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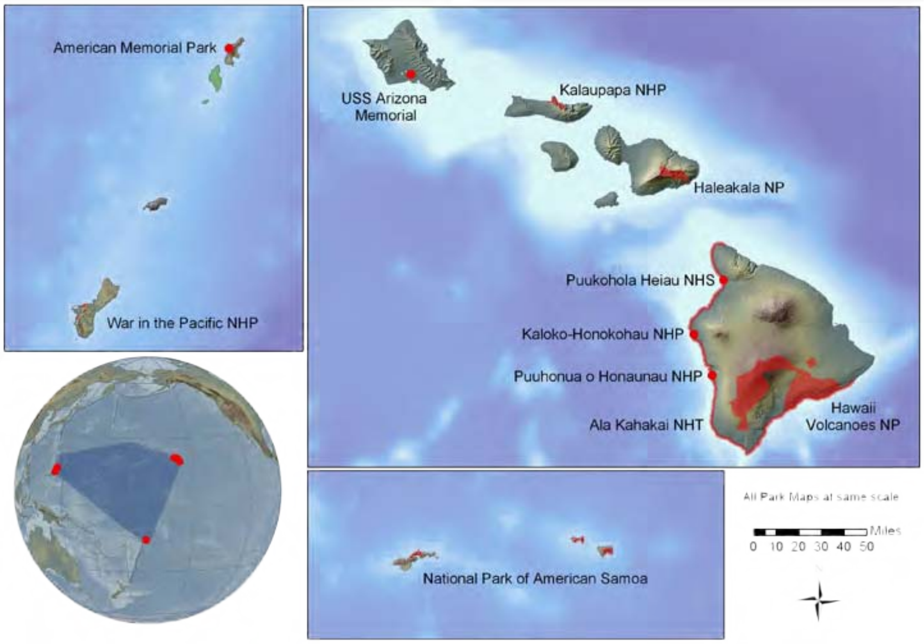
Natural Resource Program Center

Pacific Island Network Vital Signs Monitoring Plan

Natural Resource Report NPS/PACN/NRR—2006/003



Pacific Island Network
NPS Inventory & Monitoring Program

ON THE COVER

Clockwise from top left:
Tutuila Island, National Park of American Samoa
Iiwi (*Vestiaria coccinea*) at Hawaii Volcanoes National Park
Anemones (*Heteractis sp.* and *Entacmaea quadricolor*) and dusky anemone fish (*Amphiprion melanopus*) at War in the Pacific National Historical Park
Map of the 11 national parks in the Pacific Island Network
Mariana eight spot butterfly (*Hypolymnus octucula mariannensis*) at American Memorial Park

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Pacific Island Network Vital Signs Monitoring Plan

Natural Resource Report NPS/PACN/NRR—2006/003

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http://science.nature.nps.gov/im/units/pacn/monitoring/plan.cfm

Executive Summary

Monitoring and adaptive management will facilitate the ability of the National Park Service to protect our natural heritage landscapes and resources (Tau, National Park of American Samoa).

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) ability to manage park resources "unimpaired for the enjoyment of future generations." National park managers across the country are confronted with increasingly complex and challenging issues. These issues require a broad-based understanding of the status and trends of park resources as a basis for making decisions, and for working with other agencies as well as the public to benefit park resources. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas. The assessment of resource trends provides an evaluation of the efficacy of management practices and restoration efforts, and provides early warnings of impending threats. Since most parks are open systems, the challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem approach. These systems face threats such as air and water pollution, or invasive species originating outside of the park's boundaries. An ecosystem approach is further needed because no single spatial or temporal scale is appropriate for all system components and processes. The appropriate scale for understanding and effectively managing a resource might be at the population, species, community, or landscape level. In some cases, acquiring this information may require a regional, national, or international monitoring effort to understand and manage the resource. National parks are part of larger ecosystems and must be managed in that context.

Pacific Island Network Monitoring Goals

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

The Natural Resource Challenge (NRC) was launched in 2000 to revitalize and expand the natural resource program within the NPS. The NRC was also intended to improve park management through greater reliance on scientific knowledge.

The Pacific Island Network

National parks have been grouped into 32 monitoring networks that are linked by geography and shared natural resource characteristics. Individual parks within each of the networks work together by sharing professional staff and funding to plan, design, and implement an integrated long-term monitoring program. The Pacific Island Network (PACN) includes 11 units spread across the Pacific Ocean between Guam, Northern Mariana Islands, American

Samoa, and Hawaii. Annual Vital Sign Monitoring funding of the PACN from the Natural Resource Challenge is $1,570,100. In addition, the NPS Water Resources Division contributes $151,000 for water quality monitoring.

Monitoring for the PACN includes five Servicewide goals. As a reflection of the close ties of native Pacific islanders to the land and sea, the PACN added a sixth goal to the national goals which is to "provide data to better understand, protect, and manage important resources that share cultural and natural value."

While the parks of the PACN share many characteristics, the geographically vast network is marked by ecological diversity. Important natural communities include scrub land ecosystems (alpine and subalpine, non-alpine desert and lava field); forest and shrubland ecosystems (rain forest, cloud forest, montane bog and pond, Hawaiian mesic forest, Marianas limestone forest, Hawaiian dry forest and grassland, and Mariana Island savanna); subterranean ecosystems; streams; coastal ecosystems (coastal marshes, mangrove swamps, fish ponds, coastal strand, and anchialine pools); and nearshore marine ecosystems (coral reefs, intertidal, and seagrass beds). The park units also contain a high proportion of the nation's threatened and endangered species, and provide some of the last remaining habitats for these rare plants and animals. Some of the network's most challenging management issues include: invasive species, adjacent land-use, in-park resource use, fire, global climate change, and natural hazards (e.g., lava flows, tropical cyclones).

Eleven Units of the Pacific Island Network

- War in the Pacific National Historical Park (Guam)
- American Memorial Park (Northern Mariana Islands)
- National Park of American Samoa (American Samoa)
- USS Arizona Memorial (Hawaii)
- Kalaupapa National Historical Park (Hawaii)
- Haleakala National Park (Hawaii)
- Ala Kahakai National Historic Trail (Hawaii)
- Puukohola Heiau National Historic Site (Hawaii)
- Kaloko-Honokohau National Historical Park (Hawaii)
- Puuhonua o Honaunau National Historical Park (Hawaii)
- Hawaii Volcanoes National Park (Hawaii)

Vital Signs

Monitoring provides scientific information about the ecological health of our national parks. Vital Signs are a medical analogy for ecosystem health and include: (1) physical, chemical, and biological elements and processes of park ecosystems; (2) known or hypothesized effects of stressors; and/or (3) elements that have important human values. The Vital Signs selected by the Pacific Island Network (see table below) are a subset of the total suite of natural resources that park managers are directed to preserve.

PACN Vital Signs include several broad categories (Levels 1 and 2 below) of physical and chemical processes important to all park systems such as air and climate, water, geology, and soils. Because of the high rate of endemism and the pervasive threats of invasive species in network parks, biological integrity is well-represented in the PACN Vital Signs list. To better allocate financial and staff resources, 14 Vital Signs will be developed initially in phase 1, with another four to follow in phase 2, thereby staging the development and implementation of Vital Signs over time. Water quality monitoring is fully integrated within the PACN monitoring program. A water quality report is complete (appendix I), and water quality Vital Sign monitoring will be implemented in 2007.

Program Implementation

Detailed monitoring protocols will document step-by-step guidance for collecting, analyzing, and reporting information for each Vital Sign. Centralized NPS staffing, agreements with cooperators, and park supported programs are mechanisms we will use to implement monitoring efforts. In some cases, other agencies are already monitoring Vital Signs (e.g., air quality and volcanic activity). In these cases, the Pacific Island Network Vital Signs monitoring program will focus on acquiring and interpreting these data, and reporting results.

Administrative oversight for the program rests upon the Board of Directors (BOD), which consists of superintendents of the network's 11 parks, and the Technical Committee (TC). The TC is comprised of natural resource managers from the PACN parks, along with other agency representatives in order to enhance the diversity of network monitoring approaches. The TC serves as the scientific and operational body of the network that develops recommendations to the BOD on how monitoring is implemented.

Individual national parks, the Inventory and Monitoring (I&M) program, and numerous cooperators collect data annually about plant and animal populations, ecological communities, and general ecosystem health. To ensure that accurate and complete records of these observations are maintained in perpetuity, the PACN has dedicated staff and cooperators toward data management. The Data Management Plan identifies key data resources and processes to manage I&M data, along with providing assistance for park-specific data.

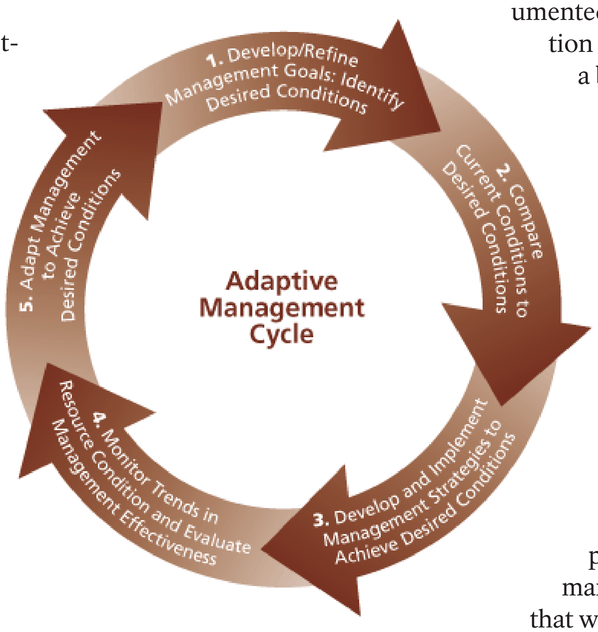
Level 1	Level 2	Vital Sign
	Phase 1 Implementation	
Air and Climate	Weather and Climate	Climate
Water	Hydrology	Groundwater dynamics
	Water Quality	Water quality
Biological Integrity	Invasive Species	Status and trends of established invasive plant species
		Early detection of invasive plants
	Focal Species or Communities	Benthic marine community
		Marine fish
		Freshwater animal communities
		Focal terrestrial plant communities
		Landbirds
		Seabirds
		Bats
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Landscape dynamics
Human Use	Consumptive use	Fish harvest
	Phase 2 Implementation	
Geology and Soils	Soil Quality	Erosion & deposition
Biological Integrity	Invasive Species	Early detection of invasive invertebrates
	Focal Species or Communities	Terrestrial invertebrate communities
		Cave community

Integration With Management

The I&M program focuses on improving park natural resource management through greater reliance on scientific knowledge. Therefore, a primary purpose of the inventory and monitoring program is to develop, organize, and make available natural resource data. This is done by transforming data into useful information through analysis, synthesis, modeling, and reporting.

Data analysis and reporting emphasizes the importance of providing park managers and other entities with synthesized monitoring information that is tiered toward the network's monitoring goals and Vital Signs objectives. This includes a conscious effort to plan for data analysis and reporting throughout all facets of the program. Two data analysis outcomes are emphasized with the PACN Vital Signs: (1) annual status summarization, and (2) long-term trend assessment.

To help deliver information needed at the park, regional, and national levels, the networks are designing a system for scientific data collection, analysis, and reporting that is unprecedented in the National Park Service. Through these efforts, the Inventory and Monitoring program strives to make well-documented scientific information readily available to a broad audience of resource managers, scientists, park interpreters, and the general public. Ultimately this information will be channeled to parks, in an adaptive management cycle that documents status and trends of Vital Signs in network parks, and enhances management decisions that will preserve the park resources for future generations.



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“Mahalo. . . . . .
. . . Thank you. . . . . .
Si Yu’us ma’ase. . .
. . . . . .Fa’afetai!”

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"Mahalo. . . . . .
. . . Thank you. . . . . .
Si Yu'us ma'ase. . .
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Chapter 1. Introduction and Background

The National Park Service (NPS) is mandated to protect, preserve, and conserve its resources, "unimpaired for the enjoyment of future generations" (NPS 1916). As part of the Natural Resource Challenge (NRC), a major effort to improve park management and expand institutional knowledge and reliance on scientific information, the NPS grouped national park system units into 32 Inventory and Monitoring networks nationwide. The Pacific Island Network (PACN), comprised of 11 units, is the network charged with creating a monitoring plan to assess the condition of park natural resources in the Pacific to uphold the mission of the NPS. This monitoring plan describes the process used by the PACN to accomplish this natural resource monitoring task. Through natural resource monitoring, managers can identify and understand normal limits of natural variation in park resources, changes, and agents of change. The network structure facilitates collaboration, information sharing, and economies of scale in natural resource monitoring. Each network also coordinates the gathering of baseline resource inventory data as well as monitoring data on long-term trends in the condition of national park system resources.

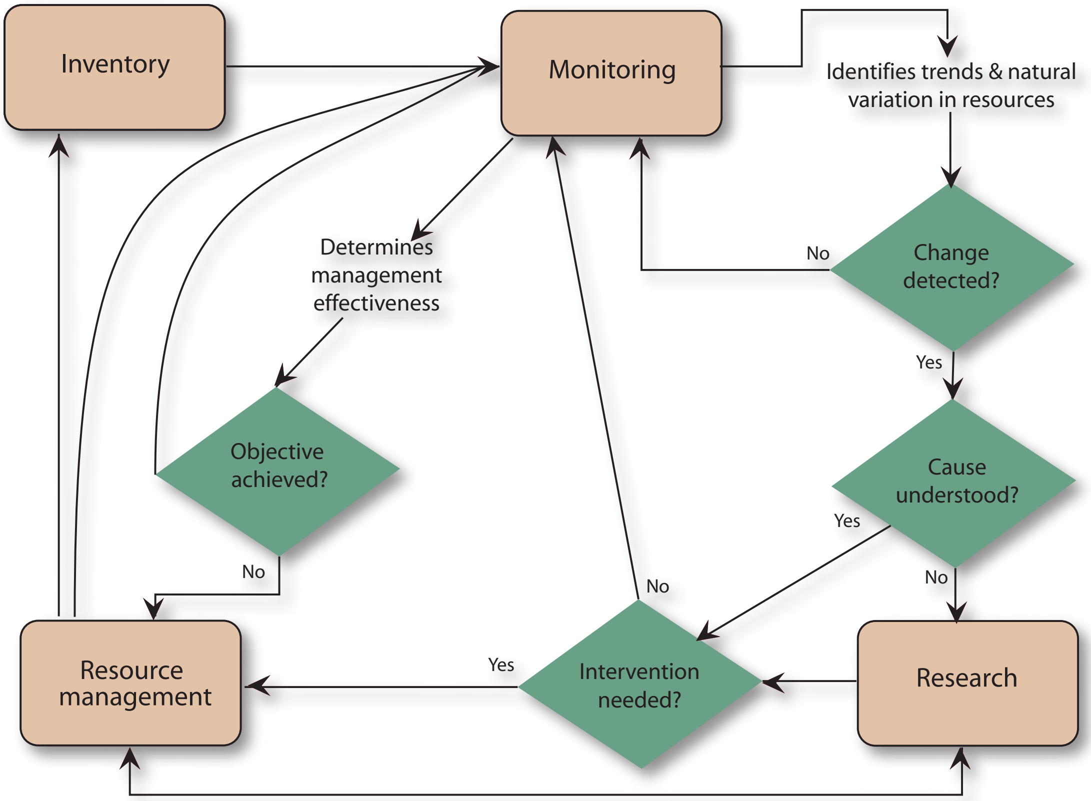
As defined by the NPS, Vital Signs are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. Vital Signs are part of the total suite of natural resources that park managers are directed to preserve "unimpaired for the enjoyment of future generations" (NPS 1916). These resources include water, air, geological features, plants and animals, and the various ecological, biological, and physical processes that act on those resources (figure 1.1). The broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research (figure 1.2), education, and promoting public understanding of park resources.

Long-term monitoring of natural resources by the NPS provides site-specific information needed to understand and identify changes in complex, variable, and inadequately understood natural systems. It also aids in determining whether observed changes are within natural levels of variability or may indicate unwanted human influences. Thus, monitoring provides a basis for understanding and identifying meaningful change in natural systems. Monitoring results may also be used to determine what constitutes impairment and to identify the need to initiate or change management practices.

"Vital Signs are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources…"

Figure 1.1. Natural resources of Haleakala National Park (endangered Haleakala silversword, *Argyroxiphium sandwicense spp. macrocephalum*, left) and Kaloko-Honokohau National Historical Park (threatened green sea turtle, *Chelonia mydas*, right).

Figure 1.2. Stewardship of natural resources in national parks involves the interconnected activities of inventories, monitoring, research, and resource management (modified from Jenkins et al. 2002).



Goals of Vital Signs Monitoring

National Park Service management policy is to use monitoring data "…to maintain and, where necessary, restore the integrity of natural systems" (NPS 2001). The Pacific Island Network intends to use monitoring data to maintain and restore ecological integrity of natural resources. Long-term monitoring serves as an "early warning system" to detect declines in ecosystem integrity and species viability before irreversible loss has occurred. In cases where natural systems in or surrounding a park have been so highly altered that natural processes no longer operate, managers must understand how the altered systems operate in order to determine the most effective approach for restoration. Monitoring program goals for the PACN are adopted directly from the Servicewide Inventory and Monitoring program goals (figure 1.3), with the addition of a sixth goal, which addresses resources that share natural and cultural value: "Provide data to better understand, protect, and manage important resources that share cultural and natural value." This sixth goal addresses traditionally associated peoples use of parks including the practice of traditional belief system and uses within parks such as visiting sacred sites or gathering plants and animals for special ceremonies, food, and medicine. This goal also encompasses cultural influences of contemporary users, those not encompassed within traditionally associated peoples uses. Adding this goal will also help us develop a monitoring program that meets legal considerations and other cultural resource mandates that PACN parks must address. Further discussion regarding the integration of natural and cultural resource values for each Vital Sign is provided in chapter 3 and appendix M.

Parks of the Pacific Island Network

The Pacific Island Network is composed of 11 national park system units spanning the tropical Pacific Ocean, and is the most geographically widespread of the 32 networks in the NPS Inventory and Monitoring (I&M) program (figure 1.4). Two PACN parks are situated in the

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

Figure 1.3. Monitoring program goals for the PACN.

western Pacific Ocean between 13° and 15° N in Micronesia: War in the Pacific National Historical Park (WAPA), on the western side of Guam and American Memorial Park (AMME), on the west coast of Saipan. The National Park of American Samoa (NPSA) is located in Polynesia on the islands of American Samoa (14° S): Tutuila, Tau, Ofu, and Olosega, the latter three of which belong to of the Manua island group. Eight parks are in the Hawaiian Islands in the Central Pacific between 19° and 22° N. The USS Arizona Memorial (USAR) is within Pearl Harbor on Oahu, the most populous island in the network. Kalaupapa National Historical Park (KALA) is on Molokai, and Haleakala National Park (HALE) is on Maui. Hawaii Volcanoes National Park (HAVO), Kaloko-Honokohau National Historical Park (KAHO), Puukohola Heiau National Historic Site (PUHE), Puuhonua o Honaunau National Historical Park (PUHO), and Ala Kahakai National Historic Trail (ALKA) are on the island of Hawaii, the youngest of the main Hawaiian Islands at the southern and eastern end of the archipelago. A more detailed description of each park is provided in appendix A.

Designing an Integrated Monitoring Program for the PACN

An important emphasis of the Vital Signs monitoring program is to facilitate communication, coordination, and collaboration among parks, programs, academia, and other government agencies. The integrated monitoring program can be viewed as an information system, a key aspect of resource management and development of institutional knowledge. Thus, Vital Signs monitoring is a partnership that will provide scientific information needed to protect and manage the national parks. One of the most difficult aspects of designing a comprehensive monitoring program is the integration of monitoring projects so that the comprehensive monitoring program yields information more useful than that of individual parts. Integration involves ecological, spatial, temporal, and programmatic aspects, as outlined below.

- *Ecological integration* incorporates the ecological linkages between system drivers and the components, structures, and functions of ecosystems when selecting monitoring indicators (i.e., marine, freshwater, terrestrial, or atmospheric). An effective ecosystem monitoring strategy will employ a suite of individual measurements that collectively monitor the integrity of the entire ecosystem.
- *Spatial integration* involves establishing linkages of measurements made at different spatial scales within or

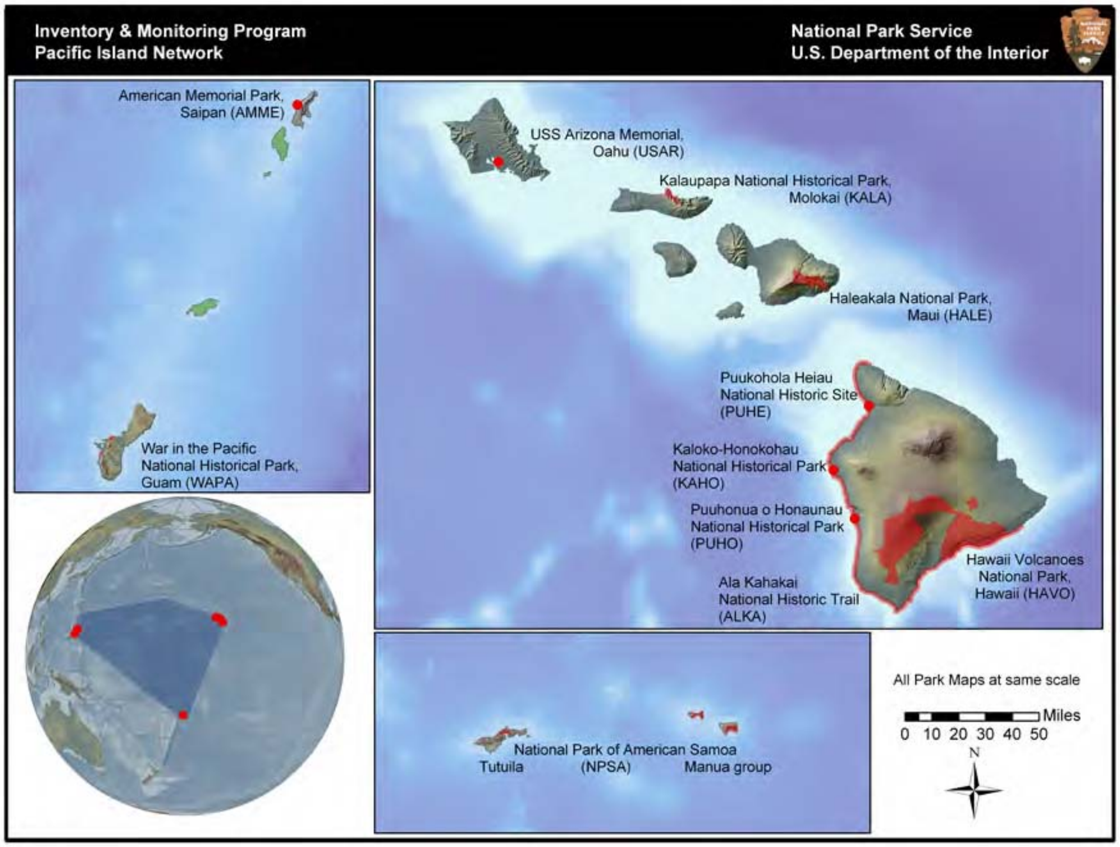


Figure 1.4. Map of the 11 PACN parks.

between parks in the network and over a broader regional context. This requires an understanding of ecological processes on different spatial scales, the co-location of measurements of comparably scaled monitoring indicators, and the design of statistical sampling frameworks that permit the extrapolation and interpolation of data on multiple spatial scales.

