National Park Service
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Natural Resource Program Center
Fort Collins, Colorado

San Francisco Bay Area Network Vital Signs Monitoring Plan

Natural Resource Report NPS/SFAN/NRR—2006/017

ON THE COVER
Susan O'Neil (Natural Resource Specialist with the SFAN Inventory and Monitoring Program) collects plants at John Muir National Historic Site. NPS photo.

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Dawn Adams, Sarah Allen, Jennifer Bjork, Mary Cooprider, Amy Fesnock, Marcus Koenen, Tom Leatherman, Susan O'Neil, David Press, David Schirokauer, Brad Welch, and Brian Witcher
San Francisco Bay Area Network
Golden Gate National Recreation Area
Fort Cronkhite
Sausalito, CA 94965

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[original signatures on file]

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Golden Gate National Recreation Area

9/8/2005
Date

Tom Leatherman, Acting Superintendent,
Pinnacles National Monument

9/8/2005
Date

Martha Lee, Superintendent, Eugene O'Neill and John Muir
National Historic Sites

9/8/2005
Date

Don Neubacher, Superintendent, Point Reyes National Seashore

9/19/2005
Date

Steve Fancy, Monitoring Program Leader

______9/30/05____
Date

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Executive Summary

In 2000, the National Park Service (NPS) created 32 networks of NPS units across the United States that were formed and funded to “improve the ability of the NPS to provide state-of-the-art management, protection, and interpretation of and research on the resources on the NPS … and to assure the full and proper utilization of the results of scientific studies for park management decisions” (National Parks Omnibus Management Act of 1998). The San Francisco Bay Area Network (SFAN) is one of eight of these networks in the Pacific West Region of the NPS. The SFAN is composed of eight park units and includes Point Reyes National Seashore, Pinnacles National Monument, John Muir National Historic Site, Eugene O’Neill National Historic Site, and Golden Gate National Recreation Area including Muir Woods National Monument, Fort Point National Historic Site, and Presidio of San Francisco. The network fosters collaboration and creates efficiencies of scale in designing and implementing a natural resource focused Inventory and Monitoring (I&M) program.

The SFAN parks are within the Central California Coast Ranges and share many ecological systems and associated anthropogenic influences which include invasions of non-native species, altered fire regimes, degraded air and water quality, heavy recreational pressure, adjacent habitat loss, and climate change with associated sea level rise. The parks are extremely diverse in natural resources and have a unique set of complex management challenges within a densely populated setting. Most of the SFAN units are part of the Central California International Biosphere Reserve (Myers et al 2000), and are part of the California Floristic Province, an area recognized by Conservation International as a hotspot of biodiversity.

The first step in developing a monitoring plan, which began in 2000, was to complete species inventories for vascular plants and vertebrate animals. These inventories are currently being certified and natural resource bibliographic and metadata information systems are being updated. In 2003, the SFAN implemented a conceptual model-based strategy to create a natural resources monitoring program. This document describes the strategy, the process, some of the background information used and articulates the resulting monitoring plan.

The broad goals of NPS and SFAN Vital Signs Monitoring program are to:

1) determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions;

2) provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management;

3) provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments;

4) provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment; and,

5) provide a means of measuring progress towards performance goals.

Subject matter experts and park natural resource managers convened to create a series of conceptual models that identified the natural drivers and anthropogenic stressors (agents of change) that are linked to key resources and natural processes of interest. The conceptual model, described in chapter 2, displays these elements and linkages at three hierarchical levels. Over 60 potential vital signs (chapter 3) were identified based on these relationships. “Vital Signs” are a subset of physical, chemical, and biological elements and processes of ecosystems, selected to represent the condition of natural resources, effects of stressors, or elements that have important management values. A group of 55 subject matter experts and natural resource managers prioritized the list of 63 vital signs using 4 ranking criteria - ecological significance, management significance, cost and feasibility, and legal mandate. The existence of active long-term monitoring datasets in the parks and region were also considered as a factor in the ranking. From the prioritized list of 63 vital signs, the SFAN I&M Technical Steering Committee identified 18 vital signs for which detailed protocol development would commence (Table I). Six of the selected vital signs (stream fish assemblages, pinnipeds, northern spotted owl, raptors and condors, landbird population dynamics, and western snowy plover) had monitoring programs in place and were incorporated into the larger SFAN I&M program.

Table I. Vital signs selected for protocol development and their rank.

SFAN Vital Signs	Rank	SFAN Vital Signs	Rank
Weather and Climate [1,2]	1	Pinnipeds [1,2]	10
Invasive Plant Species (early detection) [2]	2	Plant Community Change	11
Freshwater Quality [1,2]	3	Landscape Dynamics	12
Air Quality [1]	4	Threatened and Endangered (T&E) Butterflies [1]	13
Stream Fish Assemblages [1,2]	5	Freshwater Dynamics [1,2]	14
Rare Plant Species [1,2]	6	Wetlands	15
Northern Spotted Owl [1,2]	7	Riparian Habitat	16
Amphibians and Reptiles	8	Landbird Population Dynamics [1,2]	17
Western Snowy Plover [1,2]	9	Raptors and Condors [1,2]	18

[1]Previous monitoring data exists
[2]Scheduled to receive funding in FY2006

Sampling design (chapter 4) is generally tied to the specific trend or phenomena (e.g., detecting population change in a focal species) a vital sign is designed to detect. Many of these 18 vital signs measure trends or phenomena in different resources realms, such as hydrosphere and atmosphere, and at different spatial scales and thus do not lend themselves to co-design of sampling regimes. However, potentially close linkages exist between some vital signs, especially 1) freshwater dynamics and stream fish assemblages, 2) invasive species, threatened and endangered (T&E) butterflies, and rare plants, and 3) wetlands and riparian habitat with plant communities. A grid-based sampling design for plant community change is described. A A list-based sampling design is described for water quality, freshwater dynamics, raptors and condors, pinnipeds, and Western Snowy Plovers. Index sites will be used for weather and climate, air quality, landbirds, and Northern Spotted Owls.

One of the most significant and enduring products of the I&M program are the detailed individual monitoring protocols and associated Standard Operating Procedures (SOPs; summarized in chapter 5). These dynamic documents are designed to communicate data collection, analysis, and reporting methods to peers and managers and to allow these long-term monitoring programs to continue in the face of inevitable staff change. Protocols for six on-going vital signs have been developed and are currently in various stages of the peer review and revision process. Protocols for the remaining 12 vital signs will be developed over the next several years based on their priority, funding availability, and protocol development activity at the regional and national levels. SFAN and park-based staff are currently working on the rare plant, invasive non-native plant species-early detection, water quality, weather/climate, and freshwater dynamics protocols. Air quality, weather, water quality and invasive species early detection protocol development are also receiving significant attention at the regional and national levels within the I&M program.

The amount of data and information this monitoring program generates will steadily increase over the next several years as network and park staff complete additional protocols and monitoring begins on new vital signs. Careful data collection and management, and dissemination of data and information products are essential if the results are to be used in resource management decisions. Considerable human and technological resources are required to adequately manage the large quantities of highly complex data generated for each vital sign. The data management plan (summarized in chapter 6), describes data and information management and dissemination, and outlines the duties of the networks' three data managers. More specific procedures for information management and reporting are contained in the specific protocols. Reporting trends in park vital signs in annual reports, synthesis reports, program reviews, and peer reviewed literature are all goals of the SFAN I&M program outlined in chapter 7.

In order to ensure for a successful monitoring program, chapters 8, 9, and 10 present an operation strategy which includes the administrative plan, implementation schedule, and budget for the first few years. The administrative plan includes: a staffing plan, network integration with other park operations, key partnerships, and how in-house field work will be carried out. The network relies strongly on existing park personnel as principal investigators for some vital signs. Key partnerships include the Bureau of Land Management, California Native Plant Society, California Department of Fish and Game, California State Parks, NOAA Fisheries and NOAA Marine Sanctuaries, PRBO Conservation Science, USGS- Biological Resources Division, and Ventana Wilderness Society. Annual funding for the SFAN is $747,200 with an additional $69,000 coming from the National Park Service Water Resources Division for water quality monitoring. During the first year of full implementation of the monitoring plan (FY 2006), approximately 76% of the budget will be spent on personnel (permanent, term, seasonal) and 17% on cooperative agreements and contracts. Only three percent of the budget goes to administration and seven percent goes to operations and equipment. It should be noted that at least 30% of the budget goes to information/data management.

The SFAN I&M program is embarking on a long-term vital signs monitoring program, the full value of which will continue to increase for many years.. Many drivers and stressors of ecosystem process impose their effects at multiple time scales. The level of detail in this and the specific vital signs protocol documents is an acknowledgment of the long-term nature of this program's goals. It is likely that data collection and analysis for most of these protocols implemented by the SFAN within the next five years will span the careers of several program managers. The long-term nature of this program also dictates that stressors and resources of concern may change along with the technology and analysis methods available to the vital signs program. The periodic programmatic reviews will insure that import changes are considered and incorporated into subsequent updates of this document.

Note to the reader:

Throughout the report, references are made to supporting sections, external documents, and web sites. For those references that appear as blue underlined text when the document is viewed in its electronic format, a hyperlink will connect the reader to the supporting information. Depress the "Ctrl" button and click the left mouse button simultaneously to follow the link. The web address is supplied for web-based documents.

For updates and supporting documentation:
http://www1.nature.nps.gov/im/units/sfan/index.htm

For more information about the NPS Inventory and Monitoring Program:
http://science.nature.nps.gov/im/monitor/index.htm

Chapter 1 Introduction and Background

1.1 Purpose

1.1.1 Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources "unimpaired for the enjoyment of future generations (National Park Service Organic Act 1916)." National Park 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 basis for making decisions and working with other agencies and the public to preserve and protect these resources. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas to assess the efficacy of management practices and restoration efforts and to provide early warning of impending threats.

The challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem approach because most parks are open systems, with threats such as air and water pollution, invasive species, exotic diseases, water withdrawals, resources extraction and habitat fragmentation originating from outside of the park's boundaries. An ecosystem approach is needed because no single spatial scale is appropriate for all system components and processes; the appropriate scale for understanding and effectively managing a resource might be at the home range, habitat patch, or landscape level, and in some cases may require a regional, national or international effort to understand and manage the resource. Variations in ecological phenomena also occur at different temporal scales; for example, plant community succession occurs over decades while insect pollinator populations often vary from one year or season to the next. Furthermore, biological diversity is organized in a hierarchical manner (genetic, population, species, community, ecosystem, and landscape) and ecosystem stressors can act on any level in this hierarchy. For example, several species in SFAN parks have gone through population bottlenecks resulting in a loss of genetic diversity. Other species have been extirpated with consequences cascading to other ecosystem components. National parks are part of larger ecosystems and natural resources and processes must be understood and managed in that context.

Natural resource monitoring provides site-specific information needed to understand and identify change in complex, variable, and imperfectly understood natural systems. Monitoring is defined as the "collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective" (Elzinga et al. 1998). Monitoring data help to define the recent limits of natural variation in park resources and provide a basis for understanding observed changes; monitoring results may also be used to determine what constitutes impairment and to identify the need for change in management practices. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems (Davis 2005, Roman and Barrett 1999).

The intent of the National Park Service (NPS) monitoring program is to track a subset of park resources and processes, known as "vital signs."Vital signs are defined 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" (Davis 2005). This subset of resources and processes is part 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 these resources. In situations where natural areas have been so highly altered that physical and biological processes no longer operate under natural conditions (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is not feasible, to apply ecologically sound management. The broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

1.1.2 Legislation, Policy, and Guidance

National Park managers are directed by federal law and NPS policies and guidance to know the status and trends in the condition of natural resources under their stewardship to fulfill the NPS mission of conserving parks unimpaired (see Summary of Laws, Policies, and Guidance, http://science.nature.nps.gov/im/monitor/LawsPolicy.htm). The mission of the National Park Service is:

> "*...to 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 purposes 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* (National Park Service Organic Act 1916)."

As more natural and cultural resources were dedicated to National Park Service authority, Congress recognized that all parks are interrelated to preserve a single national heritage, require the same level of protection, and should operate under one set of guidelines. As a precursor to the concept of park networks, Congress affirmed:

> "*...that the national park system, which began with establishment of Yellowstone National Park in 1872, has since grown to include superlative natural, historic, and recreation areas in every major region of the United States...; that these areas, though distinct in character, are united through their inter-related purposes and resources into one national park system as cumulative expressions of a single national heritage; that, individually and collectively, these areas derive increased national dignity and recognition of their superb environmental quality through their inclusion jointly with each other in one national park system preserved and managed for the benefit and inspiration of all the people of the United States* **(**General Authorities Act 1970)."

The Government Performance and Results Act (GPRA 1993) was established to ensure that daily actions and expenditures are guided by both long-term and short-term goals that are, in turn, consistent with Department of Interior agency missions.

Specific, long-term goals must be quantifiable. As such, measurable outcomes provide the parks with tangible objectives and an effective means by which to measure progress toward their goals and objectives (see http://www.doi.gov/gpra/nps_sp_6.pdf for specific NPS long-term goals). A five-year strategic plan and an annual work plan outline the strategies for reaching these goals while an annual performance report evaluates the annual progress made toward GPRA goals (NPS 2000).

Recognizing the need to understand the condition of natural resources within the park system, a servicewide inventory and monitoring (I&M) program was established (NPS 1995). The I&M program was given the responsibility to determine the nature and status of natural resources under NPS stewardship and to monitor changes in the condition of these resources over time. Information from inventory and monitoring efforts can then be incorporated into NPS planning, management, tracking performance, and decision-making.

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. The Act charges the Secretary of the Interior to

"*continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System,*" and to *"...assure the full and proper utilization of the results of scientific studies for park management decisions*." Section 5934 of the Act requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

The Natural Resource Challenge (1999; http://www.nature.nps.gov/challengedoc/) action plan refined the goals delineated in the NPS Strategic Plan designed to address GPRA goals (NPS 2000). The action plan presented the challenges confronting the Park Service and strategic approaches for addressing these challenges over a five-year period. Extension of the servicewide I&M program, the formation of collaborative park networks, and active recruitment and inclusion of scientists in complex park natural resource issues were among the strategies included in the action plan.

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill:

> *The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact*

with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data.

The 2001 NPS Management Policies updated previous policy and specifically directed the Service to inventory and monitor natural systems:

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.

Further, "*The Service will:*

- *Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.*
- *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources.*
- *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.*
- *Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames.*
- *Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems* (2001 NPS Management Policies)."

Additional statutes provide legal direction for expending funds to determine the condition of natural resources in parks and specifically guide the natural resource management of network parks. Detailed information on these statues can be obtained from Bean and Rowland (1997).

1.2 Monitoring Goals and Strategies

1.2.1 Role of Inventory, Monitoring, and Research in Resource Management

Monitoring is a central component of natural resource stewardship in the NPS, and in conjunction with natural resource inventories and research, provides the information needed for effective, science-based managerial decision-making and resource protection (Figure 1.1; see Monitoring is a central component of natural resource stewardship in the NPS, and in conjunction with natural resource inventories also Definitions of Natural Resource Inventories, Monitoring, and Research, http://www1.nrintra.nps.gov/im/monitor/cupn/IM_Definitions.doc). The NPS strategy to institutionalize inventory and monitoring throughout the agency consists of a framework (see [Framework for National Park Service Inventory and Monitoring](http://www1.nrintra.nps.gov/im/monitor/cupn/IM_Framework.doc), http://www1.nrintra.nps.gov/im/monitor/cupn/IM_Framework.doc) with three major components:

1. Completion of 12 basic resource inventories upon which monitoring efforts can be based;

2. A network of 11 experimental or "prototype" long-term ecological monitoring (LTEM) programs begun in 1992 to evaluate alternative monitoring designs and strategies; and

3. Implementation of operational monitoring of critical parameters (i.e., vital signs) in approximately 270 national parks with significant natural resources that have been grouped into 32 networks linked by geography and shared natural resource characteristics.

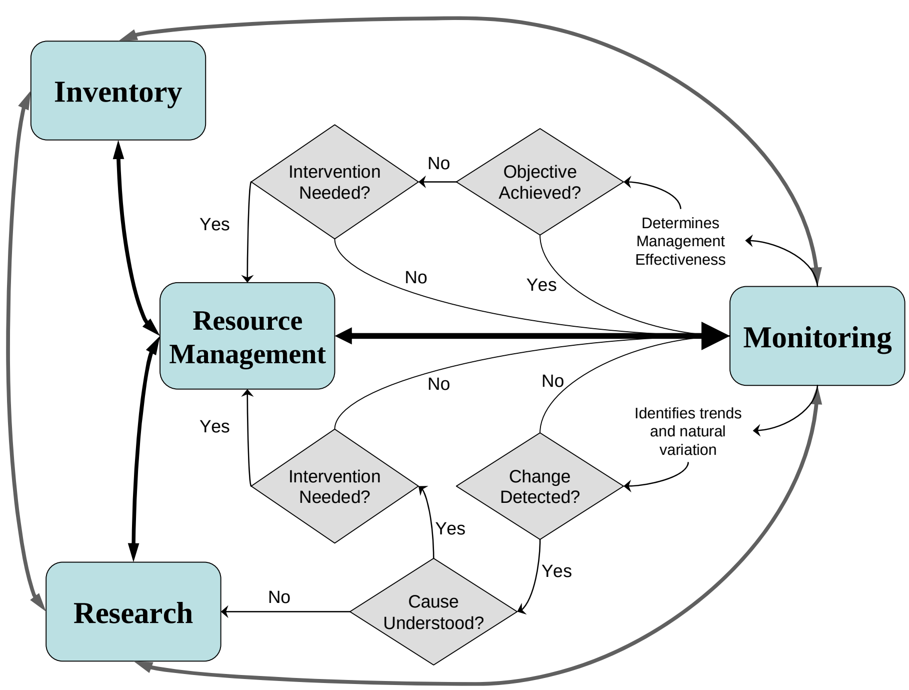


Figure 0.1. Relationships between monitoring, inventories, research, and natural resource management activities in national parks (modified from Jenkins et al. 2002).

The network approach will facilitate collaboration, information sharing, and economies of scale in natural resource monitoring, and will provide parks with a minimum infrastructure for initiating natural resource monitoring that can be built upon in the future. Ten of the 32 networks include one or two prototype long-term ecological monitoring programs, which were established as experiments to learn how to design scientifically credible and cost-effective monitoring programs in ecological settings of major importance to a number of NPS units. Because of higher funding and staffing levels, as well as U.S. Geological Survey (USGS) involvement and funding in program design and protocol development, the prototypes serve as "centers of excellence" that are able to do more extensive and in-depth monitoring and continue research and development work to benefit other parks.

In the Pacific West Region, there are eight networks. The San Francisco Bay Area Network (SFAN) consists of eight park units, including Eugene O'Neill National Historic Site (EUON), Fort Point National Historic Site (FOPO), Golden Gate National Recreation Area (GOGA), John Muir National Historic Site (JOMU), Muir Woods National Monument (MUWO), Pinnacles National Monument (PINN), Point Reyes National Seashore (PORE), and the Presidio of San Francisco (PRES).

1.2.2 Goals for Vital Signs Monitoring

The five servicewide goals for vital signs monitoring for the National Park Service are:

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 and impairment of selected resources to help develop effective mitigation measures and reduce costs of management.

3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.

4. Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.

5. Provide a means of measuring progress towards performance goals.

The SFAN used the five servicewide goals as the backbone for developing and prioritizing the monitoring program being proposed. The Network parks' management goals and servicewide monitoring goals were used to develop monitoring objectives and select vital signs for long-term monitoring. (See Table 1.1 and Appendix 1 for details on specific park management goals).

1.2.3 Strategic Approaches to Monitoring

1.2.3.1 Scope and Process for Developing an Integrated Monitoring Program: Each Network has a unique way of determining the best selection of vital signs to monitor. SFAN followed the five basic steps for developing a Network monitoring program as recommended by the NPS I & M Program, which are further discussed in the Recommended Approach for Developing a Network Monitoring Program (http://science.nature.nps.gov/im/monitor/index.htm):

1. Define the purpose and scope of the monitoring program;
2. Compile and summarize existing data and understanding of park ecosystems;
3. Develop conceptual models of relevant ecosystem components;
4. Select vital signs and specific monitoring objectives for each; and
5. Determine the appropriate sampling design and sampling protocols.

Parks need flexibility to develop an effective and cost-efficient monitoring program that addresses the most critical information needs of each park and that can be integrated with other park operations such as interpretation and maintenance activities. Additionally, this process needs to allow existing programs that have been carefully scrutinized, existing funding sources, and current staff to be combined with new funding and staffing available through the Natural Resource Challenge and the various divisions of the Natural Resource Program Center. Partnerships with federal and state agencies and adjacent landowners are necessary to effectively understand and manage resources and threats that extend beyond park boundaries, but these partnerships (and the appropriate vital signs and monitoring protocols involved) differ for parks throughout the national park system.

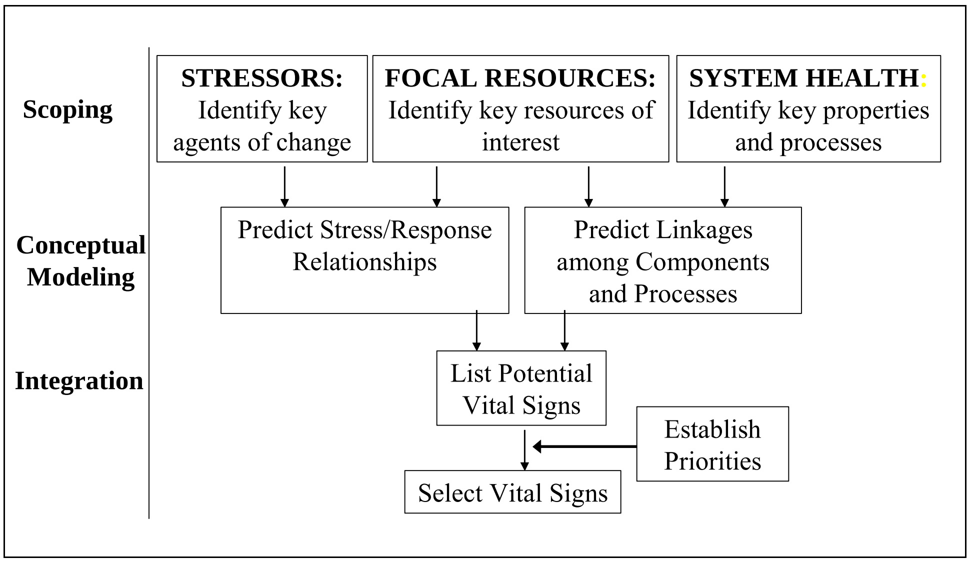


Figure 0.2. Basic approach to identifying and selecting vital signs for integrated monitoring of park resources (source: K. Jenkins, USGS Olympic Field Station).

The complicated task of developing a Network monitoring program requires an initial investment in planning and design to guarantee that monitoring meets the most critical information needs of each park, as well as the region and the nation. The program must produce scientifically credible results that are clearly understood and accepted by scientists, policy makers, and the public, and that are readily accessible to managers and researchers. These front-end investments also ensure that monitoring will build upon existing information and understanding of park ecosystems and make maximum use of leveraging and partnerships with other agencies, organizations, and academia.

1.2.3.2 Strategies for Determining What to Monitor: Monitoring is an on-going effort to better understand how to sustain or restore ecosystems, and serves as an "early warning system" to detect declines in ecosystem integrity and species viability before irreversible loss has occurred. The goals of the vital signs monitoring program recognize the dynamic nature and condition of park ecosystems and the need to identify and separate “natural” variation from undesirable anthropogenic sources of change to park resources.

One of the key initial decisions in designing a monitoring program is deciding how much relative weight should be given to tracking changes in focal resources and stressors that address current management issues versus measures that are thought to be important to the long-term understanding of park ecosystems. A vital sign is most useful when it can provide information to inform a management decision or to quantify the effects of past decisions. Vital signs must produce data that can be interpreted, clearly understood, and accepted by managers, scientists, policy makers, and the public. However, current understanding of ecological systems is imperfect, and consequently, predictions of how park resources might respond to changes in various system drivers and stressors is limited. A monitoring program that focuses only on current threat/response relationships and current issues may not provide the long-term data and understanding needed to address high-priority issues that will arise in the future.

The best way to meet the challenges of monitoring in national parks and other protected areas is to achieve a balance among different monitoring approaches, while recognizing that the program will not succeed without also considering political issues. NPS, therefore, has adopted a multi-faceted approach for monitoring park resources, based on both integrated and threat-specific monitoring approaches and that builds upon concepts presented originally for the Canadian National Parks (Figure 1.3; Woodley 1993).

Specifically, it is recommended that vital signs be chosen from each of the following broad categories:

1. Ecosystem drivers and processes that fundamentally affect park ecosystems,
2. Stressors and their ecological effects,
3. Focal resources of parks, and
4. Key properties and processes of ecosystem integrity.

Collectively, these basic strategies for choosing vital signs achieve the diverse monitoring goals of the National Park Service.

1.2.3.3 Integration: Ecological, Spatial, Temporal, and Programmatic: One of the most difficult aspects of designing a comprehensive monitoring program is integration of monitoring projects so that the interpretation of the whole monitoring program yields information more useful than that of individual parts. Integration involves ecological, spatial, temporal, and programmatic aspects. An ideal ecosystem monitoring strategy will employ a suite of individual measurements that collectively monitor the integrity of the entire ecosystem. One approach for effective ecological integration is to select vital signs at various

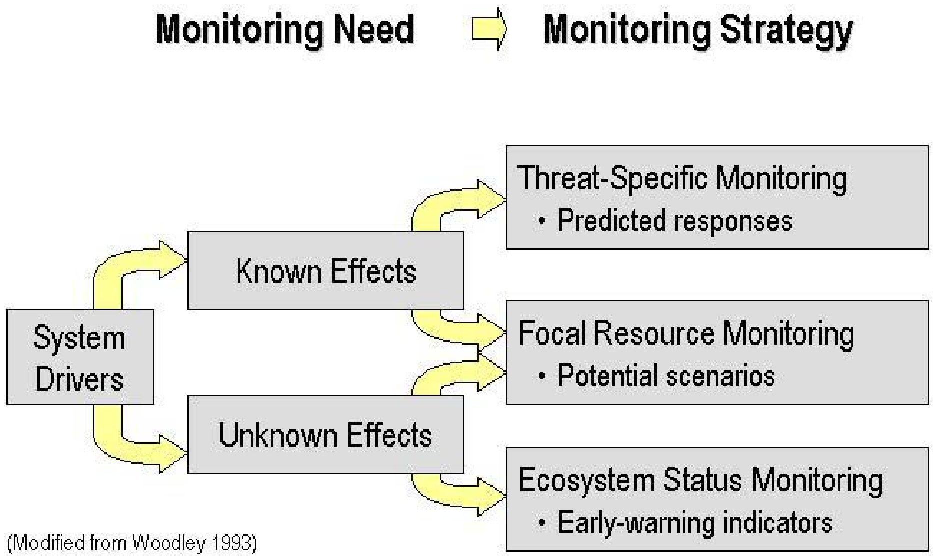


Figure 0.3. Conceptual approach for selecting vital signs.

In certain cases where good understanding exists between potential effects and responses by park resources (Known Effects), monitoring of system drivers, stressors, and effected park resources is conducted. A set of focal resources (including ecological processes) will be monitored to address both known and unknown effects of system drivers and stressors on park resources. Key properties and processes of ecosystem status and integrity will be monitored to detect changes and potentially warn managers of undesirable changes in park resources.

hierarchical levels of ecological organization (e.g., landscape, community, population, genetic; see Noss 1990). Similarly, spatial integration requires understanding of the scale at which variation in the phenomenon under investigation is best detected and how this variation presents at other scales. Subsequently, coordinated location of comparably scaled vital signs, and design of statistical sampling frameworks that permit the extrapolation and interpolation of data to scales other than the scale at which the data was collected can be considered. Temporal integration requires the development of a meaningful timeline for sampling different vital signs while considering characteristics of temporal variation in these vital signs. Programmatic integration requires coordinated monitoring planning and design by the Natural Resources Program Center (NRPC) divisions (Air Resources, Biological Resource Management, Geologic Resources, Natural Resource Information, and Water Resources) to provide guidance, technical support and funding to the networks. Furthermore, park-based, outside researcher, and project specific monitoring programs should be integrated whenever new efficiencies can be generated.

Planning for vital signs monitoring also must be coordinated and results communicated within and among parks and with other agencies and institutions. Coordinated monitoring planning, design, and implementation efforts encourage cooperative resource use, promote sharing of data among neighboring land management agencies, provide context for interpreting data, and encourage additional research.

1.2.3.4 Limitations of the Monitoring Program: All monitoring programs have limitations that are a result of the inherent complexity and variability of park ecosystems, coupled with limited time, funding, and staffing available for monitoring. Ecosystems are loosely defined assemblages that exhibit characteristic patterns on a range of scales of time, space, and organization complexity (De Leo and Levin 1997). Natural systems as well as human activities change over time, and it is extremely challenging to distinguish natural variability and desirable changes from undesirable anthropogenic sources of change to park resources.

The monitoring program simply cannot address all resource management interests because of limitations of funding, staffing, and logistical constraints. Rather, the intent of vital signs monitoring is to monitor a select sub-set of ecosystem components and processes that reflect the condition of the park ecosystem and is relevant to management issues. Cause and effect relationships usually cannot be demonstrated with monitoring data, but monitoring data might suggest a cause and effect relationship that can then be investigated with a research study. There are also inherent limitations in data due to imperfect understanding of ecosystem function and component interactions. The monitoring plan, therefore, should be viewed as a working document, subject to periodic review and adjustments over time as our understanding improves and new issues and technological advances arise.

1.2.3.5 SFAN Monitoring Plan and GPRA Goals: The SFAN Monitoring Plan is a significant and specific step towards fulfilling GPRA Goal Category I (Preserve Park Resources) for the network. The servicewide goal pertaining to Natural Resource Inventories specifically identifies the strategic objective of inventorying the resources of the parks as an initial step in protecting and preserving park resources (GPRA Goal Ib1). This goal tracks the basic natural resources information that is available to parks; performance is measured by what datasets are obtained. The servicewide long-term goal is to "acquire or develop 87% of the outstanding datasets identified in 1999 of basic natural resource inventories for all parks" based on the I&M Program's 12 basic datasets (Section 1.2.1). The SFAN Inventory Study Plan (NPS 2000) delineated what information exists for the network, its format and condition, and what information is missing.

The Monitoring Plan will identify the vital signs of the SFAN network and develop a strategy for long-term monitoring to detect trends in resource condition (GPRA Goal Ib3; see Table 1.1). The 2002 Annual Performance Report identifies what steps have been accomplished to date and the number of personnel involved. The network goal is to identify vital signs in a Monitoring Plan to be completed by September 30, 2005. GPRA goals specific to SFAN parks and relevant to the Monitoring Plan are listed in Table 1.1.

1.2.3.6 San Francisco Bay Area Network Strategic Approach to Monitoring: The SFAN has followed the basic process depicted in Figure 1.2 to select a subset of park resources and processes for monitoring. The schedule for completing the 3-phase planning and design process is shown in Table 1.2 (http://science.nature.nps.gov/im/monitor/schedule.htm).

Table 0.1 GPRA goals for each park that pertain to information generated by the Inventory and Monitoring program of the SFAN.

GPRA Goal	Goal #*	Parks with this goal
Resources maintained	Ia	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Disturbed lands restored	Ia01A	PORE
	Ia01B	PORE
	Ia1A	GOGA, PRES
	Ib01A	JOMU
Exotic vegetation contained	Ia1B	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Natural resource inventories acquired or developed	Ib01	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Stable populations of federal T&E species or species of concern have improved status	Ia2B Ib02d	GOGA, MUWO, PORE
Federal T&E species or species of concern populations have improved status	Ia2D	PORE
Improving federal T&E species or species of concern populations have improved status	Ia2A	PINN, PORE, GOGA, MUWO, PRES
Species of concern populations have improved status	Ia2X	GOGA, PRES, PORE
Vital signs for natural resource monitoring identified	Ib3a	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Vital signs for natural resource monitoring implemented	Ib3b	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Water quality improvement	Ia04	FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES

* for GPRA Goal numbers refer to the National Park Service Strategic Plan (NPS 2000)

The SFAN held several Vital Signs Monitoring Workshops to identify significant resources in the parks, identify key processes and stressors affecting the parks, potential monitoring questions, and recommend vital signs that could address the monitoring questions. An initial prioritization of vital signs and development of a conceptual model also were addressed during some of the workshops. Participants included park service managers and staff, external natural resource managers, and scientists.

PINN held a workshop in September 2001 (a summary is available at: http://www1.nature.nps.gov/im/units/sfan/reports/appendixpinn.pdf). EUON and JOMU jointly held workshops in January and August 2002 since both parks are in close proximity, have similar natural resources and issues, and are administered jointly (summaries available at: http://www1.nature.nps.gov/im/units/sfan/meeting/euonjomu2ndsummary.pdf). Because of their previous collaborative efforts and the overlap in resources and management issues, PORE and the parks administered by GOGA jointly held a workshop in 1997 and held another workshop in July 2002 to revisit changes in national guidelines

Table 0.2. Timeline for the SFAN to complete the 3-phase planning and design process for developing a monitoring program.

Program Element	**FY01 Oct-Mar**	**FY01 Apr-Sep**	**FY02 Oct-Mar**	**FY02 Apr-Sep**	**FY03 Oct-Mar**	**FY03 Apr-Sep**	**FY04 Oct-Mar**	**FY04 Apr-Sep**	**FY05 Oct-Mar**	**FY05 Apr-Sep**	**FY06 Oct-Mar**
Data gathering, internal scoping											
Inventories to Support Monitoring											
Scoping Workshops											
Conceptual Modeling											
Vital Signs Prioritization and Selection											
Protocol Development, Monitoring Design											
Monitoring Plan Due Dates Phase 1, 2, 3					Draft Phase I Oct '02		Draft Phase II Oct '03		Draft Phase III Dec '04		Final Plan Sep. '05

(http://www1.nature.nps.gov/im/units/sfan/meeting/POGO_VSsummary.pdf). Subsequently, the SFAN Steering Committee integrated findings and recommendations from the separate workshops into a conceptual model for the network of parks that includes significant natural resources, key processes and stressors, and monitoring questions with suggested vital signs (see Chapter 2). The SFAN Vital Signs Workshop held March 19-20, 2003, was organized to review the SFAN integrated model and its related components and to identify network-wide vital signs. To help expedite the prioritization process and to prepare for future sampling design and protocol development, participants also were asked to complete a protocol questionnaire for each of the high priority vital signs identified by their workshop group. Monitoring protocols used by individual parks were integrated with those obtained from the workshop and from information generated by a geology working group that met in October 2002. Additionally, vegetation and faunal working groups convened after the Vital Signs Workshop to refine the vital signs protocol questionnaires by incorporating comments and suggestions from the workshop. A detailed description of the scoping workshop is included in the San Francisco Bay Area Network Vital Signs Workshop Summary March 2003 (http://www1.nature.nps.gov/im/units/sfan/meeting/SFAN_VSsummaryV3.pdf).

Information from the protocol questionnaires was entered into a web-based, network database that was used to prioritize vital signs and to develop monitoring protocols for the individual parks and for the SFAN. Over 100 specialists participated in the vital signs prioritization process (see Chapter 3: Vital Signs for more detail).

1.2.3.6.1 Water Quality Planning (Scoping) Meetings: While the SFAN Vital Signs Workshop provided a forum for discussing and selecting water resources vital signs, additional water quality-specific information was needed from the parks. Therefore, additional planning meetings were held for JOMU and EUON, GOGA and MUWO, PINN, PORE, and PRES. The desired outcome of the meetings was to gather park information related to water quality, identify and prioritize water quality issues, and identify the resources available to monitor. The meetings also provided an opportunity to introduce the I&M Water Quality Monitoring Program and plan development process to those unfamiliar with it. Park staff, local agencies, watershed groups, and university staff were invited to participate. Results of these meetings plus a summary of water quality data is included in the SFAN Preliminary Water Quality Status Report (Cooprider 2004).

