projects inside the parks. Integration with law enforcement began for the UCBN with a training workshop at LARO geared towards learning how to use handheld computers for data collection. Monitoring crews will meet with rangers and other law enforcement staff prior to each field season to discuss types of activities law enforcement personnel want to be informed of.

The UCBN I&M Program is located in Moscow, Idaho, home of the University of Idaho, which facilitates interaction between Network staff and scientists working in the parks. This location also provides the opportunity to integrate with park staff at NEPE, located only 56 km (35 mi) to the south. As monitoring field work begins, more integration with park staffs will likely be possible. Opportunities to help all park divisions will be actively sought. The Network's Board and SAC are made up of the Superintendents and resource management specialists, respectively, which further helps integrate the Network's planning with park concerns and activities.

Partnerships

Key partners and cooperative agreements:

- Ecoanalysts – agreement being negotiated for identification and analysis of macroinvertebrate data collected from Network parks.
- Idaho Conservation Data Center – cooperative agreement for data sharing and to provide inventory crews for vascular plants and vertebrate inventories in Idaho Network parks. The ICDC is also assisting with preliminary vegetation classification in Idaho parks.
- Idaho State University - cooperative agreement for development of sagebrush-steppe vegetation monitoring protocol.
- Nez Perce National Historical Park – serves as the administrative park for the Network, provides administrative, budget, and IT support for Network activities.
- Northwest Management, Inc. – contract to provide field crews for collection of vegetation plot data at CRMO, HAFO, and LARO.

- Oregon Natural Heritage Program – using an existing cooperative agreement between NPS and Oregon Natural Heritage Program to assist with preliminary vegetation classification at JODA.
- Oregon State University – cooperative agreement for development of camas lily monitoring protocol.
- Oregon Museum of Science and Industry – Agreement being negotiated for the Museum to provide citizen science and environmental education programs in the Network in conjunction with Network I&M projects.
- Palouse-Clearwater Environmental Institute – cooperative agreement to provide Americorps members for summer positions in Idaho Network parks to assist interpretive staff in developing useful program materials for communicating information from the monitoring program to visitors.
- University of Idaho – cooperative agreement for administration of the Network office including rental of office space, support for Network staff library use, meeting room rental, IT support, and telephone services.
- University of Idaho – cooperative agreement to provide a quarter-time research support scientist to lead the aquatic monitoring team and also provide an integrated water quality monitoring protocol.
- University of Idaho – cooperative agreement to provide statistical review and support for sampling design and data analysis procedures included in monitoring protocols.
- Washington Natural Heritage Program - cooperative agreement for data sharing and to assist with preliminary vegetation classification at LARO.

Periodic Review

Periodic reviews of the Network's monitoring program and protocols are critical to ensuring the program is on the right course and, if corrections are needed, they are accomplished quickly to save unnecessary expenditures of resources and time. Review of the monitoring program will be designed to allow adaptive management of its components and will focus on implementation of the program and effectiveness in achieving programmatic goals. Implementation includes collection, management, QA/QC, analysis, summarization and reporting of data. The program will be effective when data lead to improved understanding of resource conditions and better informed management decisions. Certain types of reviews are part of annual reporting requirements. For example, the annual administrative report addresses some aspects of implementation. Other reviews, such as those for SOPs for collecting and managing monitoring data, will be incorporated into Protocol Review Reports. Program reviews will occur every 5 years.

The UCBN monitoring plan is an active document, subject to change based on monitoring results, budget, program reviews and other factors. Monitoring protocols are still in development, costs for monitoring are coarse estimates, and decisions have yet to be made regarding numbers and locations of permanent plots and other critical implementation issues. Once finished, these protocols may be revised to accommodate new methods or new understanding based on the results obtained in monitoring. For example, if a measure is much less variable than originally thought, fewer samples are necessary to reach a desired statistical power. This might lead to cost savings which could then be applied to other monitoring activities. While long-term monitoring is most valuable when it is consistent over time, the early years of this program should be seen as a time to make adjustments when the impacts of changes are slight. In the current schedule (Chapter 9) a program benchmark will be reached in 2012 when the final monitoring protocols are implemented. A program review is planned for 2013, providing a major opportunity for a course-correction for the program, should one be necessary.