- *Temporal integration* involves establishing linkages between measurements made at various time scales. It will be necessary to determine a meaningful timeline for sampling different indicators while considering characteristics of temporal variation in these indicators. For example, sampling changes in the structure of a tropical forest canopy (e.g., size class distribution) will require much less frequent sampling than that required for detection of changes in the composition or density of herbaceous groundcover.

- *Programmatic integration* involves the coordination and communication of monitoring activities within and among parks, among divisions of the NPS, between other agencies and land management organizations, and among government authorities within the PACN region. For example, the involvement of a park's law enforcement, maintenance, and interpretative staff in routine monitoring activities can garner wider support for monitoring, improve potential for involving and informing the public, and promote greater acceptance of monitoring results in the decision-making process.

Legislation, Policy, and Guidance for Natural Resource Monitoring

National park managers are directed by federal law and National Park Service policies and guidance to know the status and trends in the condition of natural resources under their stewardship. This knowledge is necessary to fulfill the NPS mission to conserve park resources unimpaired[1] for the enjoyment of future generations as stated in the National Park Service Organic Act of 1916. This act and other significant laws and policies are summarized in table 1.1. Additionally, several federal, state, territory, and commonwealth statutes exist that provide legal direction for expending funds to determine the condition of natural resources and specifically guide natural resource management in parks. For more information, see Appendix J: Summary of Laws, Policy, and Guidance.

Park Enabling Legislation— Enabling legislation of an individual park, where it exists, provides insight into the natural and cultural resources and resource values to be conserved. These values may evolve with time, through evolution of park management, legal interpretations, and explicit additions to park enabling legislation. See appendix J for information on enabling legislation for each park.

For example, Hawaii Volcanoes and Haleakala National Parks' enabling legislation provides for "*preservation from injury of all timber, birds, mineral deposits, and natural curiosities or wonders within said park, and their retention in their natural conditions as nearly as possible.*" The enabling legislation for Kaloko-Honokohau NHP directed the park to enter into air and water quality agreements with surrounding landowners using the ancient Hawaiian ahupuaa (watershed) concept of land management. In another example, the enabling legislation for the National Park of American Samoa directs the park to "*. . .preserve and protect the tropical forest and archaeological and cultural resources of American Samoa, and of associated reefs, to maintain the habitat of flying foxes, [and] preserve the ecological balance of the Samoan tropical forest. . .*" NPSA and other parks are also mandated to employ local residents to develop, maintain, and administer the parks.

State, Territorial, and Commonwealth Jurisdictions—Several PACN parks commemorate conditions from World War II or Polynesian culture. Such a mandate may include the preservation of culturally introduced species, communities, and landscape characteristics. The cultural components of many PACN parks also include mandates to provide park materials in multiple languages, (i.e., English, Samoan, Chamorro, Hawaiian, or Japanese). In some cases many local residents speak little or no English, but rather one of the many indigenous Pacific island or Pacific rim languages. A summary of documents that specifically guide natural resource management in the network parks can be found in appendix J.

Some PACN parks contain leased lands and provide for differing management (and thus monitoring) considerations based on local arrangements. For example, NPSA leases all park lands in a 50-year renewable lease (with either party able to withdraw under certain conditions). Kalaupapa NHP leases lands from the Department of Hawaiian Homelands, and works closely with the Hawaii State Department of Health in managing park resources. American Memorial Park on Saipan is an affiliated area made available to the Commonwealth of the Northern Mariana Islands (CNMI). The National Park Service has lease agreements with CNMI via the U.S. Navy. Several other parks have lease or other arrangements for use of, or access to lands within authorized park boundaries. Such agreements also provide a foundation for partnerships and leveraging of resources for the joint administration, management and long-term stewardship, and inventory and monitoring of resources.

Submerged Resources—Unlike emergent, dry, or fast (above mean high water level) lands, submerged lands and their resources are often not owned, leased, or administered by the NPS. In nearly every park, the NPS does not own or have administrative control over the submerged lands within its boundaries, and in most cases it is currently unclear what agreements, Memorandum of Understanding (MOU), or protocols are needed for the NPS to accomplish

"National park managers are directed by federal law and National Park Service policies and guidance to know the status and trends in the condition of natural resources under their stewardship."

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[1] See www.nps.gov/legacy/mission.html for the NPS mission statement.

Table 1.1. Summary of legislation and National Park Service policy relevant to the development and implementation of natural resource monitoring in national parks.

Laws	Significance to Inventory and Monitoring
National Park Service Organic Act (USC, title 16, sec.1. Aug 25, 1916)	The 1916 National Park Service Organic Act is the foundation of park service authority, and the mission of the NPS as stated in the act 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 (amended 1978)	Congress strengthened the National Park Service's protective function, and provided language important to recent decisions about resource impairment, when it amended the act in 1978 to state that "the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the national park system and shall not be exercised in derogation of the values and purposes for which these various areas have been established…"
National Park Omnibus Management Act, 1998 [PL 105-391]	This act (NPS 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 Service" 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 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."
NPS Policies and Guidance	**Significance to Inventory and Monitoring**
National Park Service Management Policies, 2001	The 2001 policy 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."

marine monitoring and conservation management goals.

This inconsistency creates particular problems when implementing or enforcing management decisions or conducting monitoring. For example, approximately one-third of the submerged lands within War in the Pacific NHP are owned by the NPS. The remaining lands are owned by the Territory of Guam, which has ceded administrative control of these lands to WAPA through a Memorandum of Understanding with NPS. Similarly, submerged lands within NPSA (figure 1.5) are owned by the Territory of American Samoa but are administered by the local villages. The State of Hawaii owns and administers the submerged lands below the high tide line within three miles of all fast land within the state. The USS Arizona Memorial (figure 1.5) is operated by the NPS through an interagency agreement with the U.S. Navy.

The Coral Reef Task Force—The National Park Service manages 10 areas containing tropical and subtropical coral reef resources, totaling 109,477 ha in the South Atlantic/ Caribbean and 3,095 ha in the Pacific islands for a total of 112,572 ha[2]. The Coral Reef Protection Executive Order of 1998 (E.O. 13089) established policies and actions needed to address the growing threats to the nation's coral reefs. The U.S Coral Reef Task Force, an interagency body of 17 federal, state, and territorial agencies is charged by the Executive Order to lead this effort. As part of the Department of the Interior, the National Park Service is a key player in the Task Force. The Task Force works to develop and implement comprehensive, multi-disciplinary, and coordinated approaches to preserve and protect U.S. coral reef ecosystems, and encourage sound coral reef conservation practices globally. It seeks to use existing agency programs, statutory authorities, competencies, and capabilities to promote coral reef conservation consistent with U.S. law and treaty obligations. The Task Force functions as a clearinghouse and coordinating mechanism for federal, state, and territorial agencies involved in coral reef ecosystem protection and management efforts. It also advises members concerning the impact of their actions and programs upon coral reefs, and encourages cooperation and partnerships to conserve coral reef ecosystems worldwide.

Strategic Planning and Performance Management

The Government Performance Results Act (GPRA) of 1993 requires federal agencies to develop strategic plans as part of a performance management business system. The National Park Service uses the strategic plan and performance management system to set goals and then align activities, staffing, and funding to meet those goals. The GPRA goals relevant to monitoring in the PACN are listed in appendix J.

Among its GPRA goals, the NPS has outlined five Land Health goals in the 2005-2008 NPS Technical Guidance for Strategic Goals[3]. They apply to uplands, wetlands, riparian/stream areas, marine and coastal areas, and mined areas. It is anticipated that in the future, the

Figure 1.5. Submerged resources include both cultural and natural resources such as the USS Arizona Memorial (left), and coral reefs, National Park of American Samoa (right).

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[2] http://www.nature.nps.gov/water/coral.cfm

[3] http://www.aoc.nps.gov/pmds/Technical_Guidance/Technical%20Guidance%20v3.pdf

"The Pacific Island Network is the most extensive network in the NPS Inventory and Monitoring program, with parks located throughout the tropical Pacific."

I&M program will contribute substantially to the national parks' abilities to report on their goals. Parks are currently directed to delay subscribing to these goals until they can meet the following three conditions: (1) a standardized basis exists for measurement of the acreage in a park, and the total acreage of the resource type is known; (2) there is documentation of a specific "desired condition" for a resource type in an approved management plan (the "desired condition" as stated in approved management documents must be in place for all occurrences of the resource type in the park); and (3) the park has knowledge of the current condition of all occurrences of a resource type within its boundaries based on objective, science-based information. I&M data and reports will be a key component of the information that parks use to report on these goals.

Overview of the Pacific Island Network

The Pacific Island Network is the most extensive network in the NPS Inventory and Monitoring program, with parks located throughout the tropical Pacific. Based on geographic, geologic, and biotic differences, the PACN can be divided into three regions: the Mariana Islands (including Guam and Saipan), American Samoa, and Hawaii. Resource management policies and practices throughout the Pacific island parks reflect the range of cultural traditions and natural resource issues that are integral to the parks. Characteristics of the PACN national parks include:

- A significant range in elevation, from -61 to 4,169 m. Coupled with steep rainfall gradients, this creates a great diversity of terrestrial, freshwater, and marine ecosystem types both within and among parks.
- Remote and widely spaced islands and ecosystems, which were prehistorically isolated from many biotic and human influences, result in ecosystem ecology very different from continental systems. This relative isolation has caused the evolution of unique flora and fauna found no where else on earth. These native ecosystems are extremely vulnerable to invasive alien species and require active, hands-on management if their unique biota is to survive.
- Several globally recognized endemic ecosystems and biodiversity hotspots (e.g., Mittermeier et al. 1999). Five of the six unique PACN ecoregions are classified as 'critical or endangered,' with the remaining ecoregion classified as 'vulnerable' (Olson et al. 2001). These ecoregions include: Hawaii tropical moist forests, Samoan tropical moist forests, Hawaii tropical dry forests, Marianas tropical dry forests, Hawaii tropical low shrublands (critical or endangered), and Hawaii tropical high shrublands (vulnerable).
- Ecosystems and parks are relatively small in size compared to many continental systems and national parks. Human activities have significantly altered most ecosystems inside or in close proximity to park boundaries through resource exploitation, development, and multiple routes of invasive species introductions.
- Marine ecosystems across the Pacific share many common features, specifically the ecological processes that shape them, such as dispersal, recruitment, growth, calcium carbonate accretion and erosion, and the stressors that alter them.
- Local community social structures within the PACN have retained a significant portion of their traditional Polynesian and Micronesian heritages. In American Samoa, villages or extended families hold land communally and chiefs make decisions about its use in the matai system (O`Meara 1987). In Hawaii, the traditional watershed-based ahupuaa system of land management has been cited as a tool for improving upon current prevailing Western land management practices that parcel the land into a checkerboard with no concern for watershed management. In Guam and Saipan, the traditional system of land tenure was

similar to that in American Samoa, but has been lost through successive periods of Western colonization (Johnson 1969, McGrath and Wilson 1987).

Characteristics of the PACN Parks—The Pacific Island Network includes 11 national park system units. Six parks contain marine resources, and the remaining five adjoin the sea (table 1.2). All parks but USAR contain freshwater resources. Four parks are located on active volcanoes (Mauna Loa: PUHO, HAVO, and ALKA; Kilauea: HAVO and ALKA; and Hualalai: KAHO and ALKA), and one park is on a volcano considered dormant, though likely to erupt in the future (East Maui Volcano: HALE); all parks are located on islands ultimately formed from volcanic activity. Threatened or endangered species have been found in all parks, as have alien and invasive species. Appendix A provides a summary of the natural and cultural resources, resource management concerns, and past natural resource monitoring for each park. Throughout this document, the parks are presented in their geographic arrangement from west to east across the Pacific, rather than in alphabetical order, to better conceptualize the geography of the network.

A synopsis of park management priorities, natural resources within each park, and the primary threats to those resources can be found in table 1.3. Due to the vast geographical range of PACN, national park system units in different parts of the network possess different species and in some cases entirely different habitats. For example, native species in one area of the network may be highly invasive in another (e.g., mangroves), creating difficulties when attempting to develop network-wide management and monitoring objectives. However, ecosystems across the Pacific share many common features such as small spatial size, susceptibility to invasions by alien species, and in some cases the same species or guilds (e.g., sea turtles, stream gobies).

Elevation, Climate, and Geology—The elevation ranges of Pacific Island Network parks vary significantly (figure 1.6; ALKA boundaries have not been finalized, but the trail is coastal in nature.). The wide diversity of climatic vegetation zones found on Pacific islands (figures1.6) is caused by a combination of elevation (figure 1.7) and rainfall gradients. Precipitation varies widely both among and within parks in the network: PUHE receives <250 mm of rain annually, while maximum rainfall at HALE is >6,000 mm on the upper northeastern slopes of Haleakala (Giambelluca et al. 1986).

Climatic consequences of the El Niño-Southern Oscillation (ENSO) are much more pronounced in the Pacific region than on the North American continent and the rest of the world. Climatic changes resulting from ENSO are dependent on the pattern of sea surface temperature and thus vary throughout the Pacific. However, they include changes to wind patterns, increased sea surface temperature, and extended drought conditions (Tsyban et al. 1990).

Pacific islands are particularly vulnerable to sea level rise. Changes in sea level occur as periodic changes associated with ENSO events, long term rise in sea level as a result of anthropogenic climate change as well as decreases due to geologic processes. According to reports by the Intergovernmental Panel on Climate Change (Tsyban et al. 1990, Burkett et al. 2001) an average 1-2 mm/yr rise of sea level has been recorded globally over the last century. In the Pacific there is no consistent trend for overall sea level (table 1.4). In some areas sea level has increased, which is attributed to global climate change, while in others it has decreased as a result of geologic uplift (Shea et al. 2001).

Although the Pacific Island Network units are geographically distinct, there are some similarities in geologic histories. Guam and Saipan are islands with long-extinct volcanoes that have complicated geologic origins involving both volcanism and subduction of the Marianas Trench. The northern half of Guam and portions of Saipan also have limestone substrates elevated above a weathered volcanic base. The islands of American Samoa and the Hawaiian Islands are oceanic volcanic islands formed by “hot spots”, or areas of thermal activity on the oceanic crust. Over time, continental drift moves the ocean floor, forming a chain of islands over the hot spot.

Underlying geology plays a large role in the occurrence and form of aquatic resources on Pacific islands. Parks on Pacific islands are iso-

“Threatened or endangered species have been found in all parks, as have alien and invasive species.”

Table 1.2. Summary of land and water spatial characteristics for each park in the PACN*.

Park	Year authorized	Coastline length (km)	Authorized marine size (ha)[a]	Authorized terrestrial size (ha)	Authorized total size (ha)[b]	Elevation range (m)
War in the Pacific National Historical Park (*WAPA*)	1978	9	401	400	801	-50 to 318
American Memorial Park (*AMME*)	1976	5	0	58	58	0 to 3
National Park of American Samoa (*NPSA*)	1988	70	2129	3786	5915	-50 to 966
USS Arizona Memorial (*USAR*[c])	1978	1	2	4	7	-12 to 23
Kalaupapa National Historical Park (*KALA*)	1980	21	834	3519	4553	-61 to 1287
Haleakala National Park (*HALE*)	1916	4	0	11849	11849	0 to 3055
Ala Kahakai National Historic Trail (*ALKA*[d])	2000	282	TBD	TBD	TBD	0 to 122
Puukohola Heiau National Historic Site (*PUHE*)	1972	0	3	32	35	-15 to 52
Kaloko-Honokohau National Historical Park (*KAHO*)	1978	5	217	264	481	-46 to 24
Puuhonua o Honaunau National Historical Park (*PUHO*)	1961	3	0	231	231	0 to 274
Hawaii Volcanoes National Park (*HAVO*)	1916	53	0	135091	135091	0 to 4169

[*] Data Sources: NPS Lands Division Authorized Park Boundary Maps, USGS DLG Political Boundaries, TMK Parcels (from GDSI), 2001 IKONOS Imagery, and USAR park webpage.

[a]. Identified as 0 where authorized park boundary ends at high tide line. Includes the shoreline and offshore waters of inholdings.

[b]. Determined by adding authorized marine size and authorized terrestrial size.

[c]. Coastline length and authorized marine size are estimates only. Terrestrial size and total size are from park webpage.

[d]. Coastline length and elevation range are estimates only.

Table 1.3. Management priorities, natural resources, and primary stressors of PACN parks.

Park	Designation	Management Priorities	Natural Resources	Primary Stressors[a]
WAPA	Historical park	Managed in accordance with World War II conditions; marine areas	Coral reefs, seagrass meadows, sandy beaches, wetlands, streams, tropical savanna, limestone, riverine forests, karst caves, offshore islets	Tropical cyclones[b], fishing, marine debris, recreational damage, urbanization, wildfire, invasive species, chemical water & soil contamination
AMME	Affiliated area	Recreational, environmental and cultural resources	Wetland, mangroves, sandy beach, stream, Coral reefs	Tropical cyclones[b], marine debris, recreational damage, increasing urbanization, invasive species, chemical water & soil contamination
NPSA	National park	Rainforest, coral reefs, cultural land use	Coral reefs, sandy and rocky beaches, wetlands, streams, rainforests, cloud forests	Tropical cyclones[b], fishing, marine debris, recreational damage, coral bleaching, agricultural expansion, invasive species, hunting
USAR	National memorial	Memorial management	Benthic community on ship hull, marine organisms in and near the ship	Increasing urbanization, invasive species, chemical water & soil contamination
KALA	National historical park	Maintain lifestyle of Hansen's disease patients; preserve historic structures, sites, & values; natural features	Coral reefs, sandy &rocky beaches, offshore islets, streams, lake, rainforest, coastal & mesic forest, caves, lava tubes	Water diversion, invasive species
HALE	National park	Natural and cultural resources	Coastal strand, streams, sub-alpine lakes, bogs, rainforest, mesic forest, sub-alpine grass/shrublands, alpine desert, caves, lava tubes	Damage from recreational activity, invasive species
ALKA	National historic trail	Cultural and natural resources along trail corridor	Sandy and rocky beaches, sea cliffs, fishponds, anchialine pools[c]	Marine debris, terrestrial & marine recreational damage, increasing urbanization, invasive species, water contamination, groundwater withdrawal
PUHE	National historic site	Historic structures, landscape similar to time of Kamehameha I (late 1700s-early 1800s)	Coral reef, sandy beach, estuarine wetland, intermittent stream, remnant dry forest	Fishing, marine debris, recreational damage, wildfire, invasive species, upland erosion, sedimentation of wetland & bay, water contamination
KAHO	National historical park	Cultural activities & resources, natural resources	Coral reefs, sandy & rocky beaches, fishponds, wetlands, anchialine pools[c], grassland, lava fields, coastal dry forest	Fishing, marine debris, recreational damage, increasing urbanization, invasive species, marine & groundwater contamination, groundwater withdrawal
PUHO	National historical park	Maintain landscape as it looked in 1819.	Rocky shores, wetlands, anchialine pools[c], caves, dry forest	Fishing, marine debris, recreational damage, invasive species, marine & groundwater contamination
HAVO	National park	Natural and cultural resources	Beaches, sea cliff, anchialine pool[c], grassland, rainforest, dry & mesic forest, mid-elevation & alpine desert, lava fields, caves & lava tubes, sub-alpine shrubland, active volcanic features	Volcanic activity, damage from recreational activity, wildlife, invasive species

[a]. All parks are coastal in nature and subject to stressors associated with sea level rise and subsidence

[b]. For simplicity, we use the term tropical cyclone in this report for the entire PACN region to refer to storms with sustained wind speeds above 63 knots/hr even though the terminology varies by geographic region.

[c]. Anchialine pools are brackish land-locked bodies of water with underground connections to the ocean and fresh groundwater. Their salinity and depth fluctuate in a delayed manner with the tides

Figure 1.6. Several climactic vegetation zones exist in close proximity in the Hawaiian Islands due to topography and rainfall gradients (Source: Mueller-Dombois and Fosberg 1998).

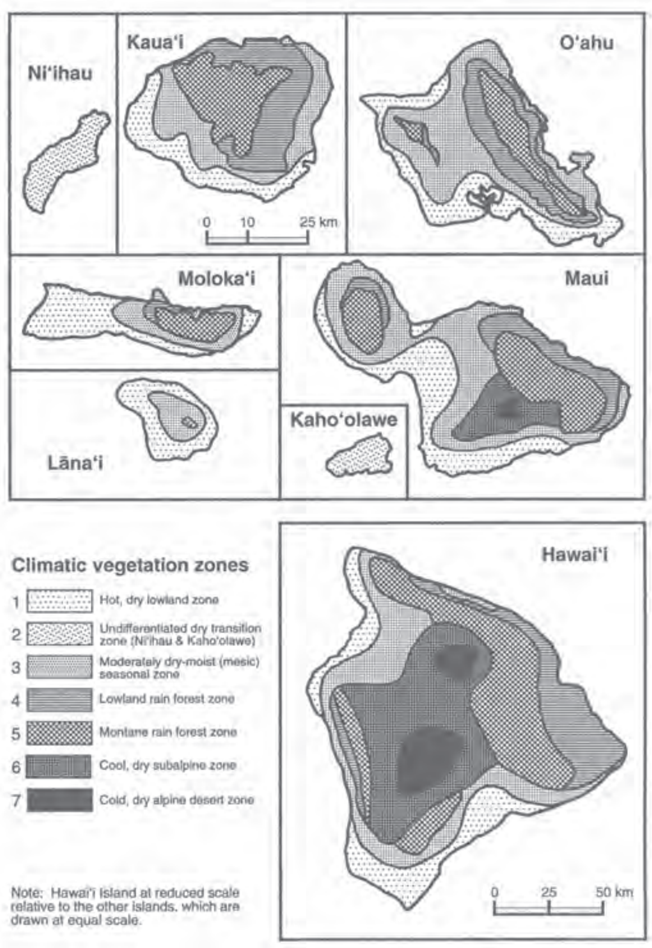
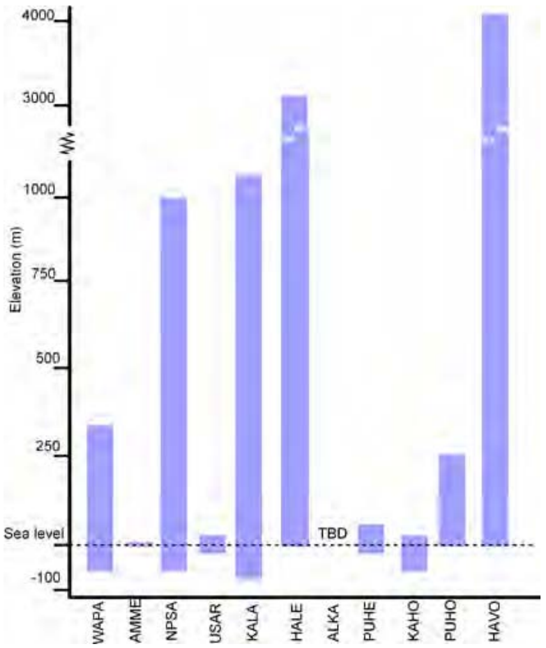


Figure 1.7. Elevation ranges of PACN parks (note change in scale at approximately 1,500 m).



lated land masses surrounded by salt water, and are geologically very young. These characteristics have a profound effect on the abundance of freshwater resources and their characteristics. Fresh groundwater "lenses" permeate areas of the bedrock above seawater and saline groundwater. These lenses form as rainwater percolates through rock layers, and are frequently located near the ground surface in coastal areas.