1.3 Overview of Network Parks and Selected Natural Resources

The SFAN is one of eight networks formed in October 2000 in the Pacific West Region (PWR) of the National Park Service. The network is composed of eight park units including Eugene O'Neill National Historic Site (EUON), Fort Point National Historic Site (FOPO), Golden Gate National Recreation Area (GOGA), John Muir National Historic Site (JOMU), Muir Woods National Monument (MUWO), Pinnacles National Monument (PINN), Point Reyes National Seashore (PORE), and the Presidio of San Francisco (PRES). PRES and EUON were not originally selected by the NPS Washington Support Office (WASO; now known as the Natural Resource Program Center - NRPC) as part of the 270 parks nationwide with significant natural resources; however, the SFAN Steering Committee and Board of Directors decided that natural resource issues within these parks were sufficient to be included in the network. The SFAN was selected as one of the first three networks in the region to obtain monitoring funds because of need, capacity, and existing monitoring effort. The San Francisco Bay Area, and the parks therein, are extremely diverse in natural resources and represent a unique set of management challenges within a very populated setting

SFAN represents one of the 6 most significant areas in the nation for biodiversity (Grossman 1998). Nationally, the parks are significant to the National Park System for: 1) supporting many endemic species and communities despite close proximity to the large urban zone of the San Francisco Bay region, 2) preserving biologically and geologically diverse habitats and their associated species, and thereby 3) providing opportunities for recreation, education and aesthetic enjoyment to a large urban population. Internationally, the SFBAN of parks falls within the 8th most significant "hot spot" in the world for biodiversity and at great risk due to rapid human population growth. With a current population of 6.9 million and large metropolitan centers, the San Francisco Bay Area is forecast to have a population of 8 million by 2020 (Association of Bay Area Governments 2000). Recognizing the extraordinary significance and exposure to threats in the region, the UNESCO Man in the Biosphere program designated the Central California International Biosphere Reserve in 1995. (See appendix 1 for descriptions of individual park units and their natural resources).

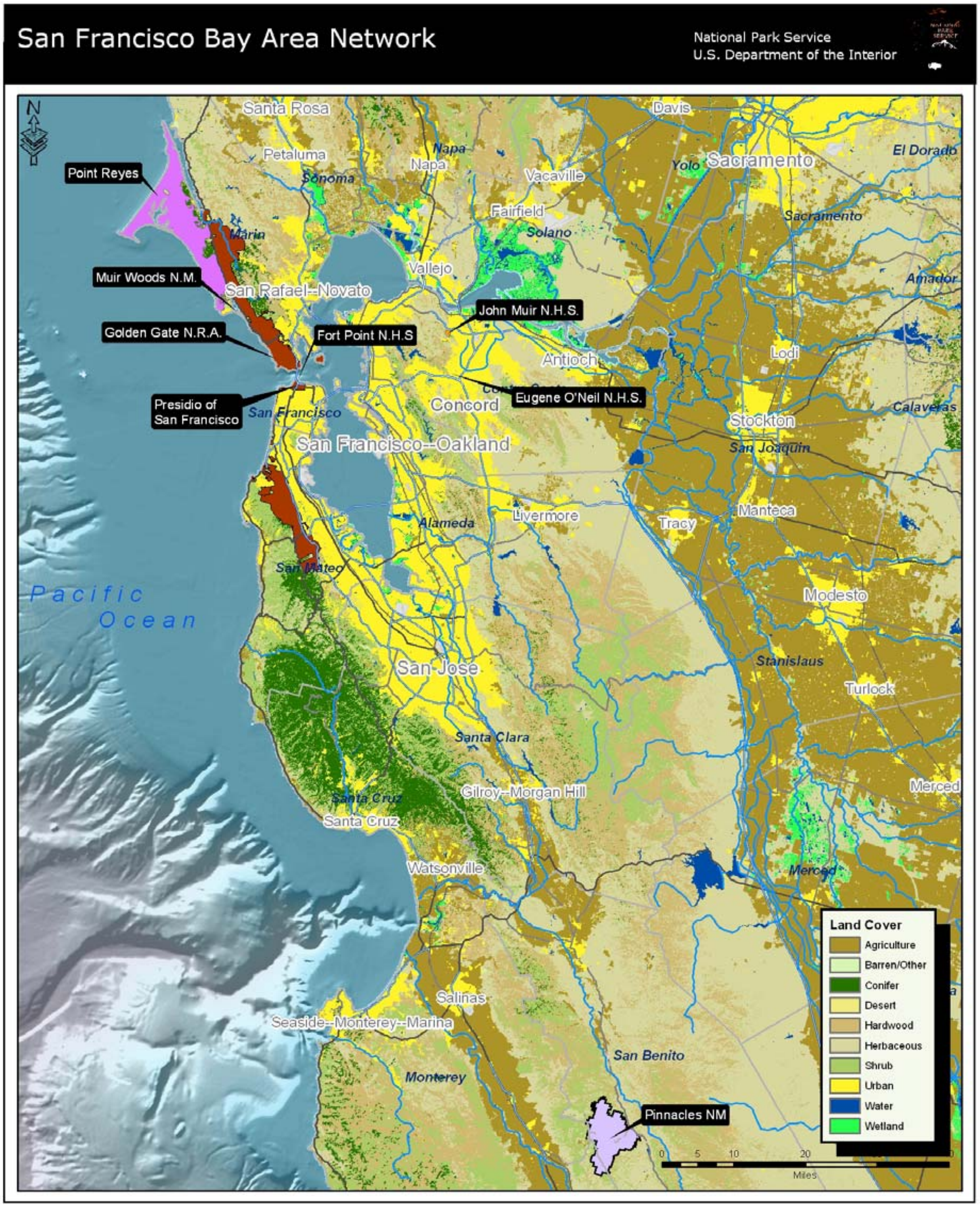


Figure 0.4. Location of the SFAN parks.

1.3.1 Ecological Context: Park Resources and Issues

The following sections briefly describe the range of environmental conditions and anthropogenic influences prevalent in the San Francisco Bay Area. The natural resources resulting from the interactions of these forces and existing raw materials also are considered.

1.3.1.1 Setting and Boundary: The parks of the SFAN are within the central California coast range and share many ecosystems, ecosystem components, and associated threats. The elements that define the limits of a boundary include leadership (as within a community), authority (as dictated by legal action), and zone of influence. The legislative boundaries of the coastal parks of central California extend from Tomales Point, Marin County in the north, south to Milagra Ridge, San Mateo County, and reach their eastern and southern extremes inland in the Gabilan Mountains of San Benito County (Figure 1.4). The SFAN parks' administrative boundaries include nearly 170,242 acres, of which about 30 mi^2 are surface waters (including streams, tributaries, lagoons, lakes, ponds, and reservoirs), and nearly 120 linear miles of shoreline.

In the vicinity of SFAN parks are three National Marine Sanctuaries (Gulf of the Farallones, Monterey Bay, and Cordell Bank), Bureau of Land Management (BLM) lands including the Clear Creek Management Area and the California Coastal National Monument, two National Wildlife Refuges, several state Areas of Special Biological Significance, and numerous state and regional parks such as Mt. Tamalpais State Park, Las Trampas Regional Wilderness Park (part of East Bay Regional Parks District), and Fremont Peak State Park. The California Coastal National Monument was designated by Presidential Proclamation in 2000, and includes all BLM administered islands, rocks, exposed reefs and pinnacles off the California coast above the high water mark. GOGA and PORE are part of an International Biosphere Reserve and function as a part of a community of internationally significant reserves. The network includes two internationally significant RAMSAR wetland sites (Bolinas Lagoon and Tomales Bay), designated under UNESCO.

The vital signs monitoring plan designates two spatially nested network boundaries. The core area is composed of the NPS boundaries, including state parks, and adjacent watersheds. The broader area is delineated by the boundary of the Golden Gate Biosphere Reserve, the three National Marine Sanctuaries, BLM lands, and the mouth and center of San Francisco Bay. The core limit takes into account the need to monitor upper and lower reaches of watersheds that extend beyond the legislative boundaries of the parks. The broader area takes into account that marine species range widely in the region, and that shared monitoring activities with other partners is encouraged.

1.3.1.2 Air quality: Parks within the SFAN are influenced by the close proximity of urban and suburban populations in a variety of ways, including air quality. Also, air quality can have biological effects on health and productivity of plants and animals. The NPS Air Resources Division (ARD) focuses on three main areas for monitoring air quality:

(1) Atmospheric deposition
(2) Ozone pollution
(3) Visibility

The two Class I air quality parks in SFAN are PINN and PORE. Both parks are experiencing an increase in development along their borders, as well as influences from major population centers in the bay area. The San Francisco Bay Area has extensive industrial facilities including petroleum refineries and energy production plants, as well as a very congested freeway system. Depending on the season, wind and temperature, the air quality at SFAN parks can be impacted by these factors.

At PINN, the NPS Air Quality Office and the Environmental Protection Agency (EPA) established a monitoring station near the east entrance in 1987. An air clarity study (using a transmissometer) has been completed, but particulate and ozone monitoring continues. Despite the occasional hazy days, the air quality at PINN is a defining feature of the Monument and an important resource. PORE has monitored air quality for over 20 years. The Interagency Monitoring of Protected Visual Environments (IMPROVE) program has been in operation since 1988 at the PORE North District Ranger Station and includes the measurement of the composition and concentration of fine particles. There is also a web-cam installed at the PORE lighthouse for visibility monitoring. The Bay Area Air Quality Management District (BAAQMD) operates an air quality station at GOGA, to monitor dioxin at Fort Cronkite.

1.3.1.3 Climate: Hot, dry summers and rainy, mild winters are typical of a moderate Mediterranean climate, that characterize the SFAN. Temperatures average 50 to 65°F in the Coast Range, but in the inland valleys and at PINN, temperatures can exceed 90°F regularly in the summer. Precipitation, which ranges from 15 to 40 inches per year, extends from fall through spring, and increases with elevation. Precipitation typically occurs as rainfall. Snowfall is rare in the region. Frost and short periods of freezing weather occur occasionally in winter and mostly in inland valleys. The growing season lasts 120 to 270 days (National Weather Service 2003).

Coastal areas have a more moderate climate than the interior and can receive significant moisture from fog in summer. Consequently, inland areas receive about half the rainfall as areas along the coastal range. With this variability, many microclimates occur. For example at PORE, Point Reyes Headland in the summer can be 55°F with fog and wind, in contrast to Olema Valley, just 15 miles distant, with temperatures above 80°F and no wind (National Weather Service 2003).

Global climate change resulting from greenhouse gas accumulation in the atmosphere is expected to increase weather variability in unpredictable ways including droughts or increased precipitation. The SFAN is predicted to have increased rainfall, and more intense and more frequent El Niño-Southern Oscillation (ENSO) events. Sea level already has risen 4-8 inches in the past century, and models predict that this rise will accelerate, potentially rising from 5 to 37 inches over the next 100 years (NAST 2001). Climate change may impact shoreline erosion, saltwater intrusion in groundwater supplies, and altering the water regimes of wetlands and estuaries. These are vital resource management concerns along the 120 miles of the SFAN shoreline. Increased and more intense precipitation would also increase erosion and flood events at all of the parks, where erodible soils occur. Sea temperature is also predicted to continue to rise. Central California waters have already increased in temperature over the past 30 years, with changes in the distribution of many marine species of invertebrates and fishes (Croll et al. 2000).
1.3.1.4 Geology: Geologic history has shaped the topography of the region creating large bays, coastal ridges paralleling the coastline, and unusual features. Coastal ridges that parallel the coast

vary in elevation between 500 to 3,500 feet. They include the Inverness and Bolinas Ridges in the north, Diablo Mountains inland of San Francisco Bay, and the Gabilan Mountains to the south. Special features include the Pinnacles rock formations and Point Reyes Headland. The area, located in the Coast Ranges geomorphic province, consists of parallel ranges, and folded, faulted, and metamorphosed strata; the rounded crests are of sub-equal height.

In geologic time, central California has been exposed to extraordinary forces that have shaped the region. The San Andreas Fault links all of the park units. The fault starts at Pinnacles as a block in the middle of Miocene volcanics and extends northward to Point Reyes where the fault ruptures the surface and forms Bolinas Lagoon and Tomales Bay. Movement of the Pacific plate northward along the San Andreas faultline continues to create the distinctive topography of the region.

Coastal processes accrete and erode shorelines seasonally and annually along GOGA and PORE, particularly at Ocean Beach and Drakes Beach. During intense winter storm years such as ENSO events, erosion can be severe causing nearshore flooding and undermining structures such as roadways. USGS mapped the coastline of PORE with LIDAR in 1997 and 1998, and will update coastal mapping in the future for both GOGA and PORE. The NPS Geologic Resources Division (GRD) and USGS-Coastal and Marine Division developed a coastal vulnerability index in 2004, mapping areas at PORE and GOGA that would be vulnerable to sea level rise (http://woodshole.er.usgs.gov/project-pages/nps-cvi/).

1.3.1.5 Water Resources: The SFAN has many unique aquatic resources that are significant in an ecological and economic context. Aquatic resources in the SFAN include streams, bays, estuaries, high energy coast, lagoons, lakes, reservoirs, freshwater and estuarine marshes, nearshore oceanic waters, and seeps. The combination of marine and freshwater aquatic systems within the network supports a variety of threatened and endangered species.

Several NPS efforts to improve the condition of water resources within SFAN are underway. The Redwood Creek watershed and MUWO are currently the focus of a variety of activities including watershed planning, transportation planning, water quality and water rights investigations, sensitive species monitoring, aquatic system and riparian restoration, invasive non-native plant removal and habitat restoration, and GIS mapping of all watershed features. Several stream restoration projects are on-going at PORE including bank stabilization and dam removal projects. Restoration efforts for Chalone Creek (PINN) and its floodplain have also been initiated. Streambank restoration (including removal of invasive species, erosion control, and bank stabilization) is also proposed along Alhambra Creek and its tributaries (JOMU). Tidal wetland restoration efforts are on-going at PORE, GOGA, and PRES.

Many of the watersheds within SFAN parks receive substantial attention from the surrounding communities and jurisdiction over water resources is shared by other agencies including the State Water Quality Control Board and water utility districts. A variety of stake-holder based watershed groups have been established in the last 10 years to address problems related to water quality and watershed health. Examples of these organizations include the Tomales Bay Watershed Council (TBWC), the Tomales Bay Shellfish Technical Advisory Committee (TBSTAC), the Tomales Bay Agricultural Group (TBAG), the Bolinas Lagoon Technical

Advisory Committee (BLTAC), the Friends of Alhambra Creek and other groups. NPS staff are involved to varying degrees with these community groups, often providing technical expertise in a variety of resource management fields.

1.3.1.5.1 Watershed Characteristics and Water Quantity: The hydrologic systems have high runoff in the wet winter, occasional flash floods, and very low to intermittent flow dominating summer conditions. In response to these hydrologic conditions and the highly active geologic processes associated with the San Andreas Fault, stream channels are typically dynamic. Outside of the SFAN parks many of these systems are highly confined, with natural processes engineered out of the stream system. Within the Marin and San Mateo County portions of GOGA, as well as PORE, watersheds remain fairly stable and functional, supporting threatened species such as coho salmon and steelhead trout. Stream systems in these areas have been impacted by historic or current agricultural activities, as well as more dispersed development.

The size of watersheds ranges throughout the SFAN: from the relatively small 1 mi^2 Franklin Creek watershed (JOMU) and 9 mi^2 Redwood Creek watershed (MUWO) to the approximately 88 mi^2 Lagunitas Creek watershed (PORE andGOGA). The drainage area of Chalone Creek (PINN) just downstream of the park is roughly 70 mi^2. There are 130 linear miles of streams within the legislative boundaries of the SFAN.

Stream discharge in network streams has been monitored by NPS for several years. Lagunitas Creek has been monitored by the USGS since 1974. The extremes for Lagunitas Creek for the period of record range from 22,100 cubic feet per second (cfs) in the floods of January 1982, to 0.01 cfs during the drought of 1977. Flows in Redwood Creek, Olema Creek, and Pine Gulch Creek range from intermittent to 3,000-4,000 cfs. The portion of Chalone Creek within PINN is ephemeral to intermittent in the summer. In winter, the highest recorded discharge of 2,850 cfs was recorded in 1998, an ENSO year.

The SFAN is located within two subregions of USGS Water Resource Region 18. These include Subregion 1805 – San Francisco Bay and Subregion 1806-Central California Coastal. PORE, GOGA, PRES, MUWO, FOPO, JOMU, and EUON fall within Subregion 1805 and PINN falls within Subregion 1806. JOMU is within the 644 mi^2 Suisan Bay hydrologic unit code (HUC). Parts of GOGA and EUON are within the 1200 mi^2 San Francisco Bay HUC. PORE and portions of GOGA are within the 339 mi^2 Tomales-Drakes Bay HUC. Portions of GOGA are within the San Francisco Coastal South HUC (256 mi^2).

1.3.1.5.2 Water Quality Criteria: The San Francisco Bay Regional Water Quality Control Board (RWQCB, part of the State Water Resources Control Board), regulates all of the park units except PINN. PINN is within the Central California Coast RWQCB. These Regional Boards establish management criteria for water bodies within the state of California. Through their Basin Plans the Regional Boards have set numerical and narrative objectives for surface waters (Cooprider 2004). Several parameters (e.g., nitrates, phosphates) that are considered of importance to existing SFAN park water quality monitoring programs do not have criteria established by the Regional Board. Basin Plans outline the beneficial uses assigned to each stream that is a significant surface water feature. The specific water quality criteria to be met will depend on the beneficial uses of each water body. The beneficial uses of the streams within the network range from wildlife habitat to municipal and agricultural supply. A separate document, the California Ocean Plan, was produced by the State Board to regulate ocean waters (California EPA 2001).

1.3.1.5.3 Significant Waters: The State Water Resources Control Board (part of the California Environmental Protection Agency) established five Areas of Special Biological Significance (ASBS) within the legislative boundaries of the SFAN parks in the 1970s. These include Point Reyes Headlands, Bird Rock, Double Point, and Duxbury Reef. The Point Reyes Headlands, Bird Rock, and Double Point are managed by PORE. Duxbury Reef is partly included within the PORE legislative boundary and extending into a Marin County park. These areas were chosen through a nomination process based primarily on habitat quality and are limited to coastal areas; inland areas have not yet been assessed. The procedure for this nomination process is in the California Ocean Plan (CEPA 2001) developed by the State Water Resources Control Board. No other "significant waters" (e.g., Outstanding Natural Resource Waters, or ONRW) exist in the SFAN or its extended watersheds.

1.3.1.5.4 Impaired Waters: In 2000, the San Francisco Bay RWQCB identified both Lagunitas Creek and Tomales Bay (PORE/GOGA) as impaired by fecal coliform, sediment, and nutrients (Cooprider 2004). In the same year, Marin County announced a fish consumption advisory for Tomales Bay due to mercury bioaccumulation associated with an abandoned mercury mine in the Walker Creek watershed. The RWQCB has established a timeline for development of Total Maximum Daily Loads (TMDLs) associated with these impairment listings. Required monitoring (by NPS and others) for the TMDL program will include monthly monitoring plus five consecutive weeks of monitoring in the winter. The preliminary water quality status report also includes a complete list of all impaired waterbodies within the SFAN and a review of past and proposed water quality monitoring (Cooprider 2004).

1.3.1.6 Biome: Biomes are large geographical areas characterized by major ecological communities of plants and animals that display distinctive adaptations to that particular environment (Botkin and Keller 1995). Climate and geology are the dominant environmental variables influencing organisms in a given area and are, therefore, the key determinants of biome types in a region. Biomes are classified according to their predominant vegetation, but associated seral communities and persistent, sub-dominant communities also are considered in most classification schemes.

The Mediterranean Division of eco-regions of California is situated on the Pacific coast between latitudes 30° and 45° N and is distinguished by alternate wet and dry seasons (Bailey 1995). Both the SFAN and the Mediterranean Network are within this division. The area is distinguished as a transition zone between the dry west coastal desert and the wet west coast. Mediterranean-type ecosystems host a disproportionate share of plant species worldwide in both the number of species and the number of rare or locally endemic species (Dallman 1998). The major biomes of the parks include forests, grasslands, savannahs, shrublands, wetlands and several types of aquatic environments.

The vegetation is typically dominated by hard-leaved evergreen trees and shrubs (sclerophyll forests) that can withstand severe drought and evaporation in the summer (Bailey 1995). The pattern of plant community distribution consistently has forest on north facing slopes and on wetter sites, chaparral/scrub on south facing slopes and drier sites, and riparian corridors between ridges and along valleys. Additionally, the plant communities vary with distance from the marine influence, and elevation. The SFAN parks span this Mediterranean transition zone and fall within three terrestrial provinces: the California Coastal Chaparral Forest and Shrub, the California Dry Steppe, and the California Coastal Steppe, Mixed Forest and Redwood Forest (Bailey 1995).

1.3.1.7 Marine Communities: Just as climate and geology determine the terrestrial biomes, so too are the marine biotic communities of central California. The California Pacific oceanic waters are in a transition zone between the Californian and Oregonian provinces (Valentine 1966). Generally, warm-temperate water species are associated with the southern, Californian province and cold-temperate species with the Oregonian province. The marine zones are generally divided into pelagic, subtidal, and intertidal zones based on water masses, distance from shore, bathymetry, and tidal exposure. The biota of these zones have distinctive communities. For example, in the pelagic zone, phytoplankton that bloom in summer and fall are the dominant vegetation type. In the subtidal zone, though, various species of kelp are dominant, and in the intertidal zone numerous algae adapted to daily desiccation are dominant. The simple classification by zonation, though, belies the complexity and dynamic nature of these ecosystems. Some habitats such as upwelling areas around islands and headlands are semi-permanent. However, nearshore currents driven by winds and tides form micro-habitats in the water column with jets, squirts and eddies are where organisms such as zooplankton are entrained. Predators are then attracted to these semi-permanent and ephemeral features.

Convergence of oceanic currents rising from the abyssal plain over a steep submarine cliff also makes the marine and coastal shoreline habitats complex and diverse. The California coast is only one of five areas of eastern boundary coastal upwelling, oceanic currents worldwide and the only one in North America (Thurman 1988). In addition, a plume of warmer, freshwater exiting the San Francisco Bay extends out into the Gulf of the Farallones. These nutrient rich waters support abundant and diverse fauna. This upwelling-driven productivity cycle is vulnerable, though, to changes in sea temperature along the equator resulting in changes in wind persistence and intensity (i.e., the Pacific Decadal Oscillation, the El Niño-Southern Oscillation, or La Niña events).

More than one-third of the world’s cetacean species occur in these waters. Significant haul-out areas for five species of pinnipeds are used year round and represent one of only eleven mainland breeding areas for northern elephant seals in the world and 20% of the mainland breeding population of harbor seals in California. Eleven species of seabirds breed within the parks and over 80 waterbird and shorebirds species were identified in the parks during the 1997-99 inventories (Kelly and Etienne 1999).

Recognizing the extraordinary significance of the marine region, the California Department of Fish and Game designated Point Reyes Headlands as a Marine Reserve and Limantour Estero as a an Ecological Reserve.

1.3.1.8 Natural and Anthropogenic Disturbances: Both abiotic and biotic processes comprise the natural disturbance regime responsible for shaping and reshaping ecosystems within the SFAN.

The dominant geological force—plate movement along the San Andreas Fault—has created unusual habitats from Pinnacles to Point Reyes for a variety of species including endemics and edge-of-range species. Seismic activity continues to alter the geologic landscape and soils, impacting the associated biota. The El Niño-Southern Oscillation and the Pacific Decadal Oscillation, natural change processes influenced by a combination of weather, climatic events, and oceanographic processes affect precipitation patterns and drought conditions, thereby enhancing fire potential, all of which affect community composition, structure, and function. They also dramatically change coastal and oceanographic processes, resulting in significant disruption of the trophic food webs of the marine ecosystems.

Fire is a significant source of ecological change that has historically shaped terrestrial ecosystems in the San Francisco area and continues to impact them (Moratto 1984). Sources of fire predominantly have been anthropogenic in nature, but non-anthropogenic wildfire has had a significant impact on SFAN ecosystems. Indigenous Americans frequently used fire in the Bay Area (Blackburn and Anderson 1993). Many managers and fire ecologists now consider pre-European indigenous burning to be part of the natural fire regime. The National Fire Plan (www.fireplan.gov) includes pre-European indigenous fire regimes in Fire Regime Condition Class analysis and in specifying desired conditions for landscape conditions. Several endemic plant species are fire adapted and require this natural disturbance for regeneration. Years of fire suppression and adjacent land management practices have altered the habitat. Poor fire timing and incorrect intensity of prescribed burns have converted entire vegetation communities, especially chaparral in PINN, to grassland (T. Leatherman, Chief of Natural Resources, Pinnacles National Monument, personal communication, 19 September 2001). Additionally, post-fire bare ground often encourages the growth of non-native plants. Human safety concerns continue to require wildland fire suppression, especially where vegetation communities are in close proximity to human structures. Air quality concerns in the Bay Area also limit park managers' ability to use prescribed fire.

Coastal ecosystems are created and recreated by erosional and accretive forces that change coastal habitats subtly over time or rapidly and dramatically as in the case of major storm events. Erosion and deposition are a part of hydrologic disturbance regimes in freshwater ecosystems, too. Flooding events shape stream morphology, deposit and flush materials from riparian wetlands, and transport materials and organisms to downstream ecosystems. Hydrologic disturbance may open small patches for colonization or restructure entire stream channels over both the long term and the short term.

With a current population of 7 million, the metropolitan centers of San Francisco, Oakland, and San Jose are forecast to have a population of 8 million by 2020 (Association of Bay Area Governments 2000). As a result, anthropogenic disturbances pose a significant threat to the integrity, connectivity and sustainability of the SFAN park ecosystems. The degree of threat to these resources is a result of the parks' juxtaposition within the urban landscape and the extensive urban/ wildland interface within the parks.

The PWR identified several of the most important anthropogenic issues to parks of the region in 2002 that included habitat fragmentation, fire management, rare and endangered species, invasive species, global climate change, and water quality/quantity (PWR Science Meeting, July 2002). These conservation issues are also the primary threats to the SFAN parks.

Recreational and development pressures on parks are intense in the SF Bay Area and will increase with the growing human population. GOGA, located in and around San Francisco has one of the largest visitation rates in NPS (19.7 million) and PORE has a visitation rate of around 2.5 million. PINN, though, is not as accessible and has a lower visitation rate of 160,000. Many activities have the potential to disrupt park resources, such as rock climbing and nesting falcons. These activities have the potential to exacerbate fragmentation by development by creating barriers to movement or isolating species. Recreational activities also have the potential to create pathways facilitating the spread of invasive non-native species.

Invasive species, plant and animal, terrestrial and aquatic, are one of the most significant threats to the long-term sustainability of the parks' native ecosystems. One third of the approximately 1200 plant species of GOGA, MUWO, and PORE are non-native. European beach grass has caused a type change in the coastal dune plant community. Feral pigs pose a major threat to native plants, displace native animals from traditional home ranges, degrade water quality, and threaten riparian habitats and species at PINN. Non-native deer and turkeys at PORE pose a serious threat to native plant and animal species.

Disease, herbivory, fire, flooding, mowing, mechanical fuel treatments, road and trail maintenance, and (human and equine) trampling are among the sources of biotic disturbance in the SFAN. Outbreaks of pine bark beetles, which can lead to pine pitch canker (*Fusarium subglutinans* ssp. *pini*) infestations destroy individual trees or entire stands, opening gaps in the forest canopy to colonization by the same or other tree species (Adams 1989). Likewise, periodic surges in ungulate populations can lead to over browsing of herbaceous vegetation, altering competitive interactions among plants and changing species composition of plants and, indirectly, animals. Sudden Oak Death (SOD) caused by an introduced pathogen (*Phytophthora ramorum*) first emerged nationally in the San Francisco Bay Area centered in Marin County in the mid-1990s. There is still a lot of research underway to determine the cause, extent and effects of this pathogen which has several native host species, and primarily kills oaks. Animal diseases have been documented in the area including Johne's disease, a paratuberculosis bacterium found in dairy cattle. This disease can infect native elk and deer populations. Human and domestic feline diseases were documented in native wildlife, including feline transmitted toxoplasmosis in California sea otters.

1.3.1.9 Species of Special Concern: The SFAN's unique ecological setting and close proximity to urban development have combined to produce an environment that is home to a variety of species of special concern. These species include endemic, sensitive, rare, threatened, or endangered species recognized by federal, state, regional, and park authorities (Appendix 2). GOGA and PORE combined have some of the highest numbers of listed species for any parks. Indeed, the Nature Conservancy identified central California as one of the 6th most biodiverse and at risk areas in the United States (Grossman 1998). Simultaneously, environmental conditions and anthropogenic activities have created suitable pathways for invasion by exotic species, exacerbating the stress on unique and at-risk species. Non-native species of concern also are listed in Appendix 2.

1.3.2 Management Objectives, Issues, and Monitoring Questions for Network Parks

1.3.2.1 Management Objectives: Each park was established to protect and preserve unique natural and cultural resources contained within its boundaries while providing for public enjoyment of these resources. Park-enabling legislation and other relevant documents such as Resource Management Plans direct park managers to identify management goals necessary to fulfill the park's founding purposes (Appendix 1). Management goals necessitate more specific management objectives. Management objectives and matching park resources need to be considered together for a monitoring plan to be successful and for the park to meet the overall goal of conservation. Table 1.3 lists the management objectives identified for the SFAN parks. These management objectives are compatible with a multi-faceted approach to monitoring natural resources that address specific management issues, focal species, and key properties and processes of ecosystem integrity. Collectively, individual park management objectives form the basis of the SFAN's management issues and monitoring questions.

1.3.2.2 Management Issues, Monitoring Questions, and Potential Vital Signs: The PWR has identified habitat fragmentation, water quality / quantity degradation, global climate change, endangered or sensitive species protection, non-native species invasions, fire management, and lack of scientific knowledge as the greatest issues facing ecosystem integrity in the region's national parks (PWR Science Needs Workshop 2002). In 2005, the Science Council and the Natural Resources Advisory Committee of the PWR identified priority conservation issues in common which reinforced and added to the 2002 priority list. Relevant issues to the I&M program include habitat fragmentation, changing fire regimes, park visitor capacity, invasive species, global climate change, soundscapes, increasing demands for energy and increasing demands for water quality/quantity (minutes from NRAC 2005 meeting; http://inside.nps.gov/regions/region.cfm?rgn=64&lv=2).

Table 0.3. Management objectives for SFAN parks.

Park	Management Objectives
Eugene O'Neill NHS	• Achieve an understanding of the natural ecosystem existing on the site prior to the O'Neill's arrival, the remnants of that ecosystem today, and preserve, protect, and interpret the natural scene associated with the estate during O'Neill's tenure. • Enhance conservation efforts of Las Trampas Regional Wilderness Area surrounding the site. • Contain or eliminate non-native invasive plants. • Evaluate the risk of and manage Sudden Oak Death.
Golden Gate NRA*	• Maintain the primitive and pastoral character of the parklands in northern Marin County. • Maintain and restore the character of natural environmental lands by maintaining the diversity of native park plant and animal life, identifying and protecting threatened and endangered species, marine mammals, and other sensitive natural resources, controlling exotic plants and checking erosion whenever feasible. • Locate development in areas previously disturbed by human activity whenever possible.

Park	Management Objectives
John Muir NHS	• Protect the natural scene associated with John Muir's days at the ranch. • Identify, monitor and manage the flora and fauna of the Mt. Wanda area. • Protect sensitive species. • Manage human and animal impacts on park natural resources. • Contain or eliminate non-native invasive plants.
Pinnacles NM	• Maintain the primitive character of the wilderness. • Preserve natural ecologic and geologic processes (e.g. fire, flood, mass wasting). • Maximize native species, assemblages, communities and ecosystems across a variety of temporal and spatial scales. • Provide for the scientific study of natural processes and species. • Recognize and allow for the natural range of variability, while promoting ecosystem resilience, incorporating adaptive management strategies. • Control and eradicate, when practical, non-native species.
Point Reyes NS	• Identify, protect, and perpetuate the diversity of existing ecosystems, which are representative of the California seacoast. • Preserve and manage wilderness. • Protect marine mammals, threatened and endangered species, and other sensitive natural resources found within the seashore. • Retain research natural area status for the Estero de Limantour and the Point Reyes Headlands. • Manage seashore activities in the pastoral and estuarine areas in a manner compatible with resource carrying capacity. • Monitor grazing and improve range management practices in the pastoral zone in cooperation with the ranchers and the Natural Resource Conservation Service. • Enhance knowledge and expertise of ecosystem management through research and experimental programs that provide sound scientific information to guide management relating to wildlife, prescribed burning techniques, exotic plant and animal reduction, regulation and control of resource use, and pollution control. • Monitor mariculture operations, in particular, the oyster farm operation in Drakes Estero, in cooperation with the California Dept. of Fish and Game.

* includes all parks administered by GOGA.

The SFAN altered the list to reflect those natural resource issues that are most pertinent to the network. Input from Resource Management Plans, internal and external reviewers, and Vital Signs scoping workshops contributed to the list of management issues and monitoring questions in Table 1.4. Monitoring questions, in turn, have helped the SFAN identify potential vital signs that may suitably address the monitoring questions related to the various management issues. Monitoring questions in Table 1.4 are applicable to all parks of the network. The SFAN intends to maintain and expand existing monitoring partnerships, so that the network can efficiently and effectively tackle the management issues.

Table 0.4. Monitoring questions and potential vital signs related to management issues for the SFAN parks.

Management Issue	Monitoring Questions	Potential Vital Signs
Climate Change	Are climate and weather changing over time? What impact does this have on biotic and abiotic resources?	Weather/Climate Shoreline change
Air Quality Degradation	Is air quality degrading? Where, why and at what rate of change? What impact does this have on biotic and abiotic resources?	Air Quality
Water Quality Degradation	What are the existing levels of water quality parameters? What is our level of compliance with beneficial uses? What are the long-term trends and ranges of core parameters? What are the pollution sources within the watersheds? Are management actions reducing pollutant loads?	Water Quality—clarity, core parameters, nutrients, pathogenic bacteria
Water Quantity Alteration	Are water storage levels in existing aquifers decreasing? Are there groundwater impacts on riparian habitat and wildlife?	Groundwater Dynamics
Human Population Increase	Where is the natural dark night sky affected by light? Is this changing over time? What impact does this have on biotic resources? Are airplane overflights increasing over the park, affecting natural quiet?	Light Quality/Quantity Noise Levels
Land Use Change/Development	What changes are occurring inside and outside park borders that may alter terrestrial and marine habitats?	Plant Community Change & Landscape Dynamics
Resource Extraction	How are commercial and recreational fisheries affecting marine resources?	Estuarine and Marine Fish Bycatch rates for non-target species
Soil Alteration	What effects do engineered structures and other anthropogenic stresses have on soil structure, texture and chemistry?	Soil Structure, Texture and Chemistry
Nutrient Enrichment	Are the effects of ranching degrading surrounding ecosystems? What are the effects of farming on surrounding ecosystems?	Riparian Habitat Water Quality Algal blooms
Park Development and Operations	Are deposition patterns changing on park beaches? Is erosion increasing in development zones?	Riparian Habitat Coastal processes
Recreational Use	Are recreational activities affecting birds including raptors, snowy plovers and spotted owls? Are recreational activities affecting breeding harbor seals?	Raptors—breeding Snowy plovers - breeding Harbor seals–breeding
Fire Management	How is the distribution and occurrence frequency, intensity or magnitude of wildland fires changing over time? What impact does this have on biotic and abiotic resources?	Catastrophic Events Documentation—Wildland Fire
Non-native Invasive Species/ Disease	What non-native taxa are present and how are they affecting distribution and abundance of other species in ecosystems such as rocky intertidal communities?	Rocky Intertidal Community; Non-native plant and animal species

Management Issue	Monitoring Questions	Potential Vital Signs
Native Species Decline and Extirpation	What are the trends in native species populations? What are the changes in cover of invasive species and native species? Are new rare plant populations becoming established within park boundaries?	Rare Plant Species Changes in biodiversity, abundance and dominance

Descriptions of the predominant drivers and stressors associated with these issues are included in Chapter 2: Conceptual Models. Specific research to address these overarching management issues are presented in the Pacific Coast Learning Center Science Needs web site for the SFAN (http://www.nps.gov/pore/science.htm). Science needs fall into fifteen categories including the definition of desired conditions, development of non-native species controls, and paleoecology.

1.3.2.3 Water Resources Monitoring Efforts and Questions, and Potential Vital Signs: Water Quality Planning meetings were conducted for each park or group of parks (GOGA/MUWO, PRES, PINN, JOMU, EUON, and PORE). A list of discussion questions was addressed at each meeting to determine park priorities, issues, and data needs (Cooprider 2004).