Chapter 9: Schedule

This chapter describes the plan for implementing the UCBN Vital Signs Monitoring program. The UCBN plans to develop 11 protocols in the next 5 years to address 14 vital signs (Table 5.1). Protocol development will occur at a pace manageable by three permanent Network staff and will be complete for all 11 protocols by 2012 (Table 9.1). One protocol, camas lily, has been completed and is peer reviewed. Three protocols are in development and will be submitted for peer-review during 2007. As each of these protocols are finished and reviewed another protocol development project will start. The development of four protocols at one time appears to be a reasonable workload but this schedule may be accelerated after completion of the final monitoring plan in September 2007. Table 9.2 shows the protocol development and implementation schedule by year through 2012.

The camas lily protocol will be implemented in 2007. Implementation for aspen, integrated water quality, and sagebrush-steppe is planned in 2008, with the first few years of data collection providing the means to test and refine existing sampling designs. Remaining vital signs protocols will be developed as the first 4 are completed.

Most vital signs will require a protocol development phase of up to 1 year with several vital signs requiring additional development before implementation. Protocol development includes refining and testing methods, pilot data collection, analyses of pilot data to determine adequate sample size, and refinement of sampling based on these analyses. Pilot data collection will occur during the field season following submission of draft protocols for review.

Reporting of monitoring results also will be phased in over time. As data are collected, annual reports of activities and findings for each monitoring protocol will be prepared. As data accumulate, reporting will be expanded to include comprehensive analysis and synthesis reports. Once the fourth year of monitoring is completed, reports will include trend assessments within park units and Network-level summaries and comparisons.

The frequency and timing of sampling for the 14 vital signs (11 protocols) is variable (Table 9.3). Some data collection will occur in all months of the year (e.g., water chemistry), while other data will be collected over several days during one time of the year (e.g., April lek surveys for sage grouse). Field efforts are weighted heavily towards the summer growing season, when field crews are on staff, but some data collection will occur by Network staff throughout the calendar year.

It is anticipated that the UCBN will recruit and hire two 2-person summer field crews each year based on the geographic location of parks and protocols that require data collection at that time. There will be a field crew designated for the northern half of the Network and a field crew designated for the southern half (Table 9.4). For example, when all protocols are implemented the northern field crew will implement protocols at BIHO, JODA, LARO, NEPE, and WHMI. The southern field crew will implement protocols at CIRO, CRMO, MIIN, and HAFO. Crews will be trained in the spring of each year on protocols being followed during the summer field season. The northern field crew will be trained on five protocols including: camas lily, integrated riparian, invasive/exotic plants, osprey, and sagebrush-steppe vegetation. The southern field crew will also be trained on five protocols including: aspen, integrated riparian, invasive/exotic plants, limber pine, and sagebrush-steppe vegetation. Training needs overlap for three protocols so one training session will be run to instruct both field crews on the integrated riparian, invasive/exotic plants, and sagebrush-steppe vegetation protocols.

The UCBN plans to develop 11 protocols in the next 5 years to address 14 vital signs.

Table 9.1. The UCBN will have four protocols in development concurrently until all protocols are complete in 2012.

Protocols (2007)	Phase 2 (2008)	Phase 3 (2008-2010)
Aspen	Osprey	Sage Grouse
Camas Lily	Bats	Land Cover and Use
Integrated Water Quality	Integrated Riparian	
Sagebrush-steppe Vegetation	Limber Pine	Invasive/Exotic Plants

Through the next 5 years, the Network will continually evaluate how implementation of the vital signs program is proceeding. On a vital sign by vital sign basis as well as program-wide, this evaluation will guide adjustments in the schedule to meet the goal of having all 11 protocols implemented by 2012.

Table 9.2. Monitoring protocol development and implementation schedule.