Biota—The native terrestrial flora and fauna in Pacific island parks lack several species groups when compared to those of the continental U.S., Asia, and islands off the coasts of continents (for example, reptiles, non-flying land mammals, and amphibians in the Hawaiian Islands). However, levels of endemism are very high, and certain taxa such as invertebrates comprise a significant percentage of endemic biodiversity (Eldredge and Evenhuis 2003). Smaller land areas and concomitantly smaller populations,

Table 1.4. Mean sea level trends at selected Pacific island stations.

Location	Rate of change (cm/decade)	Record duration	Total change (cm)
Guam	0.4 ± 0.6	1948-2000	2.0 ± 3.2
American Samoa	1.6 ± 0.5	1948-2000	8.5 ± 2.7
Hawaii			
Honolulu	± 0.2	1950-2000	14.2 ± 1.9
Kahului	± 0.5	1950-2000	10.8 ± 2.6
Hilo	3.2 ± 0.5	1927-2000	23.9 ± 3.7

Table modified from the Pacific Assessment (Shea et al. 2001); based on data from the University of Hawaii Sea Level Center.

in addition to high levels of endemism, make many threats potentially more serious in the Pacific islands than in a continental context. For example, invasive ants may have devastating effects on native insect populations, in turn causing declines in plant populations as their pollinators are eliminated.

All parks in the PACN contain or adjoin significant marine or coastal resources such as: coral reefs, mangroves (figure 1.8), seagrass beds, hard- and soft-bottom inter-tidal regions that support highly diverse species, and beaches that serve as important habitat for endangered sea turtles and monk seals (figure 1.8).

Multiple types of surface water ecosystems are found within the PACN parks including streams, wetlands, lakes, and anchialine pool systems. Freshwater and brackish organisms include species or genera endemic to individual islands or groups of islands with highly specific habitat requirements such as the endemic Hawaiian damselfly genus *Megalagrion* which contains 22 species (Polhemus and Asquith 1996). Freshwater and anchialine biological habitats are finite resources in the Pacific islands, and have often been modified or obliterated through land-use practices and invasive species introductions.

Because of the high level of endemism and evolutionary isolation of Pacific island flora and fauna, many species are now threatened or endangered. Pacific Island Network

Figure 1.8. Hawaiian monk seal (*Monachus schauinslandi*) with newborn pup at Kalaupapa National Historical Park; mangrove (*Bruguiera gymnorhiza*) forest at American Memorial Park.

"Network-wide concerns for these resources include chemical and microbial contamination, nutrient loading, . . . erosion/ turbidity/ sedimentation, invasive species, . . ."

parks support multiple species of concern. In addition, 340 federally listed threatened and endangered species are found in the PACN region (including all species whose known or predicted range covers one or more islands on which a PACN park exists); 112 of these species are found in PACN parks (table 1.5). Appendix D provides a complete inventory of federally listed threatened and endangered species in the PACN region, including information on their geographical ranges and common and scientific names.

Water Quality Designations and Monitoring—The NPS Water Resources Division (WRD) provides funds to the Pacific Island Network for water quality monitoring. NPS WRD requires that the network: (a) determines priorities for impaired and pristine waters, (b) define site-specific monitoring objectives, and (c) develops a detailed water quality monitoring plan to be implemented in close coordination with Vital Signs monitoring. The PACN recognizes that the water resources of the network, whether in the form of precipitation or in water bodies, are a primary component of all network ecosystems. Therefore, the PACN has chosen to fully integrate water quality monitoring into this monitoring plan.

Three types of water resources are shared by PACN parks: marine, inland surface waters, and groundwater. Network-wide concerns for these resources include chemical and microbial contamination, nutrient loading, changes in climate and hydrology, erosion/turbidity/sedimentation, invasive species, and atmospheric deposition. The natural cycle of water resources flowing through multiple ecosystems and jurisdictions necessitates working with other organizations that also have water quality monitoring and management responsibilities. The National Park Service already partners with federal, state, territorial, commonwealth, and local governing agencies in the PACN because submerged lands and their resources are often not owned or administered by the NPS. An extensive discussion of PACN water resource concerns, monitoring programs, and water quality data is presented in appendix I.

The most significant legislation applicable to water quality is the United States Clean Water Act (CWA) of 1977. The act requires states and territories to identify and publish water quality standards, those waters that do not meet the adopted standards, and waters not expected to meet the standards. Waters that do not meet the criteria for their designated uses are considered non-supportive. If certain conditions are met, these waters may be reported as impaired to the Environmental Protection Agency as per requirements of Section 303(d) of the CWA; often termed the "303(d) list."

PACN water quality data summary—A detailed water quality data summary for each park of the PACN is available in appendix I. The goal of this data summary is to use available information to identify water quality problems in the PACN (table 1.6). Regulatory reporting to the United States Environmental Protection Agency (USEPA) by the Territories and the State of Hawaii as required by Section 305(b) of the CWA reveals an increasing number of impaired water bodies as determined by local water quality standards for their respective designated uses. However, this statement of increasing impairments may be misleading as additional water quality monitoring takes place and previously unmonitored and unlisted resources are added to the CWA Section 303(d) list.

Trends in water quality for PACN resources are not well defined due to a lack of continuity and coordination between the various studies and monitoring programs. Data sources for this summary include: USGS, USEPA, Guam Environmental Protection Agency (GEPA), American Samoa Environmental Protection Agency (ASEPA), State of Hawaii Department of Health, and compilations prepared for each park's baseline water quality data inventory and analysis report (NPS-WRD 1996, 1998, 1999a, 1999b, 2000, 2001, in prep a, in prep b, in prep c).

Groundwater—Although groundwater quality data are lacking for most PACN parks, all parks have concerns about changes in hydrology, seawater intrusion, and chemical and microbial contamination. Pacific island communities rely heavily on groundwater to supply municipal drinking water and their respective governments provide some protection through legislation. Changes in quantity and quality occur when increasing withdrawal rates lower the water table and lead to seawater intrusion. In

Table 1.5. Numbers of known federally listed threatened, endangered, and candidate endangered species found in the USA with the numbers found in both PACN parks and in the PACN region*.

	Endangered	Threatened	Total T & E	Candidate Species	Total T & E, Candidate Species
USA[a]					
Total Animals	928	185	1113	139	1252
Total Plants	599	148	747	140	887
TOTAL SPECIES: USA	**1527**	**333**	**1860**	**279**	**2139**
PACN Parks[b]					
AMME	3	0	3	1	4
WAPA	1	0	1	2	3
NPSA	1	1	2	5	7
USAR	?	?	?	?	?
KALA	15	4	19	4	23
HALE	19	3	22	12	34
ALKA	?	?	?	?	?
PUHE	4	1	5	0	5
KAHO	15	1	16	4	20
PUHO	12	1	13	0	13
HAVO	29	4	33	10	43
TOTAL SPECIES: PACN PARKS (% of total species USA)	**66 (4.3%)**	**7 (2.1%)**	**73 (3.9%)**	**33 (11.8%)**	**106 (4.9%)**
PACN Region[c]					
Hawaiian Islands	51	5	56	18	74
West and south Pacific	12	3	15	12	27
Total Animals[d]	**61**	**6**	**67**	**30**	**97**
Hawaiian Islands	264	9	273	86	359
West and south Pacific	1	0	1	0	1
Total Plants	**265**	**9**	**274**	**86**	**360**
TOTAL SPECIES: PACN REGION (% of total species USA)	**326 (21.3%)**	**15 (4.5%)**	**341 (18.3%)**	**116 (41.6%)**	**457 (21.4%)**

[*] All Endangered, Threatened, and Candidate species data are from the U.S. Fish and Wildlife Service's Threatened and Endangered Species websites: *http://ecos.fws.gov/tess_public/StartTESS.do* and *http://www.fws.gov/pacificislands*. Information on species at individual PACN parks was augmented with data from the National Park Service's NPSpecies database.

[a]. USA numbers include the contiguous United States, Alaska, Hawaii, American Samoa, Guam, Northern Mariana Islands, Puerto Rico, and the U.S. Virgin Islands.

[b]. Several species are found in multiple parks. Therefore, the "Total Species: PACN parks" numbers are not the sum of the PACN parks numbers.

[c]. The "PACN region" numbers include all species whose known or predicted range includes an island on which a PACN park is located. Thus, it is a summary of species that *potentially* occur in PACN parks.

[d]. PACN region "Total Animals" numbers are not the sum of the Hawaii and other Pacific regions because the subtotals include 4 species (2 endangered and 2 threatened sea turtles) which are found in both the Hawaiian Islands and the west and south Pacific.

Table 1.6. Water quality problems identified in the PACN.

Park	Governing agency	Data	Threats to water resources[a]	Park (or adjacent) 303(d) waters[b]	Documented pollutants[b]
WAPA	Territory of Guam	1974 – 1991, 1997 - present	heavy metals, PCBs, soil and agricultural runoff, sedimentation of coral reefs	Agana Bay (adjacent) Northern Guam Lens Aquifer (adjacent)	turbidity and dissolved oxygen chlorides, nutrients, bacteria, and toxic contaminants
AMME	Commonwealth of the Northern Mariana Islands	1990, 1994 - present	leakage or seepage from abandoned fuel tanks and military equipment, illegal dumping, flooding, groundwater contamination from sewage, highly saline water from reverse osmosis	Saipan Lagoon (adjacent), N. Puerto Rico Dump (adjacent), S. Puerto Rico Dump (adjacent), Smiling Cove Marina, American Memorial Park, Micro Beach, Hyatt Hotel Outer Cove Marina (adjacent)	Enterococci, dissolved oxygen, and orthophosphate Enterococci and orthophosphate
NPSA	Territory of American Samoa	1998 - present	erosion aggravated by agricultural land use and feral pigs, contamination from sewage and dumps	None	n/a
USAR	State of Hawaii	1971 - present	military, industrial, and agricultural pollution, heavy metals, sediment, and debris, oil	Pearl Harbor Halawa Stream (adjacent)	nutrients, suspended solids, PCB nutrients and turbidity
KALA	State of Hawaii	1969 - 1989	Feral pigs, deer and cattle, diversion and input due to upland agriculture and urban development	None	n/a
HALE	State of Hawaii	1972 - present	encroaching development, feral animals, alien species, stream diversion, untreated sewage	None	n/a
ALKA	State of Hawaii	1971 - present	motorized vehicles, foot traffic, construction activities, sedimentation impacts to reefs, wetlands and anchialine pools, contaminants and debris	Pelekane Bay/Kawaihae Harbor (adjacent), Hapuna Beach, Kealakekua Bay Pelekane Bay/Spencer Park Beach, Magic Sands Beach Kailua Bay (adjacent)	turbidity turbidity and chlorophyll a total phosphorous

[a]. As interpreted by the PACN from available historical data

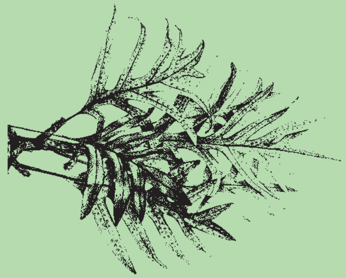
[b]. As reported to the USEPA in the current CWA Sect. 305(b) reports and/or 303(d) lists from each respective governing agency; details on which part of each water body is impaired can be found via the links provided on this website *http://www.epa.gov/region9/water/tmdl/303d-2002.html.*

Table 1.6. Water quality problems identified in the PACN—*Continued*.

Park	Governing agency	Data	Threats to water resources[a]	Park (or adjacent) 303(d) waters[b]	Documented pollutants[b]
PUHE	State of Hawaii	1972 - present	fuel spills, erosion, diversion, storm water runoff, pollution, wastewater discharges	Pelekane Bay/Kawaihae Harbor (adjacent)	turbidity
				Pelekane Bay/ Spencer Park Beach (adjacent)	turbidity and chlorophyll a
KAHO	State of Hawaii	1972 - present	industrial development, bacterial contamination, nutrient loading, petroleum, heavy metals, sedimentation	None	n/a
PUHO	State of Hawaii	1972 - 1998	sedimentation, eutrophication, agricultural chemicals	None	n/a
HAVO	State of Hawaii	1973 - 1990	volcanic activity	None	n/a

[a]. As interpreted by the PACN from available historical data

[b]. As reported to the USEPA in the current CWA Sect. 305(b) reports and/or 303(d) lists from each respective governing agency; details on which part of each water body is impaired can be found via the links provided on this website *http://www.epa.gov/region9/water/tmdl/303d-2002.html*



spite of the widespread monitoring of groundwater by municipal drinking water suppliers and the USGS, there is very little information available on groundwater quality from collection wells inside PACN parks. Only AMME, KALA, ALKA, and KAHO have groundwater wells currently available for monitoring.

Groundwater monitoring wells were installed at AMME and KAHO because of concerns about contamination of the resource and effects to the parks' coastal wetlands and nearshore reefs. At KAHO, the USGS has detected industrial chemicals, naphthalene, and phenol in the groundwater (USGS 2003). In west Hawaii, the Natural Energy Laboratory of Hawaii Authority has been analyzing groundwater samples monthly for the last 16 years adjacent to segments of ALKA passing through Keahole Point. Data from these locations indicate increasing salinity, microbial contamination, nutrient spikes, and other impacts from adjacent land uses.

Inland Surface Water—Streams in the PACN are either very pristine as in NPSA, KALA, and HALE or highly altered as in WAPA, AMME, USAR, and PUHE. Human population growth has led to channelization and pollution of streams and rivers in the latter parks. Data collected by GEPA in the 1970s indicated turbidity and suspended solids were a problem for the Namo and Salinas rivers in the Agat Unit of WAPA, primarily during flood events. Streams in AMME receive brine from desalinization plants in violation of DEQ water quality standards. Several highly impacted streams that empty into Pearl Harbor around USAR are listed as impaired by high levels of nitrate/nitrite, total nitrogen, turbidity, and trash (HI DOH 2004b). A channelized, intermittent stream at PUHE receives large sediment influxes from its degraded watershed during periods of high runoff and subsequently becomes dammed at the mouth by this silt (Steward 2003).

Wetlands and anchialine pools are rare in the PACN (anchialine pools are unique to Hawaii within the U.S.) They are vulnerable to the same threats as groundwater and streams: changes in hydrology, seawater intrusion, erosion/sedimentation, invasive species, and chemical and microbial contamination. Anchialine pools located in areas of urban expansion have demonstrated impacts from filling and nutrient loading (Brock and Kam 1994).

Marine Water—Land-based runoff and effects from harbor operations are the biggest concerns for marine waters of the PACN. Although water quality data are lacking, five PACN parks (NPSA, KALA, HALE, PUHO, and HAVO) contain or are adjacent to pristine marine resources which remain so primarily due to their inaccessibility. The other six parks (WAPA, AMME, USAR, ALKA, PUHE, and KAHO) are impacted by surrounding land uses and nearby harbors. Sedimentation from land sources and nutrients discharged in groundwater are the primary causes of reef impairment on Guam (GEPA 2004). Heavy metal contamination of marine areas in Guam is attributed to harbor operations and boat maintenance activities (Denton et al. 1999). Several coastal sites within Saipan Lagoon near AMME, are impaired by high turbidity and low dissolved oxygen (CNMI DEQ 2002).

Sediment assessments of Pearl Harbor have indicated contamination of sediments by herbicides, pesticides, heavy metals, and polychlorinated biphenyls, or PCBs (USNCEL 1973, Grovhoug 1992, Ogden Environmental 1996). Pearl Harbor has also exceeded State of Hawaii water quality standards for nutrients and suspended solids (HI DOH 2004b). Samples collected at Honokohau Bay (KAHO) had high levels of nitrogen in the 1990s. Honokohau Harbor, which lies within KAHO but is not administered by the park, has been assessed for water quality, circulation, and faunal changes. All of these variables deteriorated between the initial assessment in 1971 and the follow-up study after expansion of the harbor in 1979 (Bienfang 1980). Similar deterioration has occurred offshore of PUHE in Pelekane Bay, adjacent to Kawaihae Harbor, where land use has contributed to erosion of the watershed, damming of Makeahua Stream, and sedimentation onto the reef (Steward 2003). On the island of Hawaii, beach monitoring stations adjacent to two PACN parks (ALKA and PUHE) are listed as impaired for turbidity, chlorophyll *a*, and total phosphorous (HI DOH 2004b).

Impaired and Outstanding Natural Resource Waters (ONRW)—Federal, state, territorial, and commonwealth regulations on water quality standards provide a framework for designating and protecting water bodies for specific uses (GEPA 2001, CNMI DEQ 2002, ASEPA 1999, HI DOH 2004a). Designated uses for PACN water resources are listed for each park in appendix I. The identification of impaired waters for 303(d) listing is limited by the shortage and small scope of existing monitoring programs. Table 1.7 lists the PACN water resources that have been identified as impaired by their respective governing agency in historical data sets and regulatory reports.

Several national park system units have ecologically distinctive and/or pristine water resources that could be considered Outstanding National Resource Waters, but this classification has not been developed by governments in the region. This provides an opportunity for the NPS I&M program along with other organizations, to set the precedent for evaluation and determination of such resources in Hawaii and the Pacific Territories. Table 1.7 lists PACN water resources (or waters adjacent to parks) that the network has identified as ecologically distinctive or pristine.

Air Quality Monitoring—Under the Clean Air Act, park managers have a responsibility to protect air quality and air quality related values (AQRV) from the adverse effects of air pollution. The latter are defined as resources sensitive to air quality, including wildlife, vegetation, water quality, soils, visibility, and cultural resources. Protection of air quality in national parks requires knowledge about the origin, transport, and fate of air pollution,

Table 1.7. Park waters identified as ecologically distinctive or pristine park resources.

Park	Resource	Details
WAPA	Wetlands	Ecologically distinctive and rare in the region
AMME	Wetlands	Ecologically distinctive and rare in the region
NPSA	Coastal waters off Ofu and Tau Streams	Pristine Pristine in all units
USAR	No unique or pristine park resources	n/a
KALA	Kauhako crater lake Streams Coastal waters	Ecologically distinctive Pristine Pristine
HALE	Streams and springs Coastal waters High elevation lakes and bogs	Pristine in Kipahulu district Pristine in Kipahulu district, adjacent to park Ecologically distinctive and pristine
ALKA	Coastal waters Wetlands Streams Anchialine pool complexes	Pristine in many areas, adjacent to park Ecologically distinctive in the area and pristine Ecologically distinctive in the area Ecologically distinctive and pristine in many areas
PUHE	No unique or pristine park resources	n/a
KAHO	Wetlands Anchialine pools Coastal waters	Ecologically distinctive and rare in the region Ecologically distinctive and mostly pristine Pristine
PUHO	Anchialine pools Coastal waters	Ecologically distinctive Pristine, adjacent to park
HAVO	Anchialine pools Coastal waters Olaa bogs	Ecologically distinctive Pristine, adjacent to park Ecologically distinctive

as well as its impacts on resources. To be effective advocates for the protection of park air resources, NPS managers need to know the air pollutants of concern, existing levels of air pollutants in parks, park resources at risk, and the potential or actual impact on these resources. Through the efforts of park personnel, support office staff, and the NPS Air Resources Division, the NPS meets its clean air affirmative responsibilities by obtaining critical data and using the results in regulatory-related activities. Current air quality in PACN parks is considered pristine by national standards. However, pollution from natural sources can, at times, considerably degrade air quality. In addition long range pollution plumes have reached remote Pacific Islands (such as smog from China affecting Guam) and increased urbanization may also lead to future air pollution in the PACN. At this time air quality in PACN parks is mainly affected by wildland fires and volcanic eruptions. Air quality was designated a Vital Sign for the network because of its importance as both an anthropogenic and natural driver of change. The PACN is not developing monitoring protocols for this Vital Sign as monitoring is conducted by NPS and other federal and state agencies (table 1.8). However, the PACN will report on these monitoring results in Vital Sign monitoring reports. Air quality monitoring in PACN parks has been focused on HAVO and HALE, which are both class I areas, a designation that affords the most stringent requirements for protecting air quality under the Clean Air Act.

Development of the Pacific Island Network

The Pacific Island Network is guided by a Board of Directors (BOD) composed of Superintendents from each of the national park system units plus several advisory members (chapter 8). The BOD makes decisions regarding the development and implementation of the monitoring strategy, hiring, budgeting, and scheduling, and is responsible for ensuring the overall effectiveness and success of the network's monitoring efforts. The board has established a network charter (appendix Q) to describe the organization and administration of the network.

The network charter established a standing Technical Committee (TC) to provide technical

Table 1.8. Air quality monitoring efforts in or near PACN parks.

National park or site*	Parameters monitored	Time period	Network or program
Tutuila, American Samoa (NPSA nearby)	Aerosols, gases, radiation, weather parameters	1970's - present	NOAA CMDL
Pearl City, Oahu, Hawaii (USAR nearby)	Particulate matter	1971 – present	Hawaii DOH, Clean Air Branch
Olinda, Maui, Hawaii (HALE nearby)	Visibility (aerosols)	1991 – present	IMPROVE
PUHO	Aerosols	2003 - 2004	VOGNET
HAVO	Aerosols – dry deposition, ozone	1999 - 2004	CASTNET
Mauna Loa Observatory (HAVO nearby)	Wet Deposition	1983 - 1993	NADP/NTN
HAVO	Wet Deposition	2000 - 2005	NADP/NTN
HAVO	UV radiation	1999 - 2004	UVnet/PRIMENet
HAVO	Visibility (aerosols)	1986 - present	IMPROVE
HAVO	SO_2	1986 - present	NPS Gaseous Pollutant Network
HAVO	Cloud presence and chemistry	1997 - 2003	University of Hawaii, Huebert
Mauna Loa Observatory, (HAVO nearby)	Aerosols, gases, radiation, weather parameters	1970's - present	NOAA CMDL

[*] nearby indicates that the station is not in national park boundaries but close enough to provide relevant data for the park.

assistance and advice to the board. The Technical Committee is comprised of natural resource managers and scientists who work in the parks and are familiar with park issues. This Technical Committee, along with the Board of Directors, assists the network in refining the scope of work for this monitoring plan.

Network Approach to Program Development—The PACN has approached developing the monitoring program in a stepwise fashion such that we will implement sections of the program sequentially. It is impossible to monitor all attributes of PACN ecosystems. Therefore, the program will evolve as we document patterns of change in ecosystems. To sustain an adaptive monitoring program, we will evaluate monitoring data at regular intervals, initially every five years (chapter 7).

The early focus of the PACN program was on gathering baseline data (inventories) that will build the foundation for long-term monitoring. At its inception, the NPS Inventory and Monitoring program developed extensive guidance for program preparation and implementation[4], including a three-phase planning and design process. Phase I of this process included: (a) defining goals and objectives; (b) initiating the identification, evaluation, and synthesis of existing data; and (c) developing draft conceptual models. Phase II involved selecting and prioritizing Vital Signs. In Phase III, the monitoring plan is to be completed and implementation begun. A timeline of the progress the PACN has made through this process is presented below (table 1.9).