Information gathered from the Water Quality Planning Meetings (and from the SFAN Vital Signs Workshop in March 2003) was used to develop water resources and water quality monitoring questions and contribute to the list of potential water resources vital signs. Vital Signs Workshop participants recommended a suite of potential vital signs for monitoring water resources from harmful algal blooms to water clarity (a full list is included in the SFAN Preliminary Water Quality Status Report (Cooprider 2004)). The desired future condition is for water parameters to vary within natural ranges. The three key objectives are:

Objective1: Maintain waters that vary within their natural chemical and biological ranges and meet applicable federal and state water quality criteria (and/or parks' desired ranges)

Objective 2: Improve water quality of impaired waters (CWA Section 303d listed and other waters known to have poor water quality)?

Objective 3: Maintain high water quality where it exists.
This refers specifically to Areas of Special Biological Significance as designated by the state or other water bodies known (through past monitoring) to be of high quality (i.e., sites sometimes referred to as "reference", "control", or "wilderness" sites).

Based on these objectives, there are five monitoring questions:

1) What are the existing levels of water quality parameters (i.e., what is the baseline condition)?

2) What percentage of samples within a site and within a water body meet/exceed the criteria for aquatic health and public health (threshold values) and how does this vary seasonally (for core parameters, nutrients, and bacteria)?

3) What are the long-term trends and ranges in pH, D.O. temperature, specific conductance, and flow? (this aids in determining natural variability)

4) What are the pollution sources within the watershed?

5) Are management actions reducing pollutant loads?

1.4 Status of Monitoring Programs in and Adjacent to the SFAN Parks

1.4.1 Summary of Historical, Current, and Potential Monitoring Programs

Monitoring programs currently exist for some of the parks under previously developed vital signs models that include marine, freshwater, and terrestrial plant and vertebrate components as well as abiotic components. Several threatened or endangered (T&E) species, plant communities, water quality, air quality, geologic processes, and non-native invasive plants and animals are currently monitored (Table 1.5). The existence of these long-term data sets was considered as part of the vital signs selection and prioritization process. Many of the existing monitoring protocols for these vital signs require review and will need to be integrated into a larger, long-term monitoring program. Historic monitoring programs are described further in Appendix 3; however, it is not the intent of this document to provide an exhaustive account of other monitoring programs. Participating agencies and existing and potential monitoring partnerships are further described in Chapter 8. Much of the potential for monitoring partnerships exists because other agencies and institutions are planning or conducting their own monitoring programs on lands adjacent to the parks.

1.4.2 Summary and Analysis of Water Quality Monitoring Data

Key water quality issues in the network include impacts from agricultural operations on water quality and aquatic habitat, marine and estuarine protection and restoration, and restoration of aquatic and riparian habitat. Many of the park units in the SFAN have completed some level of land use assessment and water quality monitoring. The context of monitoring has been both regulatory and status/trends related. Through outside agency involvement and park initiative, recreational monitoring programs are in place for beaches at PORE and GOGA. NPS Director's Order # 83 is followed for beach water quality monitoring. Regional Water Quality Control

Table 0.5. Summary of current and historical monitoring programs within the SFAN parks as of 2004. Numbers in the columns for each park represent the number of years monitoring has been conducted in that park for the .orresponding program. Participating agencies and partners are listed for each program.

Monitoring Program	EUON	FOPO	GOGA	JOMU	MUWO	PORE	PINN	PRES	Participating Agencies and Partners**
ABIOTIC									
Air quality						20+	14		NPS, State
Air quality--visibility							H*		NPS
Cave conditions							6		NPS
Erosion monitoring				5			4		NPS
Fire history						30	24		NPS
Hydrologic monitoring			7-50			7			NPS, USGS
Night sky monitoring						1	3		NPS
Prescribed burn plots						14	14		NPS
Restoration site geomorphology							6		NPS
Scour chains (vertical)							H		NPS
Seismic activity	35	35	35	35	35	35	35	35	USGS
Shoreline change (LIDAR)			4			7			USGS
Stream geomorphology				2		7	6		NPS
Visitor trail use							5		NPS
Water quality			4	2	4	4	6		NPS, State
Watershed assessment			5	2	5	5			NPS, USGS
Weather	2			2		38	67		NPS, NOAA
BIOTIC									
Acorn production							H		NPS
Amphibians			10			10	4		USGS/NPS
Bank Swallows			9						NPS
Beached bird surveys			9			30			NPS,
Benthic invertebrates/intertidal zone			8			8			NPS
Butterflies (listed species)			10			10			NPS, Stanford
Cattle grazing (RDMs)			15			15			NPS
Coho salmon and steelhead trout			10			7			NPS
Cooper’s Hawk							H		NPS
Eel grass beds			10			10			NPS, CDFG

Monitoring Program	EUON	FOPO	GOGA	JOMU	MUWO	PORE	PINN	PRES	Participating Agencies and Partners**
Harbor seals			26			27			PRBO/NPS
Herons, egrets			10			7			NPS, Audubon
Juvenile rockfish			20			20			NMFS
Landbirds			9	1		39			NPS, PRBO
Mountain beaver			7			7			USGS
Nearshore productivity (CODAR)						3			UCD
Non-native plants (selected species)			10+	2		8	6		NPS
Northern elephant seals						22			PRBO/NPS
Northern Spotted Owls			9		9	9			NPS, PRBO
Oak mortality/reproduction				1			4		NPS
Pacific herring			25			25			CDFG
Prairie Falcon							16		NPS
Raptors			15						GGRO
Rare plants			10+			10+			CNPS, NPS
Red-legged frog						10	4		NPS, USGS
Seabirds (several species)			10			20			FWS, PRBO, NPS
Shorebirds/water birds			16			16			NPS, Audubon, PRBO
Small bird distribution/abundance							20		NPS
Small mammals						5	20		NPS, USGS
Steller and California sea lions						10			NPS
Stranded marine mammals			10+			20+			NMFS,MMC,MVZ
Terrestrial vertebrates			5			5			NPS, USGS
Townsend's big-eared bats						10+	6		NPS, USGS
Turkeys/Peafowl						4			NPS
Ungulates—elk						24			NPS, CDFG
Ungulates—native & exotic deer			3			3			NPS, CDFG
Western Snowy Plover			8			30			PRBO, NPS
Wildlife diseases (several)						5			NPS, UCD

*H=historical monitoring projects.
**Audubon=National Audubon Society; CNPS=California Native Plant Society; CDFG=California Department of Fish and Game; FWS=U.S. Fish and Wildlife Service; GGRO=Golden Gate Raptor Observatory; MMC=Marine Mammal Center; MVZ=Museum of Vertebrate Zoology; NMFS=US National Marine Fisheries Service; NOAA=US National Oceanographic and Atmospheric Administration; NPS=National Park Service; PRBO=Point Reyes Bird Observatory; Stanford=Stanford University; State=California state agencies; UCD=University of California at Davis; USGS=US Geological Survey.

Board requirements and American Public Health Association (1998) Standard Methods protocols are followed for all water quality monitoring. The USGS protocol is followed for all aspects of a pilot project to determine sediment load using the Turbidity Threshold Sampling Technique.

Table 0.6. Water resources monitoring summary.

Vital Sign	Monitoring Purpose	Parks Monitoring*
Water Quality	Status & trends / Regulatory	GOGA, PINN, PORE
Water Clarity	Status & trends / Regulatory	GOGA, PORE, PINN
Nutrients	Status & trends / Regulatory	GOGA, PORE, PINN
Metals	Status	GOGA, PINN
Pathogenic Bacteria	Status & trends / Regulatory	GOGA, PORE, PINN
Benthic Macroinvertebrates	Status	GOGA, PINN, PORE,JOMU
Oil/Hydrocarbons	Status & trends	
HAB	Status & trends	
Surface Water Dynamics	Status & trends	GOGA, PINN, PORE, JOMU
Groundwater Dynamics	Status & trends	PINN, PORE, GOGA
Oceanographic Physical Parameters	Status & trends	
Flooding	Status & trends	
Waves	Status & trends	
Drought	Status & trends	

* Includes past or present monitoring

Although data quality assurance indices have not been formerly developed for the water quality data, standard operating procedures were followed and metadata are available. Much of the data has been entered into established databases, but a significant amount of data also exists in spreadsheet or raw form. Portions of the existing water quality monitoring data for PORE and GOGA have been analyzed and synthesized into reports (Cooprider 2004). Data from PINN, GOGA, and PORE was analyzed through a contract with UC Berkeley. Parameters monitored include flow, temperature, pH, dissolved oxygen, salinity, specific conductance, nitrates, nitrites, ammonia, orthophosphates, indicator bacteria (fecal/total coliform, *E. coli*, and *enterococci*), metals, and total suspended solids. Not all of these parameters have been monitored at all parks or all stations within each park.

Monitoring efforts within GOGA (including PRES and MUWO) have been on going (though not continuous) since the late 1980's. Sites have been located in several different watersheds and monitoring has focused primarily on evaluating impacts associated with stable operations. PINN has conducted baseline water quality monitoring in Chalone Creek (at sites throughout the park) since 1997. PORE monitoring (since 1999) has focused on evaluating the impacts of agricultural operations (dairy cattle, beef cattle, and equestrian operations). Water quality monitoring of Tomales Bay and Drakes Estero has been ongoing since the early 1990s in conjunction with State Department of Health Services shellfish production requirements. In addition, the USGS has recently completed the last of a three-year National Water Quality Assessment Program (NAQWA) level water quality monitoring of four watersheds (within GOGA and PORE) supporting coho salmon and steelhead trout.

Pathogenic bacteria are a primary threat to water quality in SFAN. Indicator bacteria have consistently exceeded water quality criteria at many inland surface water monitoring sites at PORE and GOGA. This pollutant is also suspected to be a threat at JOMU and possibly PINN. Seasonal variability in bacteria concentrations has been detected and correlates with rainfall and runoff conditions. Efforts to improve water quality are on-going. A consultant for PORE has performed "Dairy Waste Management System Evaluations" for all of the ranches in the park. Best Management Practices have been implemented and research by local universities is proposed for the Tomales Bay watershed. For a more detailed summary of water quality data, see the SFAN Preliminary Water Quality Status Report (Cooprider 2004).

Chapter 2 Conceptual Models

2.1 Ecological Conceptual Models

An ecological conceptual model is a visual or narrative summary that describes the important components of an ecosystem and the interactions among them. Development of a conceptual model helps in understanding how the physical, chemical, and biological elements of a monitoring program interact, and promotes integration and communication among scientists and managers from different disciplines. Increased understanding and communication gained throughout this process may lead to the identification of potential vital signs (Roman and Barrett 1999). Ecological conceptual models also aid in defining relevant spatial and temporal scales to provide an appropriate context for the ecosystem components and processes being considered.

Conceptual models are expressed in many different forms, including tables, matrices, box and arrow diagrams, graphics, descriptive text, and combinations of these forms (Jenkins et al. 2002). Typically, audiences are most receptive to visual models, but the specific model form used will depend on the modeler's objectives (Noss 1990). Diagrams depict simplified relationships and system components, whereas text and tables provide details that may be lost in the simplified pictorial representations.

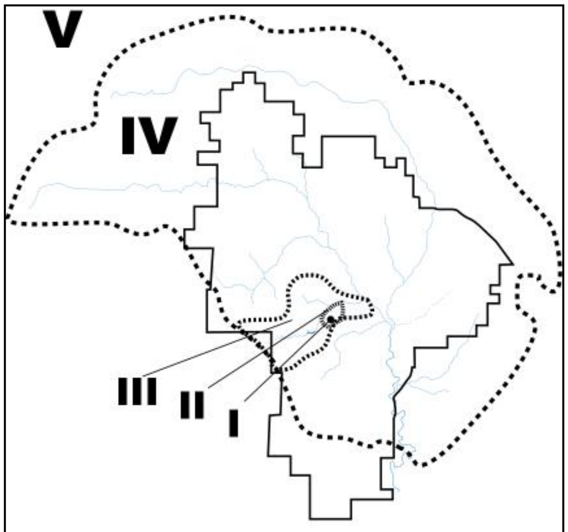
Unfortunately, no single model form describes an entire system adequately. Model generality is needed to characterize broad-scale influences and relationships among park resources, while model specificity is required to identify detailed relationships and components in the system that can be effectively monitored and subsequently managed. Consequently, both broad-scale models and specific models are needed to adequately represent ecological systems contained within large areas the size of national parks. Because of this need to integrate both broad- and fine-scale components and processes into an ecological conceptual model, the SFAN developed a hierarchical model with successive layers representing increasing model specificity.

Conceptual model development is an iterative and interactive process. Models are expected to change as a network's monitoring program develops and as ecological linkages are better understood. Details will be added to SFAN models, especially for vital sign specific models, as monitoring programs are implemented and assessed for the network.

2.2 Organizational Structure of SFAN Conceptual Models

The SFAN model is hierarchical, with each layer of the model becoming increasingly more specific. Layers of the SFAN model include:

1. A generalized conceptual model;
2. A matrix representing the relationship between drivers and stressors and general vital signs categories that group similar ecosystem components and processes; and
3. Three ecosystem models representing the dominant ecosystem types in the network - marine, aquatic/wetland, and terrestrial ecosystems.



Scale	Name	Size	Scale Synonyms
I	Habitat	20 m	Patch
II	Community	200 m	Vegetation Type
III	Sub Watershed	5 km	Landform
IV	Watershed	20 km	Park Boundary, aquifer
V	San Benito Co	50 km	Mountain range
VI	Cen Coast Ranges	100 km	Region, ecoregion

Figure 0.1. Nested spatial scale example relevant to the conceptual model, as depicted for PINN.

Coarse vital signs categories, that were more comparable for ranking purposes, were used in the matrix at the second level. The third level, ecosystem models, represent dominant drivers and stressors, the types of effects that can be measured, and specific indicators that were identified as potential vital signs for each ecosystem. Based on the third, fine-scale layer of the model, specific indicators were ranked to produce a list of high-priority vital signs. As the SFAN Vital Signs Monitoring Program develops, more refined diagrams will be created depicting understood and hypothesized relationships between drivers/stressors and specific, high-priority vital signs.

Nested spatial scales (Figure 2.1) ranging from 20-m^2 habitat patches to 100 km^2 coastal zones for marine ecosystems emphasize the importance of selecting vital signs that may be used to evaluate ecosystem integrity at various levels of ecological organization.

2.3 Description of Drivers

Ecosystem drivers are major external driving forces such as climate, biological processes, hydrologic cycles, and natural disturbance events (e.g., earthquakes, fire, droughts, floods) that have large scale influences on natural systems. Ecosystem drivers listed below are the product of network vital signs scoping workshops and represent the dominant external forces for the SFAN. Natural disturbance regimes are considered as part of each driver category. The strength, duration, and effects of these drivers will vary with the temporal scales at which they are measured. Furthermore, different species, communities and ecosystem will respond at different rates to these drivers. For example, the current species composition of some forest communities is the result of ecosystem drivers that were present several hundred years ago.

2.3.1 Solar/Lunar Cycles

Solar and lunar cycles include the rotation of Earth on its axis causing daily periodicity (i.e. night and day), the revolution of the moon around Earth creating variation in tides and lunar phases (lunar cycles), and the revolution of Earth around the sun causing seasonal changes. Over the course of time, plants, animals, and entire communities have evolved reproductive, growth, and behavioral characteristics in response to these cycles. For example, kangaroo rats avoid the heat of the desert sun through nocturnal habits, which are synchronized with lunar phases. Moonlight has been shown to affect many species including habitat use by small rodents. On full moon nights, some rodents are less likely to use open habitats for foraging (Jensen and Honess 1995). Moonlight also affects the nocturnal activities of seabirds during the nesting season (Hyrenbach and Dotson 2001). Organisms living in intertidal communities have adapted various physiologic traits and behavioral responses to contend with tidal fluctuations. Deciduous plants lose their leaves to reduce transpiration rates during winter months. Both solar and lunar cycles influence ecosystem dynamics at various spatial and temporal scales.

2.3.2 Climate/Weather

Climate is associated with the broad-scale, long-term patterns of weather which drive the distribution and abundance of biota in a given region or biome. For the SFAN, the temperature and precipitation patterns governing the flora and fauna are characterized by a moderate Mediterranean climate which offers long growing seasons and supports diverse plant and animal communities (Bailey 1995). On a geologic time scale, climate changes along with the organisms that are representative of a given biome. In contrast, weather is so variable from year to year that detection of significant change is difficult and requires long-term monitoring. Changes in the frequency and duration of weather events cause changes in the onset and duration of the growing season, phenology and other aspects of natural disturbance regimes, and may alter natural communities and facilitate general change in species/habitat distributions (Spellerberg 1991).

Regime shifts are also considered by some to be a natural driver for changes in ecosystems, especially marine systems. Regime shifts occur when previously steady patterns in population indices such as recruitment patterns and abundance or community indices, like species composition or trophic relationships, change concurrently with physical changes in climate systems (McKinnell et al.2001). Regime shifts are usually visible in multiple indices, such the Aleutian Low Pressure Index and Pacific Decadal Oscillation (Mantua et al.1997, Beamish and Bouillon 1993). For instance, recurring Pacific Decadal Oscillation or El Niño-Southern Oscillation events affect temperature and precipitation patterns and produce significant changes in abiotic and biotic ecosystem components (Thurman 1988). These changes are within the natural range of variation; although, human activities may be altering the frequency and intensity of these events (NAST 2001). Potential impacts to sensitive ecosystems, endemic species, and threatened or endangered species are of particular concern. A long-term meteorological monitoring program is essential to evaluate how meteorological change influences the functioning of ecosystems.

2.3.3 Geologic Processes

Geologic processes include tectonic, volcanic, surficial, and geomorphic processes. Volcanic activity, the force partly responsible for the Pinnacles formations, brings minerals and rock to the Earth's surface from its interior. Earthquakes, which can play a part in the physical breakdown and burial of rock surfaces, can expose new rock surfaces and minerals through uplift and rock shearing. Tectonic activity along the San Andreas Fault is a significant force shaping SFAN ecosystems and is responsible for thrusting the volcanic material at Pinnacles upward and for the formation of Tomales Bay and Bolinas Lagoon of GOGA and PORE. Newly exposed features provide opportunities for colonization by both flora and fauna, sometimes on distinctive formations or minerals of regionally unique composition. Mass movement works to breakdown geologic materials on a range of spatial scales from erosion of stream bank material to large landslides. Mass movement of rock, debris and sediment may take place suddenly (i.e. debris avalanches, lahars, rock falls and slides, or debris flows) or more slowly (i.e. slumping, creep, or slip). Other natural forces such as wind, water, and fire can affect the rate and magnitude of mass movement. In concert, geologic processes create unique formations such as caves, spires, and abyssal trenches, expose minerals such as serpentinite that influence biological activity, and alter surficial and geomorphic features to create a heterogeneous landscape (i.e. topographic and bathymetric variation; Bloom 1998). These processes set and reset the stage for colonization and establishment by diverse biological communities.

2.3.4 Nutrient Cycles

Nutrient cycles link the biotic and abiotic components of an ecosystem through a constant change of materials. The carbon cycle, for example, is an essential ecosystem process, in which insects, vertebrates, saprophytes, bacteria, fungi, and fire all play important roles. Nutrient cycling is considered an integrating variable, because the cycles occur across scales and involve the atmosphere, biosphere, lithosphere, and hydrosphere. While nutrients may be transported great distances in water or air, the key transformations that make these limiting elements available to plants (and so to animals) are driven by soil microbes, as are the reactions that release the elements back to air or water, to repeat the cycle. Ecosystems on stable trajectories have biological interactions that tend to conserve key nutrients (Chapin et al. 2002). Significant loss or gain of elements is a good indicator of change in the system such as acidification or large accumulations or losses of biomass. Upwelling of nutrient rich seawater is a primary driver behind the region's high level of productivity in the marine system.

2.3.5 Physical Oceanography

Oceanography is identified as the branch of science dealing with physical and biological aspects of the oceans. These physical and/biological aspects (including waves, oceanic circulation, tides, and the interactions with biotic elements) function together both as a driver and an indicator. Tsunamis, for example, inundate coastal areas causing changes in habitats, and species distribution and abundance. Daily, seasonal, and annual variation in tides and changes in ocean circulation (seasonal and annual) stress coastal areas. Examples of larger scale changes in ocean circulation include Pacific Decadal Oscillation, El Niño-Southern Oscillation, and North Pacific Oscillation and produce significant changes in abiotic and biotic components of the marine ecosystem (Thurman 1988). These physical and biological aspects of the oceans can also serve as excellent vital signs of ecosystem change. Examples of standard indicators measured by NOAA include sea surface temperature, sea surface salinity, seasonal and annual changes in sea level, the frequency of El Niño-Southern Oscillations, and the distribution of nearshore currents.

2.3.6 Coastal Processes

Erosion and accretion of shoreline deposits and relative shoreline position are important factors in determining the ecosystem health and appropriate land uses in coastal areas. Relative sea level variations may be natural responses to climate change, movements of the seafloor, isostatic adjustment, and other earth processes. Changes in relative sea level may alter the position and morphology of coastlines, causing coastal flooding, water-logging of soils, and a gain or loss of land (Carter 1988). Changes in the shoreline position may also create or destroy coastal wetlands and salt marshes, inundate coastal, and induce saltwater intrusion into aquifers, leading to groundwater salinization. Subtle changes in sediment supply and physical processes can shift the balance between shoreline stability and accretion or shoreline erosion (Carter and Woodroffe 1994). These shoreline changes may have significant implications for coastal ecosystems, human settlements, and land uses.

2.3.7 Hydrologic Processes

The physical, hydraulic, and chemical properties of streams and rivers determine their suitability as habitat for aquatic plants and wildlife. Conditions appropriate for salmon spawning, for example, are defined by water depth, water velocity, size of substrate, and availability of cover provided by overhanging vegetation, undercut banks, submerged logs and rocks, among other stream characteristics (Regart 1991). Similarly, flow frequency and duration, water depth and velocity, seasonality, and stream morphology dictate the composition and abundance of aquatic organisms at any given time. Hydrologic disturbance, particularly in the form of seasonal fluctuations and flooding, plays a key role in aquatic ecosystems of the SFAN. Flooding events alter succession, shift species composition, flush nutrients and other compounds into and out of the system (influencing terrestrial ecosystems, too), and reshape channel morphology (Gordon et al. 1992). Changes in sediment yield reflect changes in basin conditions, including climate, soils, erosion rates, vegetation, and topography. Fluctuations in sediment discharge affect many ecosystem processes and components downstream due to nutrient transport and sedimentation. Consequently, water chemistry fluctuates naturally as and when environmental conditions change, thereby affecting aquatic communities downstream.

2.3.8 Natural Fire Cycles

Fire is a significant driver for many ecosystems especially those characteristic of Mediterranean climates. Chaparral communities and Bishop pine forests are considered fire adapted. Fire changes community composition by consuming much of the living vegetation, litter, and dead material, releasing and killing or reducing the density of some species (Barbour et al. 1980). Fire regimes drive the distribution and abundance of serial stages of terrestrial plant communities in Mediterranean climates worldwide. Because of its prevalence as a natural disturbance, some plant communities in the San Francisco Bay Area are adapted to fire. Some species such as Bishop pine are fire dependent, relying on fire to open and release seeds from resinous cones which benefit from improved growing conditions such as available sunlight, a seedbed of bare mineral soil, and released nutrients. Other species including coast live oaks are fire tolerant, surviving and regenerating vegetatively following fire disturbance. Lightning, the most significant source of natural fires, is rare in the SFAN, but sparks from falling rocks, and spontaneous combustion of plant materials and organic matter can also ignite fires (Barbour et al. 1980). It is important to recognize that indigenous anthropogenic fire played an important role in shaping the plant communities and their distribution we see on the landscape today. The Fire Management Plans of SFAN parks and the NPS National Fire Plan acknowledge the ‘natural’ role of this historical fire regime.

2.3.9 Biological Processes

An ecosystem consists of plants, animals, and microorganisms interacting with each other (the community) and with their physical (e.g., soil conditions and disturbance regimes) and climatic environment in a given area. Communities change naturally over time in response to changes in environmental variables, disturbance regimes, and species interactions. Ecosystem integrity results from natural plant and animal interactions such as herbivory, facilitation, competition, biological invasions, predation, allelopathy, disease, and mutualism. These relationships allow for the flow of energy and the cycling of nutrients and other materials throughout the system (Chapin et al. 1997). Unnatural interactions between plants and animals may negatively affect ecosystem integrity (e.g., exotic deer browsing, invasive exotic plant species taking over dominance from native species, predation by non-native species or native species at unnatural population levels – predator pits). Natural genetic processes such as mutation, genetic drift, and natural selection are among the biological processes that occur on the wildlands managed by the NPS. The dynamic nature of interactions among species in an ecosystem may alter successional / evolutionary pathways, leading to changes in the structure, composition, and function of ecosystems (Chapin et al. 1997). For example, herbivory may lead to reductions in relative abundance or extirpation of one or more plant species, which may, in turn, reduce the abundance of certain habitat types for other organisms. These changes are part of natural fluctuations that ecosystems undergo and may lead to alternate developmental pathways for the ecosystem.

2.4 Descriptions of Stressors

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 (Barrett et al. 1976). Stressors cause changes in the patterns and processes of natural systems.

2.4.1 Climate Change

Long-term changes in weather produce The greenhouse effect, which warms the Earth's atmosphere, results from the interaction of solar radiation with accumulated greenhouse gases (e.g., carbon dioxide, methane, hydroflorocarbons, nitrous oxide, sulfur hexane fluoride, perflorocarbons, and water vapor) in the atmosphere. This warming effect has been enhanced over the past century by increased contributions of these gases, particularly carbon dioxide, from anthropogenic sources (NAST 2001). Potential consequences of this enhancement are rising ambient temperatures, changes in the initiation and duration of the growing season, increased drought occurrences, increased storm/flooding severity and frequency, increased biological invasions, shifting species ranges, and decreased predictability of weather patterns, all of which directly affect ecosystems.

These changes may also alter natural ecosystem disturbance regimes (including fire), and can facilitate nonnative species invasions. The San Francisco Bay Area is predicted to have increased rainfall, and more intense and more frequent El Niño-Southern Oscillation events (NAST 2001, Bakun 1990). Climate change models predict that sea levels may rise from 5-37 inches over the next 100 years (NAST 2001). Climate change may impact shoreline erosion, saltwater intrusion in groundwater supplies, and changes in wetland water regimes. These are vital resource management concerns along the 120 miles of the SFAN network shoreline. Increased and more intense precipitation would also increase erosion and flood events at all of the parks, which are characterized as erosible soils. Sea surface temperature is also predicted to continue to rise. Central California waters have already increased in temperature over the past 30 years, resulting in changes in the distribution of many marine species of invertebrates and fishes and the range extension of warmer water species (Croll et al. 2000).

2.4.2 Air Quality Degradation

Air quality degradation encompasses several different sources of stress including acid deposition, tropospheric ozone, an increase in the concentration and/or type of toxins and heavy metals, visibility/haze, and nitrification (EPA 1999). Any of these factors may interact with the others amplifying their effects on ecosystems. Of concern are impacts to plant communities, water quality, non-native species invasions, nutrient cycling, and unique habitats/species. For instance, acid deposition can result in the leaching of nitrogen and calcium from ecosystems thereby affecting productivity, soil chemistry, water quality, biodiversity, and resistance/tolerance of biota to other stresses (Adriano and Havas 1990). Increased deposition of heavy metals, especially mercury, may result in bioaccumulation and bioconcentration with potential toxic effects to primary, secondary, and higher consumers. Direct effects of elevated levels of carbon dioxide and tropospheric ozone on native and exotic biota include adverse changes in their competitive ability, distribution, and survival, reducing native biodiversity (Stiling et al 2002). Particulate matter reduces visibility, particularly with increased humidity, and can combine with tropospheric ozone to produce photochemical smog. Photochemical smog has been linked to respiratory ailments in fauna and reduced vigor in floral species (Chappelka et al. 1996, 1999).

2.4.3 Water Quality Degradation

Water resources are of national concern as water bodies are diverted, polluted, and used by conflicting interests. In the SFAN, water quality is a very high profile issue because of the network's proximity to a large urban area. Water quality concerns include external sources of pollution, inappropriate visitor use, atmospheric deposition (stream acidification), water pollution effects on park ecosystems and water use, and loss of aquatic biota (Karr and Dudley 1981). Industrial, agricultural and recreational pollution threatens the water resources of the parks. The Norwalk virus, for example, contaminated shellfish and sickened over 100 people in Tomales Bay in 1998 (Ketcham 2001). Where streams originate outside park boundaries, water quality changes, particularly nitrogen and phosphorus content, can be indicative of agricultural fertilizer use or signal a reduction in productivity and/or vegetative cover upstream (Fong and Canevaro 1998). Organic chemical content may indicate land use changes upstream, especially mining or industrial activity. These organics affect freshwater mussels and other aquatic organisms directly and are also indicative of overall watershed problems affecting riparian and terrestrial biota (Gordon et al. 1992). Inorganic chemicals such as pesticides and industrial waste also negatively affect aquatic biota. Increased acidity in aquatic systems can raise concentrations of dissolved aluminum, which is toxic to native aquatic and terrestrial biota (Adriano and Havas 1990).

2.4.4 Water Quantity Alteration

Streams, lakes, wetlands, and groundwater resources can be altered by impoundments, water withdrawal, expansion of impermeable surfaces in watersheds, climate change, loss of riparian buffers, and changes in runoff characteristics due to changes in plant community composition. Water transport and diversion are also stressors affecting sediment deposition/erosion, accretive/avulsive meandering, flow regimes (bankfull/dominant discharge/peak flow), and long-shore sediment transport (Brooks 2003). Impermeable surfaces and other products of urbanization can increase downstream flow extremes, causing habitat loss and fragmentation. Water level fluctuations in ponds, wetlands, and stream discharge are directly linked to groundwater levels and hydrology which influence vegetation dynamics. An understanding of water table levels is required for predicting the effects of natural and human-induced hydrological changes (e.g., sea level rise, drought conditions, municipal groundwater withdrawal) and the fate of contaminants (Fetter 2000). Groundwater may be the significant water source for certain riparian systems, wetlands, and municipal water supplies (sole-source aquifers). Altered water quantity can also affect water quality, flooding events, and water temperature profiles. Both terrestrial and aquatic ecosystems are affected by these alterations which, in turn, can lead to erosion or sedimentation, habitat degradation, non-native species invasions, riparian and wetland habitat loss, and decreased biodiversity (Gordon et al. 1992).

2.4.5 Human Population Increase

With a current population of 7 million people, the metropolitan centers of San Francisco, Oakland, and San Jose are forecast to have a population of 8 million by 2020 (Association of Bay Area Governments 2000). The preservation of biologically and geologically diverse habitats and their associated species, while providing opportunities for recreation, education and aesthetic enjoyment to a large urban population is a difficult balancing act. Population increase inevitably results in land use change. For the parks, this includes pressures from adjacent lands, as well as activities inside parks, such as trampling of sensitive plant communities, compaction of soils, creation of social trails, and excessive impact on caves, wetlands, and other sensitive ecosystems. Increasing human populations lead to sources of light and noise pollution, altering terrestrial and marine wildlife behavior and affecting feeding, migratory, and reproductive cycles (Avise and Crawford 1981, Bondello 1976, Brown 1990). Excessive noise levels also negatively affect visitor experiences. Human encroachment on park boundaries can also disrupt scenic overlooks that extend beyond park boundaries. Increasing numbers of people often increase the number of feral animals in the region, putting pressure on park wildlife and vegetation (Drost and Fellers 1995). Increasing vehicle traffic volume in and around the parks also leads to increased road mortality and the introduction of non-native species.

2.4.6 Land Use Change/Development

Land use change and development pressures manifest themselves in different forms including industrial and residential development, coastal development, aquaculture, storm water management, intensive grazing and agriculture, hazardous material spills, increased habitat loss and fragmentation, and increased visitor pressure on park resources (NAS 2000). Habitat fragmentation is one of the most significant products of land use change and encompasses many of the other issues threatening park lands. Habitat fragmentation is a function of edge-to-area ratio and habitat connectivity. Habitat fragmentation has cascading effects on habitat quality, quantity and distribution, predator and prey densities and distribution, nutrient levels, pollutant loads, and disease and pathogen incidence and distribution (Wilcove et al. 1986). Changes in land use within and adjacent to parks can also create barriers preventing the normal distribution or dispersal of species, isolating them on islands of parklands and altering gene flow. Parks may become sources or sinks for populations, and consequently, increase complexity of species management. Development can include construction of roads, buildings, and parking lots, wetland conversion, or conversion of adjacent agricultural land from grazing to vineyards. Certain species require open space for all or part of their habitat requirements, while other species require vegetation cover for their survival. Changes in the ratio of open space to cover are good indications of shifts in habitat availability for the relevant species and communities (NAS 2000). Land use changes and development can have significant impacts on habitat availability. Both the type and quantity of different land uses should be identified and monitored in and around the park.

2.4.7 Resource Extraction

Resource extraction results from dredging, sand mining, timber harvesting, harvesting of animals and herbaceous plants, recreational and commercial fishing, aquaculture and withdrawal of limited water resources. Because of these activities, dredge soil disposal, contamination, erosion, siltation, species loss, alteration of habitat, reduced water quality and quantity, and impacts from construction and access become significant management issues. In the SFAN, these issues concern all ecosystems, marine, terrestrial, and freshwater. Mineral and soil extraction can increase sedimentation of downstream water bodies or increase pollutant concentrations associated with extractive by-products. Extracting water, river rock, sand and gravel can alter habitat by changing flow volume and patterns, reducing bank stability and changing sediment deposition patterns (Brooks 2003). Water table changes may also occur as a result of mining and well drilling, which can affect ground water-dependent habitats (Fetter 2000). Poaching is also a problem for park biota within and adjacent to parks. Oil spills and hazardous chemical spills are of concern as well, since San Francisco Bay is a major shipping port. Genetic process can also be altered by anthropogenic stressors. For example several species in SFAN parks, including tule elk and northern elephant seals, have gone through genetic bottlenecks across their range due to historic harvest levels that brought populations down to a few individuals.

2.4.8 Soil Alteration

Soils are important to ecosystem integrity because they provide the primary media and components for most nutrient cycles while, in some cases, dictating the structure and functions associated with ecosystems on a given soil type. Soils can be altered by development activities, atmospheric deposition, climate change, altered precipitation patterns, water quality and quantity alteration, resource extraction, and changes in disturbance regimes. Erosion or sedimentation, soil compaction, changes in soil carbon and organic matter content, loss of soil biotic diversity, and altered soil chemistry can result from soil stressors. Erosion and sedimentation are directly indicative of soil disturbance and provide a good indicator of the rate or extent of land use change (NAS 2000). Although sediments are a natural part of most aquatic ecosystems, human activities have dramatically increased sediment inputs to lakes, streams and wetlands (Brooks 2003). Soil compaction can limit water infiltration, percolation, and storage, affect plant growth and alter nutrient cycling. Changes in soil carbon affect community productivity (Barbour et al. 1980). Soil organisms, which are sensitive to changes in soil structure and chemistry, are essential to the formation and maintenance of soils as well as being key components in nutrient cycles (Crossley and Coleman 2003). Significant alterations in soil biota will inevitably affect nutrient cycling and ecosystem functions.

2.4.9 Nutrient Enrichment

Nutrient enrichment (excess nitrogen and phosphorus concentrations) can affect marine, terrestrial, and aquatic ecosystems. Typically, nutrient enrichment results from excessive erosion, atmospheric deposition, agricultural and commercial fertilizers, aquaculture loading from feces, and runoff. Elevated concentrations of nitrogen and phosphorus instigate dramatic shifts in vegetation and macroinvertebrate communities, paving the way for non-native species invasions and reduced biodiversity. As an example, nitrogen-loading in shallow estuarine embayments can lead to shifts in the dominant primary producers (e.g., macroalgae may replace eelgrass), which can lead to declines in dissolved oxygen, altered benthic community structure, altered fish and decapods communities, and higher trophic responses (Bricker 1999).

2.4.10 Park Development and Operations

Increasing population has increased visitation in SFAN parks. The rise in visitation puts greater demand on park resources and often requires changes in the amount of infrastructure and operations. Park roads may need resurfacing or be extended. Parking lots may need to be expanded. Visitor and interpretive centers, campgrounds, and other facilities may need to be built, upgraded or maintained more frequently. Interpretive media needs to be maintained and sometimes relocated. On a broader scale, management activities such as installation of coastal barriers, fire suppression, grazing, invasive species control, removal of vegetation, and reclamation of nearshore areas can alter ecosystem structure and function. All of these activities impact the parks' natural resources and influence visitor use.