Monitoring Protocols	Winter 2006	Spring 2007	Summer 2007	Fall 2007	Winter 2007	Spring 2008	Summer 2008	Fall 2008	Winter 2008	Spring 2009	Summer 2009	Fall 2009	Winter 2009	Spring 2010	Summer 2010	Fall 2010	Winter 2010	Spring 2011	Summer 2011	Fall 2011	Winter 2011
Aspen (In development)																					
Draft protocol	■	■																			
Pilot data collection			■																		
Review data				■	■							■	■			■	■			■	■
Revise sampling					■	■															
Plot installation						■	■														
Data collection (2 weeks annually) Complete Network sample (2011)							■				■				■				■		
Bats (Phase 2 after Camas lily)																					
Draft protocol					■	■															
Pilot data collection							■														
Review data								■	■			■	■	■		■	■	■		■	■
Revise sampling									■	■											
Plot installation										■	■										
Data collection (June-July sampling period) Complete rotation (2011-3 yr rotating panel)											■				■				■		
Camas Lily (In development)																					
Draft protocol	■	■																			
Pilot data collection			■																		
Review data				■	■							■	■			■	■			■	■
Revise sampling					■	■															
Plot installation		■																			
Data collection (1 week annually) Complete Network sample (2008)						■				■				■				■			

Table 9.2. Monitoring protocol development and implementation schedule (continued).

Monitoring Protocols	Winter 2006	Spring 2007	Summer 2007	Fall 2007	Winter 2007	Spring 2008	Summer 2008	Fall 2008	Winter 2008	Spring 2009	Summer 2009	Fall 2009	Winter 2009	Spring 2010	Summer 2010	Fall 2010	Winter 2010	Spring 2011	Summer 2011	Fall 2011	Winter 2011
Integrated Riparian (Phase 2 after Integrated Water Quality)																					
Draft protocol					■	■															
Pilot data collection						■	■	■													
Review data								■	■	■						■	■	■		■	■
Revise sampling										■											
Plot installation										■	■	■									
Data collection (annual)														■	■	■		■	■	■	
Complete rotation (2012 – 3 year rotating panel)																					
Integrated Water Quality (In development)																					
Draft protocol	■	■																			
Pilot data collection		■	■	■																	
Review data				■	■			■	■			■	■			■	■			■	■
Revise sampling					■	■															
Plot installation						■	■	■													
Data collection (annual)						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Complete rotation (2011 – 3 year rotating panel))																					
Invasive/Exotic Plants (Phase 3 after Limber Pine)																					
Draft protocol									■	■											
Pilot data collection											■										
Review data												■	■				■				■
Revise sampling												■	■								
Plot installation														■	■						
Data collection (annual)															■				■		
Complete rotation (2011)																					

Table 9.2. Monitoring protocol development and implementation schedule (continued).

Monitoring Protocols	Winter 2006	Spring 2007	Summer 2007	Fall 2007	Winter 2007	Spring 2008	Summer 2008	Fall 2008	Winter 2008	Spring 2009	Summer 2009	Fall 2009	Winter 2009	Spring 2010	Summer 2010	Fall 2010	Winter 2010	Spring 2011	Summer 2011	Fall 2011	Winter 2011
Land Cover and Use (Phase 3 after Bats)																					
Draft protocol									■	■											
Pilot data collection										■	■										
Review data										■	■					■	■			■	■
Revise sampling												■	■								
Plot installation													■								
Data collection (annual)														■	■			■	■		
Complete rotation (2011)																					
Limber Pine (Phase 2 after Sagebrush-steppe)																					
Draft protocol							■														
Pilot data collection																					
Review data								■	■				■				■				■
Revise sampling								■	■												
Plot installation										■											
Data collection (annual)											■				■				■		
Complete rotation (2010)																					
Osprey (Phase 2 – after aspen)																					
Draft protocol							■														
Pilot data collection							■														
Review data								■	■				■				■				■
Revise sampling									■	■											
Plot installation											■										
Data collection (annual)											■				■				■		
Complete rotation (2009)																					

Table 9.2. Monitoring protocol development and implementation schedule (continued).