To provide a starting point for our park scoping workshops, we organized 11 topical working groups (figure 1.9) that each identified ecosystem drivers, candidate attributes to monitor, and gaps in knowledge to help direct data mining efforts. Working groups were comprised of NPS and USGS subject area experts, as well as scientists from other federal, state, territory, and commonwealth agencies and organizations familiar with the PACN parks and their resources. The working groups played a key role in identifying, reviewing, and refining Vital Signs for the parks and network. The Technical Committee established network monitoring objectives. Working group members held discussions with park staff and cooperators dur-

Table 1.9. **PACN timeline for completing the three-phase Inventory and Monitoring program planning and design process.**

	FY 2002 (Phase I)	**FY 2002 (Phase I)**	**FY 2003 (Phase I)**	**FY 2004 (Phase II)**	**FY 2005 (Phase III)**	**FY 2006 & beyond (Phase III)**
Anticipated Funding	Monitoring + inventory	Monitoring + inventory	Monitoring + inventory	Monitoring + inventory	Monitoring	Monitoring
Define goals and objectives	X	X	X			
Data gathering internal scoping	X	X	X	X	X	X
Inventories	X	X	X	X	X	
Scoping Sessions			X	X		
Conceptual Modeling			X	X	X	X
Vital Signs Prioritization and Selection			X	X		
Protocol Development Monitoring Design					X	X
Monitoring Plan Due Dates: Phases I, II, and III				Phase 1 Oct 2003	Phase 2 Oct 2004	Phase 3 Dec 2005 and Sep 2006

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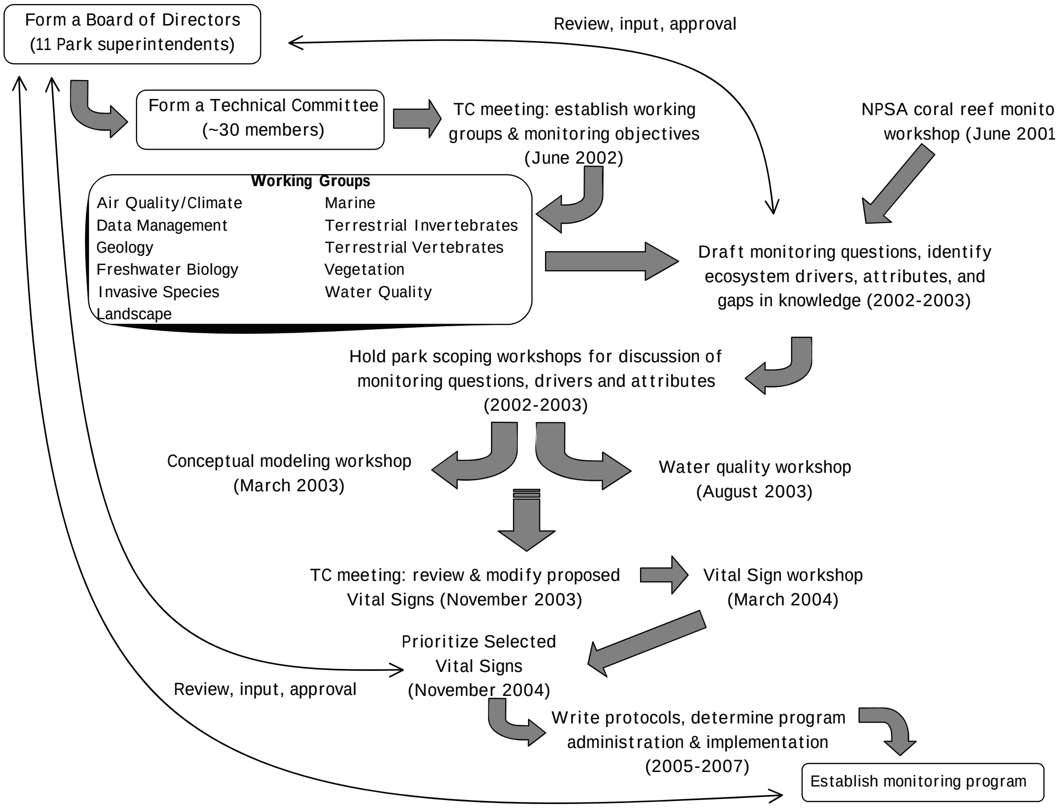
[4] See: http://science.nature.nps.gov/im/monitor/

Figure 1.9. PACN program development between 2001 and 2007.



ing park scoping workshops in 2002 and 2003. These discussions served as starting points to connect the components of the ecosystem monitoring program[5].

In addition to park scoping workshops, we held or participated in several topically focused workshops. In June 2001, a workshop at NPSA focused on evaluating coral reef monitoring from a small park perspective[6]. Desired future conditions for PACN parks were identified and a draft structure for the conceptual ecological models was initiated in a workshop in March 2003. In August of 2003 we held a water quality planning workshop[7].

Results of these workshops were used by the topical workgroups to construct an initial list of proposed Vital Signs[8]. Both Vital Signs and conceptual models were refined in the Vital Signs workshop in March 2004. The list of Vital Signs was reduced through a series of park ranking exercises and Technical Committee discussions. In November 2004, a meeting was held to prioritize the final short list of Vital Signs for initial implementation (chapter 3 provides details on the process). All park scoping and workshop reports are found in appendix O. Since Vital Signs selection and prioritization, the PACN program has focused on protocol development and determining details of program administration and implementation.

Monitoring Objectives—The overarching strategic purpose of the PACN monitoring program is to evaluate and track ecological integrity. To achieve this, monitoring objectives were identified. These network monitoring

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[5] Topical working group reports may be found in appendix E: Topical Working Group Reports, with the exception of the Water Quality report (appendix I), and the Data Management group, which initiated preparation of a data management plan.

[6] A complete report of this meeting may be found in Appendix O: Part I Developing a Coral Reef Monitoring Program for the National Park of American Samoa.

[7] A complete report of this meeting may be found in Appendix O: Part III Water Quality Workshop.

[8] A complete report of this meeting may be found in Appendix O: Part IV Vital Signs Workshop.

objectives (table 1.10), organized in the national I&M program's ecological framework, have been established to help focus the monitoring program and facilitate partnerships. Network monitoring objectives established during Vital Sign development ensured that a full spectrum of ecological attributes and management issues were considered for possible monitoring. Detailed, quantifiable, Vital Sign monitoring objectives have been identified for individual Vital Signs as part of protocol development (chapter 5).

Vital Signs Development and Selection—Selection of the set of Vital Signs for implementation has been a multi-stage process, as shown below. Additional detail on the process and criteria for ranking and selecting Vital Signs is found in chapter 3.

- Step 1: Defined goals and objectives of the monitoring program, reviewed available information about park resources, ecosystems, stressors, and concerns, and identified key characteristics of ecosystem integrity.
- Step 2: Conducted literature reviews, constructed conceptual models of ecosystem function, and developed an initial list of proposed Vital Signs. Solicited advice from the scientific community about key ecosystem attributes within particular ecosystems or topic areas.
- Step 3: Refined proposed Vital Signs based on input received, restructured our initial conceptual ecological framework to comply with the national framework, and created new Vital Signs to fill gaps identified during this stage.
- Step 4: Evaluated and prioritized proposed Vital Signs for each park. The final list of Vital Signs was selected with consideration of factors such as availability of existing protocols.

Current and Past Monitoring Within and Surrounding the Network—The Inventory and Monitoring program is an opportunity to establish new facets of ecosystem monitoring. It is also important to examine current and past monitoring conducted by national park system units and their neighbors. This will allow us to build upon those efforts and gain the maximum amount of understanding of park natural resources. The areas that are now protected in PACN parks have varying histories of scientific exploration and research. The history of monitoring (repeated data collection) is longest in the State of Hawaii parks, particularly Hawaii Volcanoes and Haleakala National Parks. Much less monitoring has been conducted in the newer Hawaii parks and the west and south Pacific parks.

The National Park Service is pursuing cooperative programs and partnerships with other agencies at a regional and a park-based level. For example, the Coral Reef Task Force partners NPS with the National Oceanic and Atmospheric Administration (NOAA), USGS, States, Territories, and universities to better understand and evaluate the condition and functioning of coral reefs in the national parks, and respond to threats to reef resources. In ALKA, community involvement and local school-based monitoring is anticipated to be integral to implementing monitoring. For the most part, on-going monitoring projects in both park and adjacent areas are specific to a single resource issue, and not oriented to an overall systems approach. Partnerships are a core component of the I&M program and are discussed in more detail in chapter 8 and appendix B.

This summary will continue to evolve over the next several years and reflects our current efforts to gather and organize information about current and past monitoring activities in and around Pacific Island Network parks. Our "data mining" task involves the entry of information into the Servicewide databases for existing data sets (Dataset Catalog), literature citations (NatureBib), and species occurrence information (NPSpecies). This data mining effort is ongoing and will continue for some time. We list current monitoring projects relevant to the network in appendix C, and describe current and past monitoring efforts at each national park system unit in appendix A. Detailed information on current and past monitoring programs grouped by subject area may be found in the topical reports in appendix E. Appendix B lists potential partners for monitoring. Table 1.11 illustrates how current monitoring fits into the national Vital Signs framework.

> *". . . a full spectrum of ecological attributes and management issues were considered for possible monitoring."*

Table 1.10. Preliminary PACN network monitoring objectives, organized in the Inventory and Monitoring program national Vital Signs framework.

Level 1	Level 2	Monitoring objective
Air and Climate	Air Quality	Determine spatial and temporal patterns and trends in atmospheric particulates, gases, and deposition.
		Track trends in sight distance and light extinction affecting visibility.
	Weather & Climate	Track the range of variation in weather patterns across PACN parks.
Geology & Soils	Geomorphology	Document short- and long-term changes in coastal, stream, and dune morphologies.
	Subsurface Geologic Processes	Understand spatial and temporal patterns and variation in volcanic and seismic activity.
		Track changes in cave and lava tube environmental and morphological characteristics.
	Soil Quality	Track physical, chemical, and biological changes in soils.
	Paleontology	Document changes in condition of paleontological resources such as archived pollen cores and fossils.
Water	Hydrology	Track spatial and temporal patterns and variation in hydrology of freshwater and marine systems.
		Determine magnitude and trends of water withdrawal for human use.
	Water Quality	Track spatial and temporal patterns and variation in water quality in freshwater and marine systems
Biological Integrity	Invasive Species	Use monitoring data for early detection & predictive modeling of incipient invasive species.
		Document changes in established populations of invasive species, including response to treatment.
	Infestations & Disease	Determine trends in incidence of disease and infestation in selected communities and populations.
	Focal Species or Communities	Determine trends in composition, structure, and function of populations of selected focal species within the parks.
		Determine trends in composition, structure, and function of selected focal communities within the parks.
	At-risk Biota	Determine trends in populations of threatened, endangered, and at-risk species within the parks.

Table 1.10. **Preliminary PACN network monitoring objectives, organized in the Inventory and Monitoring program national Vital Signs framework—*Continued*.**

Level 1	Level 2	Monitoring objective
Human Use	Point-Source Human Effects	Use monitoring data to determine patterns of litter and debris within parks and identify possible sources.
	Non-point Source Human Effects	Use monitoring data to determine patterns of litter and debris within parks and identify possible sources.
	Consumptive Use	Determine magnitude and trends in harvest of biological resources and sand.
	Visitor & Recreation Use	Determine spatial and temporal patterns of visitor use of park resources.
	Cultural Landscapes	Determine trends in condition of resources with shared natural and cultural value.
Landscapes (Ecosystem Pattern & Processes)	Fire & Fuel Dynamics	Determine spatial and temporal patterns and effects of fire on vegetation communities.
	Landscape Dynamics	Determine spatial and temporal patterns and changes in land cover and community distribution.
		Determine spatial and temporal patterns and changes in marine benthic cover and community distribution.
		Determine spatial and temporal patterns in land use and effects on park resources.
		Determine spatial and temporal patterns in marine use and effects on park resources.
	Extreme Disturbance Events	Track extreme disturbance events in parks.
	Soundscape	Determine trends in natural and anthropogenic sounds in selected areas.
	Viewscape	Determine whether viewsheds, landscapes, and underwater seascapes are changing within and surrounding the park.
		Determine trends in levels of artificial light and shading in selected areas.
	Nutrient Dynamics	Determine rates of nutrient turnover in terrestrial and aquatic systems.
	Energy Flow	Determine trends in productivity of plants and algae in terrestrial and aquatic communities.

Table 1.11. Current monitoring by individual parks and other organizations in the Pacific Island Network.

[△ = Currently monitored by park; ▲ = Currently monitored by another agency or organization]

Level 1	Level 2	Monitored variable	AMME	WAPA	NPSA	USAR	KALA	HALE	ALKA	PUHE	KAHO	PUHO	HAVO
Air & Climate	Air Quality	Particulates (IMPROVE suite)						▲					▲
		Volcanic Ash		▲									
		Contaminants (ozone, CO_2, SO_2 etc.)		▲	▲	▲						▲	▲
	Weather	Weather/ climate	▲	▲	▲	▲	▲	△▲	▲	▲	△▲	▲	△▲
Geology & Soils	Subsurface Geologic Processes	Earthquakes	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		Ground deformation						▲					▲
	Soil Quality	Erosion	△▲	△						▲			
Water	Hydrology	Stream flow		▲		▲	▲	▲	▲				
		Tsunamis		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		Groundwater levels			▲						▲		
	Water Quality	Chemistry (pH, N, DO)	▲	▲		▲			▲		△▲		
		Toxics	▲	▲		▲							
		Macroinvertebrates & algae	▲						▲		△▲		
		Microorganisms	▲	▲		▲			▲	▲			
		Water temperature	▲	▲	△▲	▲			▲	▲	△▲		

Table 1.11. Current monitoring by individual parks and other organizations in the Pacific Island Network—*Continued*.

[△ = Currently monitored by park; ▲ = Currently monitored by another agency or organization]

Level 1	Level 2	Monitored variable	AMME	WAPA	NPSA	USAR	KALA	HALE	ALKA	PUHE	KAHO	PUHO	HAVO
Biological Integrity	Invasive Species	Established alien plants			▲			△					△
		Argentine ant						△					
		Invasive small mammal monitoring & control				△		△			△		△
		Kalij pheasants											△▲
		Invasive insect monitoring & control				△							▲
		Feral ungulate monitoring & control			△			△					△▲
	Focal species or Communities (including at-risk species)	Coral reef fish communities	▲	▲	▲				▲	▲	▲	▲	
		Coral dist./abund./recruitment	▲		▲		△		▲	▲	△▲	▲	
		Effects of vegetation management/restoration									△		△
		Vegetation growth/ composition			▲			△			▲		△▲
		Terrestrial invertebrate communities											▲
		Rare upland plant species & communities											△
		Rare coastal plant species & communities											▲
		Dark-rumped petrel nesting						△					△
		Sea turtle dist./abund.		▲					▲		△▲	▲	△
		Silverswords & silversword restoration						△					△
		Nene (hawaiian goose) dist./abund., genetic info, nesting						△					△
		Shark/manta ray dist./abund.									▲		
		Leafhopper dist./abund.											▲
		Waterbird dist./abund.									▲		
		Brown tree snake	▲	▲									
		Bats			▲								
		Marine mammals				▲	△▲	▲	▲	▲	▲	▲	▲
		Forest bird dist./abund.	▲					△					
Human Use	Consumptive Use	Fisheries		▲	△▲				▲	▲	▲	▲	
	Human Use	Visitation		△		△	△	△		△	△	△	△
Landscape (Ecosystem Pattern & Processes)	Fire	Landscape pattern											△

Summary

In Chapter 1, we summarize legislation, NPS policy and guidance, Servicewide and Network-specific strategic goals for management, and park-enabling legislation relevant to PACN Vital Signs monitoring. According to federal law and National Park Service policies, national park managers are directed to know the status and trends in the condition of natural resources under their stewardship. This knowledge is necessary to fulfill the NPS mission to conserve park resources unimpaired for the enjoyment of future generations as stated in the National Park Service Organic Act of 1916. As part of the Natural Resource Challenge, efforts are being made to improve park management and expand institutional knowledge and reliance on scientific information. The PACN, comprised of 11 units, is one of 32 Inventory and Monitoring networks establishing a Vital Signs monitoring plan to assess the condition of park natural resources. Long-term monitoring of natural resources provides site-specific information needed to understand and identify changes in natural systems and to determine whether these changes are within natural levels of variability. It also helps to detect changes in ecosystem integrity and species viability before irreversible loss has occurred. It is impossible to monitor all attributes of PACN ecosystems. Therefore, Vital Signs are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, effects of stressors, or elements that have important human values. An important emphasis of the Vital Signs monitoring program is to facilitate communication, coordination, and collaboration among parks, programs, academia, and government agencies. The PACN is guided by a Board of Directors composed of superintendents from each of the national park system units, plus several advisory members and is responsible for ensuring the overall effectiveness and success of the network's monitoring efforts. A standing Technical Committee provides technical assistance to the board and is comprised of natural resource managers and scientists who work in the parks and are familiar with park issues. The PACN I&M program will evolve as we document patterns of change in ecosystems through our Vital Signs monitoring.

Chapter 2. Conceptual Models

> *"Conceptual models are a combination of visual and narrative summaries that illustrate the important components of a system and the interactions among them."*

Monitoring efforts must be based on a fundamental understanding of how an ecosystem functions. Conceptual model development, a vital part of the NPS Inventory and Monitoring program, provides a framework for clarifying meaningful monitoring strategies, enabling us to progress from more general to more specific monitoring questions (Gross 2003). Models promote communication among scientists, managers, and the public, providing a means for ecosystem monitoring evaluation and interpretation and discussion of ecosystem components.

Most conceptual models are a combination of visual and narrative summaries that illustrate the important components of a system and the interactions among them. These models can communicate system functions that may: (a) represent current knowledge of the processes occurring in systems, (b) illustrate system dynamics, (c) identify the bounds and scope of the systems of interest, and (d) provide a framework for testing hypotheses about how systems function. Conceptual models are also useful for justification of monitoring indicators. No single model depicts any "correct" system. Rather, it represents the current best understanding of system dynamics, and should be refined as our understanding of park ecosystem processes expands (Jorgensen 1988, Roman and Barrett 1999, Maddox et al. 1999).

PACN Holistic Model

The overarching goal of the National Park Service is the restoration and maintenance of ecological integrity within park boundaries (NPS 2001). Ecological integrity is the ability of an ecological system to support and maintain (a) native (appropriate) species, populations and communities, (b) the occurrence of ecological processes at appropriate rates and scales, and (c) the existence of environmental conditions that support these taxa and processes (Karr and Dudley 1991). Ecological integrity implies the physical, chemical, and biological components of an ecosystem are present, functioning, and capable of self-renewal (Parrish et al. 2003). The PACN uses this standard to guide network ecosystem monitoring efforts, including efforts to develop ecosystem conceptual models, and in choosing the monitoring Vital Signs.

Jenny's (Jenny 1941, 1980) state-factor approach has been widely applied as a framework for examining temporal and spatial variations in ecosystem structure and function (figure 2.1A) (Walker and Chapin 1987, Vitousek 1994, Seastedt et al. 2001). Chapin and colleagues (1996) extended this framework (figure 2.1B) with a set of ecological principles concerning ecosystem sustainability, describing *"…a sustainable ecosystem as one that, over the normal cycle of disturbance events, maintains its characteristic diversity of major functional groups, productivity, and rates of biogeochemical cycling"* (Chapin et al. 1996). PACN adopted a modified version of the interactive-control model (Miller et al. 2003) as a holistic network model (figure 2.1D). By substituting water quality and quantity for soil resources in the model, it can be applied to aquatic as well as terrestrial ecosystems (Chapin et al. 1996). In the PACN interactive-control model, water and soil quality are represented as water and soil resources and conditions. Climate, as represented in this model, falls underneath the broader term of atmospheric resources and conditions. This term encompasses climatic variables (e.g., temperature, precipitation), as well as atmospheric drivers and stressors (e.g., gaseous and particulate matter). This interpretation of climate is an important clarification in the context of global environmental changes. In figure 2.1B and C, higher order effects are depicted as: (1) climate, (2) soil and water resource supply, (3) major functional groups of organisms, and (4) disturbance regimes interacting with ecosystem processes (Miller et al. 2003).

A key aspect of the interactive-control model is the hypothesis that interactive controls must be conserved for an ecosystem to be sustained. Large changes in any of the four interactive controls are predicted to result in a new ecosystem

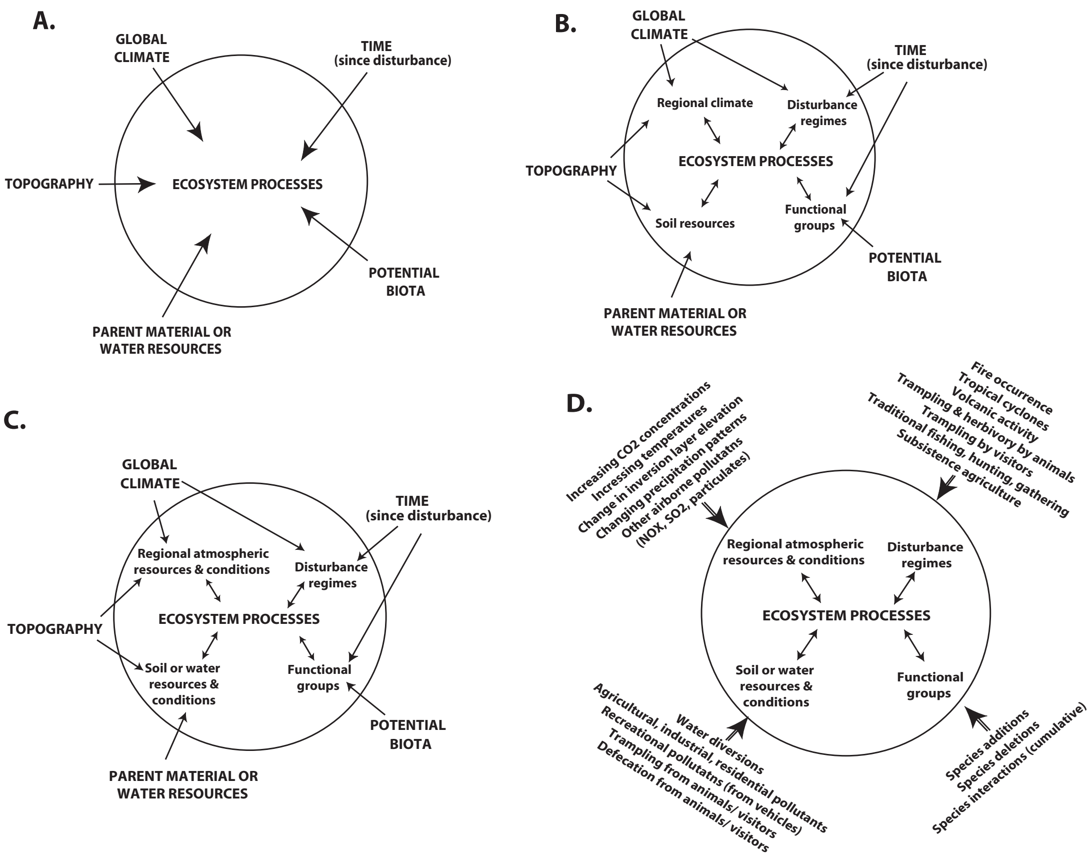

Figure 2.1. Relationships (A) between Jenny's (1941) state factors and ecosystem processes, and (B) among state factors, interactive controls, and ecosystem processes. The circle represents the boundary of the ecosystem. The modified version of the interactive-control model for the PACN is represented in (C), and (D) is the array of stressors affecting PACN ecosystems arranged in relation to their first-order effects (modified from Jenny, 1941, Chapin et al. 1996, Miller et al. 2003).

with different characteristics than the original system (Chapin et al. 1996). For example, major changes in soil resources (e.g., erosion, salinization, fertilization, or other mechanisms) can greatly affect productivity, recruitment, and competitive relations between plants which, in turn, can result in major alterations in the structure and function of plant communities as well as higher trophic levels. These factors and processes in combination can result in fundamentally different types of ecosystems, threatening ecological integrity.

Pacific Island Systems

The Pacific Island Network has created a set of holistic models that illustrate the broad characteristics of Pacific islands. We use a graphical illustration of an island as a base for which to present several of our models. This graphical island format illustrates three important features regarding island ecosystems in which all PACN parks are located: (1) islands are topographically and biologically diverse, (2) islands are governed by interconnections between land, sea, and air, and (3) islands are threatened by a common group of agents of change.