2.4.11 Recreational Use

Demographic changes can dramatically increase park visitation and recreational use, sometimes to unsustainable levels. This visitation pressure extends to trails, beaches and backcountry resources. The current broad variety of uses within the parks exacts a toll on the natural resources. Aircraft (hang gliders, ultralights, helicopters), surfing, dog walking, mountain bikes, horses, kayaking, environmental education groups and hikers combine to put continued strain on wildlife, vegetation, water resources, and soils. Also, the effects of recreational extraction (i.e. mushroom hunting, clam digging, fishing, seagrass harvesting) are poorly understood and has not been assessed for most activities. The millions of visitors that frequent the SFAN parks each year have adverse impacts to sensitive plants and wildlife. This high level of visitor use creates demands for continued park development, or upgrade of existing development, particularly of trails, which fragment wildlife habitat, bring people into sensitive areas, and contribute to off-trail use in these sensitive areas (NPS 1997). On the other hand, there is a direct correlation between visitor use and enjoyment, and public support for maintaining natural systems on NPS wildlands.

2.4.12 Fire Management

Fire can be a useful tool for managing fire adapted ecosystems in limiting invasive species, controlling fuel loads, and maintaining a mix of seral communities across the parks' landscapes. Fire prevention, suppression, and prescription all affect the trajectories of natural resource changes. While fire management may be necessary to maintain native ecosystems, our understanding of the appropriate fire intensity, frequency and duration required to do so is limited (Debano et al. 1998). Often, prescribed fires do not replicate natural fire, and burnt areas become vectors of non-native plant invasions (Meyer and Shiffman 1999). Burnt areas also are susceptible to erosion. Conversely, infrequent burns can result in excessive fuel loads leading to intense fires that damage or destroy less-tolerant species, and to the persistence of diseases.

2.4.13 Non-native Invasive Species/Disease

Non-native invasive species can reduce or eliminate native populations of flora and fauna, alter natural disturbance regimes, and change ecosystem functions. The sources of non-native species are varied and increase with the proximity to urban centers. The sustainability of threatened and endangered species and the loss of more common species are of special concern. Non-native invasive plants, animals, and pathogens also affect the structure and quality of habitat, alter species genetics and pollination dynamics, impact soil structure, biota, and chemistry, and can significantly affect watershed hydrology including evapotranspiration rates, stream flow, and erosion and sedimentation dynamics (Mack et al. 2000).

Disease is known to occur in all plant and wildlife populations and can significantly affect local demographics. However, the level of impact on a species population varies and is largely unknown. Bacteria, fungi, parasites, and viruses contribute to plant and wildlife diseases. Many disease agents and vectors are naturally found in the environment but their affect on species populations can be exacerbated by habitat fragmentation, overcrowding, genetic isolation, and climate change. Other diseases are introduced into populations by alien species and foreign sources and can have dramatic impacts on local populations. Sudden oak death syndrome is a major concern in the SFAN (Rizzo and Garbelotto 2003), and West Nile Virus is expanding in the region.

2.4.14 Native Species Decline and Extirpation

Significant change in native species diversity is a key early warning of ecosystem distress (NAS 2000). But, significant decline or loss of native species populations can also be a stress to a community or ecosystem in its own right. Maintenance of viable populations of native species is a fundamental part of maintaining ecological integrity. Declining native populations, then, can lead to impaired ecosystem functions such as productivity, nutrient cycling, nutrient retention, energy transfer, habitat diversity and quality, terrestrial and aquatic linkages, and hydrologic function (Tilman 1999). In some cases, declining biodiversity may be linked to functional impairment. In other instances, a loss of functionality may be related to the decline or loss of a particular species. Loss of keystone species (e.g., starfish), umbrella species (e.g., Northern Spotted Owl), or ecosystem engineers (e.g., mountain beaver) may be indicative of a shift in ecosystem type, resulting in cascading effects on other species (Paine 1969, Lambeck 1997, Simberloff 1998).

2.5 Generalized Conceptual Model

A generalized conceptual model was created to introduce the organizational structure of the SFAN model subcomponents (Figure 2.2). For conceptual purposes, ecosystems were divided into dominant resource realms—air resources (atmosphere), biotic resources (biosphere), water resources (hydrosphere), and earth resources (lithosphere)—to assist in organizing similar ecosystem processes and components. Then, ecosystems within the SFAN were divided into three types—marine, aquatic/wetland, and terrestrial—with each ecosystem type having associated subsystems or forms. Key drivers and stressors are also represented in this model acting on the different cosystems along pathways associated with each resource realm. Stressors can act on ecosystems through the different resource realms directly or they can affect drivers, which in turn, affect ecosystems via resource realm pathways. Note that socio-political forces influence anthropogenic stressors.

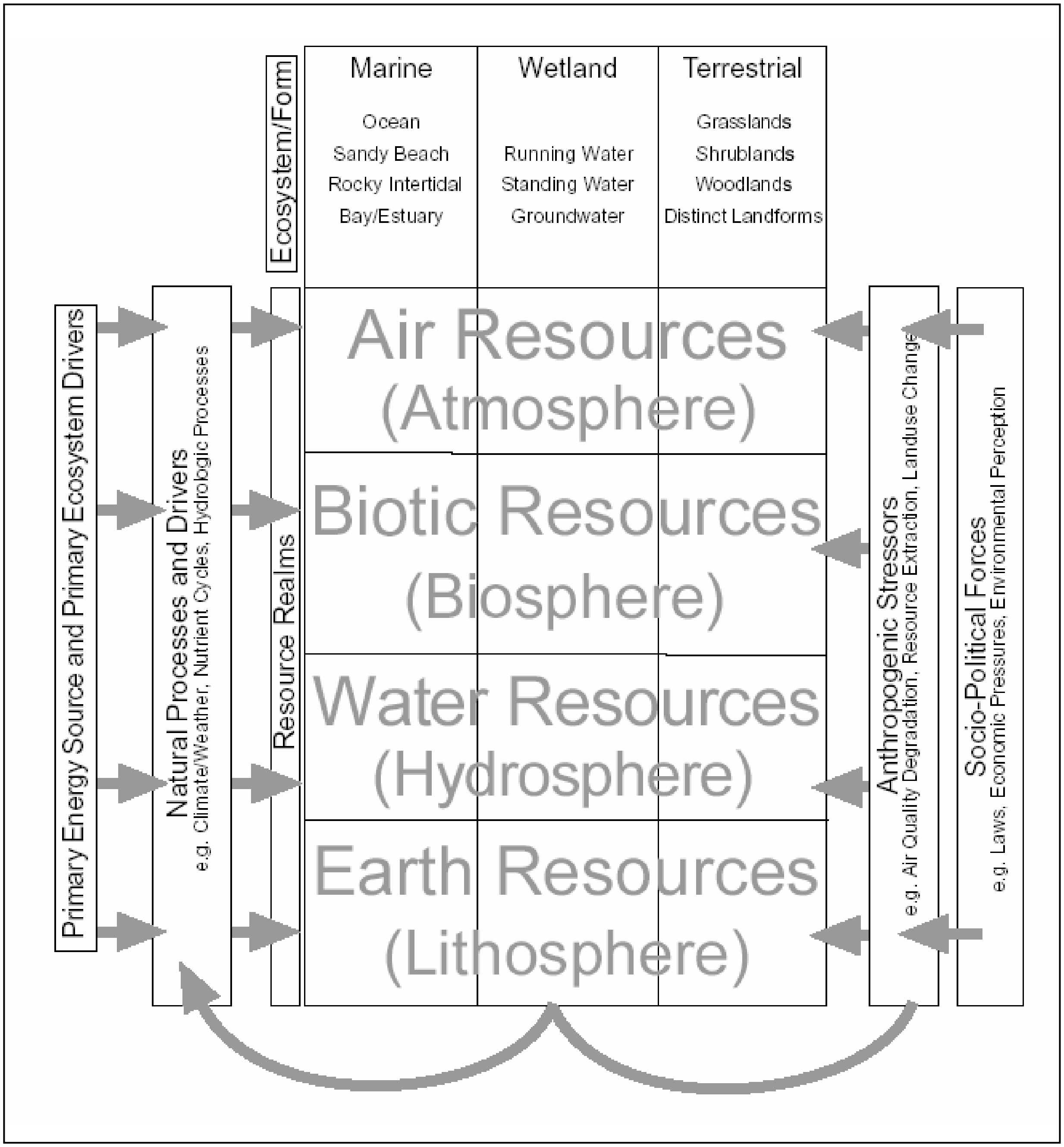


Figure 0.2. Generalized conceptual model for the SFAN.

2.6 Driver, Stressor, and Vital Signs Matrix

Significant relationships between broad-scale (general) vital signs, and drivers and stressors are summarized in matrix format (Tables 2.3 a-e). The matrix is continued on subsequent pages starting with the atmospheric realm on the initial page and ending with the lithosphere realm on the final page of the matrix. General vital signs are organized again by resource realm along the vertical axis. Drivers and stressors are aligned along the horizontal axis. Represented in each model are the dominant ecosystem drivers and stressors identified by the SFAN and through vital signs scoping workshops. An “x” is placed in any box where a vital sign intersects with a driver or stressor with which there exists a suspected or known significant relationship. General vital signs rather than specific vital signs are used to limit the model’s complexity and to simplify the initial vital sign prioritization process for this layer of the model.

Relationships represent our ecological understanding for one or more ecosystem types; therefore, not all relationships are applicable to all ecosystem types. Information collected from scoping workshops, inventory study plans, resource management plans, and from discussions with resource managers were used in the initial construction of the matrix. Relationships depicted in the final matrix are the result of expert input from network scoping workshops and may not represent all possible or “apparent” relationships. Rather, the matrix represents relationships between drivers/stressors and general vital signs identified by workshop participants as being scientifically justifiable and relevant to SFAN monitoring objectives.

The matrix allows for the qualitative comparison of general vital signs by showing which vital signs are affected by multiple drivers and stressors as well as which stressors affect multiple vital signs. In some cases, it may be desirable to choose vital signs with relative specificity to a given stressor. In others, it may be desirable to choose a vital sign that can serve as an early warning for multiple stressors. Ideally, both types of vital signs are represented in a vital signs monitoring program, as well as vital signs that represent different resource realms.

2.7 Ecosystem Models

Individual conceptual models are presented for each ecosystem type: marine (Figure 2.4), aquatic/wetland (Figure 2.5), and terrestrial (Figure 2.6). Represented in each model are the dominant ecosystem drivers and stressors identified by the SFAN, which were also listed in Tables 2.3a-e. Natural and anthropogenic forces produce changes in ecosystem processes and components through their interactions with the forms associated with each ecosystem. Example effects resulting from these interactions are listed in the models. Vital signs selected by SFAN that may assist in monitoring the effects of ecosystem drivers and stressors on ecosystems are depicted in the models. In some cases, a stressor or driver is considered a vital sign. Depicted in each model in bold are vital signs, stressors and drivers considered by the network for long-term

Table 0.1 Significant relationships between general atmospheric vital signs and drivers and stressors in the SFAN parks.

		DRIVERS									STRESSORS													
RESOURCE REALM	**GENERAL VITAL SIGNS**	Solar/Lunar Cycles	Climate/ Weather	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Natural Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
ATMOSPHERE	AIR QUALITY																							
	Chemistry - contaminants										x	x										x		
	Chemistry - nitrogen/ sulfur deposition				x						x	x										x		
	Chemistry - ozone										x	x										x		
	Chemistry - carbon dioxide, methane										x	x										x		
	Physics - fine particles										x	x										x		
	LIGHT and SOUND																							
	Lightscapes	x														x				x				
	Ultraviolet light (B)																							
	Soundscapes															x				x				
	WEATHER and CLIMATE																							
	Weather/ climate change		x	x	x	x	x	x			x	x										x		

Table 0.2 Significant relationships between general biotic (faunal) vital signs and drivers and stressors in the SFAN parks.

		DRIVERS									STRESSORS														
RESOURCE REALM	**GENERAL VITAL SIGNS**	Solar/Lunar Cycles	Climate/ Weather	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Natural Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
BIOSPHERE	FAUNAL DYNAMICS																							
	Species distribution and abundance	x	x		x	x	x		x	x			x	x	x	x	x	x	x	x		x	x	x
	Native species of special interest	x	x							x			x	x	x	x	x	x	x	x		x	x	x
	Species at risk	x	x							x			x	x	x	x	x	x	x	x		x	x	x
	Non-native invasive species/disease		x				x	x	x	x			x		x	x	x	x	x	x		x	x	x
	Patch size and proximity		x				x	x	x	x				x	x	x	x	x	x	x		x	x	
	Community area and distribution		x				x	x	x	x			x	x	x	x	x	x	x	x		x	x	x
	Land use patterns		x	x		x	x								x	x	x	x		x				

Table 0.3 Significant relationships between general biotic (vegetation) vital signs and drivers and stressors in the SFAN parks.

RESOURCE REALM	**GENERAL VITAL SIGNS**	**DRIVERS**									**STRESSORS**													
		Solar/Lunar Cycles	Climate/ Weather	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Natural Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
BIOSPHERE	VEGETATION DYNAMICS																							
	Species richness and diversity		x				x	x	x	x				x	x	x		x			x	x	x	x
	Native species of special interest	x	x				x	x	x	x				x	x	x		x				x	x	x
	Species at risk	x	x				x	x	x	x				x	x	x		x				x	x	x
	Non-native invasive species/disease						x	x	x	x				x	x	x		x	x	x	x	x	x	
	Vegetation composition and structure		x				x	x	x	x				x	x	x		x				x	x	x
	Community assemblages	x	x				x	x	x	x	x			x	x	x		x				x	x	
	Fragmentation and connectedness						x	x	x					x	x	x		x				x		
	Land use patterns													x	x	x	x	x			x		x	
	Phenology	x	x			x	x	x	x	x		x	x	x					x					
	Biological processes	x	x		x	x		x	x	x		x	x	x	x	x	x	x				x	x	x

Table 0.4 Significant relationships between general hydrospheric vital signs and drivers and stressors in the SFAN parks.

RESOURCE REALM	GENERAL VITAL SIGNS	DRIVERS									STRESSORS															
		Solar/Lunar Cycles	Climate/ Weather	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Natural Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
HYDROSPHERE	Water chemistry		x		x		x	x		x	x		x	x	x	x		x	x	x				
	Water clarity		x		x		x	x					x	x	x	x	x	x	x	x	x			
	Water contaminants		x		x			x					x	x	x			x	x		x		x	x
	Pathogenic bacteria		x		x		x	x		x	x		x	x	x			x	x		x			x
	Surface water dynamics		x	x				x		x	x			x	x	x	x			x				
	Groundwater dynamics		x	x				x						x	x	x	x			x				
	Physical oceanography		x			x				x	x					x				x				
	Flooding		x					x		x	x			x		x	x			x				
	Waves	x	x				x				x					x				x				
	Drought		x					x	x	x	x			x								x		

Table 0.5 Significant relationships between general lithospheric vital signs and drivers and stressors in the SFAN parks.

RESOURCE REALM	GENERAL VITAL SIGNS	DRIVERS									STRESSORS													
		Solar/Lunar Cycles	Climate/ Weather	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Natural Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
LITHOSPHERE	Habitat patterns/surficial processes		x	x	x		x	x		x						x				x		x		
	Soil biota									x								x						
	Soil chemistry and contaminants				x					x		x						x	x					
	Soil structure and texture				x			x	x	x						x		x		x				
	Soil erosion an deposition (paleoclimate)		x	x			x		x	x	x							x	x					
	Shoreline shifts		x	x			x			x						x				x	x			x
	Earthquakes			x			x	x								x				x				
	Mass wasting		x	x			x				x					x				x				

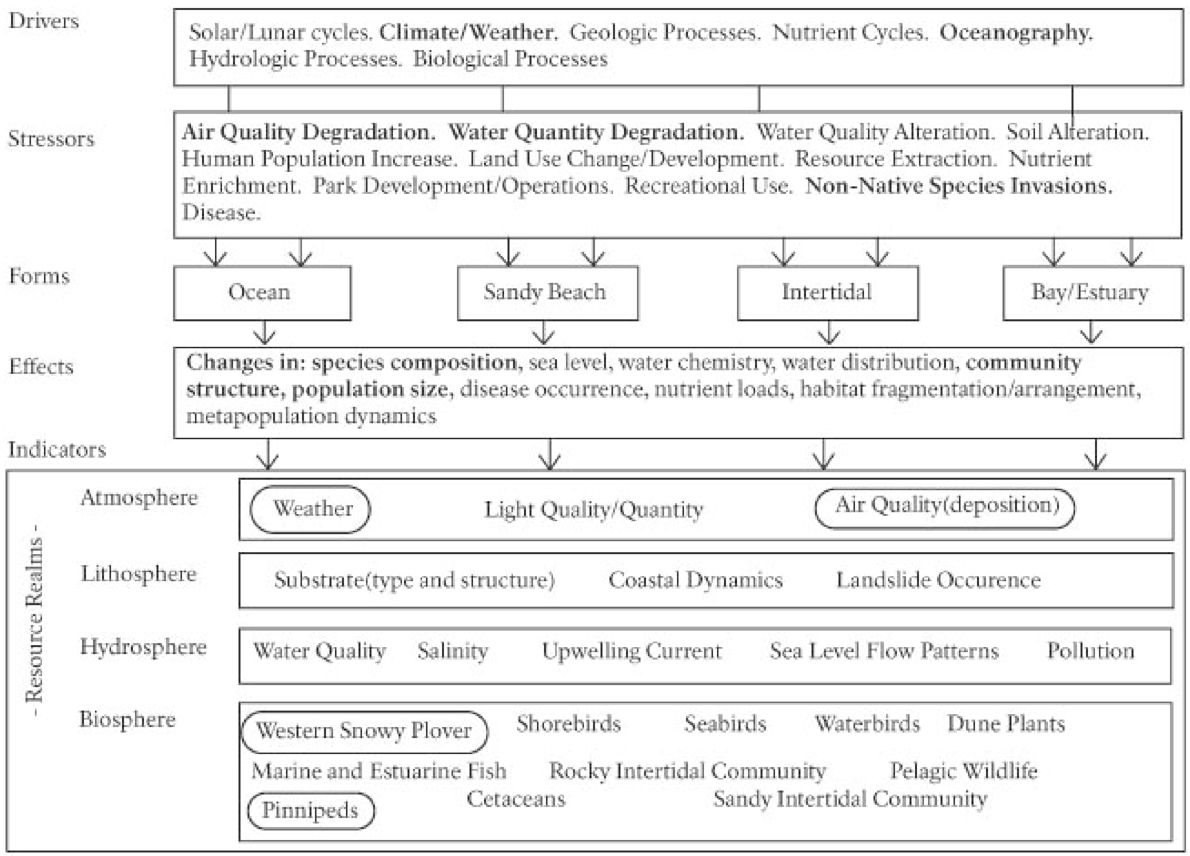
monitoring. Vital signs are organized by resource realm. Note that not all possible effects or all possible indicators are depicted in the diagrams because of spatial restrictions. Some vital signs, such as Air Quality, Water Quantity or Plant Communities, may appear in more than one ecosystem, because the changes in that indicator may reveal changes to more than one ecosystem. The bolded items that are circled indicate the high priority vital signs that have been chosen for long-term monitoring. The bolded effects will likely be monitored using the vital signs (see chapter 3 for details about the vital signs prioritization and selection process).

2.8 Specific Vital Sign Example

As the vital signs monitoring program proceeds, more detailed conceptual models will be designed focusing on chosen, high priority vital signs. Detailed models will allow the parks to evaluate and choose the most appropriate parameters to measure (Figure 2.6).

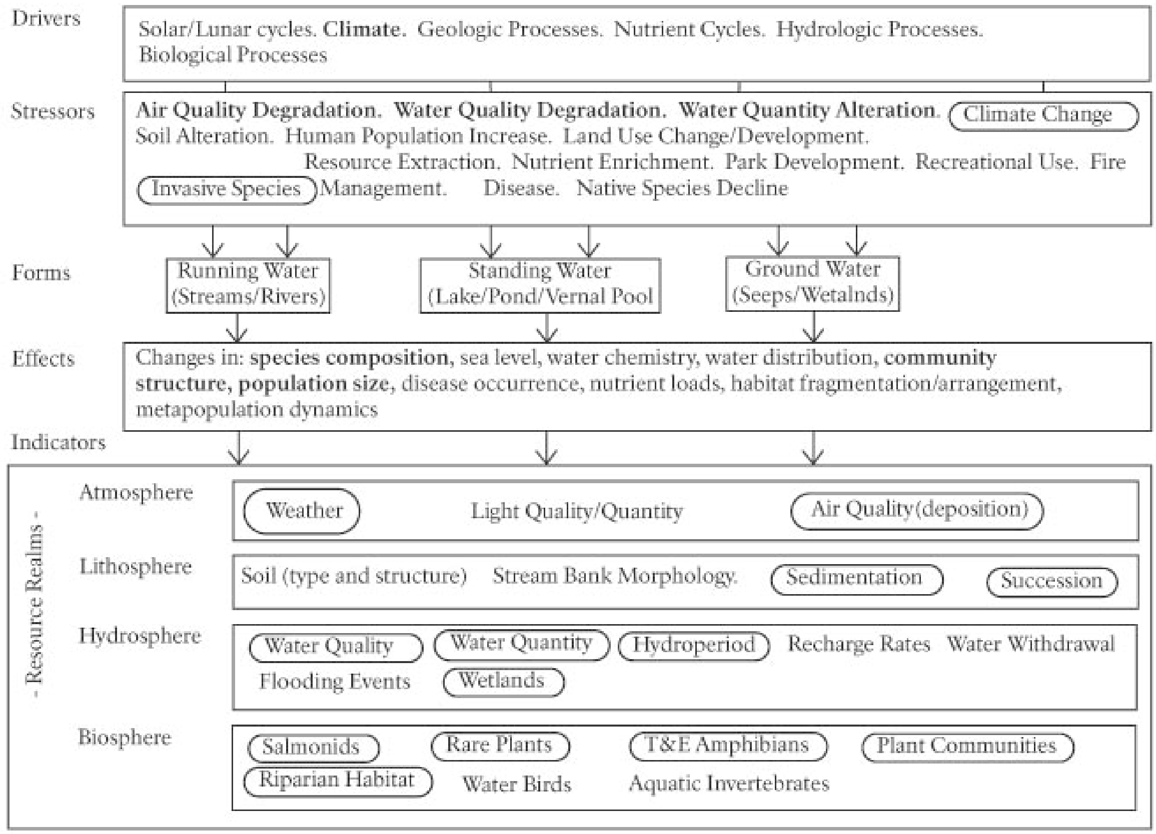
2.9 Implications for Vital Signs Selection

Ecosystems are, by definition, complex systems. Conceptual models assist in isolating ecosystem components, functions, and structures of known or potential importance to the integrity of the system. Each of these "vital" attributes can, therefore, serve as an indicator of ecosystem integrity. Still, the list of possible and credible vital signs is long, and there are often multiple metrics that can be measured for each vital sign. Spatial sampling design and sampling methods can be complex and may require expensive equipment or analyses. Park networks also have limited fiscal, temporal, and human resources. It is, therefore, necessary to prioritize the list of potential vital signs, to determine what vital signs are most important for individual parks and for the network. It is also necessary to select from the prioritized list of vital signs that integrate multiple attributes of ecosystem structure and function and that represent a variety of spatial and temporal scales (Holling 1986). Development of ecological conceptual models is the first step toward selecting appropriate vital signs.



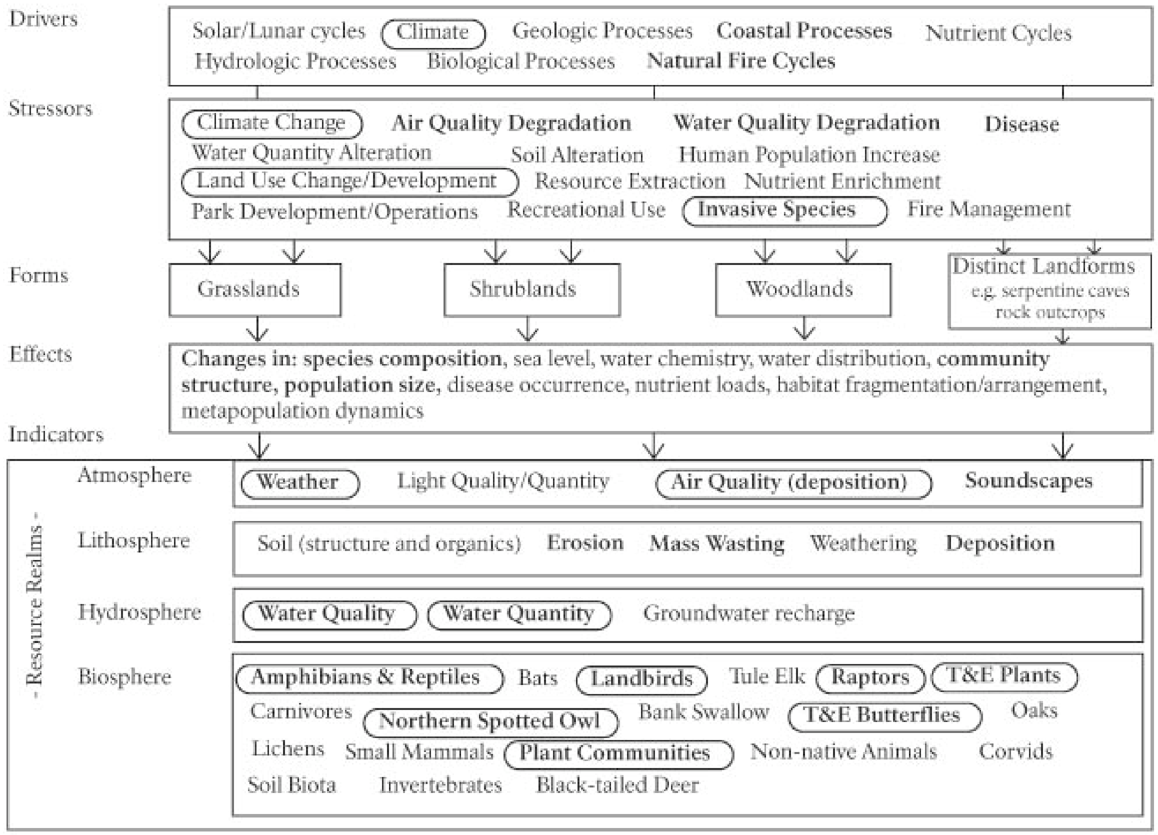
Marine ecosystems conceptual model.

Figure 0.3. Marine ecosystems conceptual model of how drivers and stressors act through different marine ecosystem forms to produce changes in components of different resource realms within the SFAN.



Aquatic/Wetland ecosystem conceptual model.

Figure 0.4. Aquatic/Wetland ecosystem conceptual model of how drivers and stressors act through different aquatic ecosystem forms to produce changes in components of different resource realms within the SFAN.



Terrestrial ecosystem conceptual model.

Figure 0.5. Terrestrial ecosystem conceptual model of how drivers and stressors act through different terrestrial ecosystem forms to produce changes in components of different resource realms within the SFAN.

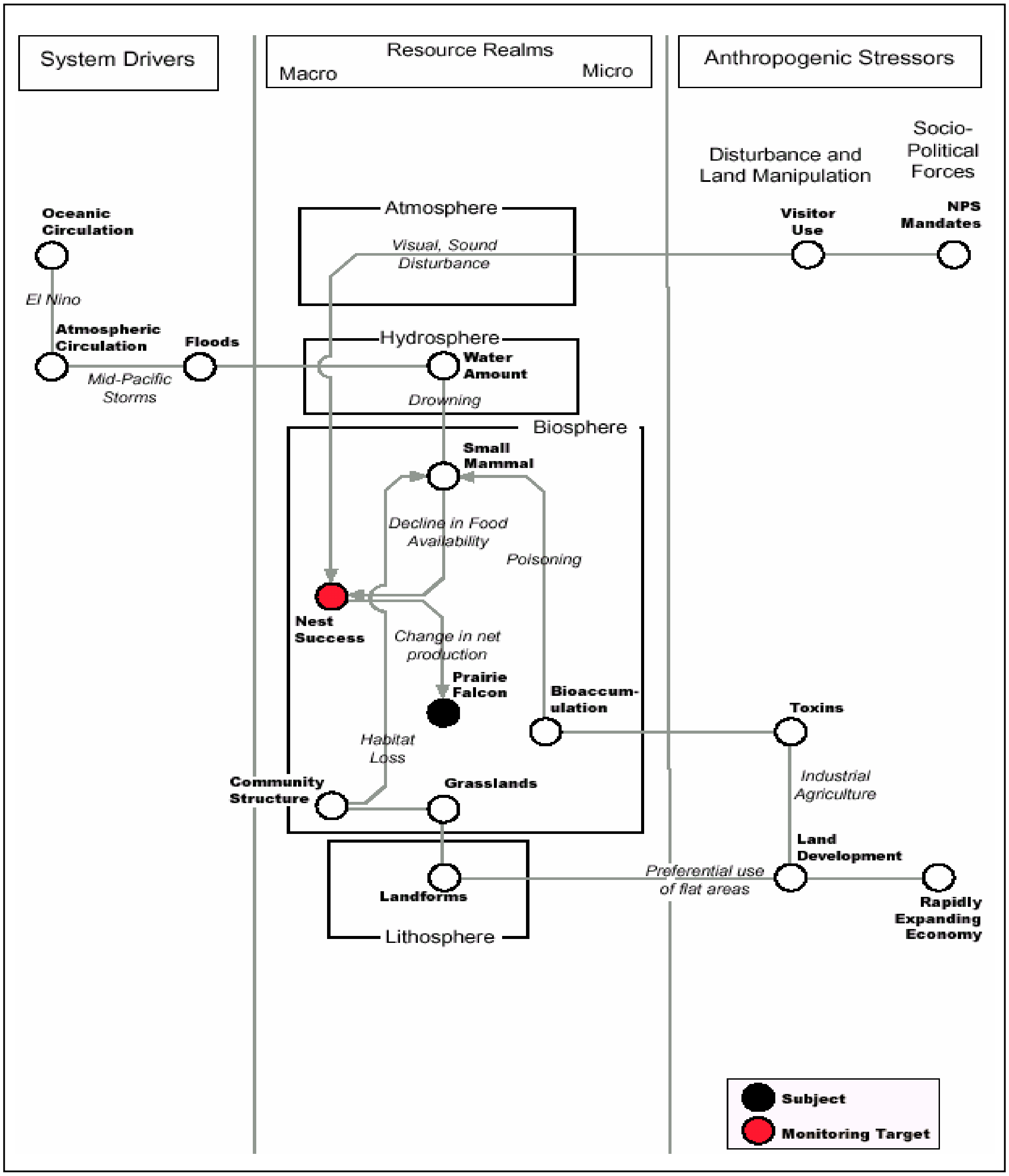


Figure 0.6 Example of a conceptual model for a specific vital sign (raptors and condors) and a measurable parameter (prairie falcon nest success).

Chapter 3 Vital Signs

3.1 Overview of the Vital Signs Selection Process

Vital signs are defined 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” (Davis 2005). 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 complex task of developing a network vital signs monitoring program requires a front-end investment in planning and design to ensure that monitoring will meet the most critical current and future information needs of each park and produce scientifically credible data that are accessible and meaningful to managers and researchers in a timely manner. The investment in planning and design also ensures that monitoring will build upon existing information and understanding of park ecosystems and make maximum use of partnerships with other agencies and academia.

Vital signs selection is an iterative process; as our understanding of ecological processes, the nature of variation within and between vital signs and linkages grows, vital signs may change. Adjustments to the monitoring program also may occur as subsequent programmatic and individual protocol reviews provide feedback on the value of the selected vital signs toward the monitoring objectives. The following sections briefly explain the SFAN decision–making and prioritization process. A more detailed description of the process, methods, and products can be found in the SFAN Phase II Monitoring Plan (SFAN 2003).

3.2 SFAN Vital Signs Selection Process

The SFAN vital signs selection process began with a series of park scoping workshops and a network wide Vital Signs Workshop to create an initial broad list of potential vital signs. The list of potential vital signs was refined by technical expert focus groups and ranked by NPS staff and experts. SFAN and park staff reviewed the resulting, prioritized list to ensure that vital signs represented a range of resource realms. Table 3.1 highlights some of the important steps in the SFAN process and their action dates.

Table 0.1 Important activities and dates in the SFAN vital signs selection process.

Activity	Date(s)
GOGA and PORE workshop to identify joint vital signs	July 1997
Individual park workshops to identify vital signs	2001-2002
SFAN Vital Signs Workshop	March 19-20, 2003
Ranking through online vital signs database	June 20 – July 11, 2003
Vital Signs Prioritization meeting with SFAN Park Staffs	July 29-30, 2003
Recommendations to Board of Directors	August 25, 2003
Submit draft Monitoring Plan (Phase II) to WASO	September 26, 2003
Submit draft Monitoring Plan (Phase III) to WASO	December 15, 2004
Submit final Monitoring Plan to NRPC	September 30, 2005

3.2.1 Scoping Workshops

Vital signs scoping workshops at each SFAN park in 2001 provided the foundational materials and direction on which to build the SFAN vital signs selection process. In each of these workshops, participants identified significant resources in the parks, identified key processes and stressors affecting the parks, drafted potential monitoring questions, and recommended vital signs that could address the monitoring questions. An initial prioritization of vital signs and development of a conceptual model were also conducted at the park level.

The March 2003 SFAN Vital Signs Workshop consolidated the park-specific information into a conceptual model, relevant monitoring questions, and potential vital signs that could be applied across the network. Information from the park workshops and the March scoping workshop was used to:

- Revise conceptual model components;
- Develop a vital signs list derived from completed protocol questionnaires;
- Identify gaps in our understanding and organization of potential vital signs;
- Select methodologies for prioritizing vital signs; and
- Identify initial sampling designs and monitoring protocols related to the potential vital signs discussed in the workshops.

A summary of the comments resulting from the workshops can be found in the SFAN Phase I Draft Report and the SFAN Phase II Draft Report (SFAN 2001b, SFAN 2003).

3.2.2 Technical Expert Focus Groups

Recommendations made during all of the workshops were further refined using technical expert focus groups, i.e. vegetation, wildlife, marine, geology, and water resources. Focus groups consolidated several of the potential vital signs so that comparisons could be made among larger groups of vital signs. Focus groups also developed the initial protocol development summaries, which provide in-depth information about vital sign justification, vital sign metrics, monitoring scale and methodologies, assumptions, constraints, potential thresholds for monitoring, and management actions if the thresholds are reached or exceeded.

3.2.3 Ranking Criteria

The four criteria utilized to rank vital signs reflect important qualities of an effective vital signs monitoring program and were modified from the Cumberland-Piedmont Network ranking criteria, Jackson et al. (2000), Tegler et al. (2001), and Andreasen et al. (2001) (Table 3.2). The four criteria are Ecological Significance, Management Significance, Legal Mandate and Cost and Feasibility. Sub-criteria describe the decisive factors associated with each primary criterion, and the prioritization scheme defines the rationale behind assigning a given value to each criterion. Only NPS staff ranked vital signs using the Legal Mandates criterion, because of the specific knowledge of NPS and federal policies used in the description of the prioritization scheme. Each criterion was weighted to reflect its relative contribution to the selection of SFAN vital signs.

Table 0.2 Criteria used to prioritize SFAN vital signs.

Primary Criteria	Sub-criteria*	Prioritization Scheme
Ecological Significance	o There is a strong, defensible linkage between the vital sign and the ecological function or critical resource it is intended to represent. o The vital sign represents a resource or function of high ecological importance based on the conceptual model of the system and the supporting ecological literature. o Data from the vital sign are needed by the parks to fill gaps in current ecological knowledge. o The vital sign provides early warning of undesirable changes to important resources. It can signify an impending change in the ecological system. o The vital sign has a high signal to noise ratio and does not exhibit large, naturally occurring variability. o The vital sign is sufficiently sensitive; small changes in the vital sign can be used to detect a significant change in the target resource or function. o Reference conditions exist within the region, and/or threshold values are specified in the available literature that can be used to measure deviance from a desired condition. o The vital sign complements vital signs at other scales and levels of biological organization.	*Very High*—I **strongly agree** with at least 7 of these statements. *High*—I **strongly agree** with at least 5 of these statements. *Moderate*—I **strongly agree** with at least 4 of these statements. *Low*—I **strongly agree** with at least 1 of these statements. *Very Low*--This is an important vital sign to monitor, but I do not **strongly agree** with any of these statements. *No opinion*--I do not know enough about this criterion for this vital sign to rank it.