Monitoring Protocols	Winter 2006	Spring 2007	Summer 2007	Fall 2007	Winter 2007	Spring 2008	Summer 2008	Fall 2008	Winter 2008	Spring 2009	Summer 2009	Fall 2009	Winter 2009	Spring 2010	Summer 2010	Fall 2010	Winter 2010	Spring 2011	Summer 2011	Fall 2011	Winter 2011
Sage Grouse (Phase 3 after Osprey)																					
Draft protocol									■	■											
Pilot data collection										■											
Review data											■	■									
Revise sampling													■	■							
Plot installation														■							
Data collection (annual)														■				■			
Complete rotation (2010)																					
Sagebrush-steppe Vegetation (In development)																					
Draft protocol	■	■	■																		
Pilot data collection						■															
Review data							■	■				■	■			■	■			■	■
Revise sampling							■														
Plot installation						■	■														
Data collection (annual)										■				■				■			
Complete rotation (2012)																					

Table 9.3. Annual frequency and timing of sampling for the 14 vital signs the UCBN plans to be monitoring by 2012.

Vital Sign	Sample Type/Interval	January	February	March	April	May	June	July	August	September	October	November	December
Aquatic Macroinvertebrates	Pre-runoff and late fall			*							*	*	
Aspen	2 weeks/year							W	W	W			
Bats	8 weeks/year						W	W					
Camas Lily	1 week/year					**	**						
Invasive/Exotic Plants	TBD					W	W	W					
Land Cover and Use	Annual single day	*	*	*	*	*	*	*	*	*	*	*	*
Limber Pine	1 week/year							**	**	**			
Osprey	1 week/year						**						
Riparian Vegetation	2-3 weeks/year					W	W	W					
Sage Grouse	Spring lek count				**								
Sagebrush-steppe Vegetation	6 weeks/year				W	W	W						
Stream/River Channel Characteristics	2-3 weeks/year					W	W	W					
Surface Water Dynamics	Weekly	W	W	W	W	W	W	W	W	W	W	W	W
Water Chemistry	Weekly	W	W	W	W	W	W	W	W	W	W	W	W

Legend:

* = single event in a month (one day)

** = two to three day sampling event

W = Sampling events of a full week or more throughout the month

Table 9.4. Field crew assignments based on parks and protocols. Two (2-person) field crews will collect data across the Network based on park location and protocols to be implemented.

Protocol	BIHO	CIRO	CRMO	HAFO	JODA	LARO	MIIN	NEPE	WHMI
Aspen		South	South						
Bats		*	*		*				
Camas lily (with volunteers)	*							*	
Integrated riparian	North	South	South	South	North			North	North
Integrated water quality	*	*	*	*	*			*	*
Invasive/ Exotic Plants	North	South	South	South	North	North	South	North	North
Land Cover and Use	*	*	*	*	*	*	*	*	*
Limber Pine		South	South						
Osprey						North			
Sage Grouse		*	*						
Sagebrush-steppe Vegetation	North	South	South	South	North	North		North	North

Legend:

South – The southern field crew will implement 5 protocols in 4 parks.

North – The northern field crew will implement 5 protocols in 5 parks.

* = Park and permanent Network staffs are responsible for data collection for this protocol.

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Glossary of Terms used by the NPS I&M Program

Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **Indicator** is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2002). See Indicator.

Ecological condition is the sum total of the physical, chemical, and biological components of ecosystems and how they interact. Ecological condition reflects the non-equilibrium character of ecosystems, in which routine natural disturbances such as fire, herbivory, and climatic extremes play important roles.

Ecological integrity is a concept that expresses the degree to which physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes.

Ecosystem is defined as, "a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries" (Likens 1992).

Ecosystem drivers are major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems.

Ecosystem management is the process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem. It is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal to sustain ecosystem structure and function, recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. The whole-system focus of ecosystem management implies coordinated land-use decisions.

Focal resources are park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Indicators are a subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2002). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system.

Measures are the specific feature(s) used to quantify an indicator, as specified in a sampling protocol.

Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level. Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution.

Vital Signs, as used by the National Park Service, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored 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 level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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