Figure 2.2 presents a generalized Pacific island that illustrates typical ecosystem zonation as it relates to altitude and characteristic rainfall patterns generated by trade winds. Elevations of all PACN islands rise into the montane mesic/cloud forest or mid-elevation seasonal/rainforest ecological zones. However, the islands of Maui and Hawaii also extend into the sub-alpine, alpine, and alpine Aeolian[1] zones. Most parks occupy only a portion of the generalized island. Cave and lava tube systems may be located at any elevation.

Saipan, Guam, and islands of American Samoa differ somewhat from this model, as they lack substantial windward-leeward distinctions. Rel-

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[1] The alpine aeolian zone, primarily wind-supported, is differentiated from the alpine zone in that little or no photosynthetic production occurs in this ecosystem.

atively low relief, coupled with their locations in the Pacific, have not created a trade wind-generated rain shadow effect (Mueller-Dombois & Fosberg 1998) as with the Hawaiian islands.

Lower elevation ecosystems on all PACN islands have been heavily altered by humans since first colonization (Kirch 1982, Burney et al. 2001), and anthropogenic impacts continue at an accelerated rate. All ecosystem zones were used by native peoples to some degree, although the extent and exact nature is not fully known. Traditional uses and practices continue today in many national parks, though more recent land use practices have dominantly superseded traditional cultural impacts on ecosystems.

Key PACN Ecosystems—Knowledge of island biogeography is essential to understanding Pacific island ecosystems. As a general rule, the number of functional biotic groups decreases with increasing distance from continental source populations, resulting in less taxonomic groups in the Hawaiian Islands, relative to the west and south Pacific islands (i.e., numbers of Pacific reef fish and invertebrate species are highest near their source populations in Indo-Malaysia) (Connell 1978, Briggs 1999). Because a low number of species have colonized the islands (Keast 1996, Convention on Biological Diversity 2003), fewer functional groups exist than in most continental regions. Islands farther from source populations tend towards higher levels of endemism than those near source populations (Munroe 1996, Font 2003). Endemism can arise from both evolution of single species in isolation and from adaptive radiation, where multiple species are derived from a single ancestral species. Both of these speciation mechanisms have occurred among native species that inhabit PACN ecosystems (Keast 1996, Polhemus and Asquith 1996, Brasher 2003). Thus, despite the low number of colonizing species, Hawaiian island ecosystems are considered remarkable for the high levels of endemism exhibited by their flora and fauna (Loope and Gon 1989, Slikas 2003).

The Pacific Island Network has identified six key ecosystem groupings: (1) scrub land, (2) forest and shrubland, (3) subterranean, (4) stream, (5) coastal, (6) nearshore marine.

Distinctive communities within each of these categories vary by park. Because of the vast geographical range of the network, community composition varies in different regions (Hawaiian Islands, American Samoa, and Marianas Islands) within each of these ecosystem types.

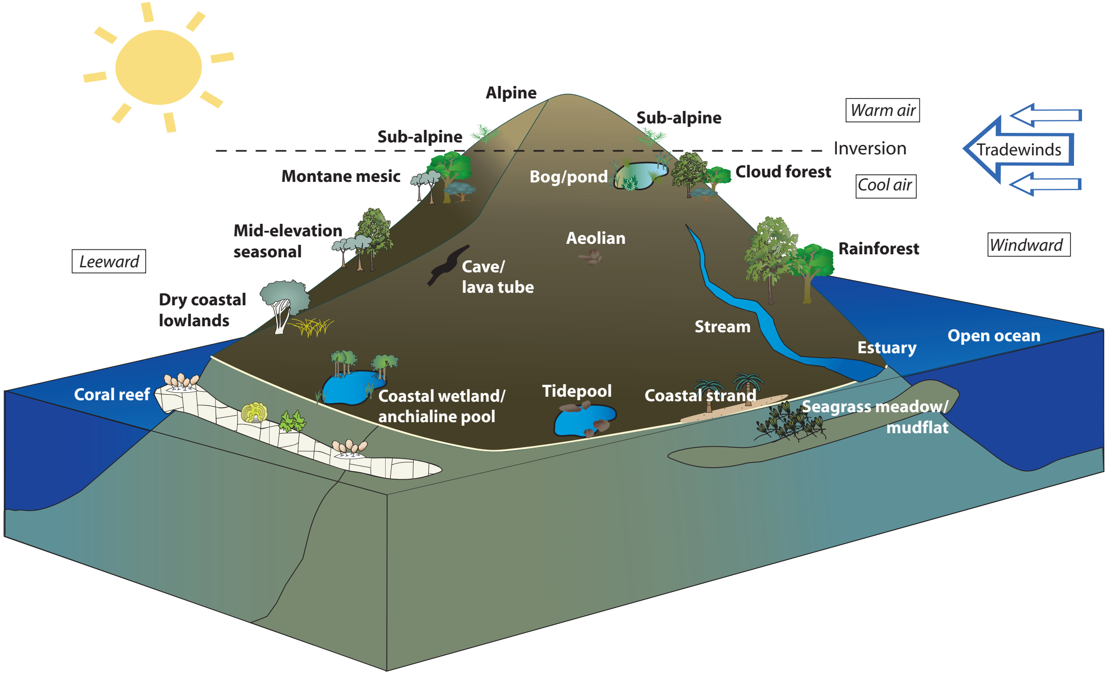

Figure 2.2. Generalized Pacific island ecosystem zonation showing altitudinal gradients and windward-leeward distinction.

Figure 2.3. Riparian area at Puukohola Heiau National Historic Site (left) and Puu Alii bog at Kalaupapa National Historical Park (right).

Interactions of Pacific Island Ecosystems

Ecosystems do not exist in isolation, but are linked by movement of air, water, and organisms (Polis et al. 1997). To demonstrate these interactions, including processes that occur outside park boundaries and island-wide, we used a standard Pacific island conceptual diagram (figure 2.4). Water is one of the main linkages between systems. Surface water systems often connect terrestrial and marine systems (e.g., transport of nutrients and organic matter from forests to coral reefs via streams). Surface water and groundwater systems are also highly

Table 2.1. Six dominant ecosystem types located within or immediately adjacent to PACN parks.

Ecosystem Type	Description	Parks[a]
1. Scrub land	Alpine and subalpine, very low rainfall, and includes non-alpine lava fields.	HALE, HAVO
2. Forest and shrub land	Rain forest, cloud forest, montane bog and pond, Hawaiian mesic forests, Marianas limestone, Hawaiian dry forest and grassland, and Mariana Island savanna.	WAPA, NPSA, KALA, HALE, PUHE, KAHO, PUHO, HAVO, ALKA
3. Subterranean	Cave and lava tube ecosystems.	WAPA, HALE, KAHO, HAVO, ALKA
4. Stream	Perennial and intermittent streams and seeps, including sources, riparian areas, and estuaries.	AMME, WAPA, NPSA, KALA, HALE, ALKA, PUHE, PUHO, HAVO
5. Coastal	Coastal marshes, mangrove swamps, anchialine pools, man-made enclosed fishponds, sea cliffs, limestone and basalt rocky shores, sand and cobble beaches, and strand vegetation communities.	all parks
6. Nearshore marine	Coral communities, fringing reefs, seagrass beds, and shoreline intertidal.	all parks

[a]. Resources of ALKA have not been inventoried, as the trail is in planning stages. Resources listed for ALKA in this table are found along the proposed route.

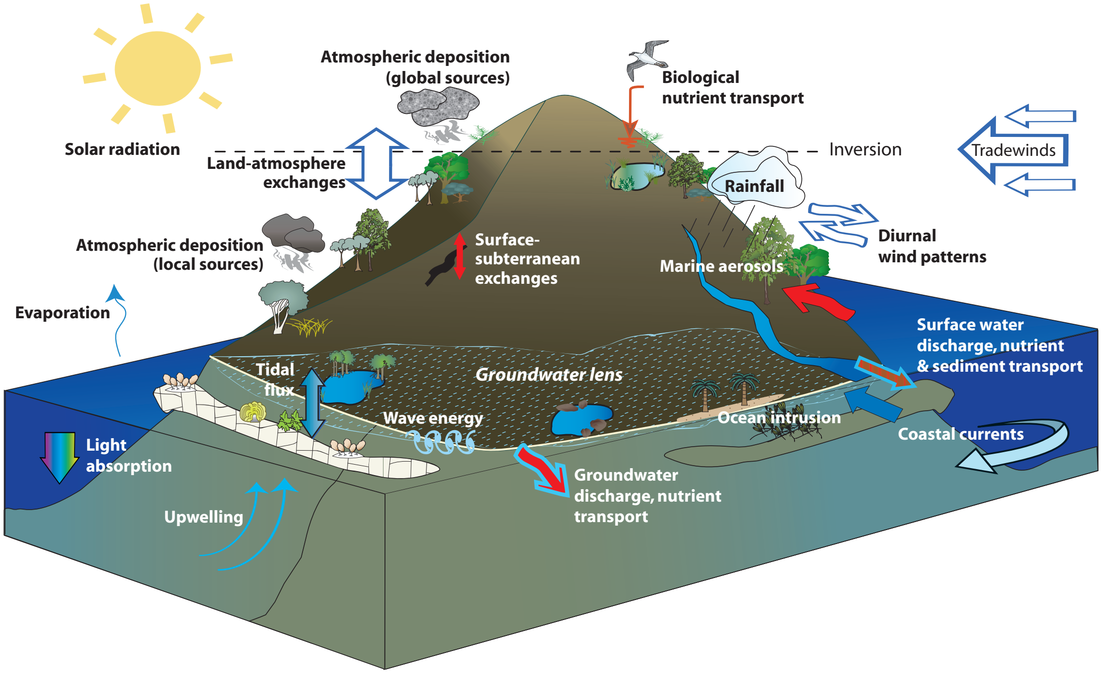

Figure 2.4. Key interactions between the atmosphere and marine, freshwater, and terrestrial ecosystems.

interconnected. All groundwater resources on Pacific islands are formed by the percolation of rainwater into bedrock. Fresh groundwater also exists in a “lens” that floats upon seawater. Additionally, freshwater springs may be found under the ocean surface, providing a source of nutrients to nearby organisms. Withdrawal of freshwater for human consumption often reduces the flow of streams and lowers the water table in wells and wetlands, illustrating the interconnectivity of these resources.

Several important marine processes also affect terrestrial and surface water systems. Wave action (figure 2.5) and ocean intrusion affect the physical and chemical environment of coastal habitats. Deep-water upwelling provides an important source of nutrients to both marine and coastal communities, although this effect is less pronounced than in temperate regions. Coastal currents are highly important in the dispersal of larvae and adult marine organisms, including the larvae of freshwater fish species and terrestrial plants such as mangroves.

Numerous additional linkages exist. An important interaction that has greatly diminished over time is the transport of nutrients from the ocean to land by mountain-nesting seabirds. Many of these seabird species are now extinct or greatly reduced in numbers (Loope 1998). Solar radiation also affects ecosystem productivity. In marine systems, for example, selective absorption of light wavelengths by the water column has a significant effect on ecological communities (e.g., zonation of macroalgae). Important atmospheric processes affecting terrestrial and aquatic ecosystems include: (a) evaporation, (b) rainfall, (c) deposition of marine aerosols, locally and globally generated particulate matter and nutrients, and (d) short and long-term wind patterns.

Pacific Island Agents of Change

Pacific islands share several primary stressors, or agents of change. Common stressors arise from both anthropogenic and non-human sources (figures 2.6 and 2.8). These stressors affect multiple ecosystems, and can represent possible threats to human health or safety. The ecological

Figure 2.5. Wave action at Hawaii Volcanoes National Park.

"Oceanic islands are particularly susceptible to biological invasions. A strong correlation exists worldwide between percentage of biotic endemism and vulnerability of the biota to displacement by biological invaders."

impacts and effects of these stressors arise from the small size, isolation, geological activity, and histories of human occupation in the Pacific islands. Effects of disturbance at one scale may affect structure, function, and community composition at another scale. For example, urbanization affects streams at multiple scales including microhabitat-scale changes in temperature, siltation, and substrate, reach-scale riparian canopy removal and channelization, and watershed-scale reduction in native fish and invertebrate populations (Brasher 2003). Similarly, land clearing in lowland ecosystems can alter energy budgets and rainfall over a broad scale (Lawton et al. 2001). As another example, increasing global CO2 levels are predicted to reduce the ability of calcareous marine organisms to calcify, causing the physical structure of coral reefs to weaken (Andersson et al. 2003).

It is important to understand the distinction between natural and anthropogenic agents of change, in order to manage NPS ecosystems for ecological integrity. Many Pacific island ecosystems have evolved with natural disturbances, such as tropical cyclones and volcanic activity (figure 2.7). We include both natural and anthropogenic agents of change in our ecosystem models as the latter also alters natural ecosystem succession and ecological integrity (Vitousek et al. 1998, Chapin et al. 1996).

Most stressors in PACN parks occur throughout the region, and are not confined to a single park. To better illustrate these stressors, they are summarized by individual PACN parks in table 2.2. They include natural and anthropogenic, as well as local and global agents of change. The section below table 2.2 further explains the categories of stressors.

Invasive Species—Invasive species are one of the most significant stressors to Pacific island ecosystems. Additionally, introductions of invasive species not yet present in the parks represent one of the greatest threats. Changes resulting from introduction of invasive species extend beyond alteration of ecosystem composition to impacts on ecosystem structure and function (Cuddihy and Stone 1990, Vitousek et al. 1996, Brasher 2003). In several Pacific island ecosystems, alien species now form the dominant biological components, and restoration of native systems will require an enormous effort. In cases of species extinction (e.g., lowland birds and tree snails, Burney et al. 2001), complete system restoration is not possible.

Oceanic islands are particularly susceptible to biological invasions (Loope and Mueller-Dombois 1989, Denslow 2003). A strong correlation exists worldwide between percentage of biotic endemism and vulnerability of the biota to displacement by biological invaders (Loope and Mueller-Dombois 1989). In many cases, new introductions meet less resistance and have proportionately greater negative effects on Pacific islands than in continental settings (UNEP 2003, Denslow 2003).

Various facets of land use and human activity drive biological invasions such as the breakdown of biogeographic barriers through intentional or unintentional transport of biological organisms by humans. Such transport of organisms by humans is increasing through the process of globalization (Ehrenfeld 2005, Wilson 1995). Therefore, species invasions will only be slowed in the immediate future by measures purposely implemented to prevent, detect, rapidly respond to, and manage invasions (Vitousek et al. 1997, Loope et al. 2001).

Adjacent Land and Resource Use—Adjacent land and resource use is of concern to all PACN parks, although resources in some parks are threatened by adjacent use more than others. Several small PACN parks are located in or near developed areas which are experiencing rapid population growth (e.g., West Hawaii parks). Adjacent land and water use are also a concern for the large parks. Specific concerns for these parks include land and marine uses (e.g., development, light pollution, increased vehicular traffic, increased fishing pressure), water withdrawal, water quality, petrochemical spills, solid waste disposal, and erosion and sedimentation.

Fire—Before human colonization, fire was rare on most Pacific islands (Mueller-Dombois 1981) as lightning is uncommon. Fires are, however, associated with volcanic activity. Pacific island species and ecosystems evolving under these conditions are extremely sensitive to fire which kills native vegetation, facilitates invasion by alien species (particularly fire-prone grasses), modifies soil surfaces, and contributes to erosion

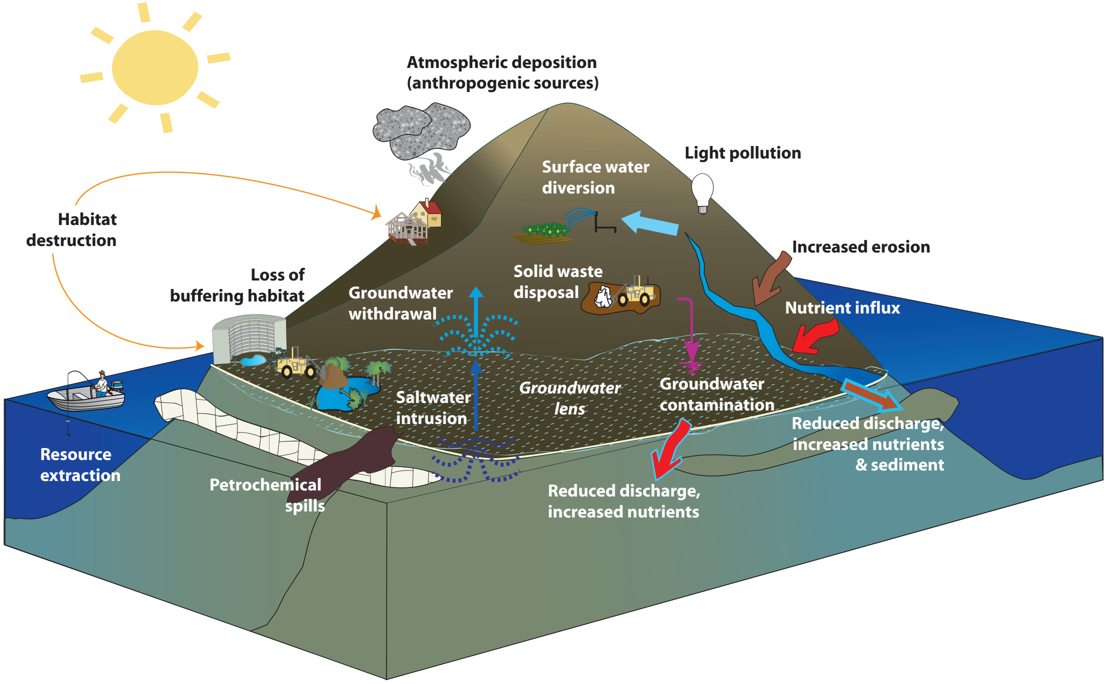

Figure 2.6.
Generalized model of anthropogenic stressors for Pacific islands and ecosystems.

Figure 2.7.
Volcanic activity at Hawaii Volcanoes National Park has large effects on ecosystems. Photo by USGS/Don Swanson.

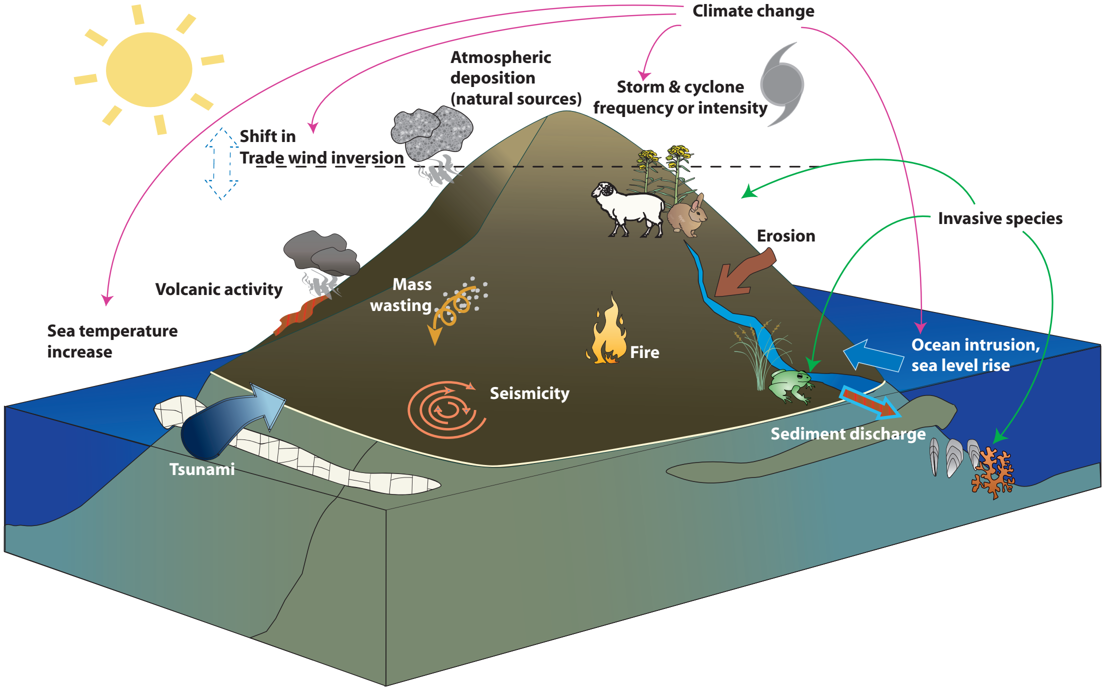

Figure 2.8. Generalized model of non-human stressors for Pacific islands and ecosystems.

(Minton 2005). Many Pacific island ecosystems have been extensively modified or destroyed through the use of fire.

In-Park Use—Most national parks in the Pacific continue to experience an increase in visitation[2] due to spectacular scenic vistas, wilderness areas, historical resources (both natural and cultural), and numerous other features. The primary mission of the National Park Service is to provide the public with a venue to experience natural and cultural resources, while preserving resources "unimpaired for enjoyment of future generations." PACN park usage causes measurable impacts to natural resources. Specific concerns include damage due to visitation (e.g., trail compaction, boat anchoring, trash, petrochemical spills), subsistence agriculture, hunting, gathering, and fishing.

Natural Hazards—Pacific islands are subject to a variety of natural hazards due to their geographic and geologically active setting. While Pacific island ecosystems have evolved in concert with these natural events, large-scale disturbances may facilitate the invasion of alien species, which are a particular threat to disturbed ecosystems. Such events include volcanic activity, earthquakes, mass wasting (i.e., landslides), tsunami, and tropical cyclones (figure 2.9).

Climate Change—Climate change is a potential threat to all PACN parks. While climate change may be an on-going natural phenomenon recorded throughout the planet's geologic history, the rate of climate change (including increasing atmospheric carbon dioxide, ozone depletion, and concomitant increases in air and sea surface temperatures) is unprecedented (Hughes et al. 2003, Board on Atmospheric Sciences and Climate 2006). Increases in atmospheric carbon dioxide could lower sea water pH and reduce calcification rates for corals, and many other marine organisms, thus significantly impacting reef accretion rates (Kleypas and Langdon 2000, Langdon et al. 2000, McNeil et al. 2005).

Sea Temperature Increase—Global mean sea surface temperatures have increased 0.6±0.2 degrees Celsius during the twentieth century (Intergovernmental Panel on Climate Change 2001) and pose a significant threat to coral reefs, particularly in the shallow lagoons of NPSA in American Samoa where water temperatures

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[2] Online at http://www2.nature.nps.gov/stats/

Table 2.2. Summary of stressors and natural resource management concerns of PACN parks.

	AMME	WAPA	NPSA	USAR	KALA	HALE	ALKA[a]	PUHE	KAHO	PUHO	HAVO
Invasive Species	X	X	X	X	X	X	X	X	X	X	X
Adjacent Land & Resource Use											
Land use	X	X	X	X	X	X	X	X	X	X	X
Water withdrawal and/or diversion	X	X	X	X	X	X	X	X	X	X	
Erosion & sedimentation	X	X	X		X	X	X	X			
Water quality (freshwater & marine)	X	X	X	X	X	X	X	X	X	X	
Marine use[b]	O	X		O	X		X	O	X	O	O
Air quality	X	X		X		X	X		X	X	X
Fire		X			X	X	X	X	X	X	X
In-Park Use											
Visitor damage	X	X				X	X	X	X	X	X
Fishing[b]	O	X	X		X		X		X	O	O
Subsistence agriculture			X			X					
Hunting & gathering (not including fishing)	X	X	X		X	X	X		X		X
Natural Hazards											
Volcanic activity	X	X				X	X	X	X	X	X
Frequent tropical cyclones	X	X									
Sea Temperature Increase		X	X	X	X				X		
Sea Level Rise	X	X	X	X	X	X	X	X	X	X	X
Global Climate Change	X	X	X	X	X	X	X	X	X	X	X

[a] The managed areas of the trail corridor have yet to be determined; these stressors are present within the corridor and will likely be included.