Primary Criteria	Sub-criteria*	Prioritization Scheme
Management Significance	o There is an obvious, direct application of the data to a key management decision, or for evaluating the effectiveness of past management decisions. o The vital sign will produce results that are clearly understood and accepted by park managers, other policy makers, research scientists, and the general public, all of whom should be able to recognize the implications of the vital sign's results for protecting and managing the park's natural resources. o Data are badly needed to give managers a better understanding of park resources so that they can make informed decisions. o Monitoring results are likely to provide early warning of resource impairment, and will save park resources and money if a problem is discovered early. o In addition to addressing a specific management decision, data provide information that strongly support other management decisions. o Data are of high interest to the public. o There is an obvious, direct application of the data to performance (GPRA) goals.	*Very high*—I **strongly agree** with at least 6 of these statements. *High*—I **strongly agree** with at least 5 of these statements. *Moderate*—I **strongly agree** with at least 3 of these statements. *Low*—I **strongly agree** with at least 1 of these statements. *Very Low*— Some of the statements above apply to some degree, but I do not **strongly agree** with any of these statements. *No opinion*—I do not know enough about this criterion for this vital sign to rank it.
Legal Mandate	This criterion is part of 'Management Significance' but is purposely duplicated here to emphasize those vital signs and resources that are required to be monitored by some legal or policy mandate. The intent is to give additional priority to a vital sign if a park is directed to monitor specific resources because of some binding legal or Congressional mandate, such as specific legislation and executive orders, or park enabling legislation. The binding document may be with parties at the local, state, regional, or federal level.	*Very High*—The park is **required** to monitor this specific resource/ vital sign by some specific, binding, legal mandate (e.g., Endangered Species Act for an endangered species, Clean Air Act for Class 1 airsheds), or park enabling legislation. *High*—The resource/vital sign is specifically covered by an Executive Order (e.g., invasive plants, wetlands) or a specific Memorandum of Understanding signed by the NPS (e.g., bird monitoring), as well as by the Organic Act, other general legislative or Congressional mandates, and NPS Management Policies. *Moderate*— There is a GPRA goal specifically mentioned for the resource/vital sign being monitored, or the need to monitor the resource is generally indicated by some type of federal or state law as well as by the Organic Act and other general legislative mandates and NPS Management Policies, but there is no specific legal mandate for this particular resource.

Primary Criteria	Sub-criteria*	Prioritization Scheme
		<u>*Low*</u>— The resource/vital sign is listed as a sensitive resource or resource of concern by credible state, regional, or local conservation agencies or organizations, but it is not specifically identified in any legally-binding federal or state legislation. The resource/vital sign is also covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management Act and GPRA, and by NPS Management Policies. <u>*Very Low*</u>— The resource/vital sign is covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management Act and GPRA, and by NPS Management Policies, but there is no specific legal mandate for this particular resource. <u>*No opinion*</u>—I do not know enough about this criterion for this vital sign to rank it.
Cost and Feasibility	o Sampling and analysis techniques are cost-effective. Cost-effective techniques may range from relatively simple methods applied frequently or more complex methods applied infrequently (e.g., data collection every five years results in low annual cost). o The vital sign has measureable results that are repeatable with different, qualified personnel. o Well-documented, scientifically sound monitoring protocols already exist for the vital sign. o Implementation of monitoring protocols is feasible given the constraints of site accessibility, sample size, equipment maintenance, etc. o Data will be comparable with data from other monitoring studies being conducted elsewhere in the region by other agencies, universities, or private organizations. o The opportunity for cost-sharing partnerships with other agencies, universities, or private organizations in the region exists.	<u>*Very High*</u>**—**I **strongly agree** with all 6 of these statements. <u>*High*</u>**—**I **strongly agree** with at least 4 of these statements. <u>*Moderate*</u>**—**I **strongly agree** with at least 3 of these statements. <u>*Low*</u>**—**I **strongly agree** with at least 1 of these statements. <u>*Very Low*</u>**—**This is an important vital sign to monitor, but I do not **strongly agree** with any of these statements. <u>*No opinion*</u>**—**I do not know enough about this criterion for this vital sign to rank it.

3.2.4 Initial Prioritization Process and Results

NPS staff and experts ranked the initial vital sign list using an online vital sign database and vital sign ranking criteria. Participants from previous workshops, additional subject experts, regional NPS staff, and other selected agency officials completed the ranking process. Of the 156 people invited to rank the proposed SFAN vital signs, 55 people participated; 35 of the 55 participants were NPS employees. Participants were asked to rank each vital sign from very low to very high with respect to each criterion. Participants also had the option of choosing "no opinion" for each criterion if they had insufficient knowledge about the criterion or the vital sign to evaluate it. Participants were given two locations in which to provide feedback on the process or to provide additional information on the vital sign. Comments were taken into consideration as vital sign ranking results were reviewed and will be considered during protocol development.

Weighted scores for the vital signs were calculated using three methodologies (i.e., weighted mean scores for each individual for each vital sign, weighted mean scores for each criterion for each vital sign, and mean weighted scores per individual without accounting for missing values). The resulting rank order of vital signs did not differ appreciably among methodologies suggesting that the results were relatively robust. In particular, the positions of the ten highest ranked vital signs and three lowest ranked vital signs changed very little. Most shifts in rank position from one calculation type to another occurred between adjacently ranked vital signs and were the result of slight differences in the second, third, or even fourth decimal place (accuracy beyond the limits of the data but useful for display purposes).

The mean of weighted scores for each individual was calculated for each vital sign and analyzed using descriptive statistics (e.g., mean, mode, range, standard deviation). Analyses were performed on the complete data set as well as on subsets of the data. Vital sign rankings were sorted and compared based on management significance (only), ecological significance (only), NPS or non-NPS status, the participants' areas of expertise, vital sign categories, and spatial scale. Although comparisons were also made with non-weighted mean scores, no comparisons were made with scores unadjusted for missing values since missing values could skew the data appreciably. Descriptive statistics were displayed for all data permutations. Detailed descriptions of the data calculations and the resulting data comparisons are presented in the Phase II Vital Signs Prioritization Meeting Summary (http://www1.nature.nps.gov/im/units/sfan/reports/phasereports.htm).

3.2.5 Vital Signs Prioritization Meeting

The purpose of the Vital Signs Prioritization Meeting was to have the Board of Directors and the Technical Steering Committee review the vital signs selection process and results, identify monitoring gaps in the prioritized list, adjust the order of the vital signs as necessary, and justify any changes made to the prioritized list. Alterations made to the initial prioritized list of vital sign were based on the need to cover, a variety of spatial scales, monitoring objectives, and vital sign types.

Most changes to the vital sign list did not affect the outcome of the high priority list of vital signs on which the group is focused for the purposes of this monitoring plan. The most notable changes were 1) moving Weather and Climate to #1, because the data from this vital sign are essential to support most other vital signs, and 2) moving the Air Quality vital sign from #26 to

#4, because of legal mandates (PORE and PINN both are Class I airsheds), ecological importance (air quality affects water and terrestrial resources), and significant contributions from partners. Wetlands were added as a vital sign. For the purposes of the vital sign, wetlands include not only plant communities, but also the hydrologic regime and the physical aspects of the land in both freshwater and marine wetland ecosystems. Wetlands were placed on the list next to related vital signs, such as riparian habitat and freshwater dynamics.

3.3 Selected Vital Signs

The SFAN presented the prioritized vital signs in rank order to emphasize the importance of each vital sign proposed during the selection and prioritization process. One contiguous list also emphasizes the partnership and monitoring potential that exists among many vital signs. The full vital sign list is placed in the three-level framework designed by the national I&M program (Table 3.3), which is a organizational tool for promoting communication, collaboration, and coordination among parks, networks, programs, and agencies involved in ecological monitoring. The network plans to develop monitoring protocols and databases consistent with national I&M standards for implementation of the highest ranked 18 (bolded in Table 3.3) vital signs first. Vital signs such as tule elk, rocky intertidal communities, non-native animals and Sudden Oak Death, which were ranked lower on the list, will continue to be monitored to some degree by SFAN parks and partners, because they are state species of special status, important communities, threats to native communities or emerging diseases (See Appendix 3 for additional monitoring programs).

It is necessary to emphasize that many vital signs, especially those vital signs in the middle of the ranked list, had virtually identical mean weighted scores. As a result, there was very little distinction between many adjacently ranked vital signs. Adjustments to the monitoring program may occur as reviews provide feedback on the efficacy of the selected vital signs approximately every five years. Therefore, vital signs may be chosen for monitoring out of rank order if partnerships present themselves, management issues change, ecological information is updated, or linkages vital signs allow for efficient and effective monitoring. Modifications to well-established, long-term vital signs (e.g., weather data, freshwater dynamics) will be limited.

3.3.1 Water Resources Vital Signs

Water resources-related vital signs were discussed in Section 1.3.2.2: Water Resources Monitoring Efforts and Questions, and Potential Vital Signs. Modifications to that original list of vital signs/parameters resulted in broader vital signs (Table 3.4). For example, water clarity, water quality, nutrients, and pathogenic bacteria were combined into the “Freshwater Quality” vital sign. The Freshwater Quality Vital sign is the focus of the WRD Water Quality Monitoring Plan for the network.

Table 0.3 Vital signs selected by the SFAN within the NPS Ecological Monitoring Framework. Vital signs selected by SFAN are assigned to the national framework Level 3 category that most closely pertains to that vital sign. Bolded vital signs ranked in the top 18 of the list of 63 vital signs and will be implemented first.

Level 1 Category	Level 2 Category	Level 3 Category	Vital Sign	EUON	FOPO	GOGA	JOMU	MUWO	PINN	PORE	PRES
Air and Climate	Air Quality	Ozone	**Air Quality**	◊	◊	◊	◊	◊	●	◊	◊
		Wet and Dry Deposition	**Air Quality**	◊	◊	◊	◊	◊	●	◊	◊
		Visibility and Particulate Matter	**Air Quality**	◊	◊	●	◊	◊	●	+	◊
	Weather and Climate	Weather and Climate	**Weather and Climate**	+	+	+	+	+	+	+	+
Geology and Soils	Geomorphology	Hillslope Features and Processes	Mass Wasting (Landslide)	◊	◊	◊	◊	◊	◊	◊	◊
		Coastal / Oceanographic Features and Processes	Coastal Dynamics	-	●	●	-	-	-	●	◊
		Stream / River Channel Characteristics	Stream Channel and Watershed Characterization	◊	◊	●	◊	●	●	●	◊
			Erosion and Deposition	◊	◊	●	●	◊	◊	◊	◊
	Soil Quality	Soil Function and Dynamics	Soil Biota	◊	◊	◊	◊	◊	◊	◊	◊
			Soil Structure, Texture, and Chemistry	◊	◊	◊	◊	◊	◊	◊	◊
Water	Hydrology	Groundwater Dynamics	Groundwater Dynamics	◊	◊	●	◊	◊	●	◊	◊
		Surface Water Dynamics	**Freshwater Dynamics**	-	-	+	+	◊	+	+	●
			Resilience Monitoring – Flood	-	-	◊	-	◊	◊	◊	-
		Marine Hydrology	Physical Oceanography	-	●	●	-	-	-	●	-
	Water Quality	Water Chemistry	**Freshwater Quality**	-	-	+	+	+	+	+	◊
		Nutrient Dynamics	**Freshwater Quality**	-	-	+	+	+	+	+	◊
			Marine Water Quality	-	-	●	-	-	-	●	-
		Microorganisms	**Freshwater Quality**	-	-	+	+	+	+	+	◊
		Aquatic Macroinvertebrates and Algae	Aquatic Invertebrates	-	-	●	●	◊	●	●	◊
Biological Integrity	Invasive Species	Invasive/Exotic Plants	**Invasive Plant Species**	+	+	+	+	+	+	+	+
		Invasive/Exotic Animals	Non-native Animals	◊	◊	◊	◊	◊	◊	●	◊
	Infestations and Disease	Plant Diseases	Sudden Oak Death	◊	-	●	◊	●	◊	●	◊
		Animal Diseases	Wildlife Diseases	◊	◊	◊	◊	◊	◊	●	◊
	Focal Species or Communities	Marine Communities	Subtidal Monitoring	-	◊	◊	-	-	-	◊	◊
			Sandy Intertidal Community	-	◊	◊	-	-	-	◊	◊

Level 1 Category	Level 2 Category	Level 3 Category	Vital Sign	EUON	FOPO	GOGA	JOMU	MUWO	PINN	PORE	PRES
			Dune Vascular Plant Assemblages	-	◊	◊	-	-	-	●	◊
		Intertidal Communities	Rocky Intertidal Community	-	●	●	-	-	-	●	-
		Wetland Communities	**Wetlands**	-	-	+	+	+	+	+	+
		Riparian Communities	**Riparian Habitat**	-	-	+	+	◊	+	+	+
		Grassland Vegetation /Herbaceous Communities	Grassland Plant Communities	-	◊	◊	◊	◊	◊	◊	◊
		Forest/Woodland Communities	Oak Woodlands	-	-	◊	◊	◊	◊	◊	◊
		Cave Communities	Cave Communities	-	◊	◊	-	◊	●	◊	-
		Fishes	**Stream Fish Assemblages**	-	-	+	+	+	+	+	-
			Marine and Estuarine Fish	-	◊	●	-	-	-	●	-
		Amphibians and Reptiles	**Amphibians and Reptiles**	◊	◊	+	+	+	+	+	+
		Birds	**Landbird Population Dynamics**	◊	◊	+	+	◊	+	+	+
			Raptors and Condors	-	◊	●	◊	◊	+	◊	◊
			Shorebirds	-	◊	◊	-	-	-	◊	●
			Seabirds	-	◊	●	-	-	-	●	-
			Waterbirds	-	◊	●	-	-	◊	●	●
			Corvids	◊	◊	◊	◊	◊	◊	◊	◊
			Pelagic Wildlife	-	-	●	-	-	-	●	-
		Mammals	**Pinnipeds**	-	-	+	-	-	-	+	-
			Tule Elk	-	-	-	-	-	-	●	-
			Medium to Large Carnivores	-	-	◊	◊	◊	◊	◊	◊
			Small Mammals and Herpetofauna	◊	◊	◊	◊	◊	◊	◊	◊
			Bat Guild	◊	◊	◊	◊	◊	◊	◊	◊
			Black-tailed Deer	◊	◊	◊	◊	◊	◊	◊	◊
			Cetaceans	-	-	●	-	-	-	●	-
		Vegetation Comples	**Plant Community Change**	-	+	+	+	+	+	+	+
			Ozone Sensitive Vegetation	◊	◊	◊	◊	◊	◊	◊	◊
			Plant Species (on edge of range)	-	-	◊	◊	-	◊	◊	◊
		Terrestrial Complex	Lichens	◊	◊	◊	◊	◊	◊	◊	◊
			Terrestrial Invertebrate Community	◊	◊	◊	◊	◊	◊	◊	◊
	At-risk Biota	T&E Species and Communities	**Rare Plant Species**	-	-	+	●	-	+	+	+
			Northern Spotted Owl	-	-	+	-	+	-	+	-
			Western Snowy Plover	-	-	+	-	-	-	+	-
			T&E Butterflies	-	-	+	-	-	-	+	-
			Townsend's Big-Eared Bats	◊	◊	◊	◊	◊	◊	●	◊

Level 1 Category	Level 2 Category	Level 3 Category	Vital Sign	EUON	FOPO	GOGA	JOMU	MUWO	PINN	PORE	PRES
			Bank Swallow	-	-	●	-	-	-	◊	-
Human use	Non-point Source Human Effects	Non-point Source Human Effects	Natural Lightscape	◊	◊	◊	◊	◊	●	◊	◊
	Cultural Landscapes	Cultural Landscapes	Viewshed	◊	◊	◊	●	◊	◊	◊	◊
Landscapes (Ecosystem Pattern and Processes)	Fire	Fire and Fuel Dynamics	Resilience Monitoring - Fire	-	-	●	◊	◊	●	●	-
	Landscape Dynamics	Land Cover and Use	**Landscape Dynamics**	+	+	+	+	+	+	+	+
			Landform Type	◊	◊	◊	◊	◊	◊	◊	◊
	Extreme Disturbance Events	Extreme Disturbance Events	Catastrophic Event Documentation	◊	◊	◊	◊	◊	◊	◊	◊
	Soundscape	Soundscape	Natural Soundscapes	-	◊	●	●	●	●	●	●

+ Vital signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs.

● Vital signs that are monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these monitoring efforts.

◊ High priority vital signs for which monitoring will likely be done in the future, but which cannot currently be implemented because of limited staff and funding.

- Vital sign does not apply to park, or for which there are no foreseeable plans to conduct monitoring.

Table 0.4 Revised vital sign names for water resources vital signs from scoping workshops.

Former Water Resources Vital Signs from Vital Signs Scoping Workshop	New Vital Sign for Ranking
Water Quality	Freshwater Quality
Water Clarity	Freshwater Quality
Nutrients	Freshwater Quality
Metals	Freshwater Quality
Pathogenic Bacteria	Freshwater Quality
Benthic Macroinvertebrates	Aquatic Invertebrates
Oil/Hydrocarbons	Marine Water Quality
HAB (Harmful Algal Blooms)	Marine Water Quality
Surface Water Dynamics	Freshwater Dynamics
Groundwater Dynamics	Groundwater Dynamics
Oceanographic Physical Parameters	Physical Oceanography
Flooding	Resliance Monitoring-Flood
Waves	Physical Oceanography
Drought	Catastrophic Event Documentation

The following list of SFAN ranked vital signs includes all water resources related vital signs.

#1 Weather and Climate
#3 Freshwater Quality
#14 Freshwater Dynamics
#15 Wetlands
#16 Riparian Habitat
#20 Erosion and Deposition
#21 Marine Oceanography
#31 Stream Channel and Watershed Characterization
#33 Marine Water Quality
#42 Groundwater Dynamics
#49 Resiliance Monitoring-Flood
#61 Aquatic Invertebrates

The inclusion of these vital signs in the ranking list is indicative of the significance of aquatic resources in the network. Several NPS efforts to improve water resources within SFAN are underway; continued and augmented monitoring is needed to ensure that existing linkages among these vital signs remain viable.

Because of the presence of threatened and endangered species, Section 303d listed waters, significant coastal waters, unstable geomorphology, and public water use and health issues, network watersheds receive substantial attention from the surrounding communities and government agencies. The San Francisco Bay Regional Water Quality Control Board identified both Lagunitas Creek and Tomales Bay (PORE/GOGA) as impaired by fecal coliform, sediment, and nutrients. San Francisquito Creek is also sediment-mpaired; one of its sub-watersheds is located within GOGA boundaries. Erosion is not only a significant issue for these sediment-impaired waters, but it is also the major watershed issue at JOMU.

The State Water Resources Control Board has established four coastal Areas of Special Biological Significance (ASBS) within the legislative boundaries of the SFAN parks. Because of the significance of these areas as high quality habitat and the need to protect human health (i.e., contact and non-contact recreation), marine water quality will remain an important aspect for the network. Monitoring groundwater dynamics will become more important at PINN as water demand (primarily related to viniculture surrounding the park) increases, thereby applying greater stress to the ecosystem.

3.4 Connectivity Between Selected Vital Signs and the SFAN Conceptual Model

Justification for selection of monitoring vital signs is ultimately dependent on a linkage between the selected vital signs and the network conceptual models. To ensure that the major conceptual model components are represented by the selected vital signs, vital signs were organized by resource realm, vital sign categories, and by dominant ecosystem types depicted in the models (Table 3.5; refer to Chapter 2: Conceptual Models). Vital signs in the top 18 of the ranked list are noted in bold. Linkages with habitat components, physical resources, and other vital signs will be presented as part of the individual conceptual models developed for each vital sign. (See Figure 2.6 for an example.)

Table 0.5 List of specific vital signs linked to conceptual models. Rank number is the priority number from the ranking procedure. Letters signify the application of a given vital sign to the ecosystem types: M=marine, T=terrestrial and W=wetland. Bolded vital signs ranked in the top 18 and will be implemented first.

Resource Realm	General Vital Sign	Specific Vital Sign	Rank	Ecosystem Connections
ATMOSPHERE	AIR QUALITY			
	Chemistry – contaminants (persistent organic pollutants (POPs), mercury, lead, zinc, cadmium)	**Air Quality**	4	MTW
		Lichens	45	T
	Chemistry – nitrogen/ sulfur deposition	**Air Quality**	4	TW
	Chemistry – ozone	**Air Quality**	4	T
		Ozone Sensitive Vegetation	54	T
	Physics - fine particles (human health, visibility concerns)	**Air Quality**	4	MT
	LIGHT AND SOUND			
	Dark night sky/ light pollution	Natural Lightscape	53	MT
	Natural sound levels	Natural Soundscape	29	MTW
	WEATHER and CLIMATE			
	Weather/ climate change	**Weather and Climate**	1	MTW
	SOIL BIOTA AND QUALITY			

Resource Realm	General Vital Sign	Specific Vital Sign	Rank	Ecosystem Connections
	Soil chemistry and contaminants	Soil Structure, Texture and Chemistry	62	MTW
	Soil structure and texture	Soil Structure, Texture and Chemistry	62	MTW
	Soil erosion and deposition	Erosion and Deposition	20	MTW
	Soil biota	Soil Biota	55	MTW
	DISTURBANCE EVENTS			
	Coastal dynamics	Coastal Dynamics	19	MW
	Mass wasting	Mass Wasting (Landslide)	57	MTW
	Catastrophic event	Catastrophic Event Documentation	43	MTW
	HABITAT PATTERNS			
	Physical Habitat changes—physical (terrestrial, stream substrate change, channel and drainage morphology, seabed change)	Landform type	52	T
		Stream channel and Watershed Characterization	31	W
		Cave Communities	47	TW
HYDROSPHERE	WATER QUALITY			
	Chemistry--core elements (temperature, specific conductance, pH, DO)	**Water Quality**	3	MTW
	Clarity (turbidity and sediment)	**Water Quality**	3	MTW
	Nutrients, organic/ inorganic contaminants	**Water Quality**	3	MTW
	Groundwater quality			TW
	Indicator bacteria (fecal and total coliform, e.coli.)	**Water Quality**	3	MW
	WATER QUANTITY			
	Surface water dynamics (flow, discharge, use)	**Freshwater Dynamics**	14	TW
	Groundwater dynamics (water tables, recharge, draw down, use)	Groundwater Dynamics	42	TW
	OCEANOGRAPHY			
	Physical parameters (sea level change, current patterns, upwelling intensity)	Physical Oceanography	21	MW
	Marine water quality	Marine Water Quality	33	MW
	DISTURBANCE EVENTS			
	Resilience monitoring--floods	Resilience Monitoring – Flood	49	MTW
	Catastrophic events	Catastrophic Event Documentation	43	MTW
BIOSPHERE	FAUNAL CHARACTERISTICS			
	Species richness and diversity – selected communities	**Stream Fish Assemblages**	**5**	**W**
		Amphibians & Reptiles	**8**	**TW**
		Pinnipeds	**10**	**MW**
		Raptors and Condors	**18**	**T**
		Shorebirds	24	M
		Seabirds	25	M
		Waterbirds	26	M
		Marine and Estuarine Fish	28	M
		Medium to Large Carnivore	30	TW

Resource Realm	General Vital Sign	Specific Vital Sign	Rank	Ecosystem Connections
		Small mammal and Herpetofauna	36	T
		Bat Guild	41	T
		Terrestrial Invertebrate Community (non-T&E)	48	T
		Pelagic Wildlife	50	M
		Soil Biota	55	T
		Cetaceans	60	M
		Aquatic Invertebrates	61	W
	Native species of special interest (presence, population size, trends)	**Pinnipeds**	**10**	**MW**
		Landbird Population Dynamics	**17**	**TW**
		Raptors and Condors	**18**	**T**
		Medium to Large Carnivore	30	TW
		Small Mammal and Herpetofauna	36	T
		Corvids	46	TW
		Black-tailed Deer	56	T
	Faunal species at risk (presence, trends, population size, genetic diversity)	**Stream Fish Assemblages**	**5**	**W**
		Northern Spotted Owl	**7**	**T**
	(See Appendix 2 for more complete list of species at risk.)	**Amphibians and Reptiles**	**8**	**TW**
		Western Snowy Plover	**9**	**M**
		Pinnipeds	**10**	**M**
		T&E butterflies	**13**	**T**
		Landbird Population Dynamics	**17**	**TW**
		Raptors and Condors	**18**	**T**
		Seabirds	25	M
		Tule elk	27	T
		Marine and Estuarine Fish	28	M
		Townsend's Big-eared Bat	34	T
		Bank Swallow	35	TW
		Small mammal and Herpetofauna	36	T
	Exotic animal species/ disease (population size, area covered, rate of spread)	Non-native Animals	23	MTW
		Wildlife diseases	52	MTW
	INTERSPECIFIC INTERACTIONS			
	Selected species' interactions (herbivory, predation, competition)			
	FLORAL CHARACTERISTICS			
	Species richness and diversity – selected communities	**Wetlands**	**15**	**W**
		Riparian Habitat	**16**	**W**
		Dune Vascular Plant Assemblages	22	M
		Rocky Intertidal Community	32	M
		Grassland Plant Communities	37	T

Resource Realm	General Vital Sign	Specific Vital Sign	Rank	Ecosystem Connections
		Oak Woodlands	38	T
		Subtidal Monitoring	44	W
		Lichens	45	T
		Sandy Intertidal Community	59	MT
	Native species of special interest (presence, population size, trends)	Oak Woodlands	38	T
		Ozone Sensitive Vegetation	54	T
	Floral species at risk (presence, trends, population size, genetic diversity)	**Rare Plant Species**	**6**	**TW**
		Wetlands	**15**	**W**
	(See Appendix 2 for a more complete list of species at risk.)	Dune Vascular Plant Assemblages	22	T
	Invasive exotic plant species/ disease (#, area covered, rate of spread of selected species)	**Invasive Plant Species – early detection**	**2**	**TW**
	(See Appendix 2 for a more complete list of targeted exotic plant species.)	Sudden Oak Death	39	T
	Plant community composition and structure - change at multiple scales	**Plant Community Change**	**11**	**TW**
		Plant Species at the Edge of their Range	58	TW
	LANDSCAPE PATTERNS			
ABIOTIC/ BIOTIC INTERFACE	Community assemblages (area/ distribution)	**Plant Community Change**	**11**	**TW**
		Wetlands	**15**	**W**
		Riparian plant community	16	TW
		Dune Vascular Plant Assemblages	22	MTW
		Grassland Plant Communities	37	T
		Oak woodland community	38	T
		Subtidal community	44	M
	Fragmentation and connectivity	**Landscape Dynamics**	**12**	**TW**
	Landscape and land use change (urban, agriculture, residential, grazing)	**Landscape Dynamics**	**12**	**TW**
	ECOSYSTEM PROCESSES			
	Succession	**Plant Community Change**	**11**	**TW**
	Nutrient dynamics			
	DISTURBANCE EVENTS			
	Fire	Resilience Monitoring – Fire	40	TW
		Resilience Monitoring – Flood	49	MTW
	VISITOR USE			
SOCIAL	Viewshed	Viewshed	63	MT

Chapter 4 Sampling Design

4.1 Overview of Sampling Design

This chapter outlines the overall statistical sampling design for all vital signs in the SFAN parks. The statistical sampling design describes how spatial locations are chosen for sampling and how sampling effort will be rotated among those spatial locations. Certain details of the sampling designs will not be included here. For example, detailed maps showing realized sample locations are included in each vital sign protocol. Data analysis plans are described generally in Chapter 7 and specifically in the individual protocols. Here, we focus on the overall sampling designs that will permit statistical inferences to large areas.

This chapter is organized as follows. In section 4.2, Sampling Concepts and Definitions, several statistical concepts and terms are defined for use later in the chapter. Section 4.3, an overview of the proposed sampling approaches, introduces and explains the sampling plans that follow. Later discussions are grouped into sections by the general type of sampling proposed for particular vital signs. These sections are 4.4 Grid-based Sampling, 4.5 List-based Sampling, and 4.6 Index Sites. Lastly, section 4.7 outlines protocols that use multiple types of sampling approaches. In all of these sections, the overall statistical design for vital signs to be monitored at the outset of the program will be described. The areas of inference and general considerations for each vital sign will also be given.

4.2 Sampling Concepts and Definitions

Subsequent sections of this chapter describe various sampling plans proposed for parks in the SFAN. These sampling plans rely on a few underlying concepts and use specific statistical terms. This section describes some of the background concepts behind the recommended designs and defines sample unit, panel, rotation design, and membership design.

During development of the sample designs, our working definition of “monitoring” was the collection and analysis of repeated observations or measurements over a long period of time to document the status and trend in ecological parameters. Monitoring is usually designed to provide unbiased statistical estimates of status and trends in large areas or entire study units.

Monitoring programs, in our minds, do not set out to investigate a single question or test a specific hypothesis; rather they attempt to collect objective and scientifically defensible data to answer wide-ranging broad hypotheses, some of which may not be finalized at the outset. Using data collected by monitoring programs, long-term correlations between management or natural changes and ecological parameters can occasionally be documented and can provide the most compelling and complete picture of ecosystems and ecosystem changes. Monitoring, however, will not establish cause and effect relationships between external changes and the status of ecological parameters. Because of its long-term nature, monitoring usually collects relatively quick and easy-to-measure field data that are repeatable in the sense that different people taking the same measurement will likely produce the same value. Successful monitoring programs produce compelling evidence of ecological status and change because they collect long-term data, the object of study is representative of ecosystem condition, and their inferences apply to large areas. Successful monitoring programs are difficult to implement, however, because they require data to be collected for many years, which requires consistent motivational and financial support.

The monitoring plans proposed for SFAN rely on concepts in finite population sampling. In finite population sampling, the area for which inferences are desired (e.g., a park or ecoregion) is generally viewed as a finite collection of *sample units* (or just *units*).

In general, sample units are the smallest entities upon which measurements are taken. The total collection of sample units is called the *population.* In some studies, sample units will be discrete entities such as stream segments, ponds, lakes, or individual animals. Sample units for remote sensing studies may be aerial survey routes, small areas, or pixels. *Responses* are defined to be measurements taken on the sample units. The subset of units from the population for which we collect responses is called the *sample.* If the sample is chosen using some type of random draw, the sample is said to be a *probability sample.* Whenever possible we have opted for a probability sample to monitor vital signs of the SFAN.

In selecting a sample design for SFAN, we must select:

1. a method of distributing the sample
    a. unstratified – all areas of the park are sampled at the same rate (number of sample sites per square mile),
    b. stratified – the park is divided into strata that do not overlap and that cover the entire park. Some strata are sampled at a higher rate than others, but the sampling rate is the same within a stratum, or
    c. unequal probability – The sampling rate varies continuously, rather than being set by discrete strata.

2. a method of selecting the sample
    a. random
    b. systematic (grid), with a random start
    c. *Generalized Random-Tessellation Stratified* (GRTS) design (Stevens and Olsen 2004).

Any method of distributing the sample can be combined with any method of selecting the sample. In addition, field sampling may rotate through various sets of sample units over time.

Unstratified sampling samples each habitat type in the same proportion as it occur in the park. Stratified and unequal probability sampling allows one to increase the sample size in less common or more important habitat types. Unequal probability sampling is more flexible but more complex than stratified sampling. Random sampling is less precise than systematic or GRTS sampling, because sample points tend to clump and not be evenly distributed over the park. GRTS sampling has the advantage of combining the strengths of systematic and random sampling and unlike systematic sampling, GRTS sampling allowing the sample size to be easily changed, if for example some of the points selected may not be suitable for monitoring.

If all sample points will not be observed every year, it is useful to define several *panels* of sample points. A panel is a group of sample points that are always all sampled during the same sampling occasion or time period (McDonald 2003). For example, panel 1 points might be observed every year and panel 2 points every 5 years. The way in which units in the population become members of a panel will be called the *membership design* and pattern of visits through time to all panels is the *revisit design* (McDonald 2003). For example, if two panels are to be constructed from a systematic sample of points, every other point could be placed into panel 1, starting with the first and every other unit starting with the second could be placed in panel 2. If the sample points are to be observed annually for 10 years, the revisit design might specify that units in panel 1 be visited in years 1, 3, 5, …, 9, and the units in panel 2 be visited during years 2, 4, 6, …, 10. An alternative revisit design might specify that units in panel 1 be visited every year, while those in panel 2 are to be visited every third year.

McDonald (2003) proposed a notation system for revisit designs that may help with describe the sampling design. Under this notation, the revisit plan is represented by a pair of digits, the first of which is the number of consecutive occasions that a panel will be sampled, the second of which is the number of consecutive occasions that 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, then visited again for one occasion, not visited for two occasions, and so on. If a single panel is to be visited every sample occasion, its revisit design would be [1-0]. The notation [1-1] means a panel is to be sampled every other sampling occasion. The notation [1-n] means a panel is to be visited once and never again. The notation [1-0,1-5] means that units in one panel will be visited every occasion, while units in 6 other panels will be visited once every 6 years. The schematic representation and notation for five example revisit designs appears in Table 4.1.

4.3 Sampling Approaches

Historically, monitoring efforts at parks in SFAN consisted of:

- Weather and air quality data collected throughout the parks
- Landbird population dynamics
- Northern Spotted Owl productivity
- Pinniped productivity and distribution
- Prairie Falcons productivity and distribution
- Western Snowy Plover productivity and distribution
- Stream fish productivity

At the beginning of the planning process, the SFAN monitoring program attempted to integrate all of the vital signs studies under a single overarching survey design. This included many historical monitoring programs for which survey designs already existed, such as monitoring of stream fish, water quality, landbirds, and snowy plovers. A single overarching sample design, however, was impossible given the different fundamental types of sampling required by each study.

Certain ecological parameters, such as vegetation composition or landbird abundance, were specific to two-dimensional locations and required a sample of two-dimensional landscapes. Certain other parameters, such as those measured in freshwater systems or on spotted owls, were specific to an entity that existed only as an identity, and those identities were amenable to placement in a one-dimensional list. Still other parameters, such as air quality or climactic measurements, were more-or-less constant at the scale of a single park and could be adequately monitored by collecting data at one or two sites. In the end, we relaxed our

Table 0.1 Notational representation of five revisit designs. An 'X' in a cell indicates that all members of the panel are visited that occasion.

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

requirement that all monitoring utilize a single sampling scheme in favor of separate survey designs that shared a common sample design when at all possible.

Although a shared overall sampling design was not possible, co-locating of some sampling sites was still possible in order to enhance efficiency during field sampling and for correlation analyses. For example, some stream fish assemblage and water quality sampling sites are located at the same sites. Data analysis will also correlate results from the different vital signs. For example, there is an interest to correlate Northern Spotted Owl reproductive success with climatic variation. Likewise, landbird population data may be correlated with vegetation monitoring of riparian or chaparral/scrub habitat.

During development of the sampling plans for SFAN, many milestones were passed and decisions made that influenced the ultimate plan. One of the key milestones was overcoming the aversion to judgment sampling. Initially, a number of lead investigators, statisticians and consultants recommended against judgment sampling (judgment sampling = non-probability sampling). We found, however, that probability sampling was not economically realistic in some cases, and eventually adopted judgment sampling for a few studies. In these cases, judgment samples were justified either because the vast majority of the entities under study were to be sampled, or because the spatial variation in responses at the scale of a park were inconsequential to long-term monitoring.

The second milestone was based on the advent of the “grid” approach and GRTS based site selection. This was a milestone because it was the first feasible sample design under which it was possible to fully realize the utility of probability samples for making inferences to large expanses of a park. The SFAN, however, deemed that a simple random sample was not appropriate for selecting points. A simple random sample might result in some parts of the network being heavily sampled while other parts have few samples, which could skew the conclusions drawn from the monitoring.

Finally, the concepts of rotation design and membership design were introduced and discussed. Prior to these discussions, it was unclear when and how field efforts were to be employed. In the end, three fundamentally different schemes for collecting measurements in the field were adopted for the SFAN monitoring studies. The first scheme (grid-based sampling) constructs a grid of either points or cells to use as sample units and draws a probability sample. The second scheme (list-based sampling) constructs a list of sample units and either draws a probability sample or attempts to census all units. The third scheme collects information on areas or at points (index sites) that were hand-picked by lead investigators to yield adequate data on a particular vital sign. Some sampling designs capitalize on multiple approaches that combine, for example, a grid based approach within an index site (area handpicked by investigator). The remainder of this chapter contains one main section for each of the three types of sample schemes, and the schemes are summarized in Table 4.2.

4.4 Grid-based Sampling

Although the plant community change protocol has not yet been established, grid-based (systematic) sampling is being considered. Grid-based sampling may also be considered as one part of a multi-pronged approach to monitor specific habitats including riparian, wetland, or oak dominated forests. Grid sizes have not yet been established.

4.4.1 Plant Community Change

The plant community change protocol has not yet been developed but will likely take a grid-based approach. Stratification of natural elements such as the underlying geology or elevation

Table 0.2 The overall sample design approach, methods for spatially allocating samples, and the revisit plan for vital signs monitoring.

Level 1	Level 2	Level 3	Network Vital Sign Name	Overall Sample Design Approach	Spatial Allocation	Revisit Plan
Air and Climate	Air Quality	Ozone	Air Quality	Index	Judgment	Continuous
		Wet and Dry Deposition	Air Quality	Index	Judgment	Continuous
		Visibility and Particulate Matter	Air Quality	Index	Judgment	Continuous
	Weather and Climate	Weather and Climate	Weather	Index	Judgment	Continuous
Water	Hydrology	Surface Water Dynamics	Freshwater Dynamics	List-based	Criteria	Monthly
	Water Quality	Water Chemistry	Water Quality	List-based	Criteria	Monthly
		Nutrient Dynamics	Water Quality	List-based	Criteria	Monthly
Landscape (Ecosystem Patterns and Proceses)	Landscape Dynamics	Land cover and use	Landscape Dynamics	TBD	TBD	TBD
Biological Integrity	Invasive Species	Invasive/ Non-native Plants	Invasive Plant Species (early detection)	Grid, List-based, or Index	TBD	TBD
	Focal Species or Communities	Wetland Communities	Wetlands	TBD	TBD	TBD
		Riparian Communities	Riparian Habitat	TBD	TBD	TBD
		Fishes	Stream Fish Assemblages	List-based	Complete census	Monthly
		Amphibian and Reptiles	Amphibian and Reptiles	TBD	TBD	TBD
		Birds	Landbird Population Dynamics	Index	Judgment	Annual
			Raptors and Condors	List-based	Complete census	Annual
		Mammals	Pinnipeds	List-based	Complete census	Annual

Level 1	Level 2	Level 3	Network Vital Sign Name	Overall Sample Design Approach	Spatial Allocation	Revisit Plan
		Vegetation Community	Plant Community Change	Grid-based	GRTS	Panel
		Threatened and Endangered (T & E) Species and Communities	Rare Plants	Grid-, List-based, or Index	Random transect	Annual
			Northern Spotted Owls	Index	Random sample	Annual
			Western Snowy Plover	List-based	Complete census	Annual
			T & E Butterflies	List-based	Random transect	Annual

may also be considered. A spatially balanced (GRTS) as described above will also be considered to ensure that all communities of interest are sampled adequately. Grid size has not yet been determined. Panel designs with various membership schemes will also be considered in order to ensure a cost efficient design and to interpolate over the entire parks.

4.5 List-based Sampling

List-based sampling will be the primary sampling method for monitoring freshwater quality, stream fish assemblages, Western Snowy Plovers, pinnipeds, threatened and endangered butterflies, and raptors and condors. Snowy plover and pinniped monitoring will maintain a list of breeding beaches and haul outs where complete counts will be made every year. Rare butterflies will be sampled at known habitats. Prairie falcons will be sampled in known nesting areas annually.

4.5.1 Freshwater Quality

The SFAN approach to water quality monitoring focuses on collecting water quality parameters in freshwater streams. Basic freshwater quality monitoring includes the collection of a core set of parameters (e.g., pH, dissolved oxygen, specific conductance, flow, and temperature) at the same location.

In order to select sample sites for freshwater quality sampling, SFAN will employ a list or frame-based sampling design, much like the EPA Environmental Monitoring and Assessment Program (EMAP). The first step included identification of sites that were listed as Category 1 (including Section 303d listed streams and significant water bodies) and Category 2 (streams lacking baseline data) as established by the NPS WRD guidance from the freshwater work group subcommittee (NPS 2002). Additional criteria were used to narrow the field of potential sampling sites to include areas of concern for individual parks that did not necessarily fall within categories established by WRD. These additional criteria included: 1) past data indicated pollutant/parameter levels of concern, 2) sites where public health was an issue, 3) sites where land use impacts were suspected or point sources were known (e.g., faulty septic systems, agricultural use, pet waste, outfall pipe), 4) site access/private property issues; and 5) wadeable.

Once all of the potential streams were mapped out, the selection narrowed to particular habitats of interest. The habitats included pools, riffles, and runs which represent the greatest importance to species of concern including California freshwater shrimp (*Syncharis pacifica*), coho salmon (*Oncorhynchus kisutch*), steelhead trout (*Oncorhynchus mykiss*), the California red-legged frog (*Rana aurora*), or Western Pond Turtle (*Clemmys marmorata*). Upon applying all of the criteria, 30 sites were identified at watersheds in GOGA, JOMU, PINN, and PORE. Watersheds will be monitored on a two-year rotating schedule; one set of watersheds will be monitored the first two years and a different set will be monitored the following two yeares. Sites will be sampled monthly within the two-year time period. Randomization occurs at the sampling site in order to identify where at each sampling site the probes are placed. If new areas meeting the site selection criterion are identified they will be considered for inclusion in the sampling design.

In addition to the overall sampling design, Olema Creek, which flows into Tomales Bay, will be tested for fecal coliforms where as part of the Tomales Bay Pathogen Total Maximum Daily Load (TMDL) program. Additional information about the sampling design including a discussion of sampling frequency and detailed maps of all sampling locations can be found in the protocol (SFAN 2005).

4.5.2 Stream Fish Assemblages

The stream fish assemblages protocol calls for monitoring of species of concern which includes California freshwater shrimp, coho salmon, and steelhead trout. Sampling sites are collocated with freshwater quality sites described above. The aim of the protocol is to census the entire population at each sampling site. The assumption that all parameters are accurately counted, such as number of fish or redds, will be tested by conducting a pilot project using a double-observer approach.

4.5.3 Western Snowy Plovers

Snowy plovers have been monitored at GOGA and PORE for more than 20 years. The beaches used by the small birds are well known. The monitoring consists of two components. One component will consist of total counts on accessible beaches at GOGA (Ocean Beach only) and PORE during the winter season. The second component consists of nest searches at PORE during the breeding season. Although all beaches are known where plovers occur, if new habitats are found, they will be added to the sampling population. Observers receive training in order to ensure that no birds are missed. In order to ensure that all birds are counted, detectability will be tested with double observer counts.

4.5.4 Pinnipeds

Like snowy plovers, pinniped monitoring has a long history at GOGA and PORE in collaboration with other agencies and organizations. Monitoring is conducted during the breeding season and on a year round basis. During the breeding season, complete counts of adults and pups are conducted at known haul out sites. Locations of haul out sites are well established; however, if new haul out sites are identified, they will be added to the sampling population. Bi-monthly counts are made only at PORE year round. Observers receive training in order to ensure that no seals are missed or misidentified.

4.5.5 Threatened and Endangered Butterflies
This protocol focuses on the Mission blue butterfly and the Myrtle's silverspot butterfly. Potential habitats with lupine host plants have been mapped. Transects will be placed randomly through each species habitat in order to count adults. In addition, stems of larval host plats and nectar sources are counted along the transect. Data can be extrapolated for the known habitat. In addition, new surveys will be conducted to identify new potential habitats every five years. If new habitats are found, they will be added to the sampling population.

4.5.6 Raptors and Condors
Prairie Falcons have been monitored at PINN for more than 20 years and historic nesting sites are well established. All known nest locations will be monitored in order to track annual productivity. New areas are inventoried as time allows to find new potential nest sites. If new nests are found they will be added to future nest surveys.

4.6 Index Sites

Weather and climate, air quality, and landbird monitoring components in SFAN will collect data at a small number of representative sites located in the parks. This focus on index areas or sites is justified due to the high costs of the surveys or equipment involved in the measurements. Technically, statistical inference to a larger area, such as a park or a portion of a park, is not possible using data collected in areas or at sites that were not chosen by a probability sample. However, monitoring of parameters in specific areas or at specific sites is adequate for these studies because either the index area contains the vast majority of the population of monitored subjects, or the spatial fluctuation in measurements across a park is inconsequential for long-term monitoring purposes.

4.6.1 Weather and Climate
The weather and climate monitoring at SFAN will maintain or establish several different types of climate and precipitation monitoring stations. One component of the climate monitoring study will maintain data collected at stations that represent a broad range of climate gradients and where data have been collected for a number of years. A full set of weather parameters will be collected at these sites. SFAN will minimally support data management at secondary sites where a full set of weather parameters are not collected but the stations represent park interests, such as rainfall patterns.

4.6.2 Air Quality
At present, air quality monitoring is only occurring at Class 1 parks including PINN and PORE. Monitoring is implemented by the NPS Air Resources Division (ARD). SFAN will continue to work with ARD and will maintain and archive data, and report results.

4.6.3 Landbird Population Dynamics
Monitoring of landbird populations has a long history at SFAN extending over 30 years. Point counts with variable point count distance sampling, and Monitoring Avian Productivity and

Survivorship (MAPS) have been established by PRBO Conservation Science (PRBO). The point count and MAPS stations represent an index of all landbirds in habitats of interest which include riparian and coastal scrub/chaparral. MAPS stations were established based on the best judgment of experienced bird banders. Survey areas for point counts were also selected based on judgment. The actual points where the counts are made, however, were established by a systematic grid superimposed over the MAPS stations. Because of the use of judgment sampling, interpolation to areas beyond those sampled is not possible.

Current priorities for GOGA and PORE are to: (1) continue mist-netting at all previously established / currently monitored mist-netting study sites year-round at Palomarin, Muddy Hollow, and Pine Gulch, and only during the breeding season at Lagunitas Creek and Redwood Creek; (2) continue nest monitoring at Palomarin; (3) conduct point count surveys annually at all previously established / currently monitored stations in coastal scrub / chaparral and riparian habitats;

Current priorities for JOMU and PINN are to conduct point count surveys annually at all previously established stations.

4.6.4 Northern Spotted Owl

Spotted owls have been monitored at SFAN parks as part of the Northwest Forest Management Plan. Sites occupied by owls are well known. Among the 80 historically occupied sites, 46 sites are monitored annually for occupancy. A random subset of 30 sites are monitored for reproductive success. Sample site selection is based on those that are easily and safely accessible or have management concerns. These sites represent an index and data can not be interpolated to a larger area. In the future, it is proposed to randomly select monitored sites and to monitor for new sites in potential habitat. This would allow for interpolation to larger areas.

4.7 Multi-Pronged Approaches

Because some of the protocols are broad and may include multiple species, this section will summarize protocols that may incorporate multiple approaches listed above including grid, list, and index based. The protocols for invasive species and for rare plant species include species specific standard operating procedures (SOP). Each SOP, for example, may describe a different sampling approach based on life history, location, and monitoring objective.

4.7.1 Invasive Species

Although the invasive species monitoring protocol has not yet been developed it is envisioned that a list based monitoring scheme will be a significant component. One of the first steps is to generate a list of priority species for which monitoring will be conducted. The next step is to map known locations supplemented with predictive modeling which incorporates potential vectors to identify areas where the species occurs or is expected to occur. For some species it may be possible to monitor the entire population while in other cases monitoring will only focus on index sites. The index sites may be identified as those that are the most susceptible to invasion or areas that contain rare species where managers wants to keep all invasive species out. If too many priority areas are identified or a species covers too large of an area to track the entire population, a probabilistic design will be considered so that a certain portion of the known and expected population is sampled at random. In this case, a grid based approach may be most appropriate.

A pilot program is in place for monitoring Yellow starthistle in order to test the possibility of using park staff and volunteers to assist monitoring.

4.7.2 Rare Plant Species

One protocol will be established for monitoring rare species and each species specific standard operating procedures may take a variety of approaches depending the species phenology, life history, detectability and habitat. The first step for developing this protocol was to develop a list of priority species for each park based on a matrix which incorporated a species' rarity and management potential. For example,a species for which management is possible, has a higher rank than a species for which there are no known management options. PORE has over 50 plant species with federal, state or local status. GOGA has over 35 plant species with federal, state or local status. The inventory for PINN needs to be refined and better documented, but there is currently evidence for over 10 species.

For some rare plant species, it may be possible to conduct counts of the entire population. Tests will have to be made to account for detectability with double observers. We want to make sure that we understand the likelihood of missing stems or misidentifying species of interest.

To date, one SOP has been developed for the rare plant protocol. The SOP was written for the *Chorizanthe valida*. Based on previous inventories, the entire population has been mapped. Within the mapped area, a 40x100 m permanent plot was establish which covers about 40% of the known population. A randomly placed transect is placed through the known population to cover at least 5% of the mapped area. Stem counts are made along the transect to detect changes in the population. In addition, the plant will be surveyed for regularly and the population mapped to ensure that we are documenting changes in aerial extent of the population.

4.7.3 Habitats of special interest (wetlands, riparian)

Park managers are especially interested in a variety of habitats that may be rare, contain rare species or represent a unique ecological function. These include wetlands, riparian habitats, and oak woodlands, among other habitats. Protocols and parameters to be measured have not yet been identified but sampling may include a multi - pronged approach. Remote sensing may be used to develop polygons of priority habitats. A grid based approach may be used to collect certain parameters such as plant species composition, soil water retention, etc. in order to validate remote sensing techniques or to provide more information. Before a full sampling design can be developed, monitoring objectives need to be refined.

Chapter 5 Sampling Protocols

5.1 Overview of High Priority Vital signs

This chapter includes more detail regarding the top 18 protocols the network prioritized for development, and in some cases implementation, within the next 5 years. Table 5.1 shows the suite of SFAN protocols, the parks in the Network in which they will be monitored and the monitoring objectives for each vital sign. Complete protocol development summaries can be found in Appendix 4.

Protocols will follow guidelines published by Oakley et al. (2003) and will specify sampling units and sampling methods. The protocols will also define target populations for monitoring and discuss the level of inference that a park will be able to make from analysis of monitoring data. Data management, analysis, and reporting make up significant portions of the protocols.

Protocols for two of the 18 vital signs have been completed and are undergoing peer review. Both of these (water quality and streamfish assemblages) will be implemented in FY06. Protocols for spotted owls and pinnipeds are still being reviewed and will be completed in FY06. Five protocols are still in the process of being drafted including weather, raptors and condors, freshwater dynamics, landbirds and snowy plovers. The remaining set of protocols are slated for development beginning in late FY06 and beyond. Specific monitoring questions and objectives are still being explored and refined.

As protocols are completed they will become stand alone documents and posted to the SFAN webside: http://www1.nature.nps.gov/im/units/sfan.

Table 0.1 Key information from Protocol Development Summaries (PDS) for each of the top 18 vital signs (see Appendix 4).

Vital sign Name (rank)	Justification	Monitoring Objectives	Parks Involved
Weather and Climate (1)	The Weather/Climate vital sign is ranked first among all of the potential vital signs evaluated by the SFAN. Knowledge about weather and climate is critical because they affect not just geophysical and biological resources but ecosystem drivers and processes. Key reasons for monitoring weather and climate in network parks are because the effects can be long-lasting on (1) plant and animal populations, some of which are listed as endangered or threatened species, (2) on air and water quality, and (3) on drought and flood cycles, fires, mass wasting and other catastrophic events. Long-term weather data can also contribute to the understanding of global climate change and its effects on Network ecosystems.	Determine variability and long-term trends in climate through monthly and annual summaries of selected weather parameters (temperature and precipitation). Identify and determine frequencies and patterns of extreme climatic conditions for common weather parameters.	EUON, GOGA, JOMU, PINN, PORE
Invasive Plant Species (early detection) (2)	Invasive plant species ranked second in the prioritized list of vital signs to be monitored for ecosystem changes and trends. Early detection of invasive plant species is a proven method for preventing the establishment of new species and limiting the spread of existing species into uninfested areas. This protocol provides information that can be used immediately by park managers to target new or expanding infestations. The data can also track long-term infestation patterns and potentially evaluate long-term effectiveness of invasive species management.	Develop and maintain a list of target species that do not currently occur in the parks, occur in localized areas of parks, or are extremely rare, but that would cause major ecological or economic problems if they were to become established. Detect new species and new populations of invasive species before they become established in areas of high and moderate management importance.	FOPO GOGA, JOMU, MUWO, PINN, PORE, PRES

Vital sign Name (rank)	Justification	Monitoring Objectives	Parks Involved
Freshwater Quality (3)	The SFAN has many unique aquatic resources that are significant in an ecological and economic context. Freshwater systems within the network support a variety of threatened and endangered species. Freshwater quality has direct impact on several other vital signs including: marine water quality, stream T&E species and fish assemblages, T&E amphibian and reptiles, riparian habitat, wetlands, and aquatic macroinvertebrates. Freshwater quality also indirectly impacts plant and animal life. In addition, Tomales Bay is a major commercial shellfish growing area. The Tomales Bay Pathogen Total Maximum Daily Load (TMDL) program requires NPS to conduct fecal coliform analysis of streams entering the bay to ensure that allowable standards are not exceeded.	Determine variability and long term trends in water quality through monthly summaries of select parameters (temperature, pH, conductivity, dissolved oxygen, total nitrogen, nitrate, ammonia, flow, fecal and total coliforms), in priority freshwater sites. Determine the existing ranges and diurnal variability of water temperature, pH, conductivity, and dissolved oxygen at selected sites in priority streams within SFAN. Determine the extent that priority streams within SFAN meet federal and state water quality criteria for fecal indicator bacteria, un-ionized ammonia, dissolved oxygen, and pH through monthly sampling. Determine the annual, seasonal, and 30-day mean fecal coliform load to Tomales Bay (in impaired water body) from Olema Creek as required by the San Francisco Bay Regional Water Quality Control Board's Tomales Bay Pathogen TMDL Program.	GOGA, JOMU, PINN, PORE
Air Quality (4)	Clean unpolluted air is essential for all life on earth. Air quality is linked to many natural processes, i.e. soil and water nutrients, photosynthesis, acidification of lakes and streams. PINN and PORE are rated as Class 1 areas by the Clean Air Act and are protected by strict air quality regulations. The rest of the parks in the SFAN are Class 2 areas and pollution regulations are less strict. However, in some instances federal land managers apply the "precautionary principle" and treat Class 2 areas with the same standards as Class 1 Areas.	Report on seasonal and annual status and trends of N and S concentration and deposition in precipitation at existing monitoring stations in SFAN parks. Report on seasonal and annual status and trends of fine particle concentrations and composition at existing monitoring stations in SFAN parks. Report on seasonal and annual status and trends of ozone concentrations in NCRN parks using metrics that are indicative of human health (e.g., 8-hour average) and plant response (e.g., SUM06).	GOGA, PINN, PORE

Vital sign Name (rank)	Justification	Monitoring Objectives	Parks Involved
Stream Fish Assemblages (5)	As an indicator of ecological health of freshwater stream systems, this vital sign category includes monitoring for a suite of species and conditions within stream aquatic habitat including habitat condition, fish assemblage, population, and community structure, as well as three threatened and endangered species: coho salmon (*Oncorhychus kisutch*); steelhead trout (*O. mykiss*); and the California freshwater shrimp (*Syncharis pacifica*). Coho salmon and steelhead are anadromous and the life stage requirements demand year-round, high-quality cold water, continuous riparian cover, and complex habitat and structure to accommodate development from egg to smolt stage. Monitoring of these species at multiple life stages is valuable to the understanding of aquatic conditions and a good measure of watershed health. Because coho salmon and steelhead live for more than a year in freshwater, and the conditions required to support them are highly restrictive, they are susceptible to anthropogenic impacts to the stream and riparian systems. Because salmonids are sensitive to watershed and habitat impacts, they are effective indicators of stream and aquatic health. The California freshwater shrimp are also highly sensitive to water quality and changes to habitat.	Determine long-term trends in size and age class distribution and production of salmonid smolts through spring trapping at select streams at PORE, MUWO, and GOGA. Determine long-term trends in timing and distribution of salmonid spawning, adult sex ratios, and escapement in select streams at PORE and GOGA. Track the distribution and relative abundance of California freshwater shrimp within known freshwater shrimp habitat in SFAN. Determine the trends in distribution, abundance, composition, and size/age structure of fishes at summer index reaches of SFAN streams of PORE, MUWO, and GOGA. Measure the long-term trends in distribution and assemblage of fish species through annual spring surveys of Chalone Creek at PINN. Measure the long-term trends in the annual fish assemblage, distribution and abundance through fish surveys within the NPS managed section of Franklin Creek at JOMU.	GOGA, JOMU, PINN, PORE

Vital sign Name (rank)	Justification	Monitoring Objectives	Parks Involved
Rare Plant Species (6)	PORE has over 50 plant species with federal, state or local status. GOGA has over 35 plant species, including those at PRES, with federal, state or local status. The inventory for PINN needs to be refined and better documented, but there is currently evidence for over 10 sensitive species. In the summer of 2004, a ranking system was developed to help the parks determine which species are the "most rare" within the park boundaries regardless of official listing status. A different version of the ranking matrix will be used to determine which species are the most appropriate for long-term monitoring for trends and ecosystem health. We are developing a systems approach to monitoring rare plants, while also addressing management needs. This vital sign is also part of a hierarchy of vegetation monitoring being developed by the working group, in which some rare species will be monitored via the plant community change protocols.	Develop and maintain a list of target rare species based on a regional rarity matrix and in order to prioritize RTE monitoring efforts. Determine long-term trends of population abundance by conducting species specific surveys as needed of mapped populations. Identify potential threats (e.g. visitor trampling, presence and encroachment of invasive plant species, pest infestation), and estimate degree of threat to rare species at mapped locations in order to identify management needs. Monitor suitable habitats every 5-10 years in order to identify presence/absence of target species and incorporate them into annual abundance estimates.	GOGA, PORE, PRES, PINN
Northern Spotted Owl (7)	The federally threatened status of this species requires the NPS monitor the long-term status and trend of the population and maintain stable or increasing populations of spotted owls. Owls are also good indicators of forest ecosystem condition because they area associated with multi-tiered, old growth forests. This monitoring program provides the data required to accurately assess the status and trend of this isolated, potentially vulnerable spotted owl population, where it occupies a land use matrix strikingly different from that found throughout most of the owl's range. Our monitoring program contributes to the Northwest Forest Plan which is working to arrest the downward trend in spotted owl populations and in maintaining and restoring the habitat conditions necessary to support viable populations of the northern spotted owl. The program has an eight-year history of monitoring spotted owls in the SFAN parks, which contributes to region and range-wide monitoring programs and park management activities.	Monitor changes in spotted owl abundance and reproductive success at known owl activity sites within the NPS legislated boundaries of Marin County, California. Determine the long-term changes of nest site characteristics (e.g. tree species selected for nest sites, vegetation community selected for nest sites) at Northern Spotted Owl at known activity sites in order to evaluate habitat selection. Monitor suitable habitats every 5-10 years in order to identify population expansion of target species and incorporate them into annual abundance estimates.	MUWO, PORE

Vital sign Name (rank)	Justification	Monitoring Objectives	Parks Involved
Amphibians and Reptiles (8)	Due to their habitat and physiology, these taxa are particularly sensitive to environmental degradation, such as air and water pollution. The number of species and populations of amphibians are declining worldwide. Because they are mid-level predators, population trends in these taxa may indicate trends in populations of animals at both higher and lower trophic levels. Standard protocols are available for sampling these animals in the San Francisco Bay Area, in some cases long-term data sets already exist. In addition to monitoring the two federally protected herptile species found in the network, the protocol will also address monitoring of terrestrial amphibian and reptile assemblages.	Determine variability and long-term trends in amphibian and reptile assemblages in key terrestrial habitats. Determine relative abundance of populations of key threatened and endangered amphibians and reptiles, such as California red-legged frogs (*Rana aurora draytonii*) and the San Francisco garter snake (*Thamnophis sirtatlis tetrataenia*) within the network parks. Determine distribution of populations of key threatened and endangered amphibians and reptiles within the network parks. Monitor habitat variables at breeding sites for the key threatened and endangered species.	PORE, GOGA, PINN, JOMU, MUWO, PRES
Western Snowy Plover (9)	Western snowy plovers are listed as federally threatened under the Endangered Species Act. They are also part of the coastal dune ecosystem, which is identified in the PORE enabling legislation. Western snowy plovers are good indicators of the condition of the coastal dunes ecosystem and are the only nesting shorebird in the coastal strand. There is a long history of monitoring snowy plovers at PORE and GOGA. in collaboration with other organizations and agencies. Several park management actions, including major dune habitat restoration projects to enhance the recovery of snowy plovers.	Determine long-term changes in the breeding population size, distribution, and reproductive success of snowy plovers at known breeding beaches at PORE. Determine changes in wintering population size and distribution of snowy plovers at known wintering beaches at GOGA and PORE. Determine trends in pollutant loads (e.g. mercury and selenium) in plover eggs, chicks, and adults, as funds are available in order to evaluate potential hazards. Monitor suitable habitats every 5-10 years in order to identify population expansion of target species and incorporate them into annual abundance estimates.	GOGA, PORE

Vital sign Name (rank)	Justification	Monitoring Objectives	Parks Involved
Pinnipeds (10)	Pinnipeds come under the legal mandates of the Endangered Species Act and Marine Mammal Protection Act. They are also specifically identified in the enabling legislation of and management objectives of PORE. Pinnipeds are good indicators of the condition of the marine ecosystem and global climate change because they respond quickly to oceanic conditions and food resources, such as El Nino events. There is a long history of monitoring pinnipeds at PORE and GOGA in collaboration with other agencies and organizations. Identifying natural and anthropogenic threats and quantifying the level of disturbance to harbor seals will also be critical in order to effectively manage and protect pinnipeds.	Determine long-term trends in annual population size and annual and seasonal distribution of pinniped populations at PORE and GOGA. Determine long-term trends in reproductive success of elephant seals and harbor seals populations through annual estimates of productivity at PORE and GOGA. Identify potential threats (i.e. presence of hikers, motor boats, or airplanes presence), and estimate degree of threat at harbor seal haul outs in order to identify management needs.	GOGA, PORE
Plant Community Change (11)	Numerous biotic and abiotic factors have altered and continue to threaten plant communities within SFAN. As plant communities continue to recover from past resource extraction and grazing, there is a need to understand how current activities are effecting this recovery. It is also important to monitor and evaluate changes to the composition of plant communities and type changes occurring on the landscape. The monitoring program proposed assimilates multiple vital signs including invasive plant species, threatened and endangered plant species, wetlands, grassland plant communities, oak woodlands, and plant species at the edge of their range. There are also significant ties between plant community change and almost all of the faunal indicators being monitored such as landbirds, Northern spotted owls, endangered butterflies, etc.	Develop and maintain a list of priority plant communities based on their rarity and degree of protection. Detect long-term trends in native and non-native abundance and distribution within selected plant communities. Detect changes in overall vegetation cover, vegetation type and species composition of selected SFAN plant communities through monitoring every 7-10 years.	FOPO, GOGA, JOMU, MUWO, PINN, PORE, PRES

Vital sign Name (rank)	Justification	Monitoring Objectives	Parks Involved
Landscape Dynamics (12)	Key reasons for monitoring regional landscape & land use change are (1) the rapid development of neighboring lands (2)the fragmentation of wildlife habitat (3) the need to detect life-form change within parks, and (4) to provide early warning of large-scale community shifts.	Determine status and trends in the areal extent and configuration of land-cover types (Anderson Level II) on park lands in order to evaluate large scale changes affecting park resources. Determine status and trends of key landscape metrics (e.g. proportion of area in different cover types, number and density of patches, mean patch size) of park lands and a ½ mile buffer in order to determine land use patterns in the parks.	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Threatened and Endangered (T & E) Butterflies (13)	The protected legal status of these taxa require the NPS to evaluate the condition of these populations. Because they are closely tied to host and nectar plants, butterfly populations are good indicators of general health of habitat.	Determine the trends in population distribution and abundance of threatened and endangered butterflies within known habitats in GOGA and PORE. Detect changes in acreage of habitat available for butterfly populations at GOGA and PORE such that potential impacts on the butterfly populations may be identified. Predict and identify new lupine habitat annually in order to identify new butterfly populations.	GOGA, PORE
Freshwater Dynamics (14)	Freshwater Dynamics is ranked 14th among all of the potential vital signs evaluated by the SFAN. Streamflow characteristics offer some of the most appropriate and useful indicators for assessing river ecosystem integrity over time. The hydrologic output of a watershed is a function of the land characteristics and human use, the weather and climate conditions, urbanization and soil characteristics. Hydrologic variation plays a key part in structuring the biotic diversity within river ecosystems by controlling critical habitat conditions within the river channel, the floodplain, and hyporrheic zones. Stream hydrology data provides key "support" data for vital signs including stream T&E species and fish assemblages, T&E amphibians and reptiles, wetlands, and riparian habitat.	Monitor the variability and long-term trends in stream flow based on monthly and storm event-related discharge measurements at fixed stations in GOGA, JOMU, MUWO, PINN, and PORE. Monitor the frequency, magnitude and duration of peak flow events at fixed water level monitoring stations by producing instantaneous peak, hourly, daily, monthly and annual summaries of stage height and discharge in GOGA, JOMU, MUWO, and PORE. Monitor the frequency, magnitude and duration of unnatural or extreme low water/low flow events in stream reaches known to support threatened and endangered aquatic species in the dry season at GOGA and PORE.	GOGA, JOMU, PINN, PORE

Vital sign Name (rank)	Justification	Monitoring Objectives	Parks Involved
Wetlands (15)	Wetlands are keystone ecosystems in the San Francisco Bay Area. Some ecologists call wetlands "the kidneys of the landscape" as they provide water quality protection, flood and drought mitigation, erosion control, and groundwater recharge functions. Wetlands support complex food webs, housing a rich biodiversity of wetland-endemic species, and providing habitat functions for many aquatic and terrestrial species. An estimated 46% of US endangered and threatened species and 50% of all bird species require wetland habitat (USFWS). Wetland habitats are vulnerable to alteration due to global climate change and associated potential temperature, hydrology, and salinity regime changes. Understanding the condition of wetlands may be a good proxy for understanding the condition of many taxa of concern in the network.	Determine if the extent, type, condition and function of wetlands is changing.	GOGA, JOMU, MUWO, PINN, PORE, PRES
Riparian Habitat (16)	Riparian habitat is closely tied to the health of wetlands, streams and stream fish assemblages. Characteristics of riparian habitat structure such as the ratio of edge to interior, the degree of canopy complexity within riparian strata (e.g., herb/forbs, shrubs, sub-canopy tree, and overstory tree), and the degree of fragmentation is highly associated with amount and type wildlife use.	Determine status and trend of riparian habitat by measuring species composition, habitat structure, and width along streams in SFAN parks.	GOGA, JOMU, MUWO, PINN, PORE, PRES
Landbird Population Dynamics (17)	Landbirds are good indicators of terrestrial ecosystems and numerous dynamic processes interacting together have the potential to affect their abundance and distribution. Landbird monitoring is focused in priority areas including riparian and coastal scrub/chaparral habitats. Changes in species abundance, distribution, reproductive success, and annual survival may be caused by changes in habitat, food supply, park management strategies, disturbance to nesting areas by recreational users, or environmental factors on multiple scales (localized storm events to decadal shifts in climate).	Determine the annual changes in species composition, distribution, and abundance for landbirds in priority habitats including riparian and coastal scrub / chaparral habitats. Determine long-term changes in reproductive success of landbirds in priority habitats including riparian and coastal scrub / chaparral habitats. Determine long-term changes in annual survival for landbirds in priority habitats including riparian and coastal scrub / chaparral habitats.	GOGA, JOMU, PINN, PORE, PRES

Vital sign Name (rank)	Justification	Monitoring Objectives	Parks Involved
Raptors and Condors (18)	Long-term trends in the nesting success and productivity of prairie falcons provide a means for assessing the park's ability to adequately manage climbing use and the overall ecological integrity and sustainability of the rock/cliff ecosystem. Long-term patterns in population size and breeding behavior (e.g. feeding rates of chicks) are compared to long-term climate change, effects of conversion and development of agricultural lands surrounding the monument, and visitor use of the monument. This information will improve the understanding of raptor ecology and the effects of park management decisions.	Determine annual nesting success at Pinnacles NM as measured by territories occupied, number of chick produced and number of chicks fledged. Monitor potential threats (i.e. presence of hikers or climbers), and estimate degree at nesting sites in order to identify management needs.	PINN

Chapter 6 Data Management

6.1 Overview of Data Management

Collecting natural resource data is the first step toward understanding the ecosystems within the national parks. These ecosystems are evolving, as is the knowledge of them and how they work. Researchers use these “raw” data to analyze, synthesize, and model aspects of ecosystems. In turn, the results and interpretations are used to make decisions about the parks’ vital natural resources. Thus, *data* collected by researchers and maintained through sound data management practices will become *information* through analyses, syntheses, and modeling. This transformation can only be achieved through the development of a modern information management infrastructure (e.g., staffing, hardware, software) and procedures to ensure that relevant natural resource data collected by NPS staff, cooperators, researchers, and others are entered, quality-checked, analyzed, reported, archived, documented, cataloged, and made available to others for management decision making, research, and education.

This chapter summarizes the SFAN data management strategy, which is more fully presented in the SFAN Data Management Plan (DMP; Press 2005). The SFAN DMP serves as the overarching strategy for achieving the goals noted above. The plan supports I&M program goals and objectives by ensuring that program data are documented, secure, and remain accessible and useful indefinitely.

6.1.1 Data Management Strategy

The SFAN data management strategy holds that all data and derived information generated or otherwise used by the program will meet a high level of quality standards. Further, all data and information the SFAN program deems necessary to meet objectives, and that are not otherwise maintained, will be archived, documented, and made easily available and accessible. Data and information will be managed in a transparent manner such that all components may be easily compared by location, time and subject. Data and information will be accompanied by supporting documentation (metadata) that provide context, value, utility, and longevity, thereby facilitating broad understanding of SFAN program output to current and future end users.

The overarching goals of SFAN data management are to:

- ensure the highest quality and accuracy of program data
- fully qualify, document, and catalog all data to ensure their proper interpretation and use
- maintain data in an environment that ensures the long-term security and integrity of data
- ensure the longevity of data by keeping data formats standardized and current
- provide data in a variety of formats and venues to reach all potential users

The following objectives of the SFAN Data Management Plan help frame the strategy to meet SFAN data management goals:

Overall objectives:

- Outline the long-term goals of a comprehensive data management strategy for the SFAN I&M program
- Associate data management goals with the long-term goals of the network and service-wide I&M program
- Outline the procedures and work practices that support effective data management
- Guide current and future staff of the SFAN to ensure that sound data management practices are followed
- Guide the enhancement of legacy data to match formats and standards put forth in this plan
- Encourage effective data management practices as an integral part of project management so all data are available and usable for park management decisions now and into the future

Specific Objectives:

- Establish roles and responsibilities of SFAN program staff for managing data
- Identify necessary elements for a functional data management program and describe any anticipated changes to those elements
- Establish an organizational scheme for SFAN program data and information so that they are retrievable by staff, cooperators, and the public
- Establish basic quality control standards
- Establish standards for data, data distribution, and data archiving to ensure the long-term integrity of data, associated metadata, and any supporting information

6.1.2 Types of Information Managed by the SFAN

The term "data" is frequently used in a way that also encompasses other products that are generated alongside the tabular and spatial data that are the primary targets of data management efforts. These products fall into five general categories: raw data, derived data, documentation, reports, and administrative records (Table 6.1).

These data categories can contain one or more of the following data formats:

- hard-copy documents (e.g., reports, field notes, survey forms, maps, references, administrative documents)
- objects (e.g., specimens, samples, photographs, slides)
- electronic files (e.g., Word files, email, websites, digital images)
- electronic tabular data (e.g., databases, spreadsheets, tables, delimited files)
- spatial data (e.g., shapefiles, coverages, remote-sensing data)

Each of these data formats has specific requirements for ongoing management and maintenance, which are addressed in the SFAN DMP.

Table 0.1 Categories of data products and project deliverables.

Category	Examples
Raw data	GPS rover files, raw field forms and notebooks, photographs and sound/video recordings, telemetry or remote-sensed data files, biological voucher specimens
Compiled/derived data	Relational databases, tabular data files, GIS layers, maps, species checklists
Documentation	Data collection protocols, data processing/analysis protocols, record of protocol changes, data dictionary, NPS- Federal Geographic Data Committee (FGDC) standard metadata, database design documentation, quality assurance report, catalog of specimens/photographs
Reports	Annual progress report, final report (technical or general audience), periodic trend analysis report, publication
Administrative records	Contracts and agreements, study plan, research permit/application, other critical administrative correspondence

6.2 Data Management Roles and Responsibilities

For the SFAN I&M program to work effectively, everyone within the network will have stewardship responsibilities in the production, analysis, management, and/or end use of data and information. The SFAN Data Management Plan specifies basic roles and responsibilities spanning the spectrum of data handling from collection to archiving. This spectrum includes field technicians, projects leaders, GIS specialists, and data managers. More detailed roles and responsibilities are given in the protocol for each monitoring project. Table 6.2 lists these basic roles and principal responsibilities.