[b] X= cases where marine resources are located within park boundaries; O= cases where park boundaries end at the high-tide line and marine resources lie outside park boundaries.

can reach 35°C (Hoegh-Guldberg et al. 2000, Craig 2005). Increased sea surface temperatures contribute to bleaching, a process in which corals expel zooxanthellae (algal symbionts) leaving bleached tissue and white skeletons (e.g., Hoegh-Guldberg 1999). If prolonged, bleaching can result in coral mortality.

Sea Level Rise—The effect of global climate change on sea level is expected to be a concern for all PACN parks. Sea level rise is an immediate concern in the coastal parks including the West Hawaii parks, coinciding with subsidence of the island resulting from active volcanism. All PACN parks are affected by storm damage due to the reach of breaking waves which, coupled with salt stress, can lead to the destruction of coastal habitat. Ecosystems that are particularly affected include coastal marshes, anchialine pools, fishponds, mangrove swamps, and the coastal spray zone. The growth of coral may also be inhibited due to decreased light availability in increased water depth (Kennedy et al. 2002, Baker et al. 2006).

The Watershed as a Key Geographic Unit

The watershed is an important geographic unit for evaluating ecosystem structure, function, and composition, coupled with understanding drivers and stressors in PACN parks. A watershed-based approach emphasizes the interconnections and interactions at the landscape level. Watershed-based management is also a traditional cultural means of land and resource distribution in the Pacific. For example, the traditional Hawaiian ahupuaa land management system (figure 2.10), consisting of strips of land that extend from the ocean to the mountains, provides a holistic framework for sustainable use and conservation of natural resources by the local community.

While the ahupuaa system is an excellent form of watershed management, none of the PACN parks' legislative boundaries, expect NPSA, include an entire watershed from mountain to nearshore marine habitat. Most of the parks contain either fragments of ecosystems within a watershed, or they terminate at the mean high-tide line and abut marine ecosystems (e.g., HAVO and HALE).

The national Inventory and Monitoring program guidance for design of sampling schemes[3] does not recommend a watershed-based approach for study design. This type of approach would select a single watershed for intensive study, with results inferred to other watersheds. Nevertheless, the PACN recognizes that we must consider a landscape scale broader than the watershed when considering issues such as marine transport of propagules, air quality, or volcanic activity. This landscape-scale view of ecological processes emphasizes the need for interactive management partnerships with external agencies and organizations.

For further information on the PACN ecosystem and Vital Sign conceptual

Figure 2.9. Effects of typhoon Pongsona at War in the Pacific National Historical Park.

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[3] Online at http://science.nature.nps.gov/im/monitor/docs/nps_sg.doc

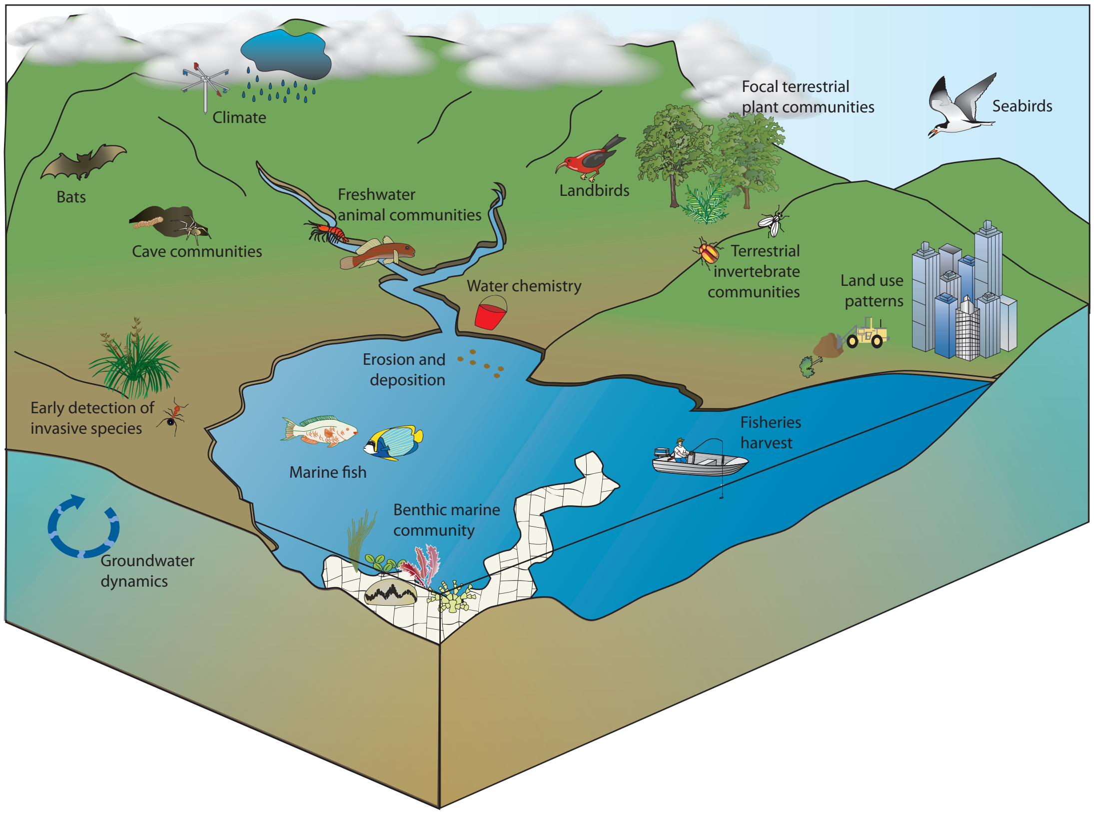


Figure 2.10. Conceptual illustration of Vital Signs important in a watershed, and in an ahupuaa (a traditional land and resource management system in the Hawaiian Islands).

models, we direct the reader to Conceptual Models and Ecological Overview in appendix H. In this appendix, a description of each ecosystem group is provided. Each description includes several "layers" of models as follows:

1. In all cases, we have identified or developed a generalized ecosystem-specific model that includes the primary biotic and abiotic resources found within the ecosystem, and their relationships to one another. We also discuss the major stressors, or agents of change, that affect these ecosystems.
2. Where appropriate, we provide narratives and models of distinctive systems (e.g., anchialine pools).
3. Each ecosystem-specific description contains an ecosystem dynamics diagram that depicts the major agents of change, interactions among those agents, and the resources that they affect.
4. Each Vital Sign selected for monitoring accompanies a conceptual model stressing its importance.

Each system is also discussed in both a regional and a network or park-specific context. For further information on components of each model, a literature review on the agents of change and park resources included within the models is also contained within appendix H. Literature reviews are to a large extent summarized from the topical reports in Appendix E: Topical Working Group Reports, and Appendix I: Water Quality Report.

Summary

Conceptual models simplify the organization and communication of information about ecosystem structure, function, and composition, along with drivers and stressors of each system. Knowledge gained from defining, testing, and applying the PACN models can be utilized in park management, as well as provide a framework for selecting which Vital Signs to monitor.

The Pacific Island Network's nested system of models is designed to demonstrate similarities between network parks and allow use of different scales and factors while developing the monitoring program. In this chapter, we outline the overall theoretical framework of our conceptual model development. We also present the PACN landscape-scale view of ecological processes, which emphasizes the need for interactive management partnerships with external agencies and organizations.

Appendix H: Conceptual Models and Ecological Overview contains the finer-scale models developed by the PACN network. This appendix is organized into four sections. The first section consists of a general, simple network model (also presented in this chapter) describing factors and processes controlling the structure and function of ecosystems. The second section introduces ecosystem conceptual models that articulate ecosystem composition, structure, and function. The second section also conveys our understanding of how natural ecosystem drivers and major agents of change influence key structural components, functional relationships, interactions, and system dynamics. The third section contains narrative descriptions of major agents of change affecting the network that are integrated on a landscape level. The fourth section of the appendix contains conceptual models specific to individual Vital Signs. These models will be expanded within protocols as they are developed. Further details about model elements may be found in the topical reports in Appendix E as well as Appendix I: Water Quality Report.

Chapter 3. Vital Signs

Vital Signs are "a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values." The Pacific Island Network used a multi-step process to select and prioritize the list of network Vital Signs.

The NPS Water Resources Division requires that the network determine priorities for impaired and pristine waters, define site-specific monitoring objectives, and develop a detailed water quality monitoring plan to be implemented in close coordination with Vital Signs monitoring. The PACN has chosen to fully integrate water quality monitoring with the Vital Signs monitoring plan, thus Water quality Vital Signs are discussed in this chapter as well.

Identifying Potential Vital Signs

The Pacific Island Network used a combination of network-wide meetings, topical working groups, and individual park scoping sessions to identify potential Vital Signs. Through these processes, we also evaluated the attributes that make potential Vital Signs high-quality indicators of ecosystem health.

Topical Working Groups and Park Scoping Sessions—The first stage in Vital Sign identification included a review of available information about park resources, ecosystems, stressors, and concerns, as well as identification of key characteristics of ecosystem integrity. The ten topical working groups each constructed a general model identifying ecosystem drivers and candidate attributes to monitor for their subject area. The working groups were extensively involved in revising and refining Vital Signs throughout the prioritization process.

Scoping sessions and workshops (documented in appendix O) were also held at each of the PACN parks (figure 3.1), allowing staff to critique conceptual models on park resources and attributes that stress or serve as drivers to those resources. The scoping sessions also provided information on park-specific concerns which may not have previously been identified.

Vital Signs Evaluation and Ranking— In the subsequent phase of Vital Signs selection, the PACN conducted literature reviews and began to develop conceptual models of ecosystem functions. The list of proposed Vital Signs was compiled, and later adapted to the national Inventory and Monitoring framework.

Figure 3.1. A Pacific Island Network Technical Committee meeting, August 2003.

Park staff members ranked potential Vital Signs based upon four weighted criteria: ecological significance, management significance, legal mandate, and cost-effectiveness (table 3.1). Use of a database allowed each park to independently rank each Vital Sign according to the above criteria. PACN staff provided a detailed justification statement for each Vital Sign that included information about ecological significance and legal/policy mandates. However, park staff were expected to base cost effectiveness and feasibility rankings on their own practical experience and expectations, and to rank management significance according to the park's priorities. The database allowed parks to review detailed information about each Vital Sign, rank Vital Signs, view Vital Sign ranking summaries, and revisit the rankings as desired.

Completion of our ranking database process was iterative. Hence, the network went through two significant refinements of the proposed Vital Signs list and sent the database to the parks for ranking over three iterations.

Vital Signs Workshop—A Vital Signs workshop was hosted by the PACN in March 2004 to gain

Table 3.1. Vital Sign ranking criteria (see appendix G for sub-criteria).

Criterion	Weight
Management Significance	30 %
Ecological Significance	30 %
Legal / Policy Mandate[a]	20 %
Cost Effectiveness and Feasibility	20 %

[a] This criterion is separated from "Management Significance" to emphasize those Vital Signs and resources that are required to be monitored by legal or policy mandates.

"Knowledge of park-specific management brought to the I&M network by Technical Committee members was crucial to the process of selecting and prioritizing Vital Signs."

input from subject area experts and network park staff. Goals of the three-day workshop held in Honolulu, Hawaii were to: (1) make suggestions for prioritization for the proposed list of Vital Signs; (2) identify existing sampling methods and needs for development of new methods; and (3) recommend partnerships for Vital Signs monitoring. A report detailing the outcome of the workshop, the resulting list of 115 Vital Signs (each Vital Sign representing an individual monitoring protocol), and a list of participants is in appendix O.

Vital Signs Selection

PACN staff met with Technical Committee members in November 2004 to prioritize the PACN Vital Signs. Knowledge of park-specific management brought to the I&M network by TC members was crucial to this process. Initially, a reduced list of 47 Vital Signs was created based on the results of the ranking exercise. Several Vital Signs were added to the list because they involved well-established monitoring programs by other agencies (e.g., monitoring of air quality and volcanic activity) and because these subjects had been identified as important ecosystem drivers in our conceptual models.

The goal of the workshop was to prioritize 12 Vital Signs for initial implementation, with an additional short list of 5 Vital Signs to be "wait-listed" for future implementation. Potential Vital Signs were grouped by subject area into three sets: (1) terrestrial biology; (2) aquatic biology, hydrology, and water quality; and (3) human use, geology, and air quality. Technical Committee members broke into groups by area of expertise to discuss these potential Vital Signs. Group members were also tasked with lumping the 47 prioritized Vital Signs based on thematic similarity and network monitoring objectives (table 1.10) into a more compact list affording greater flexibility when preparing monitoring protocols. Based on further discussions with the whole group, a list of 19 lumped Vital Signs were selected for implementation during this final TC meeting. This list included several Vital Signs monitored by other agencies.

During preparation of protocol development summaries (PDS) for the Vital Signs, it became apparent that it would be more practical to split some Vital Signs. For example, the Vital Sign "Focal bird species" was split into two: Landbirds and Seabirds (figure 3.2). Therefore, the final number of Vital Signs under development was increased to 21.

Following this process, the PACN Board of Directors preliminarily approved the Technical Committee's recommendations while recognizing the following points:

- Some minor name changes to Vital Signs may occur in the future.
- As protocol development occurs during Phase III, some major changes may be requested for BOD approval, including addition or deletion of Vital Signs.
- A strong possibility exists that the current list is beyond the program's resource capabilities, and further partnerships will be sought.

In November 2005, the BOD requested that the network reduce the number of Vital Signs from 21 to a list of 12 or 14. Consequently, network and regional staff proposed a phased implementation, with 14 Vital Signs in phase 1 and 4 Vital Signs in phase 2. Phase 2 implementation will not occur until all phase 1 Vital Signs are successfully implemented. Several Vital Signs were combined with a reduction in the scope of the protocol (e.g., frugivorous bats and insectivorous bats). The BOD approved the reduced list on November 30, 2005. The final prioritization of Vital Signs for network funding was based on the following factors: (1) information gained from the monitoring program would aid in making management decisions; (2) information gained from the monitoring program would help explain changes in ecosystem structure, function, and composition; and (3) opportunities exist to augment network funds through partnerships and agreements. Figure 3.3 illustrates the complete steps taken by the Pacific Island Network during the process of Vital Signs development, selection, and prioritization.

The list of 31 Vital Signs for the Pacific Island Network is presented in table 3.2, along with the parks in which each Vital Sign will likely be monitored. The table includes the 14 PACN phase 1 Vital Signs and 4 phase 2 Vital Signs for which the PACN is developing protocols. In addition, table 3.2 includes 13 Vital Signs that are being monitored by an individual park or another agency.

Figure 3.2. The Hawaiian petrel (*Pterodroma sandwichensis*) (left) will be included under the Seabirds Vital Sign, while the Hawaii amakihi (*Hemignathus virens*) will be part of the Landbirds Vital Sign (photo by © Jack Jeffrey).

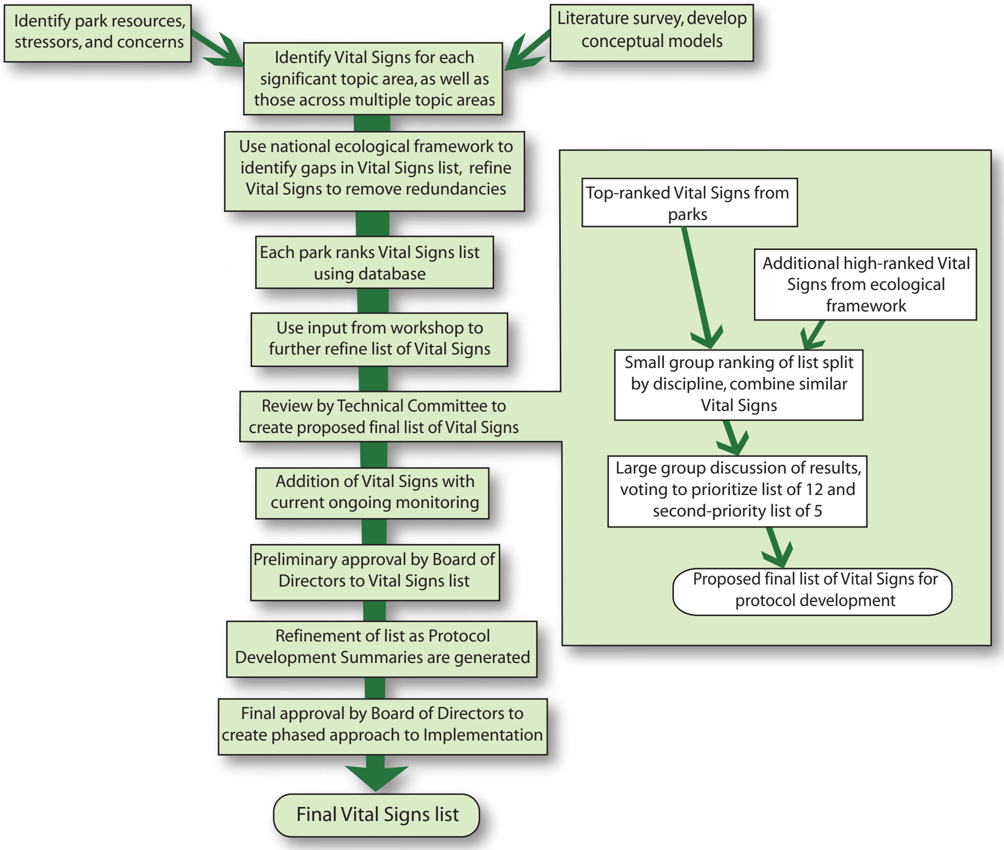


Figure 3.3. Steps followed in Vital Signs selection.

Table 3.2. PACN list of Vital Signs. Shaded are Vital Signs for which the network is developing monitoring protocols. Other Vital Signs are monitored by individual parks or state and federal agencies.

Level 1	Level 2	Vital Sign	AMME	WAPA	NPSA	USAR	KALA	HALE	ALKA	PUHE	KAHO	PUHO	HAVO
Air & Climate	Air Quality	Visibility & particulate matter	–	–	–	–	–	•	–	–	–	–	•
		Atmospheric gases	–	–	•	–	–	–	–	–	–	–	•
	Weather & Climate	Climate	+	+	+	+	+	+	+	+	+	+	+
Geology & Soils	Subsurface Geologic Processes	Volcanic ground deformation/lava flows	*	–	–	–	–	•	–	–	–	–	•
		Seismic activity	•	•	•	•	•	•	•	•	•	•	•
	Soil Quality	Erosion & deposition	–	x	x	x	x	x	–	x	–	–	–
Water	Hydrology	Stream flow	*	•	•	•	•	•	•	*	–	*	–
		Sea level	•	•	•	•	*	•	*	•	*	•	*
		Groundwater dynamics	+	•	•	*	+	*	+	*	+	*	*
	Water Quality	Water quality	+	+	+	+	+	+	+	+	+	+	+
		Toxics	•	•	•	•	*	*	*	*	•	*	*
		Microorganisms	•	•	•	•	*	*	•	•	*	*	*

+ = Protocol development & implementation in phase 1. Funding from VS or water quality monitoring programs.
x = Protocol development & implementation in phase 2. Funding from VS or water quality monitoring programs.
* = Vital Sign which cannot currently be implemented; future monitoring possible.
• = Monitored by a network park, other NPS program, or other federal or state agency.
– = VS does not apply to park, or no foreseeable plans to conduct monitoring

The Relationship of PACN Vital Signs to Cultural Resources

Each of the selected Vital Signs have shared cultural and natural significance. This is reflected in the addition of the PACN I&M program's sixth monitoring program goal: to "*provide data to better understand, protect, and manage important resources that share cultural and natural value*." The PACN I&M program recognizes that the cultural values and practices of people may be interwoven with the biologic, climatic, geologic, hydrologic, and landscape resources we have chosen as Vital Signs. In some cases, they are one in the same (e.g., Marine fish). In other cases, the Vital Sign to be monitored may impact cultural sites (e.g., Invasive species, Climate) or habitats of culturally important plants and animals (e.g., Water quality, Focal terrestrial plant communities). Discussions of the significance of PACN Vital Signs would, therefore, be incomplete without an understanding and appreciation of the cultural values placed on these natural resources.

"The selected Vital Signs have shared cultural and natural significance."

In all Pacific island cultures, natural resources are collected for food, medicines, and tools. Many individuals of these Pacific island cultures continue to invoke their gathering rights in PACN parks today. For example, various native plants, freshwater stream animals (gobies, shrimp, eels, snails), and marine fishes and seaweeds are collected for food (figure 3.4), or medicinal uses. Historically and currently, many of these natural resources are also of utilitarian value and used in daily life. In PACN national parks, cultural practitioners are allowed to practice their traditions and religions through the collection of resources, visiting sites of religious value, and other activities. It is therefore important to determine if cultural practices impact

Table 3.2. **PACN list of Vital Signs. Shaded are Vital Signs for which the network is developing monitoring protocols. Other Vital Signs are monitored by individual parks or state and federal agencies—*Continued*.**

Level 1	Level 2	Vital Sign	AMME	WAPA	NPSA	USAR	KALA	HALE	ALKA	PUHE	KAHO	PUHO	HAVO
Biological Integrity	Invasive Species	Status and trends of established invasive plant species	+	+	+	*	+	+	+	+	+	+	+
		Early detection of invasive plants	+	+	+	–	+	+	+	+	+	+	+
		Early detection of invasive invertebrates	*	*	x	–	x	x	*	*	*	*	*
	Focal species or Communities (including at-risk species)	Benthic marine community	*	+	+	*	+	*	*	*	+	*	*
		Marine fish	*	+	+	*	+	*	*	*	+	*	*
		Sea turtles	*	*	*	*	*	*	•	*	•	•	•
		Hawaiian monk seal	–	–	–	•	•	•	•	•	•	•	•
		Freshwater animal communities	*	+	+	–	+	+	+	+	+	+	+
		Cave community	–	x	x	–	*	x	*	–	x	x	x
		Focal terrestrial plant communities	+	+	+	–	+	+	*	*	+	*	+
		Terrestrial invertebrate communities	x	x	x	–	x	x	*	x	x	x	x
		Nene distribution/abundance	–	–	–	–	–	•	*	*	*	*	•
		Waterbird distribution/abundance	*	•	*	*	*	*	*		•	*	*
		Landbirds	+	–	+	–	+	+	–	–	–	–	+
		Seabirds	*	*	+	*	+	+	*	*	+	+	+
		Bats	–	+	+	–	+	+	+	+	+	+	+
Human Use	Consumptive Use	Fish harvest	*	+	+	*	+	*	*	*	+	*	*
	Visitor & Recreation Use	Visitation	*	•	•	•	•	•	*	•	•	•	•
Landscapes	Landscape Dynamics	Landscape dynamics	+	+	+	+	+	+	+	+	+	+	+

+ = Protocol development & implementation in phase 1. Funding from VS or water quality monitoring programs.
x = Protocol development & implementation in phase 2. Funding from VS or water quality monitoring programs.
* = Vital Sign which cannot currently be implemented; future monitoring possible.
• = Monitored by a network park, other NPS program, or other federal or state agency.
– = VS does not apply to park, or no foreseeable plans to conduct monitoring

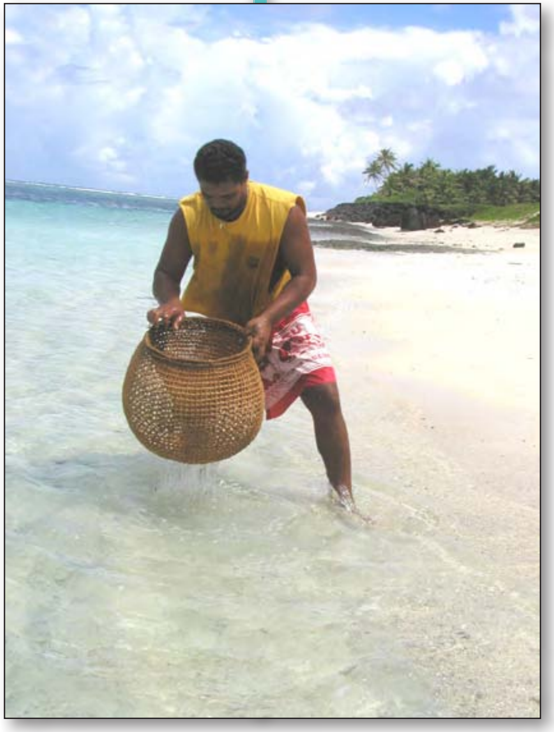
the natural resources selected as Vital Signs and, conversely, how the resources impact and are valued in cultural practices.