Chief personnel involved with data management include project leaders and data managers. Figure 6.1 illustrates the core data management duties of the project leader and data manager and where those duties overlap. The Network coordinator interacts with project leaders to ensure that timelines for data entry, validation, verification, summarization/analysis and reporting are met.

6.2.1 Project Leaders

Project leaders oversee and supervise all phases of a monitoring project and are the point of contact for that project. Each project has two project leaders (one lead, one backup), which may consist of network, park or regional staff. They are responsible for the coordination and supervision of all phases of the project, from raw data collection to data validation and documentation to data analysis and reporting. They are also responsible for complying with the protocol methods and data management plan. They are responsible for the final submission of all products and deliverables. For projects involving contractors and/or cooperators, the project leader is also the Contracting Officers Technical Representative (COTR), and must insure that

Table 0.2 Summary or programmatic roles and responsibilities for data stewardship.

Role	Data Stewardship Responsibilities
Network Coordinator	Ensure programmatic data and information management requirements are met as part of overall Network business. Communicate with Network staff, park staff at all levels, and other appropriate audiences to support and emphasize data management as a critical aspect of network business.
Lead Data Manager	Serve as Point of Contact for National Park Service database applications (NPSpecies and NatureBib). Communicate with national-level I&M Program for updates on NPS database applications and data standards.
Project Leader	Ensure useful data is collected and managed by integrating natural resource science in network activities and products, including objective setting, sample design, data analysis, synthesis, and reporting. Develop, document and implement standard procedures for field data collection and data handling. Supervise and certify all field operations. Produce regular summary reports and conduct periodic trend analysis of data.
Project Data Manager	Develop and maintain the infrastructure for metadata creation, project documentation, and project data management. Create and maintain project databases in accordance with best practices and current program standards. Establish and implement procedures to protect sensitive data.
GIS Specialist	Coordinate and integrate local GIS and resource information management with Network, regional, and National standards and guidelines.
Project Technician	Record, enter and verify measurements and observations based on project objectives.
Information Technology/ Systems Specialist	Provide and maintain an information systems and technology foundation to support data management
I&M Data Manager (National Level)	Provide servicewide database support and services.
End Users (managers, scientists, public)	Provide necessary and requested feedback, review, and comments in order to sustain the continuous improvement of network operations and services.

the contractor complies with the terms of the contract or cooperative agreement. Their active involvement in data management determines the quality and usefulness of the project data and overall success and longevity of the I&M Program.

6.2.2 Data Manager

Data Managers oversee the development, implementation, and maintenance of data infrastructure and standards for specific parks. Each I&M project is assigned a Data Manager for the duration of the project. Data Managers facilitate coordination between projects and protocols to allow for interchange of information wherever possible. Data Managers work with project leaders to design databases and software applications, facilitate data dissemination and coordinate long-term storage and maintenance of the data

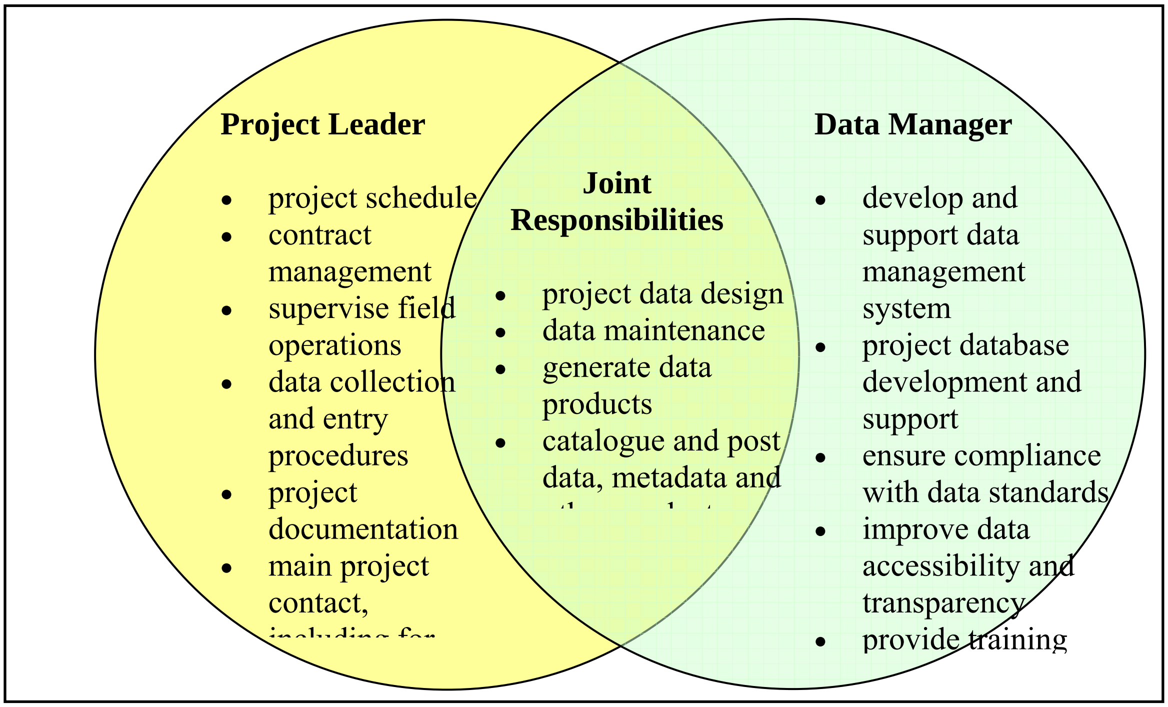


Figure 0.1 Core project data stewardship duties of project leaders and data managers.

6.3 Data Management Infrastructure

The information system architecture necessary to fulfill the role of program data management includes national, regional, and park level infrastructure. Systems architecture signifies the applications, database systems, repositories, and software tools that make up the framework of the data management enterprise. The national level I&M data management infrastructure and strategy are used as a basis for data management in the SFAN.

6.3.1 National Level I&M Data Management Infrastructure

The NPS Natural Resource Program Center (NRPC) and the I&M Program actively develop and implement a national-level, program-wide information management framework. NRPC and I&M staff integrate desktop database applications with internet-based databases to serve both local and national-level data and information requirements. Centralized data archiving and distribution capabilities at the NRPC provide for long term data security and storage.

To achieve an integrated information management system, three of the national-level data management applications (NatureBib, NPSpecies, and NR-GIS Metadata Database) used by the SFAN utilize a distributed application architecture with both desktop and internet-accessible (master) components (Figure 6.2). In addition, the SFAN has adopted relational database design standards in accordance with the Natural Resource Database Template, a relation database model developed in MS Access by the NRPC (Figure 6.2).

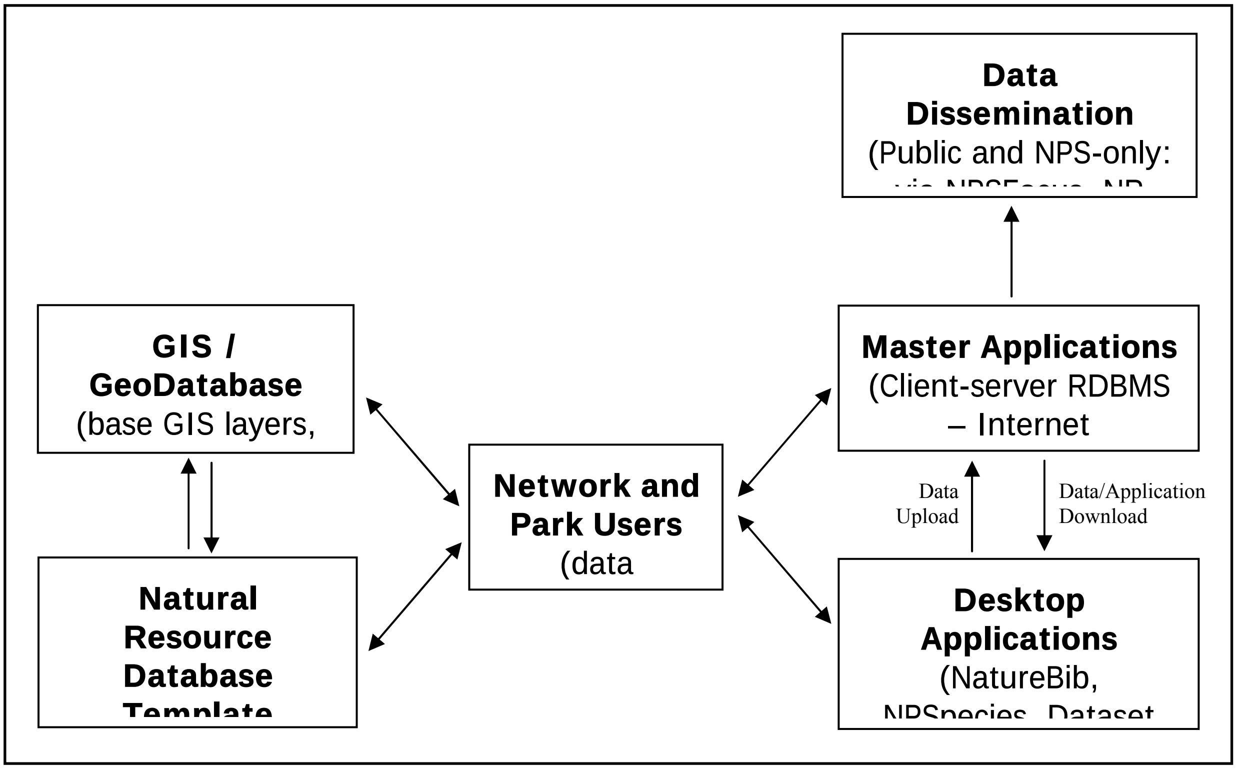


Figure 0.2 Model of the national-level application architecture.

6.3.2 Network and Park Level Data Management Infrastructure

An important element of a data management program is a reliable, secure network of computers and servers. The SFAN digital infrastructure has three main components: servers maintained at the national level, park-based local area networks (LAN) nested within the Pacific West Region wide area network (WAN), and a Network directory nested within the GOGA LAN (Figure 6.3). This infrastructure is maintained by park, regional, and national IT specialists, who administer all aspects of system security and backups.

These components each host different parts of the natural resource information system.

Park LANs

- Local applications – desktop versions of national applications such as NPSpecies, Dataset Catalog, and NPS Metadata Tools and Editor
- Working files – working databases, draft geospatial themes, drafts of reports, administrative records
- Park digital archives – base spatial data, finalized datasets, and finished versions of park project deliverables
- Park GIS files – base spatial data, imagery, and project-specific themes

Network Directory

- Master project databases – compiled data sets for monitoring projects and other multi-year efforts that have been certified for data quality
- Network digital archives – network repository for finished versions of project deliverables for I&M projects (e.g., reports, methods documentation, data files, metadata, etc.)

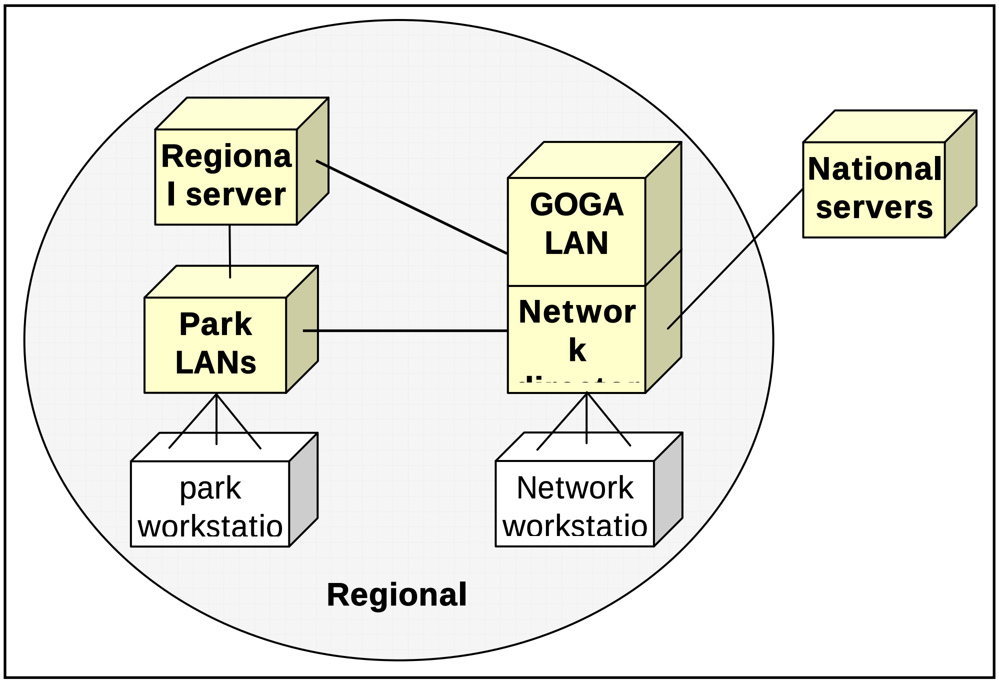


Figure 0.3 Schematic representing the layout and connectivity of SFAN computer resources.

The Marin Headlands GOGA server is a critical component of the SFAN computer infrastructure. A separate directory on this server houses the Network directory, which includes all of the SFAN central files and digital archives. The server has power supply and storage redundancy built to ensure data are kept safe. A tape drive is also connected to back up data on a regular weekly schedule. The last tape of the month is taken offsite to further protect the data.

6.4 Data Management Standards

The SFAN will conform to NPS standards and policy in all aspects of program data management operations in the interest of program integration and information sharing. The SFAN DMP specifies the standards by which data will be handled. Data management elements or principles common to more than one vital sign will be managed in a conventional manner to allow for greater comparison of data across the network, as well as to ensure further general data integrity.

6.5 Data Acquisition and Processing

The NPS I&M Program is responsible for acquiring the necessary information required by park managers to properly manage and maintain the natural resources of their park. To successfully accomplish this task, information from multiple sources is collected by the SFAN I&M Program and processed to ensure that it meets the data standards established by the SFAN. The DMP describes the general procedures the SFAN follows for acquiring and processing natural resource-related data. Procedures will vary depending on the data source, which can be placed into three general categories:

- **SFAN data:** data resulting from projects that are initiated, sponsored, or funded by the San Francisco Bay Area Network.

- **Other NPS data:** data resulting from projects that are initiated, sponsored, or funded by park units, or by regional or national NPS programs.

- **External data**: data produced or managed by agencies, organizations, or individuals other than the NPS.

The collection of programmatic data under the purview of the SFAN I&M Program is connected to either natural resources inventories or to vital signs monitoring. Data for each of these projects will enter and flow through the system illustrated in Figure 6.2.

Information and data sets available from other NPS (i.e., Exotic Plant Management Teams, Joint Fire Science Program) and external programs (USGS, NOAA) are utilized by the SFAN to strengthen and support its inventory and monitoring programs. These data sets can help to establish base resource conditions and aid in the detection of long-term monitoring trends.

6.6 Quality Assurance/Quality Control

The network will establish and document protocols for the identification and reduction of error at all stages in the data lifecycle. Although specific QA/QC procedures will depend upon the individual vital signs being monitored and must be specified in the protocols for each monitoring vital sign, some general concepts apply to all network projects.

Each vital sign protocol will include specifics that address quality control. These may include:

- Field crew training
- Standardized data sheets
- Use of handheld computers
- Equipment maintenance and calibration
- Procedures for handling data (including specimens) in the field
- Data entry, verification and validation

Data entry after the field season represents a critical data life stage in terms of QA/QC. To facilitate data entry, data for each vital sign will be entered via customized MS Access applications modeled after the Natural Resources Database Template developed by the National I&M Program. These applications help enforce data standards by constraining the type, value, and format of data as appropriate to each vital sign.

The SFAN DMP presents several options for carrying out data verification (ensuring data on field sheets match data entered into a database) and validation (ensuring that the data make sense). Each vital sign protocol specifies procedures for completing proper verification and validation of data.

6.6.1 Documentation of Quality

The final step in data QA/QC is the preparation of summary documentation that assesses the overall data quality. A statement of data quality will be composed by each vital sign project leader and incorporated into formal metadata, as well as the SFAN primary data repository. Metadata for each data set/database will also provide information on the specific QA/QC procedures applied and the results of the review. Metadata and data will be available via the NPS NR-GIS Data Store.

6.7 Data Documentation

Data documentation is a critical step towards ensuring that data are useable for its intended purposes well into the future. This involves the creation of metadata. Metadata can be defined as data about the content, quality, condition and other characteristics of data. Additionally, metadata provide the means to catalog datasets, within intranet and internet systems, thus making these datasets available to a broad range of potential data users.

Metadata for all SFAN monitoring data will conform to the NPS Metadata Profile, which combines the FDGC standard, elements of the ESRI metadata profile, the Biological Data Profile, and NPS-specific elements (FDGC 1998). The SFAN metadata plan is limited to four recommended desktop applications for collecting metadata. These include Dataset Catalog and the NPS Metadata Tools and Editor, both developed by the NPS I&M Program, and two commercial off the shelf metadata tools, ArcCatalog and SMMS.

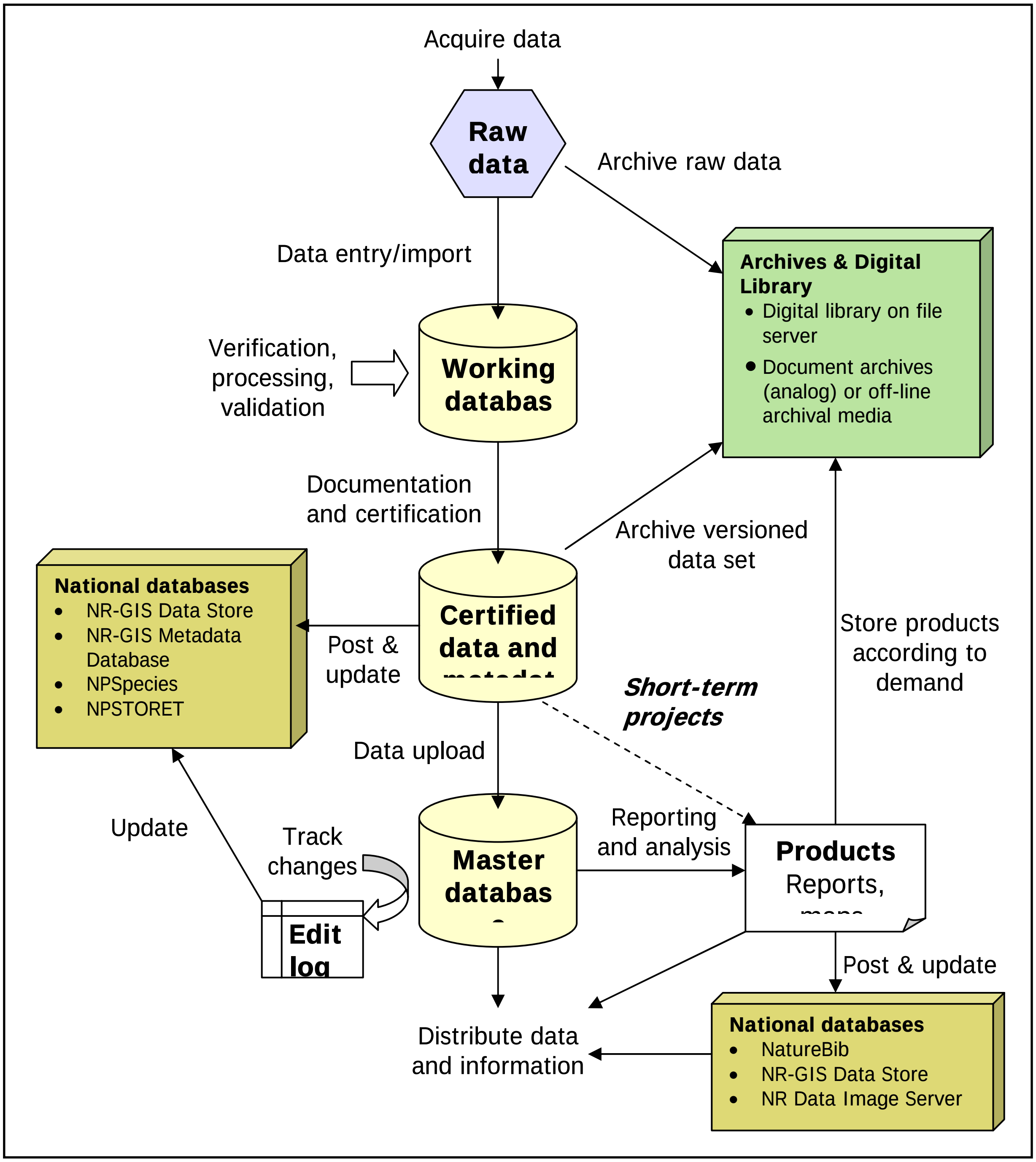


Figure 0.4 Diagram of the typical project data life cycle.

All relevant data products and associated metadata generated through the SFAN I&M Program will be posted to the NR-GIS Data Store. Launched in June 2005, the NR-GIS Data Store is a web-based system designed to integrate data dissemination and metadata maintenance for Natural Resource, GIS, and other program data sets, digital documents, and appropriate digital photos. The NR-GIS Data Store provides two functions: the NR-GIS Metadata Database and the NR-GIS Data Server. The NR-GIS Metadata Database is a repository of and search engine for metadata describing natural resource and GIS data. The NR-GIS Data Server hosts natural resource and GIS data (documented by the metadata in the NR-GIS Metadata Database) for download.

6.8 Data and Information Dissemination

Access to SFAN monitoring products will be facilitated via a variety of data and information systems employing tools that allow potential users to browse, query, and obtain data, information, and supporting documents easily.

Providing well-documented data in a timely manner to park managers is especially important to the success of the program. The SFAN will make certain that:

- Data are easily discoverable and obtainable
- Data that have not yet been subjected to full quality control (legacy data, unknown data quality, Freedom of Information Act (FOIA) requests will be released with a disclaimer stating as such
- Distributed data are accompanied by metadata that clearly establishes the data as a product of the NPS I&M Program
- Sensitive data are identified and protected from unauthorized access and inappropriate distribution
- A complete record of data distribution/dissemination is maintained

The network's main mechanism for distribution of I&M data will be the internet. Use of the internet will allow the dissemination of data and information to reach a broad community of users. As part of the NPS I&M Program, web-based applications and repositories have been developed to store a variety of park natural resource information. Table 6.3 outlines the applications and repositories that the SFAN will use to distribute data developed by the program.

6.8.1 Data Ownership, FOIA, and Sensitive Data

SFAN products are considered property of the NPS. However, the FOIA establishes a general right for any person to access federal agency records that are not protected from disclosure by any exemption or by special law enforcement record exclusions. The SFAN complies with all FOIA strictures regarding sensitive data. Each vital sign project leader, as the chief data steward, determines data sensitivity in light of federal law and stipulates conditions for release of the data in the project protocol and metadata.

Table 0.3 Repositories for SFAN products.

Repository	Product
SFAN Digital Archive	Project data, metadata, and other products Raw and certified data sets Metadata, protocols, SOPs Reports and administrative records Digital photographs, derived products
SFAN Project Databases	Comprehensive data for multi-year projects
Park Collections, Museums, Herbariums, and/or National Archives	Administrative records, voucher specimens, raw data forms, hard copy reports
National Databases - NPSTORET, NPSpecies, NatureBib	Compiled information about water quality, park species lists and taxonomic documentation, park resource bibliographies
NR Data Image Server	Copies of digital reports and other documents (catalogued in NatureBib)
NR-GIS Data Store	Metadata and data sets (spatial and non-spatial and products)
SFAN Website	Protocols, SOPs, and reports for all I&M data produced by the network.

6.9 Data Maintenance, Storage, and Archiving

The SFAN DMP describes procedures for the long-term management and maintenance of digital data, documents, and objects that result from SFAN projects and activities. The overall goals of these procedures are:

- to avert the loss of information over time
- to ensure that information is properly interpreted by a broad range of users
- to ensure that information can be easily obtained and shared through future decades

6.9.1 Digital Data Maintenance

In general, digital data maintained over the long term will be one of two types: short-term data sets, for which data collection and modification have been completed (i.e., inventory projects); and long-term monitoring data sets, for which data acquisition and entry will continue indefinitely.

Maintaining digital files involves managing the ever-changing associated infrastructure of hardware, software, file formats, and storage media. As software and hardware evolve, data sets must be consistently migrated to new platforms.

Data sets created or managed by the SFAN will be archived in read-only format with accompanying metadata, other data documentation, protocols, and final reports according to a specified project schedule (monitoring) or upon project finalization (inventory). All finalized files will be stored in the SFAN archive directory on the GOGA Headlands server..

6.9.2 Storage and Archiving Electronic Data and Documents

Digital archives of completed I&M products, including SOPs, reports, and data sets, will be maintained at the park and Network levels. For long-term monitoring projects, data sets will be uploaded to both digital archive locations on an annual basis according to schedules outlined in the SOPs.

Final digital products, including SOPs, final reports, and data sets will be placed in a read-only format in the SFAN digital archives located on the Headlands server, Network I&M directory.

Only final documents will be archived – no drafts or works in progress. Only the lead data manager will archive data sets. Data sets must be validated and verified, must represent a complete set of records, and must have accompanying metadata and readme text files. Archived digital documents will then be entered online into NatureBib.

To ensure long term management of and protection for the work that is generated by the I&M program, a hardcopy of final products will be sent to the GOGA Records Center located in the Presidio of San Francisco and to individual park's archives as necessary.

6.9.3 Storage and Archiving Hardcopy Documents and Objects

Documents that are not available in digital format will either be scanned and saved as PDF files in the SFAN archive directory or saved in hardcopy format for larger documents. Scanned documents will then follow procedures outlined for electronic digital archives, which include entering the document into NatureBib and forwarding the original document to the GOGA Records Center and individual park's archives. Hardcopy documents will be maintained in a local library being developed at GOGA's Fort Cronkhite, with original copies forwarded to the GOGA Records Center and a record entered into NatureBib.

Specimens collected under the auspices of SFAN I&M program will be cataloged and maintained according to NPS Director's Order #24: NPS Museum Collections Management. Specific repositories for specimens are detailed in the inventory contracts or study plans, monitoring protocols and SOPs, and collection permits.

Several of the SFAN I&M projects incorporate digital, film (slides or negatives), and/or print photography into their protocols. Archiving procedures for digital and print photos will follow guidelines previously established for digital and hard-copy documents, respectively.

6.10 Water Quality Data

Water quality data collected to meet regulatory requirements is managed according to guidelines from the NPS WRD. This includes using the NPSTORET desktop database application at the parks to help manage data entry, documentation, and transfer. The network oversees the use of NPSTORET according to the network's integrated water quality monitoring protocol and ensures the content is transferred at least annually to NPS WRD for upload to the STORET database maintained by the U.S. Environmental Protection Agency (Figure 6.5).

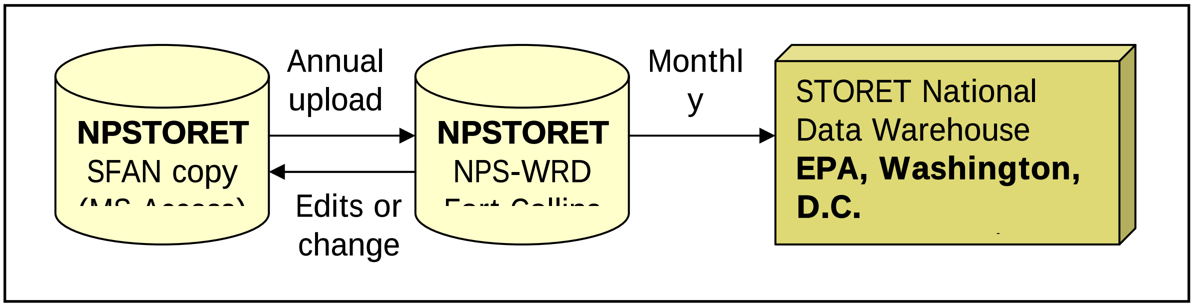


Figure 0.5 Data flow diagram for water quality data.

Chapter 7 Data Analysis and Reporting

7.1 Overview of Data Analysis and Reporting

Sound data management practices are a key component to having a credible monitoring program that provides data to managers. In order to be meaningful, however, data must be analyzed, synthesized, interpreted, and provided to managers, decision-makers, or other interested parties in a usable form at regular intervals. Different types of reports are needed to provide information to multiple audiences. This chapter presents an overview of the types of analyese that the I&M program will produce and the resulting reporting mechanisms.

In Table 7.1, we present an outline of data management tasks (data collection, data entry, and archiving), types of analysis and reporting, the position(s) responsible for the analysis and reporting, and the frequency for the long-term trend analysis reports. All of these considerations are important to clarify not only the nature of and logistics required for these analyses and reports, but also to ensure that there is sufficient program accountability, documentation, and evaluation.

7.2 Data Analysis

Many of the monitoring programs utilize summary statistics (mean, median, range, standard deviations, etc.) in the annual report to provide results such as, population size estimates, reproductive rates, and annual precipitation. In addition, geographic information systems (GIS) analysis is an important component of annual monitoring. GIS analyses include measuring invasive species rates of spread, population density, and changes in land use over time. The vital sign protocol explains the type of data analyses used in annual and long-term trend data analysis.

7.2.1 Water Quality Data Analysis

Non-parametric statistical tests will primarily be used to describe water quality data. The median and interquartile range (IQR) (middle 50% of data points) will be used in addition to the mean and standard deviation. Confidence intervals (95%) will be used to bound uncertainties in means and medians. Summary statistics and correlation techniques will be used to quantify relationships between water quality variables. To limit seasonal variability, statistical tests will be performed on each of the different seasons. The Seasonal-Kendall test will be used for trend analyses.

For each monitoring question, individual station data will be summarized seasonally and annually. Data from all stations within each watershed will also be summarized seasonally and annually. All data will be compared with water quality standards by graphing the data along with a “criteria line” on the graph that clearly shows which measurements fall above or below the standards. Within each watershed, data from stations upstream and downstream of a suspected pollution source or tributary will be compared. Summary tables, histographs, and box and whisker plots will be used to show median and interquartile ranges, mean and standard deviation, and 95% confidence intervals for means and medians. Summary reports and an updated NPSTORET database will be sent to WRD annually.

7.3 Reporting

The I&M program has multiple audiences that need to receive and understand the information learned through the monitoring program. Congress, the Office of Managemend and Budgets (OMB), national and regional offices, superintendents, resource managers, park interpreters, cooperators, volunteers, friends groups, and the public all need to be provided the opportunity to learn about and understand the SFAN Vital Signs Monitoring Program. Each group will require a different level of information and a different method of delivery. Within the next year, the SFAN will develop an explicit communication strategy to explore, plan and prioritize the types of information and communication tools to use for the different audiences. A variety of reporting tools are already being considered.

- Annual Reports
- Annual Briefings to Park Managers
- Analysis and Synthesis Reports
- Program and Protocol Reviews
- Scientific Journal Articles
- Internet and Intranet Websites

7.3.1 Annual Reports

The major purpose of annual reports is to:

- Summarize public interest highlights,
- Archive annual data and document monitoring activities for the year,
- Describe current condition of the resource,
- Detect change in resource condition outside of normal range of variation,
- Increase communication within the park and network,
- Provide summary reports and updates to region and national levels, and
- Provide summary reports and updates to collaborators.

7.3.1.1 Annual Project Reports: Many monitoring programs will be active each year, and those programs will generate annual reports; however, some sampling regimes do not require annual activity. Those programs will produce "annual" reports only during those years where there are significant monitoring activities to document. For those protocols, which require multi-year implementation or pilot testing, an annual report will be created that summarizes the protocol development steps accomplished during that year.

With a higher level of database design and effort applied to the vital signs, one of the goals is to develop databases with automated summary reports and data analysis capabilities. The standard use of Microsoft Access software, the standardization of database design, and the automation of data summaries and reporting all contribute to a more efficient reporting ability. With proper metadata available for each vital sign dataset and GIS component as outlined in Chapter 6 and the Data Management Plan, raw data could be provided to collaborators for additional data analysis (Press 2005).

All reports will be written using language understandable to a general audience not conversant with the specific technical details of the subject matter. Main sections will include:

- Executive Summary
- Overview
- Study Area
- Methods
- Significant findings
- Public Interest Highlights
- Management Recommendations
- Research Recommendations
- Photographs

The executive summary will be written in the form of a 1- or 2-page “briefing statement” that summarizes the key findings and recommendations for their protocol or project; these written briefing statements will then be integrated into project specific annual reports and the Annual Administrative Report and Work Plan.

7.3.1.2 Water Quality Annual Reports: Water quality monitoring will occur on an annual basis. Data will be provided to the Water Resources Division annually following. In addition, a summary report will be provided that includes a paragraph summary for each parameter plus summary graphs of each site; and, summary paragraphs will be provided for each watershed including any proposed management activities related to water quality improvements. Recommendations for revising the protocol (changing monitoring intervals and timing, moving/adding sites, etc.) will also be proposed.

7.3.2 Annual Administrative Report and Work Plan

Each year, the Monitoring Program will produce an annual report in the form of the Annual Accomplishments Report and Work Plan (AARWP) as required by the national I&M office. The purpose of the report is to account for funding and program personnel expenditures, describe objectives, tasks, accomplishments, and products of the monitoring effort for the past year. The report serves as an administrative record of the program as well as a tool that informs the park, network and regional staff on the progress of the SFAN Vital Signs Monitoring Program.

Table 0.1 Data analysis and reporting schedule for SFAN vital signs monitoring program.

Level 1	Level 2	Level 3	Network Vital Sign Name	Data Analysis / Reporting	Type of Data Analysis	Person Responsible for Data Analysis & Reporting	Data Archival	Long-term Trends Reporting
Air and Climate	Air Quality	Ozone	Ozone	Annual	Summary statistics	ARD	Continuous	10 years
		Wet and Dry Deposition	Wet and Dry Deposition	Annual	Summary statistics	ARD	Continuous	10 years
		Visibility and Particulate Matter	Visibility and Particulate Matter	Annual	Summary statistics	ARD	Continuous	10 years
		Air Contaminants	Air Contaminants	Annual	Summary statistics	ARD	Continuous	10 years
	Weather and Climate	Weather and Climate	Weather and Climate	Annual	Summary statistics	Western Regional Climate Center, Network Coordinator	Continuous	10 years
Water	Hydrology	Surface water dynamics	Freshwater Dynamics	Annual	Hydrographs, rating curves, other hydrologic summaries	GOGA Aquatic Ecologist, Network Coordinator	Annually	5 years
	Wat er Qual ity	Water Chemistry	Freshwater Quality	Annual	Summary statistics, seasonal trends	Network WQ Specialist	Annually	5 years
Biological Integrity	Invasive Species	Invasive/Exotic Plants	Invasive Plant Species (early detection)	Annual	GIS analysis, summary statistics	Network Veg. Ecologist	Annually	5 years
	Focal Species or Communities	Wetland Communities	Wetlands	TBD	TBD	TBD	TBD	TBD
		Riparian Communities	Riparian Habitat	TBD	TBD	TBD	TBD	TBD
		Fishes	Stream Fish Assemblages	Annual	Population estimates	PORE Hydrologist	Annually	3 years
		Amphibians and Reptiles	Amphibians and Reptiles	TBD	TBD	TBD	TBD	TBD

Level 1	Level 2	Level 3	Network Vital Sign Name	Data Analysis / Reporting	Type of Data Analysis	Person Responsible for Data Analysis & Reporting	Data Archival	Long-term Trends Reporting
		Birds	Landbirds	Annual	Summary statistics, population trends	PRBO	Annually	5 years
		Birds	Raptors and Condors	Annual	Nesting success, locations, summary statistics	PINN Wildlife Biologist	Annually	5 years
		Mammals	Pinnipeds	Annual	Summary statistics	PORE I&M Coordinator	Annually	5 years
		Vegetation Communities	Plant Community Change	TBD	TBD	PORE GIS Biologist, Network Veg. Ecologist	TBD	TBD
	At-risk Biota	T&E Species and Communities	Northern Spotted Owl	Annual	Summary statistics	PORE I&M Coordinator	Annually	5 years
		T&E Species and Communities	Rare, T&E Plant Species	Annual	Summary statistics, population trends	Park Plant Ecologists	Annually	3 – 5 years
		T&E Species and Communities	T&E Butterflies	Annual	Nectar source density trends, relative population estimates	PORE I&M Coordinator, GOGA Wildlife Ecologist	Fall./ Annually l	6-8 years
		T&E Species and Communities	Western Snowy Plover	Annual	Population and productivity estimates, summary statistics	PRBO, PORE I&M Coordinator, GOGA Wildlife Ecologist	Fall./ Annually	5 years
Ecosystem Patterns and Processes	Land Cover and Use	Land Cover and Use	Landscape and Land Use Change	TBD	TBD	TBD	NA	TBD

7.3.3 Annual Briefings to Park Managers

Each year, in an effort to increase the availability and usefulness of monitoring results for park managers, the network coordinator will take the lead in organizing annual briefings to the park managers. The briefings will include visits to each park to present highlights and results from ongoing monitoring efforts to all park staff. Project leads and principal investigators will be encouraged to participate. Highlights will include discussions of significant findings, public interest stories, and potential management action items. These briefings may include specialists from the air quality program, fire ecology program, Research Learning Center, and collaborators from other programs and agencies to provide managers with an overview of the status and trends in natural resources for their parks.