"The significance of resources to indigenous and other cultural groups extends beyond tangible examples…"

The significance of resources to indigenous and other cultural groups extends beyond tangible examples (e.g., archeological sites, artifacts, plants and animals). Natural resources can be inseparable from the spiritual and religious values that give the resources and traditional practices their context (see table 3.3 for examples). Some of the resources, which carry food, spiritual/religious, medicinal, biological, and utilitarian value to the cultural groups represented in PACN parks are summarized in table 3.3. Biological value in the table refers to items of both ecological and cultural significance. Appendix M provides expanded examples of these cultural resources, values, and associated threats.

In PACN parks, strong bonds often exist between local individuals, families, communities, and these resources. Specific archeological sites and artifacts are not only held in trust for the people of the United States, but may be familial artifacts, history, or components of a community's culture. Cultural sensitivity appropriate to these stewardship concerns will be reflected in monitoring activities and section 106 (historic preservation) compliance. Culturally sensitive activities may include but are not limited to: (a) collaborating with NPS cultural resources (CR) staff, traditionally associated families, and cultural practitioners when planning monitoring projects; (b) removal of markers or equipment used in temporary monitoring projects; (c) taking care not to introduce invasive species that might degrade the landscape; (d) consulting NPS CR staff if suspected artifacts are found; and (e) returning sites to their original state after monitoring.

Figure 3.4. Fishing with traditional enu or fishtrap, (i.e., Fish harvest Vital Sign) at National Park of American Samoa.



The Relationship of Vital Signs to PACN Conceptual Models

The Pacific Island Network's Vital Signs are designed to improve our understanding of changes to and management of the composition, structure, and function of the network's natural resources. The list of Vital Signs includes significant biotic and abiotic natural resources, stressors or agents of change to those resources, and important ecological processes as illustrated in the expanded interactive control model below (figure 3.5). Selected Vital Signs are all linked to one or more of our conceptual models in appendix H. Additionally, focused conceptual models will be created for each Vital Sign as monitoring protocols are developed. General conceptual models for each Vital Sign are included in appendix H.

The list of Vital Signs was created in an effort to encompass the dominant PACN ecosystem types (table 3.4). Thus, many of the Vital Signs span two or more ecosystem types. Therefore, we included all objectives for the Vital Signs framework (table 1.10) for the range of ecosystems in our network. The 'motivations for monitoring' identified in table 3.4 were identified in the process of conceptual model development, and were considered during the ranking and prioritization process.

Integration of Vital Sign Monitoring With Other Park Monitoring Programs

The PACN program must integrate with other ongoing park monitoring programs to enhance available information that facilitates informed management decisions in PACN parks. To successfully synthesize and report on the state of the parks' ecosystems, in addition to I&M program activities, the network will work with the parks to update and revise existing protocols, as well as provide direct assistance with data management. The network will collaborate with park staff to develop mutually accepted minimum requirements for existing and future monitoring protocols in the parks. This process will allow for shared involvement in the development of protocols for monitoring (new or ongoing) that are funded by parks and should lead to consistency among projects. While modifications to protocols necessitated by guidelines will vary, the network will provide

Table 3.3. Cultural and natural resource values of PACN Vital Signs.

Climate
• Pacific islanders revered aspects of nature, including weather and climate, in song and dance. Numerous words for wind, rain, and cloud forms reflect the importance of weather and climate to early Polynesians and Micronesians. • Global climatic changes will likely raise sea levels and inundate low-lying, culturally important sites, regions, and resources.
Erosion & deposition
• Erosion and deposition are a threat to cultural sites, natural communities of cultural significance (coral reefs, anchialine pools), and culturally significant species (wetlands, fishponds).
Groundwater dynamics & Water quality
• Fresh water is a vital resource for all island cultures for drinking, cooking, bathing, and agriculture. Its significance is reflected in names of various forms or locations of water (Valentine n.d.). In origination stories and dances, names were given to places that served as sources of water. • Water sources influenced settlement patterns; many natural habitats were modified.
Status and trends of established invasive plant species
• Established invasive plants threaten native ecosystems of cultural value and degrade archeological sites.
Early detection of invasive plants & invertebrates
• Incipient populations of invasive plants and invertebrates can negatively impact culturally important plant or animal populations, change culturally significant viewscapes, and disturb archeological sites.
Benthic marine community, Marine fish, & Fish harvest
• Pacific island cultures are highly dependent on marine resources for food, tools, weaponry, medication and ornamentation (Bishop Museum 2003). Fishing is still an important cultural practice for subsistence, income, and sport. Fish parts (e.g., bones, teeth) are used commercially in contemporary reproductions of Pacific island weapons. • Many marine animals (e.g., turtles, sharks) are prominent figures in Hawaiian, Samoan, Chamorro, and Carolinian legends. Some represent family gods or guardians (Brandt 1999, Kamakau 1987).
Freshwater animal communities & Terrestrial invertebrate communities
• Stream and anchialine pool animals were important food sources. Shrimp, fish, nerites, and/or eels from freshwater streams in Hawaii, the Marianas, and Samoa are still collected by indigenous groups for food. Wild-collected and raised opae ula (red shrimp) are presently marketed as a novelty and as fish food in Hawaii. • Native aquatic invertebrates were family gods (Juvik and Juvik 1998) and were used in indigenous rituals (Howarth et al. 1998).
Cave community
• Caves were culturally important for water collection, shelter, and as burial sites throughout the PACN. • Access to freshwater seeps in caves influenced settlement patterns. • Caves remain important for their cultural significance and for their endemic invertebrate communities.

Table 3.3. **Cultural and natural resource values of PACN Vital Signs—*Continued*.**

Focal terrestrial plant communities

- Collections of plant material for medicines, food, fish poison, dyes, basket or helmet plaiting, cordage, weaponry, musical instruments, utensils, house construction, clothing, digging tools, & decoration were an integral part of Pacific island cultures. Cultural practitioners continue to collect plant material today.
- Specific sites, ecosystems, and regions were places of reverence, requiring specific protocols to enter (e.g., prayers, request for permission). Chamorro, Carolinian, Samoan, and Hawaiian cultures continue these practices.

Landbirds

- Landbirds were important food sources for some indigenous peoples (e.g., nene).
- Forest bird feathers were once collected for clothing, adornments, and ceremonies. Due to extinctions or rarity of native forest birds, collection is now prohibited; colored duck or goose feathers are used instead.
- Certain bird species are associated with deities (e.g., elepaio).
- In PACN parks, native birds play an important role as pollinators of culturally significant plants.
- Recent introductions of predatory alien animals and invasive plants have significantly reduced native forest bird populations. Many species are now rare, species of concern, threatened, or endangered.

Seabirds

- Some seabird species are collected for food, while bones were used for tools by Hawaiians, Samoans, Chamorro, and Carolinian (Moniz 1997). In Hawaii, seabird feathers were used in ceremonial standards (Rose et al. 1993).
- Pacific islanders use seabirds to locate fish and to navigate back to land while at sea (Irwin 1992).
- Seabirds are prominent icons in Pacific island mythology and described in ancient chants and dances (Kamakau 1987). Some modern families identify themselves with particular seabird species as guardians.

Bats

- Frugivorous bats were culturally significant for use as food (Sheeline 1991). Collection of fruit bats is now prohibited, but they are undoubtedly harvested illegally for food or poached for export, although on a smaller scale than in the 1980s (Craig et al. 1994, Sheeline 1991).
- In Samoa, fruit bats are prominent figures in legends (Sinavaiana and Enright 1992), tattoos, and lava lava designs. In Guam, fruit bats are valued as an important Chamorro cultural symbol (Sheeline 1991).
- Hawaiian hoary bats were given the name opeapea, which means “half-leaf”, said of a taro plant remaining on the stalk after the top half has been removed for cooking (Pukui and Elbert 1986). Opeapea are the only extant native terrestrial mammal in Hawaii (Stone and Pratt 1994).
- Insectivorous bats feed on agricultural pests and are commercially, agriculturally, and ecologically valuable.

Landscape dynamics

- Cultural land uses have influenced how land is used today (e.g., agriculture in and around PACN parks). Land and marine areas were not divided into parcels, but managed on an integrated basis, analogous to watersheds (called ahupuaa in Hawaii).

technical resources when possible to facilitate development of other park protocols.

In addition to updating and revising park-based protocols, the network will work with park staff to adapt their databases and information management procedures to existing NPS templates and standards, adhering to the goal of increasing the usefulness of collected data. For example, this process will involve building database models through user requirements and systems analysis for marine and water quality information management. The purpose of this exercise is to outline the information needs of both park and Vital Sign monitoring programs, before adapting the database model for park- or I&M program-specific needs.

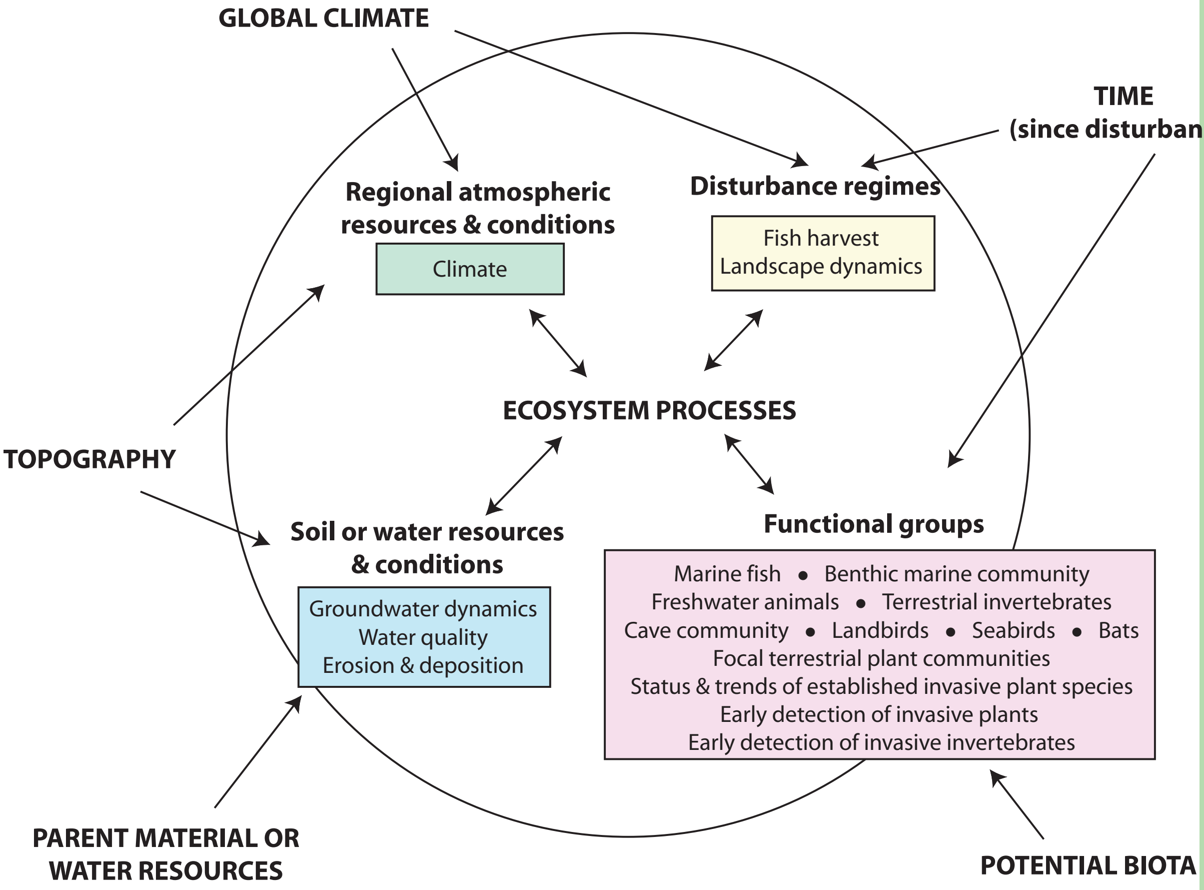


Figure 3.5. Modified interactive control model including PACN Vital Signs.

Table 3.4. Vital Sign monitoring across PACN ecosystem types.

PACN Vital Sign	PACN Ecosystem Type	Monitoring motivation
Climate	All ecosystem types	Climate is widely recognized as a major driver for terrestrial as well as marine ecosystems, affecting biotic as well as abiotic ecosystem attributes. Land cover and use in parks and surrounding lands also have cascading effects on a myriad of ecosystem processes and characteristics. Monitoring climate and landscape dynamics on various temporal and spatial scales is essential for the understanding of processes and changes in all ecosystem types.
Landscape dynamics		
Status and trends of established invasive plant species	Coastal to subalpine, including wet forest, mesic forests, dry forests, and grassland	The PACN encompasses many specialized habitats which include species highly adapted to their surroundings. A high level of interconnectedness exists among all the terrestrial ecosystems. Thus, PACN Vital Sign monitoring in terrestrial ecosystems includes species (native or alien) that require (or invade) specialized habitats, as well as species that exist in a broad range of habitats.
Early detection of invasive plants		
Early detection of invasive invertebrates		
Landbirds		
Bats*		
Focal terrestrial plant communities		
Terrestrial invertebrate communities		
Water quality	Streams, coastal, nearshore marine	As a result of the small size of PACN islands and porosity of the substrate, all types of aquatic habitats in the PACN are highly interconnected. For instance, anchialine pools are influenced by both freshwater influx and tidal fluctuations. This connection to ocean and freshwater influences salinity levels and brings species into and out of the pools. Furthermore, the presence of amphidromous species emphasizes the importance of monitoring across ecosystem types. Integrated water quality monitoring facilitates understanding of ecosystem processes, particularly effects on populations which span several habitat types.
Freshwater animal communities		
Seabirds	Coastal, nearshore marine, subalpine	Coastal and nearshore marine ecosystems are interconnected. For example, seabirds rely on marine fish for food and rely on high elevation terrestrial sites (e.g., Hawaiian petrels nest at non-forested subalpine sites, Tahiti petrels nest in high elevation wet forest sites). Another example is coral reef destruction by deposition of sediments through coastal erosion. Likewise, declines in the groundwater level allow influx of seawater. Evaluation of ecosystem dynamics and changes in ecosystem processes are likely only successful if both stressors and focal species are monitored across these ecosystems.
Erosion and deposition	Coastal, nearshore marine	
Groundwater dynamics		

[*] Bats monitored in the PACN are tree-roosting. Thus, bats will not be monitored as part of the cave community.

Table 3.4. Vital Sign monitoring across PACN ecosystem types—*Continued*.

PACN Vital Sign	PACN Ecosystem Type	Monitoring motivation
Fish harvest	Nearshore marine	Consumptive use (harvest) and/or focal species and communities are not well described in this ecosystem for most PACN parks. However, studies outside of PACN parks indicate that nearshore marine systems are complex, fragile, and threatened by a number of stressors. Long term monitoring of stressors and focal species communities in nearshore marine ecosystems is a high priority for the PACN.
Benthic marine community		
Marine fish		
Cave community*	Subterranean	This specialized habitat may be the least known in the PACN parks. However, preliminary studies indicate that this ecosystem may include un-described species. Caves are at risk due to stressors such as visitor use, introduced species, and climate change.

[*] Bats monitored in the PACN are tree-roosting. Thus, bats will not be monitored as part of the cave community.

Summary

The Pacific Island Network initially identified 115 potential Vital Signs for monitoring. An iterative selection process yielded 13 Vital Signs that will be monitored by individual parks or cooperators and 18 Vital Signs for which the PACN is pursuing development of protocols. Of these 18, 14 will be implemented in the first phase of monitoring. The remaining four, as well as expansions of three phase 1 Vital Signs, will be implemented in phase 2 if funding allows.

The network's 18 Vital Signs were chosen to: (a) augment current monitoring in the parks, (b) focus on issues with high management relevance, and (c) ensure monitoring of natural resources, stressors, and ecological processes in the dominant ecosystem types found in the PACN.

Chapter 4. Sampling Design

Each Vital Sign protocol of the Inventory and Monitoring program will have a clear, statistically defensible, and detailed sampling design. Four key characteristics of a sampling design occur for monitoring: (a) the ability to make valid inferences beyond an area actually sampled (when applicable), (b) representativeness of a sample across space and time, (c) the minimum quality of data (i.e., precision and bias) necessary to achieve objectives, and (d) feasibility such as logistics and cost-effectiveness. Proper monitoring of natural resources is often quite expensive and time-consuming. Therefore, sampling designs should provide reliable information in a cost-efficient manner.

Monitoring in the PACN is particularly challenging because our parks are geographically dispersed on islands separated by an area of Pacific Ocean larger than the contiguous U.S. In addition, the PACN includes working with Territorial or Commonwealth governments and cultures, which may operate differently than in the contiguous U.S. Therefore, time, logistics, costs, and access can be challenging when designing sampling approaches. For example, in many locations we are limited to airplane and/or boat transport, which can be expensive and time consuming, so co-location and co-visitation are highly desirable. Monitoring activities can be disrupted by climate (e.g., storms, typhoons) or socio-cultural practices which require planning flexibility in order to conduct monitoring in the PACN national parks. These logistical obstacles require some adaptability when designing sampling schemes.

In the initial section of this chapter, we discuss sampling concepts and definitions, as well as basic sampling design considerations. These provide a framework for statistical concepts and design issues that are used throughout the chapter. In the next section, we present an overview of sampling approaches which introduces and explains sampling plans for each Vital Sign. Subsequent sections are grouped into the four types of sampling proposed: (a) linear-based sampling, (b) list-based, (c) index-based, and (d) a census. In these sections, the overall statistical design is described for each Vital Sign that will be monitored in the earlier phases of the long-term monitoring program. Beyond this chapter, further details of the sampling designs will be included in Appendix L: Protocol Development Summaries. Complete details will be provided in the individual protocols, which will include detailed maps of sample locations.

Sampling Concepts and Definitions

In this section we describe background concepts for sampling designs and define sample unit, panels, rotation design, and membership design, among other terms. Our working definition of *monitoring* is the collection and analysis of repeated observations (figure 4.1), or measurements over a long period of time to document status and trends in ecological parameters. Monitoring is often designed to provide unbiased statistical estimates of status and trends in large areas (e.g., a national park) or across study units (e.g., ohia forest in PACN parks). Long-term monitoring programs collect unbiased and scientifically defensible data to address specific hypotheses, and/or monitoring objectives. Through monitoring activities, long-term correlations may be drawn between ecological changes, natural ecosystem perturbations, and anthropogenic activities. This information can provide compelling information for managers, and enhance our overall understanding of ecosystems and ecosystem changes in PACN parks.

The monitoring plans proposed for the PACN Vital Sign protocols typically rely on concepts in finite population sampling. For 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*. In general, sample units are the smallest entities upon which measurements are taken. The total collection of sample units is called the *population*, and the defined area from which sample units is drawn is the *sampling frame*. In some protocols, sample units will be discrete entities

"Proper monitoring of natural resources is often quite expensive and time-consuming. Therefore, sampling designs should provide reliable information in a cost-efficient manner."

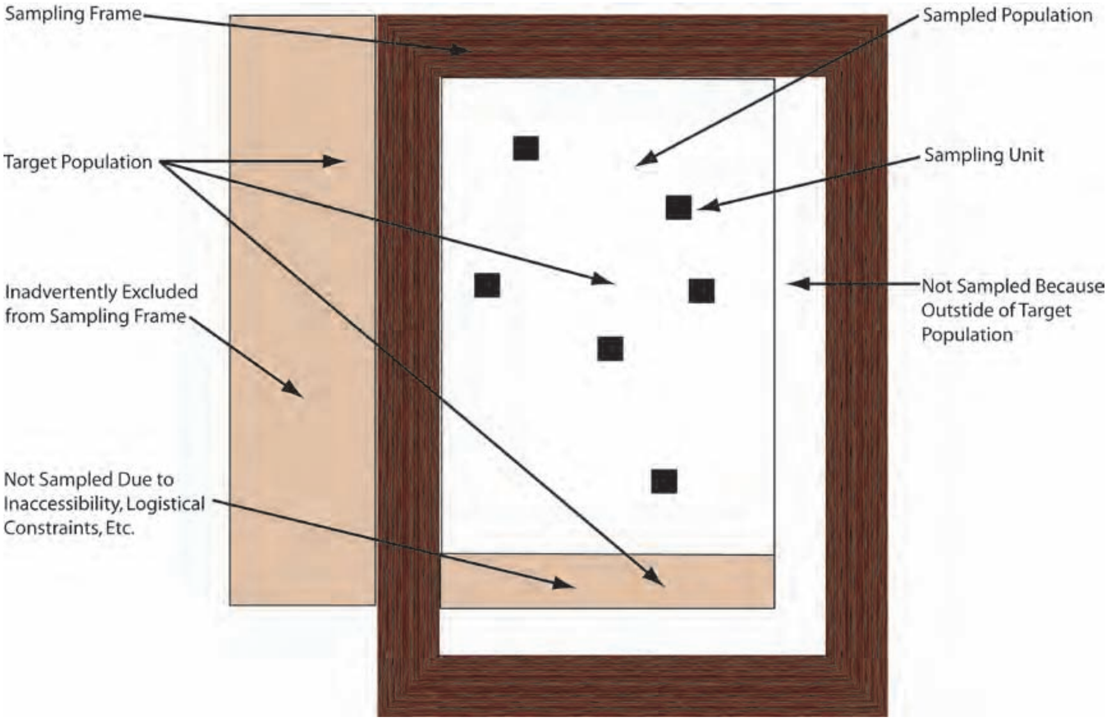
Figure 4.1. Field sampling lizards at Puukohola Heiau National Historic Site (left) and field sampling in Kalaupapa National Historical Park (right).

such as stream segments, ponds, or lakes. In other protocols, sample units will be standardized areas such as transects, plots, or pixels in an image. The subset of units from the population for which we collect responses is the *sample* (figure 4.2). *Response variables* (or *responses*) are defined as measurements recorded on the sample units.

Sampling Design Considerations

Spatial Allocation of Sampling and Sample Selection—If a sample is chosen using random selection, the sample is a *probability* sample, free of bias and hence representative of the population. Whenever possible, PACN has opted for a probability sample to monitor Vital Signs. A **simple random sample** is a method in which n units are selected from a population of size N via a random process, such that every sample unit has the same probability of being

Figure 4.2 Diagrammatic depiction of sampling concepts.



included in the sample. A **systematic random sample** is a sampling method in which one subject is typically selected at random and subsequent subjects are selected according to a systematic pattern. A common form of systematic sampling is randomly selecting one unit from the first *k* units in the sampling frame and every k^{th} unit thereafter (Mendenhall et al. 1971). **Stratified sampling** is used when relatively homogeneous sub-populations (*strata*) can be identified. Stratified sampling may be used to reduce cost per observation, estimate population parameters for each sub-population, and increase precision of estimates across strata. Stratification within sampling is analogous to blocking in experimental design. The precision of stratified sampling is improved by eliminating between-strata variance.