7.3.4 Long-term Trend Analysis Reports

The role of long-term trend analysis reports is to:

- determine patterns/trends in condition of resources being monitored,
- discover new characteristics of resources and correlations among resources being monitored,
- detect change in resource condition outside of normal range of variation
- analyze data to determine amount of change that can be confidently detected by this type and level of sampling,
- provide context, interpret data for the park within a multi-park, regional or national context,
- inform resource management programs (feedback for adaptive management), and
- provide summary reports and updates to collaborators

These reports can provide critical insights into resource status and trends, which can then be used to inform resource management efforts and regional resource analyses. This type of in-depth analysis typically requires several seasons of sampling data. Therefore, these reports are not written more frequently than every three to five years, for resources sampled annually. For resources sampled less frequently, or which have a particularly low rate of change and variability, intervals between reports may be longer. The target audiences for analysis and synthesis reports are superintendents, park resource managers, network staff, and external scientists. Trend analysis reports will generally be published in hardcopy and electronic formats, posted to the Network web site and shared with external scientists working on similar vital signs.

7.3.5 Program and Protocol Reviews

The purpose of program and protocol reviews is to:

- Conduct periodic formal reviews of the monitoring program including program administration, staffing plan, budgets, and products in order to evaluate program effectiveness (every 5-10 years)
- Conduct periodic formal reviews of individual monitoring protocols including objectives, design, operations, and products in order to evaluate new scientific information and determine if changes are needed (5-10 year intervals).

The primary audience for these types of reviews includes superintendents, park resource managers, network staff, servicewide program managers, and external scientists. Program and protocol reviews will generally be initiated by the Regional I&M Coordinator or Network Coordinator. The program and protocol reviews will include peer review, either through participation in the process or review of a recommendations report.

The following is an example of the sequence of events in a program review:

- Program manager/network team summarizes program and activity to date.
- Outside contractor or academic enlisted to conduct program assessment (e.g., power analyses of the data) and report findings.
- Broad spectrum of peers invited to review the program's products.
- Peers invited to a workshop to discuss the program, the analyses it was subjected to, whether or not it is meeting program goals, how it might be improved, what should be changed, left behind, or tried anew, and what new partners might be enlisted to join.
- Program manager or contracted personnel writes up results of this workshop, circulates to participants, and posts final report on SFAN web site, sends to NPS regional and WASO program offices.
- Program manager develops strategy with SFAN team on implementing recommendations.

Typical topics addressed are a general review of program efficacy, accountability, scientific rigor, contribution to park management and larger scientific endeavors, outreach, partnerships and products. These reviews are among the most in depth—not only will monitoring results be analyzed over a longer period of time, but the entire program, its structure, and function are evaluated to determine not only whether the program is achieving its objectives, but also whether the list of objectives is still relevant, realistic, and sufficient.

7.3.6 Scientific Journal Articles

This aspect of the program will be directed by the program managers or cooperators, and is more at the discretion of the individual investigators than any of the previous report types. Publishing scientific journal articles is primarily conducted to communicate advances in knowledge, and is a very important, widely acknowledged means of quality assurance and quality control, via the peer review process. Putting a program's methods, analyses, and conclusions under the scrutiny of a scientific journal's peer review process is basic to science and one of the best ways to ensure scientific rigor. Accordingly, the journal or book editor will conduct the peer review process. No coordination at the network level is required except for the Network Coordinator and other involved program managers to review the article before submittal to a journal. The SFAN Monitoring Program should be acknowledged as providing funding and support.

The SFAN monitoring program tracks scientific journal articles produced by SFAN efforts; new publications are a standard part of the AARWP, which the network updates and sends to the regional and national offices each year. Additionally, all scientific journal articles, which are reported in the AARWP will be entered into the NatureBib database by network data managers.

7.3.7 Internet and Intranet Websites

Internet and (restricted) intranet websites are key tools for promoting communication, coordination, and collaboration among the many people, programs, and agencies involved in the network monitoring program. All written products of the monitoring effort, unless they contain sensitive or commercially valuable information that needs to be restricted, will be posted to the main network website:

http://www1.nature.nps.gov/im/units/sfan

Documents to be posted to the network website include this monitoring plan, all protocols, annual reports, analysis and synthesis reports, and other materials of interest to staff at the park, network, regional, and national levels, as well of being of interest to our collaborators.

In addition, to promote communication and coordination within the network, we will maintain a password-protected "team website" where draft products, works in progress, and anything that needs to have restricted access can be shared within the program.

7.4 Interpretation and Outreach

In is anticipated that a variety of interpretation and outreach products will be identified through the communication strategy. Parks in the SFAN have already developed a variety outreach tools upon which the I&M network can build. PORE, for example, has an informal "brown bag" program which brings network researchers and park staff together to share results of ongoing research. Presentations are often videotaped so interpreters or other park staff who were not available to participate can view them. Network staff may also get involved with annual Interpretive Docent Training sessions which are provided for interpreters and docents who lead tours.

Interpretation and outreach is a perfect place for the SFAN Vital Signs Monitoring Program to team up with the Pacific Coast Science and Learning Center (PCSLC). The PCSLC promotes research in parks and acts as a bridge between science being conducted in parks and the public, particularly students. One of the successful programs initiated by the PCSLC employs high school students to assist with research that is being conducted at the park.

In order to ensure that information is widely available, SFAN will encourage project leads to develop up to date fact sheets, brochures, or posters about their projects. Similar products are already being developed by park staff in order to share ongoing monitoring results. During the elephant seal breeding season, for example, weekly charts showing the numbers of seals are distributed to all visitor centers at PORE and posted on the park website between December 15 and March 30. During the plover breeding season, park staff receives weekly electronic mail updates on the progress of the plover nesting season from a seasonal plover program park guide.

Another example of using monitoring information for outreach to visitors occurs with the raptor monitoring program at PINN. Raptor updates are biweekly summaries of raptor observations and activity, documented by the raptor monitor in field notes, and by other park staff or visitors on wildlife observation cards (available in the Visitor Centers). Raptor updates are important as a communication tool, providing park staff with current information on the status of raptors in the park. This information allows rangers to more effectively enforce raptor advisories, and give more complete reports on observed raptor activity. In this sense, the updates help to ensure the success of the raptor monitoring effort, and the protection of breeding raptors at the park. The updates also support interdivisional relationships by letting other park employees know what raptor monitors are doing, and encouraging other staff to assist with the monitoring effort.

Chapter 8 Administration/Implementation of the Monitoring Program

8.1 Board of Directors

The overall administration structure and implementation of the SFAN monitoring program was specified in the Charter of the San Francisco Bay Area Network for Inventory and Monitoring Board of Directors (BOD; SFAN 2001a). The BOD is comprised of park superintendents of the four park units that comprise the network (GOGA, PORE, PINN, JOMU/EUON). The Pacific West Region I&M Coordinator and the Network I&M Coordinator are ex officio members of the BOD. There will be no officers. Any park superintendent who cannot attend or otherwise participate in a meeting of the Board may assign an alternate. A park superintendent from the network may not serve as the alternate, or carry the proxy of, another park superintendent. Three BOD members constitute a quorum.

The SFAN Board of Directors shall:

- Promote accountability and effectiveness for the I&M Program by reviewing progress and results to ensure goals and targets are being achieved;
- Assist in defining the vision, long-term goals, and objectives for the program;
- Review strategies and procedures for utilizing both new and existing network resources (i.e., funding, staff, and tools) to best accomplish I&M Program goals; and
- Assist with redefining objectives and realigning resources to meet new challenges and opportunities.

All BOD decisions will be made by consensus. Consensus is defined as an outcome that all BOD members can live with even if not ideal from any one viewpoint. If the BOD cannot reach a consensus decision, the matter with all viewpoints represented, will be referred to the Deputy Regional Director of the Network. All decisions will be documented with responsible individuals and deadlines identified, as appropriate. Such decisions will be distributed to all BOD members as well as the Regional I&M and Network I&M Coordinator.

To be most effective, the BOD will maintain a close working relationship with the Chief of Natural Resources of each park in the network, members of the Technical Steering Committee (TSC), and the Regional and Network I&M Coordinator. BOD members are encouraged to participate in and/or keep informed with respect to the work of the TSC. The Network I&M Coordinator will be expected to provide regular briefings (by memoranda, electronic mail or telephone conference) to the BOD.

8.2 Technical Steering Committee

The TSC is comprised the network coordinator and one representative each from GOGA, PINN, and PORE. JOMU and EUON have one joint representative. Decisions are made by concensus. Additional non-voting members include the PORE Senior Science Advisor, the Lead Data Manager, and any park staff that supervises an I&M technician (e.g. PORE Hydrologist). The

Board will approve its composition as well as its charter and the Network I&M Coordinator will chair its meetings and coordinate its efforts. The TSC will be responsible for:

- Acting as a liaison to their parks' natural resource management and science division staff for communicating I&M program objectives and issues;
- Compiling and summarizing existing information about park resources;
- Participating in the identification of monitoring objectives;
- Evaluating sampling designs, methods and protocols;
- Reviewing annual monitoring reports and interpretation;
- Participating in the preparation of the Monitoring Plan, Annual Work Plan, Annual Accomplishments Report and other Network documents; and
- Developing materials for and facilitating the Five Year Program Review.

The products and recommendations of the TSC will be presented to the BOD for approval. TSC meetings are open to any interested park staff. The Network I&M Coordinator will be responsible for maintaining the administrative record. Copies of all documentation will be made available to the Regional I&M Coordinator, BOD and TSC through emails, phone calls, or on the Network's web site.

8.3 Other Committees

The BOD may form a standing Information and Education Committee comprised of interpretation, education and public affairs staff at a later date. When needed, the BOD, TSC, or Network I&M Coordinator may form groups of specialists to work on a particular task or a particular sub-program area.

8.4 Network Staff

Vital signs monitoring will be implemented by a combination of network and park staff. A lead will be selected to implement each protocol. In some cases, the lead may oversee and implement all aspects of a monitoring protocol from the design phase through the implementation phase including data collection, management, analysis, and reporting. Where opportunities for collaboration exist, the lead may be responsible for overseeing a contract or agreement (e.g., cooperative agreement or interagency agreement). Protocols will specify the roles and responsibilities of each project lead.

The I&M Program currently supports 12 employees. This includes two permanent employees who are housed at GOGA (Network Coordinator and Lead Data Manager). The other positions consist of one natural resources specialist, six technicians, two data managers, and one Student Conservation Association (SCA) volunteer. Additional volunteers support data collection efforts whenever possible. PORE partially funds two of these positons. The I&M program also contributes to PORE in return for administrative support.

The TSC and BOD have decided to make all new positions subject-to-furlough (STF) in order to build maximum flexibility into the program. It is expected that some STF positions will be reconsidered as the the program continues to move from protocol development to full implementation. Position management is a BOD responsiblility, but recommendations will be made to the BOD from the TSC when and how to fill any vacancies in network positions that occur. No position shall be converted from non-permanent to permanent status without the explicit written approval of the Board of Directors.

8.4.1 Network Coordinator

The permanent Network I&M Coordinator (GS-12; subject to furlough) is duty stationed at GOGA. The Network I&M Coordinator works closely with park biologists and physical scientists to plan and implement the vital signs long-term monitoring plan. The Coordinator is responsible for the overall SFAN I&M program administration (budget, property, staffing, reporting, project completion, and data archiving). The Coordinator seeks strategic partnerships to further the monitoring plan goals. The Coordinator may also conduct ecological studies concerning a range of resource attributes and associated habitats. The Network Coordinator is supervised by the GOGA Assistant Superintendent and takes direction from the BOD.

8.4.2 Data Manager

Data management is accomplished through a team of three data managers.

8.4.2.1 Lead Data Manager: The permanent Lead Data Manager (GS-11; subject to furlough) is duty stationed at GOGA. The lead data manager provides programmatic oversight on all issues relating to data management. The incumbent serves as the liaison for the I&M Program to the national, regional, and network parks. The position provides oversight to all data management products. The position is supervised by the Network Coordinator.

8.4.2.2 Park Data Managers: Two supporting Data Mangers are funded by the I&M program and are based at PORE and PINN. Both positions are funded at the GS-9 level. The PORE position is split among two employees and was raised to a GS-11 by the park. The positions are designed to provide assistance to the Lead Data Manager including database development and GIS support. As databases are populated and processes implemented to input, archive, and manage the databases, the data management staffing plan will be evaluated to determine if it still serves the Network needs sufficiently.

8.4.2 Natural Resource Specialist

The term, subject-to-furlough, Natural Resource Specialist (GS-9) is duty stationed at GOGA. The position serves as the lead biologist developing the protocols for the early detection of invasive plant species, rare plant species, and components of the plant community change protocol. The position is supervised by the Network Coordinator.

8.4.3 Fisheries Biologist

The Fisheries Biologist (GS-9) is responsible for field work associated with monitoring freshwater assemblages. In addition, at least 20% of the technician's time is dedicated to maintaining accurate field data and entering data into appropriate databases in order to prepare it for analysis and reporting. The position is funded at the GS-7 level for 25 pay periods and is stationed at PORE. PORE has allocated additional funding to support the position at a GS-9 level.

8.4.4 Hydrologic Technician

The term, subject-to-furlough, Hydrologic Technician (GS-7) is duty stationed at PORE and is supervised by the PORE Hydrologist. The position is responsible for implementing the Water Quality Monitoring Plan.

8.4.5 Wildlife Biological Technician

The Wildlife Biological Technician (GS-7) is responsible for field work associated with pinniped and spotted owl monitoring. In addition, at least 20% of the technician's time is dedicated to maintaining accurate field data and entering data into appropriate databases in order to prepare it for analysis and reporting. The position is funded for 20 pay periods and is stationed at PORE.

8.4.6 Vegetation Biological Technician

The Vegetation Biological Technician is responsible for field work associated with invasive species monitoring. In addition, at least 20% of the technician's time is dedicated to maintaining accurate field data and entering data into appropriate databases in order to prepare it for analysis and reporting. The position is funded for 16 pay periods during FY06. The number of people in this position may be increased and funded for more pay periods as the program moves toward implementation of both invasive species and rare species monitoring.

8.4.7 Avian Biological Technician

The Avian Biological Technician (GS-7) is responsible for field work associated with raptor and condor monitoring. In addition, at least 20% of the technician's time is dedicated to maintaining accurate field data and entering data into appropriate databases in order to prepare it for analysis and reporting. The position is funded for 13 pay periods and is stationed at PINN.

8.4.8 Student Conservation Association

The I&M program will provide training opportunities through the Student Conservation Association (SCA) in exchange for assistance with field monitoring. SFAN is budgeting for at least one SCA volunteer annually to assist with a variety of projects including weather monitoring, freshwater dynamics, or other vital signs monitoring. Approximately 40% of the position will be dedicated to fieldwork and 40% to data management.

8.5 Shared Positions

8.5.1 Budget Analyst

The I&M program contributes $15,250 to support a budget analyst for 0.25 FTE. The position helps track budgets including purchases and credit cards, vehicles, and assists with travel. The position is based at PORE.

8.5.2 Administrative Support

The I&M program contributes $10,000 to PORE for administrative support. This provides the program with assistance from contracting, procurement, and human resources.

8.5.3 Regional Aquatic Ecologist

The Regional Aquatic Ecologist (GS-12) is partially funded by the WRD. The I&M Program, however, has contributed amounts up to $14,000 toward the ecologist's salary for assistance on various projects. In FY05, for example, the Aquatic Ecologist coordinated an amphibian and reptile monitoring workshop to identify appropriate monitoring questions and to develop monitoring goals and objectives. She also assisted with establishing a robust experiental design for monitoring a rare plant species. It is anticipated that I&M will continue to contribute project specific funds to this position.

8.6 The PWR Inventory and Monitoring Coordinator

Program coordination and oversight at the regional level is provided by a full-time Regional Inventory and Monitoring Coordinator who reports to the region's senior natural resource staff member or other regional staff person designated by the Regional Director. Regional I&M Coordinators are responsible for providing technical support along with day-to-day coordination among networks, the regional office, and the National Inventory and Monitoring Program.

8.7 Integration with Other Divisions

Each vital sign requires different levels of coordination with other divisions, such as resource protection, maintenance and interpretation. The members of the TSC, park I&M project leaders, and Network staff coordinate with resource management staff at the parks to ensure monitoring goals are being met and to keep parks informed of monitoring activities. Division Chiefs pass on information about monitoring events and results to senior park management staff at regular weekly briefing meetings. Regular updates support interdivisional relationships by letting other park staff know what the monitoring staff is doing, and by encouraging other staff to assist with the monitoring effort.

8.8 Existing and Potential Monitoring Partnerships

The potential for conducting collaborative monitoring programs in the San Francisco Bay region is high. It is incumbent upon the Network to establish partnerships and to find additional grants to implement vital signs monitoring since NPS I&M funding will not cover all monitoring needs. Partnerships assist the SFAN in implementing more vital vigns monitoring projects than would be possible without assistance. Organizations, agencies, and institutions ranging from watershed management councils to state and federal agencies have existing monitoring programs in the area. In fact, many of the SFAN's existing monitoring efforts have been ongoing for decades and are the result of partnerships. These partnerships provide the NPS the opportunity to play a key role in the development of region-wide natural resources assessment and monitoring programs.

The network has formal agreements, such as interagency agreements and cooperative agreements, as well as informal partnerships with groups that share common goals with the NPS. A few of the partners are:

Interagency Agreements:

- The U.S. National Marine Fisheries Service (NMFS) has large scale, long-term monitoring studies of marine mammals, sea turtle and fish in the region. The parks currently participate in studies of pinnipeds, including harbor seals and northern elephant seals, which contribute to the rangewide analyses completed by NMFS.

- USGS Biological Research Division (BRD) has had Research Scientists located at both PORE and GOGA since BRD was established. USGS Research Scientists have assisted with vertebrate inventories and planning the monitoring program.
- The U.S. Fish and Wildlife Service has large scale, long-term monitoring studies focused on water birds and seabirds at Golden Gate and Point Reyes. Both parks benefit from over twenty years of data developed and analyzed by this agency. The Service is involved in the re-introduction and monitoring of California condors at PINN.
- The U.S. National Oceanographic and Atmospheric Administration (NOAA) manages three large National Marine Sanctuaries (NMS) off central California, which abut or are near PORE and GOGA. The Gulf of the Farallones includes nurseries and spawning grounds for commercially valuable species of fish, at least 26 species of marine mammals, and the largest concentration of breeding seabirds in the continental United States. Monterey Bay Marine Refuge, the nation's largest NMS, spans 5,300 square miles with an array of habitats from rugged rocky shores and lush kelp forests. Cordell Bank NMS is located 40 miles west of PORE and is a significant seamount where many marine species forage. The refuges are a focal point for research. Each of these sanctuaries is presently conducting inventories and identifying elements to monitor. PORE and GOGA already cooperatively monitor several marine species with NOAA including seabirds, pinnipeds and intertidal communities.

Cooperative Agreements:

- PRBO Conservation Science (PRBO), an ecosystem research group located near PORE, has several broad-scale bird monitoring efforts. For example, PRBO has assisted the SFAN with monitoring and protocol development of the Northern spotted owl, Western snowy plover, and landbird vital signs.
- The Golden Gate Raptor Observatory located at the Marin Headlands at GOGA has been monitoring raptors for over 20 years.
- SFAN parks have had a long-term relationship with local universities including University of California (UC) and California State University. Researchers helped develop and implement the coastal biophysical inventory, the subtidal and deep water inventory, and Phases I, II, and III of this Monitoring Plan. They participated in workshops, reviewed previous versions of this monitoring plan, and peer-reviewed protocols for individual vital signs.
- The Point Reyes National Seashore Association is a non-profit partner and assists the SFAN in raising and managing donations for monitoring projects, such as Northern spotted owl, Western snowy plover, stream fish assemblage, pinniped, and rare plant monitoring.
- Golden Gate National Parks Conservancy is also a non-profit partner and assists SFAN in raising and managing donations for monitoring project such as Mission blue butterfly, rare plant, invasive plant, stream fish assemblage, Western snowy plover, and landbird monitoring.
- Ventana Wilderness Society is involved in the reintroduction of condors with the USFWS at PINN.

- The Nature Conservancy borders several parks and existing collaboration occurs to monitor resources.

Additional Partners:

- Tomales Bay Watershed Council, Marin County Environmental Health Services, and the Regional Water Quality Control Boards are all integral partners in the water quality monitoring programs at the SFAN parks.
- California Native Plant Society volunteers have conducted rare plant inventory surveys at all the SFAN parks, assisted with plant community mapping and will likely be partners in the monitoring program for rare, threatened and endangered plant species.
- SFAN cooperatively monitors Northern spotted owls with the Marin County Open Space District and Marin Municipal Water District (MMWD), both of which are adjacent to PORE, GOGA and MUWO forested lands. SFAN also works with MMWD to monitor stream fish assemblages.
- Six California State Parks are adjacent to or encompassed by the SFAN and have a similar conservation and educational mission. SFAN currently coordinates with State Parks for monitoring Northern spotted owls, stream fish assemblages, and landbirds.
- Los Padres National Forest encompasses nearly two million acres in the coastal mountains of central California. The north division around Monterey and Santa Lucia is directly east of Pinnacles.
- The Mid-peninsula Regional Open Space District currently manages nearly 50,000 acres of land in 26 open space preserves. Their purpose is to permanently protect and restore acquired lands forming a regional open space greenbelt.
- The Peninsula Open Space Trust is a nonprofit group dedicated to preserving the beauty, character and diversity of the coastal areas of the San Francisco Peninsula. Since its founding twenty years ago, it has protected more than 40,000 acres of San Francisco Bay open space.
- The Muir Heritage Land Trust preserves undeveloped land to provide a buffer between cities and suburbs of Contra Costa County. They are interested in establishing wildlife migratory corridors by connecting protected lands. One current campaign is to protect 1,500 acres of land linking ridge lands from the Carquinez Strait, extending south to Briones Regional Park, and continuing to areas near Las Trampas Regional Wilderness. This may help provide some connectivity for EUON and JOMU.
- Marin Municipal Water District monitors several species in common with GOGA and PORE, including stream fish assemblages and Northern Spotted Owls.

8.9 Program Integration

SFAN has made a commitment to implement long-term monitoring, analyze data, and report findings to various audiences in the parks including resource management, park administration, and interpretation. Integrating science into park management, however, is more complex than simply reporting results. The SFAN will be working closely with each park through the Board of

Directors, the Technical Steering Committee, and with other senior management staff to make sure all SFAN products are fully integrated and used by park management. Regular meetings between SFAN staff and park staff including senior management, planners, interpreters, maintenance, and park rangers will ensure that final products will meet park needs and appropriate deadlines. As part of the program review (see section 8.10), SFAN will analyze how well SFAN is integrated into park operations.

8.10 Program Reviews

The SFAN Charter (SFAN 2001a) established a schedule program reviews starting in 2007 and every 5-10 years thereafter. The purpose of this review will be to evaluate the overall vital signs monitoring program accomplishments,staffing and products, data management, fiscal management, cost-effectiveness of each vital sign. The program review shall provide the principal basis for any significant changes in program direction as well as reassignment of resources to any park or office. Participants in the review could include the TSC, BOD, and additional personnel to be determined later. The SFAN Charter will be revised following a programmatic review to serve as the document of record for the program's administration and management structure.

A group of three technical peers will review individual vital sign protocols every five years or three cycles, depending on the cycling schedule and history of the vital sign. Annually monitored vital signs will be reviewed every five years. A cycled vital sign such as plant community change may only be monitored every five to ten years. Therefore, the initial review will likely occur after three cycles of the monitoring activities.

The review of vital sign protocols will examine whether the vital sign is measuring the defined monitoring goals. The review will include a statistical analysis of the results. In addition, the vital sign report will contain a list of the information used for the review, an evaluation of program costs, monitoring schedule, data management protocols, and management benefits from the monitoring program.

Chapter 9 Schedule

9.1 Timing and Frequency

This chapter explains the schedule that the Network will follow during the next five years to develop vital signs monitoring protocols and to implement the Monitoring Plan. The following schedule (Table 9.1) lists the eighteen top priority vital signs scheduled for monitoring and describes when protocol development and peer review will be completed. Table 9.1 also describes key issues that must be addressed in establishing protocols for each for the 18 vital signs.

Table 0.1 Schedule of vital signs protocol development.

Vital Sign Name	Target Year for Protocol Completion and Implementation	Key Issue to be Addressed Before Implementation
Air Quality	TBD	Data collection for air quality monitoring is ongoing. Protocols outlining data management, analysis, and reporting are being developed and implemented by the NPS Air Resource Division (ARD). Data are already being collected by partnering agencies.
Weather and Climate	FY 06	Data collection for weather and climate monitoring is ongoing. A draft protocol outlining data management, analysis, and reporting has been developed by I&M Staff and will be peer reviewed in FY06. Protocols will be revised upon receiving review comments.
Freshwater Dynamics	FY 06	A draft protocol outlining data management, analysis, and reporting has been developed by I&M Staff and will be peer reviewed in FY06. Data collection will continue and protocols will be revised upon receiving review comments.
Water Quality	FY 06	A draft protocol outlining data management, analysis, and reporting has been developed by I&M Staff and will be peer reviewed in FY06. Data collection will continue and protocols will be revised upon receiving review comments.
Invasive Plant Species	FY 06	A draft protocol using a volunteer based methodology has been developed by I&M staff in FY05. The protocol will be field tested in FY06 and submitted for peer review.
Wetlants	TBD	A strategy including a timeline and budget for developing and implementing monitoring protocols will be initiated in FY06.
Riparian Habitat	TBD	A strategy including a timeline and budget for developing and implementing monitoring protocols will be initiated in FY06.
Stream Fish Assemblages	FY 06	Data collection for stream fish assemblage monitoring is ongoing. A draft protocol outlining data management, analysis, and reporting has been developed by I&M Staff and will be peer reviewed in FY06. Protocols will be revised upon receiving review comments.
Amphibians and Reptiles	TBD	A strategy including a timeline and budget for developing and implementing monitoring protocols will be initiated in FY06. The first workshop of this planning process is scheduled for end of FY05.
Landbird Dynamics	FY06	Data collection for landbird monitoring is ongoing. A draft protocol

Vital Sign Name	Target Year for Protocol Completion and Implementation	Key Issue to be Addressed Before Implementation
		outlining data management, analysis, and reporting has been developed by I&M Staff and will be peer reviewed in FY06. Protocols will be revised upon receiving review comments.
Raptors and Condors	FY06	Data collection for raptor and condor monitoring is ongoing. A draft protocol outlining data management, analysis, and reporting has been developed by I&M Staff and will be peer reviewed in FY06. Protocols will be revised upon receiving review comments.
Pinnipeds	FY06	A protocol outlining data management, analysis, and reporting has been developed by I&M Staff and was reviewed in FY04 and will be finalized in FY06.
Plant Community Change	TBD	Protocols will be initiated by I&M staff in FY06 and FY07. Funding for completion and implementation of the protocol must also be established.
Rare Plant Species	FY 07	A draft protocol outlining data management, analysis, and reporting has been developed by I&M Staff and will be peer reviewed in FY06. Protocols will be revised upon receiving review comments. Standard Operating Procedures will be added for priority rare plants over a multi year period.
Northern Spotted Owl	FY 04	A protocol outlining data management, analysis, and reporting has been developed by I&M Staff and was peer reviewed in FY05 and will be finalized in FY06
Western Snowy Plover	FY 06	Data collection for snowy plover monitoring is ongoing. A draft protocol outlining data management, analysis, and reporting has been developed by I&M Staff and will be peer reviewed in FY06. Protocols will be revised upon receiving review comments.
Threatened and Endangered Butterflies	TBD	Protocols will be developed by I&M staff in FY06 and FY07. Once peer review is completed, long-term monitoring will be implemented.
Landscape Dynamics	TBD	A strategy including a timeline and budget for developing and implementing monitoring protocols will be initiated in FY06.

Table 9.2 depicts the frequency and timing of sampling. While some data will be collected continuously (e.g., climate data), other data will be collected for several weeks at one time of year (e.g., snowy plovers surveys). It can also be seen from this table that our field efforts are not entirely weighted to one season but are distributed throughout the calendar year.

Table 0.2 Annual schedule of vital signs data collection.

Vital Sign Name	Sampling frequency	January	February	March	April	May	June	July	August	September	October	November	December
Air Quality	Continuous	X	X	X	X	X	X	X	X	X	X	X	X
Weather	Daily	X	X	X	X	X	X	X	X	X	X	X	X
Freshwater Dynamics	Monthly & storm based	X	X	X	X	X	X	X	X	X	X	X	X
Freshwater Quality*	Monthly	X	X	X	X	X	X	X	X	X	X	X	X
Invasive Plant Species	Annually				X	X	X	X	X	X			
Wetlands	TBD												
Riparian Habitat	TBD												
Stream Fish Assemblages	Monthly	X	X	X	X	X	X	X	X	X	X	X	X
Amphibians and Reptiles	TBD												
Landbirds	Weekly				X	X	X	X	X				
Raptors and Condors	Weekly	X	X	X	X	X	X	X					
Pinnipeds	Weekly during breeding seasons/Bi-weekly year round	X	X	X	X	X	X	X	X	X	X	X	X
Plant Community Change	TBD												
Rare Plants	Spring/Summer		X	X	X	X	X	X	X	X			
Northern Spotted Owl	Spring/Summer			X	X	X	X	X					
Western Snowy Plover	Summer/Winter	X	X	X	X	X	X	X	X	X	X	X	X
Threatened and Endangered Butterflies	Spring				X	X	X	X	X				
Landscape Dynamics	TBD												

* = See Table 9.3 for a monitoring schedule for specific streams within SFAN.

9.2 Water Quality Schedule

As with other vital signs, the monitoring schedule for the water quality is dependent on the sampling design. The monitoring protocol will identify when each stream is monitored, the number of sample sites, and the sampling frequency. Refer to the monitoring protocol in for specifics (Cooprider 2005).

Opportunities for phasing-in additional water bodies (e.g., Presidio streams) or eliminating the rotating basin approach will continue to be considered. Due to the Pathogen TMDL program monitoring on Olema Creek, it will continue to be monitored annually for the foreseeable future. Ideally, Lagunitas Creek tributaries would also be monitored annually since this stream is an impaired water body. However, nutrient and sediment TMDL monitoring programs are not yet in place for this creek (they should be in place by 2008).

Table 0.3 Water quality monitoring schedule. Note that the table displays on monitoring cycle; therefore FY10 will mirror FY06.

Stream	Park Unit	FY06	FY07	FY08	FY09
Olema Creek	PORE	M, S, W	M, S, W	M,S, W	M,S,W
Lagunitas Creek	PORE/GOGA			M	M
Pine Gulch	PORE	M	M		
Lower Redwood Creek	GOGA/MUWO			M ,S	M, S
Upper Redwood Creek	GOGA/MUWO			M	M
Rodeo Creek	GOGA	M, S	M, S		
Tennessee Creek	GOGA	M, S	M, S		
Nyhan Creek	GOGA	M, S	M, S		
Oakwood Creek	GOGA	M, S	M, S		
West Union Creek	GOGA			M	M
Franklin Creek	JOMU	M	M		
Strentzel Creek	JOMU	S	S		
Chalone Creek	PINN	M, S	M, S		

M monthly monitoring (Winter and Spring only for Chalone Creek and West Union Creek)
S monitoring during at least one storm event
W weekly monitoring for five weeks in winter and summer

Chapter 10 Budget

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Glossary

Adaptive Management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. In its most effective form–"active" adaptive management–employs management programs that are designed to experimentally compare selected policies or practices by evaluating alternative hypotheses about the system being managed.

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 et al. 1999). See Indicator.

Biological integrity has been defined as the capacity to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region (Karr and Dudley 1981).

Co-location refers to **s**ampling of the same physical units in multiple monitoring protocols

Conceptual Models are purposeful representations of reality that provide a mental picture of how something works to communicate that explanation to others.

Driver are the major external driving forces that have large-scale influences on natural systems. Drivers can be natural forces or anthropogenic.

Ecological effects are the physical, chemical and biological responses to drivers and stressors.

Ecological integration involves considering the ecological linkages among system drivers and the components, structures, and functions of ecosystems when selecting monitoring indicators.

Ecological (ecosystem) integrity is a concept that expresses the degree to which the 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. Indicators of ecosystem integrity are aimed at early-warning detection of presently unforeseeable detriments to the sustainability or resilience of ecosystems.

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). Three main ecosystems were identified for the network of parks; terrestrial, wetland and marine.

Ecosystem drivers are major <u>external</u> 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. Trends in ecosystem drivers will suggest what kind of changes to expect and may provide an early warning of presently unforeseen changes to the ecosystem. **Natural ecosystem processes** include both external and internal forces and processes (e.g., herbivory, respiration, productivity).

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 and is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal of sustainability of 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. Coordination of land-use decisions is implied by the whole-system focus of ecosystem management.

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.

Forms are sub-categories within each ecosystem. Marine forms include ocean, sandy beach, rocky intertidal, bay/estuary; aquatic/wetland forms include running water, standing water, and ground water and apply to both freshwater and saltwater wetlands; and terrestrial forms include grassland, shrubland, woodland, and distinct landforms (e.g., serpentine).

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 et al. 1999). 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, known or hypothesized effects of stressors, or elements that have important human values.

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

Metadata: Data about data. Metadata describes the content, quality, condition, and other characteristics of data. It's purpose it to help organize and maintain a organization's internal investment in spatial data, provide information about an organization's data holdings to data catalogues, clearinghouses, and brokerages, and provide information to process and interpret data received through a transfer from an external source.

Monitoring: collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (Elzinga et al. 1998). Detection of a change or trend may trigger a management action, or it may generate a new line of inquiry. Monitoring is often done by sampling the same sites over time, and these sites may be a subset of the sites sampled for the initial inventory.

Programmatic integration involves the coordination and communication of monitoring activities within and among parks, among divisions of the NPS Natural Resource Program Center, and among the NPS and other agencies, to promote broad participation in monitoring and use of the resulting data. At the park or network level, for example, the involvement of a park's law enforcement, maintenance, and interpretative staff in routine monitoring activities and reporting results in a well-informed park staff, wider support for monitoring, improved potential for informing the public, and greater acceptance of monitoring results in the decision-making process.

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 (Oakley et al. 2003).

Resource realms include four major categories— biosphere, hydrosphere, atmosphere, and lithosphere. These realms were used to conceptualize broad categories of interrelated ecosystem processes and components.

Socio-political forces are the laws, mandates, economic pressures and environmental perceptions influencing political decisions that bear upon anthropogenic stressors, and thereby, have a cascading effect on ecosystem function. These can include environmental laws (ESA, CWA, etc.), budgets, and changing social values.

Spatial integration involves establishing linkages of measurements made at different spatial scales within a park or network of parks, or between individual park programs and broader regional programs (i.e., NPS or other national and regional programs).

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 (Barrett et al. 1976). 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. **Anthropogenic stressors** are those perturbations to a system that directly result from human activity. Monitoring of stressors and their effects, where known, will ensure short-term relevance of the monitoring program and provide information useful to management of current issues.

Temporal integration involves establishing linkages between measurements made at various temporal scales. It requires nesting the more frequent and, often, more intensive sampling within the context of less frequent sampling.

Trend refers to directional change measured in resources by monitoring their condition over time. Trends can be measured by examining individual change (change experienced by individual sample units) or by examining net change (change in mean response of all sample units).

Umbrella species are typically large-bodied, wide-ranging species that require large patches of habitat and corridors connecting these patches to maintain viable populations. By protecting areas large enough to maintain these species, sufficient habitat can also be maintained which ensures the viability of most other species in that area.

Vital Signs, as used by the National Park Service, are the subset of indicators chosen a by park or park network as part of the vital signs monitoring program. They are defined as any measurable feature of the environment that provides insights into changes in the state of the ecosystem. Vital signs are intended to track changes in a subset of park resources and processes that are determined to be the most significant indicators of ecological condition of those specific resources that are of the greatest concern to each park. This subset of resources and processes is part 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 these resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic levels, 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).