The **Generalized Random Tessellation Stratified (GRTS)** design is a method that produces a spatially well-balanced stratified random sample (Stevens and Olsen 2004). Simple random samples may yield 'clumps' of sample sites and relatively large, unsampled areas, while systematic samples do not allow for random selection of sample sites once the first site has been identified (Stevens and Olsen 2004). The GRTS methodology is based on creating a function that maps two-dimensional space onto one-dimensional space, and uses a restricted randomization algorithm to produce a sample that is well balanced, yet randomly selected with known probabilities for each sample (Stevens and Olsen 2004). Below in figure 4.3, we illustrate the different types of spatial allocation units.

The PACN will follow four sampling schemes to collect Vital Sign monitoring data: (1) **Linear-based sampling** which delineates sampling units along a linear segment and draws a probability sample; (2) **List-based sampling** which uses a list of sample units and selects a probability sample, or attempts to census all units; (3) **Index-sites** which are areas or points that are hand-picked to yield adequate data for a specific Vital Sign; and (4) **Census** which is used when it is possible to collect data on the full spatial extent of an area (e.g., national park).

Temporal Allocation of Samples—A monitoring program must face the trade-off between precision in estimating trends (i.e., revisit design, minimizing temporal and spatial variance), and precision in estimating current status (variance minimized by visiting new sites). Most sampling designs in the PACN will address this trade-off by assigning field sampling efforts to a combination of fixed and randomly chosen sample units over time.

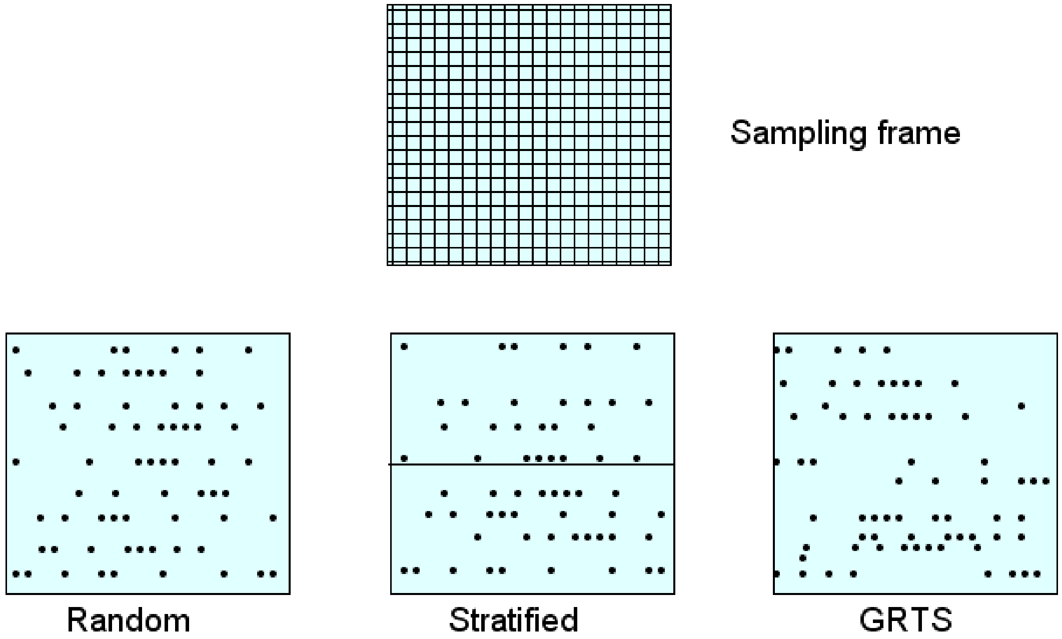


Figure 4.3 Graphical representation of 3 spatial sampling schemes used in the PACN monitoring program.

"While not providing cause-and-effect linkages, identifying potential correlations across Vital Signs will permit broader synthesis and stronger linkages to management decisions."

The temporal sampling schedule which specifies the pattern of visits through time is the **revisit design** (McDonald 2003). The notation commonly used for a revisit design is a pair of digits. The first digit is the number of consecutive occasions that a panel (sampling area) is sampled, and the second is the number of consecutive occasions that a panel is not sampled. For example, if a single panel is visited every sampling occasion, its revisit design can be expressed as [1,0]. If a panel is to be sampled once, and then never revisited, the notation is [1,n]. The notation [1-0, 1-4] indicates a dual frame revisit design and signifies that units in panel 1 are visited every occasion, and units in panel 2 are visited once every 5 years (table 4.1). In table 4.1, the revisit design 1, notated [1-1, 1-1] indicates that units in panel 1 will be visited during occasions 1, 3, 5, . . ., 9, and units in panel 2 be visited during occasions 2, 4, 6, . . ., 10. Revisit design 2 notated [1-0,1-2] specifies that units in panel 1 be visited every occasion, while those in panel 2 are visited every third occasion. Revisit designs that incorporate dual frames are particularly effective in monitoring the resources where sample size presents a challenge to sampling design, such as landbirds, seabirds, bats, plant species, and freshwater animals in the PACN.

Another method of sampling rare resources is to use *adaptive sampling*, which selects sample sites or units dependent on observed values of the variable of interest. The primary purpose of adaptive sampling is to utilize population characteristics to obtain more precise estimates of population abundance or densities. The Focal terrestrial plant communities' protocol will employ an adaptive sampling design to monitor selected plant species in PACN parks. Because many populations of rare and endangered plants have aggregation tendencies, due to patterns of dispersion or environmental patchiness, the locations of new aggregations cannot be predicted. Once original locations of focal plants are identified, nearby sites can be investigated to increase the potential for capturing data on other individuals in the population.

Table 4.1. Two sample revisit designs.

Sampling occasion	Revisit design 1		Revisit design 2	
	Panel 1	Panel 2	Panel 1	Panel 2
1	X		X	X
2		X	X	
3	X		X	
4		X	X	X
5	X		X	
6		X	X	
7	X		X	X
8		X	X	
9	X		X	
10		X	X	X

Co-location and Co-visitation—Another method of sampling sites efficiently is to co-locate and co-visit across Vital Signs. *Co-location* refers to sampling the same physical units for multiple Vital Signs. *Co-visitation* refers to sampling the same units for multiple Vital Signs on the same occasion, thus reducing travel and personnel costs. In addition, co-location and co-visitation increase the potential for documenting potential correlation between Vital Signs. While not providing cause-and-effect linkages, identifying potential correlations across Vital Signs will permit broader synthesis and stronger linkages to management decisions. In an effort to reduce time, personnel, and travel costs between different park units, we plan to coordinate membership, revisit designs, sampling co-location, and co-visitation of different monitoring protocols as much as possible (described below). Hence, co-location and co-visitation should maximize spatial balance and optimize sampling logistics when applied across all Vital Signs in the respective 11 PACN parks, while keeping within the limits of resources available for field work. Table 4.2 summarizes potential areas of co-location and co-visitation among the PACN monitoring protocols.

Table 4.2. Summary of potential co-location and co-visitation of monitoring for PACN Vital Signs.

Vital Sign	Other protocol(s) for co-location	Other protocol(s) for co-visitation
Phase 1 implementation		
Climate	N/A	N/A
Groundwater dynamics	Water quality	Water quality
Water quality	Benthic marine, Marine fish, Freshwater animals, Groundwater dynamics, Erosion & deposition	Freshwater animals, Benthic marine, Marine Fish, Groundwater dynamics, Erosion & deposition
Status and trends of established invasive plant communities	Plant communities, Terrestrial invertebrates, Landbirds	Plant communities, Terrestrial invertebrates, Erosion and deposition
Early detection of invasive plants	Landscape dynamics (field ground-truthing)	Status & trends
Benthic marine community	Marine fish, Water quality, Erosion & deposition	Marine fish, Water quality, Erosion & deposition
Marine fish	Benthic marine, Water quality	Benthic marine, Water quality
Fish harvest	None	None
Freshwater animal communities	Water quality, Erosion & deposition	Water quality, Erosion and deposition
Focal terrestrial plant communities	Status & trends, Landbirds, Terrestrial invertebrates	Status & trends, Erosion and deposition, Terrestrial invertebrates
Landbirds	Plant communities	Frugivorous bats, Seabirds
Seabirds	Bats	Caves, Bats
Bats	Seabirds	Seabirds, Landbirds
Landscape dynamics	Early detection	Status and trends, Early detection
Phase 2 Implementation		
Erosion and deposition	Plant communities, Benthic marine, Marine fish, Water quality, Freshwater animals	Plant communities, Benthic marine, Marine fish, Water quality, Freshwater animals
Cave community	None	Seabirds
Terrestrial invertebrate communities	Focal Plants	Focal Plants, Status and Trends, Erosion & Deposition
Early detection of invasive invertebrates	TBD	TBD

Overview of Sampling Approaches

Table 4.3 summarizes the sampling design, spatial and temporal sampling allocation, as well as response variables (e.g., biological or physical processes).

The PACN Vital Signs are categorized below into the four dominant sampling designs earlier discussed. The Vital Signs sampling section is then separated into Aquatic, Marine, or Terrestrial ecosystems. The PACN recognizes the importance of integrating Vital Signs, and below describe which Vital Signs monitoring will be co-located and/or co-visited.

Linear-Based Sampling Design – Marine Ecosystems—Three marine/aquatic protocols will be collocated and co-visited: Benthic marine community, Marine fish, and Water quality. Monitoring for Benthic marine and Marine fish Vital Signs will be conducted using transect-based sampling.

Benthic Marine Community—This protocol will initially be implemented at WAPA, NPSA, KALA, and KAHO. The sampling frame for this protocol is hard-bottom marine areas in the 10 to 20 meter depth range (figure 4.4). Several 25 meter permanent transects will be established in each park to monitor five parameters: (a) cover, (b) coral disease, and (c) benthic rugosity, (d) coral recruitment, and (e) growth. These will be monitored at discrete sites along transects. The sampling frame will not be stratified. For the parameters of cover, disease, rugosity, and growth, the transects will be sampled in a split panel design with 0.5 of the transects fixed and 0.5 non-revisit random (i.e., 15 transects in each park will be fixed sites and revisited; the other 15 will be new random locations each sampling event). Figure 4.5 illustrates the non-revisit random points at KALA. Recruitment will be monitored at fixed sites along the permanent transects. This protocol will be co-located and co-visited with the Marine fish protocol, and partially co-located and co-visited with Water quality monitoring.

Figure 4.4. Marine ecologist collecting benthic marine monitoring data at Kaloko-Honokohau National Historical Park.

Marine Fish— The sampling frame for the Marine fish protocol is hard-bottom marine areas in the 10 to 20 meter depth range, as with the Benthic marine community protocol. Marine fish monitoring will initially be implemented at WAPA, NPSA, KALA, and KAHO. The two variables monitored for this protocol are (a) fish count, and (b) fish length. Three sampling methods will be used: belt transects, line transects, and circular plots. The sampling frame will be stratified by hard-bottom type.

Transects will be sampled in a split-panel design, stratified by habitat type, with 0.5 of the transects fixed and 0.5 rotational (i.e., 15 transects in each park will be fixed sites and revisited; the other 15 will be new random locations each sampling event). This protocol will be co-located and co-visited with the benthic marine protocol, and partially co-located and co-visited with water quality monitoring. Further details on monitoring design and co-visitation may be found in table 4.5

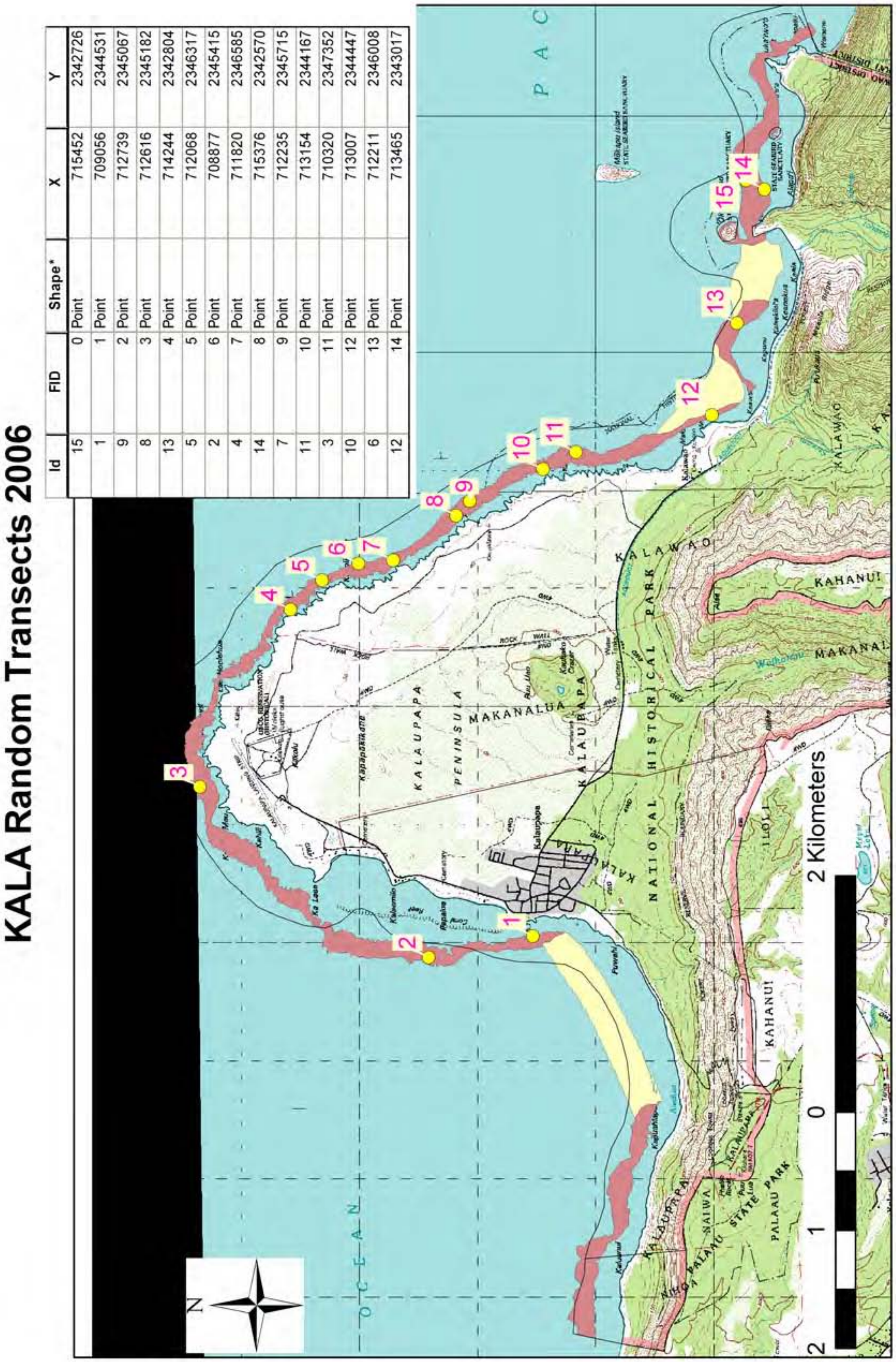
Linear-Based Sampling Design – Terrestrial Ecosystems—Three terrestrial and transect-based Vital Signs will be co-located and partially co-visited in PACN national parks: Focal terrestrial plant communities, Status and trends of established invasive plants, and Terrestrial invertebrate communities. These three Vital Signs will use a linear-based approach, and sample according to a GRTS spatial allocation. Temporal allocation may differ for Terrestrial invertebrates. Integration of Vital Signs will occur with Landbirds co-locating with Focal terrestrial plant communities (but not co-visiting) and co-visiting with Bats (frugivorous, NPSA) and Seabirds (Hawaiian petrels).

Table 4.3. Sampling schemes, sample units, spatial and temporal allocations, and response variables for PACN Vital Signs.

Protocol	Sampling Scheme	Spatial Allocation	Temporal Interval	Response Variables
Focal terrestrial plant communities	linear + list	panel	[1-0, 2-4]	spp abundance/unit
Status and trends of established invasive plants	linear +list	GRTS	5 year intervals; more frequent for urgent invasions	proportion of transect with occurrence, abundance per site
Terrestrial invertebrate communities	linear + index	judgment + stratified random	TBD	organisms/station
Early detection of invasive plants	list+ index + linear	judgment + stratified random	2-3 years revisit	# hits/site
Early detection of invasive invertebrates	list+ index	judgment	TBD	organisms/station
Landscape dynamics	census	census	5-10 yrs	spectral signature; road density, population change
Cave community	index	judgment	TBD	species observed and indices
Climate	list	existing + judgment	continuous	weather data
Landbirds	linear + index	panel	[1-0, 2-4]	# birds/transect
Seabirds:			TBD	#observations/unit
Low elevation	transect	stratified random		
Hawaiian petrel	list	stratified random		
Special Interest	index	judgment		
Bats:			TBD	#detections/time unit #observations/unit
Insectivorous	index	GRTS + judgment		
Frugivorous	index + list	judgment		

Table 4.3. Sampling schemes, sample units, spatial and temporal allocations, and response variables for PACN Vital Signs—*Continued*.

Protocol	Sampling Scheme	Spatial Allocation	Temporal Interval	Response Variables
Water quality	linear + list + index	GRTS + judgment	monthly & TBD	temperature, conductivity/ salinity, pH, dissolved oxygen, chlorophyll, turbidity, flow/ stage level, PAR, total nitrogen and total phosphate
Benthic marine community	linear	random	1 year	% coral cover, rugosity, growth, recruitment
Marine fish	linear	random	1 year	# spp fish/site
Freshwater animal communities	list + index	GRTS	3 years	# of organisms/quadrat # organisms/station
Erosion and deposition	index	judgment	TBD	amount sediment/trap
Groundwater dynamics	list	existing	3 years	water chemistry & level in wells
Fish harvest	index	stratified	5 years	catch/unit effort, fish length



Id	FID	Shape*	X	Y
15	0	Point	715452	2342726
1	1	Point	709056	2344531
9	2	Point	712739	2345067
8	3	Point	712616	2345182
13	4	Point	714244	2342804
5	5	Point	712068	2346317
2	6	Point	708877	2345415
4	7	Point	711820	2346585
14	8	Point	715376	2342570
7	9	Point	712235	2345715
11	10	Point	713154	2344167
3	11	Point	710320	2347352
10	12	Point	713007	2344447
6	13	Point	712211	2346008
12	14	Point	713465	2343017

Figure 4.5. Map of Benthic marine non-revisit random points at Kalaupapa National Historical Park (Molokai).

Focal Terrestrial Plant Communities— The sampling frame for this protocol may include eight focal plant communities within the parks: rain forest/cloud forest (HAVO, HALE, NPSA, and KALA), subalpine/alpine communities (HAVO, HALE), limestone forest (WAPA), diverse mesic and dry forest (HALE, HAVO), summit scrub (NPSA), pioneer communities on new lava flows and lava flow/kipuka mosaics (HAVO), montane bogs (HALE), and coastal communities (KAHO, HAVO, AMME). This list will be refined during protocol development in consultation with local park managers. The sampling frame will consist of units within these communities, with unit size adjusted by community size (ranging from small, discrete sites up to 10 ha areas). Three parameters will be monitored using this protocol: plant density, cover, and species composition. Within-year temporal variance and measurement error for each of these three parameters are low, yet spatial variance is high.

Sample units will use a rotating panel design. For the rotating panel design, the plots will be permanent and will be revisited every 5 years (table 4.4). Longer sampling intervals could occur for selected PACN parks, and will be finalized when the protocol is fully developed. For trees, the entire plot will be sampled, but for smaller plant forms, random subplots will be sampled. Specific plant species (i.e. rare, threatened and endangered) will also be monitored. Plant distribution, abundance, and stand structure will be monitored for specific plant species while collecting data on the grid system of transects. Adaptive sampling will be used due to the highly aggregated distribution of these plants.

This protocol will be co-located and co-visited with the Status and trends of established invasive plants protocol, and only co-located with the Landbirds protocol. Further details on monitoring design may be found in table 4.5.

Status and Trends of Established Invasive Plant Communities—Status and trends of invasives monitoring will partially occur within the sampling units established for the focal plant communities protocol. This Vital Sign will be monitored using detection sampling, also known as "hot spot" sampling, a strategy based on the target species natural history characteristics. Three discrete types of monitoring will occur with this protocol: status and trends, incipient species, and selected secies. Status and trends monitors invasive established species within Focal terrestrial plant communities: rain forest/cloud forest [HAVO, HALE, NPSA, and KALA], subalpine/alpine communities [HAVO, HALE], limestone forest [WAPA], diverse mesic and dry forest [HALE, HAVO], summit scrub [NPSA], pioneer communities on new lava flows and lava flow/kipuka mosaics [HAVO], montane bogs [HALE], coastal [KAHO, HAVO, AMME], and selected intensively managed communities. Incipient species monitors invasive species established next to park borders. Incipient species monitoring will employ a census design for monitoring along linear transects of roads, trails, and other developed areas within the park. Selected species monitoring will also be conducted along roads, trails, and developed areas, but a linear lattice transect and detection array will be used, rather than exhaustive sampling, or a census. This protocol will be co-located and co-visited with the Focal terrestrial

Table 4.4. Sampling frame for collecting data on focal plant communities and species within a PACN park.

Plot Set	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
A	X	X	X	X	X	X	X	X	X	X
B	X	X				X	X			
C		X	X				X	X		
D			X	X				X	X	
E				X	X				X	X
F	X				X	X				X

plant communities protocol, and the incipient detection component may be co-located with the Early detection of invasive plants protocol. Further details on monitoring design may be found in table 4.5.

Terrestrial Invertebrates (phase 2)—The Terrestrial invertebrate protocol will be monitored using a dual linear-and index-based approach. This protocol will initially be implemented at AMME, WAPA, NPSA, KALA, HALE, KAHO, PUHO, PUHE, ALKA, and HAVO. The single parameter monitored by this protocol is species and individual counts. Spatial and within-year temporal variance are both high. A transect-based approach will allow monitoring of several community-level species of invertebrates. The index-based approach will need to be utilized in focal searches for rare, and at-risk biota. Co-location or co-visitation will partially occur with the Focal terrestrial plant communities and Status and trends of invasive plants protocol. Further details on monitoring design may be found in table 4.5.

Landbirds—The Landbirds protocol will initially be implemented at AMME, NPSA, KALA, HALE, and HAVO. The sampling frame will consist of selected biomes within parks, and sample units will be tracts within these biomes. The sampling design will be based on linear transects, except in the case of rare bird searches which will utilize an index approach using specifically selected monitoring sites. The single parameter monitored by this protocol is species and individual count. Spatial and within-year temporal variance are both high. Standard approaches to monitoring land birds have been refined for Pacific islands (Camp, pers. com.). For species detected frequently, variable circular plot counts (along transects) can generate density estimates and proportion of area occupied, whereas rare bird searches offer another quantitative approach to monitoring populations of seldom encountered species.

Sampling will be systematic with random placement of the first sampling unit and systematic distribution of remaining sample units. A rotating panel design will be used with membership panel and revisit panel specific to the membership: [1-0, 2-4]. This protocol will be co-located with the Focal plant communities protocols, and co-visited with the Bats (Frugivorous) and Seabirds (NPSA) protocols. Further details on monitoring design and co-visitation may be found in table 4.5. A graphical representation of the Landbirds Vital Sign sampling scheme at NPSA is represented in figure 4.6.

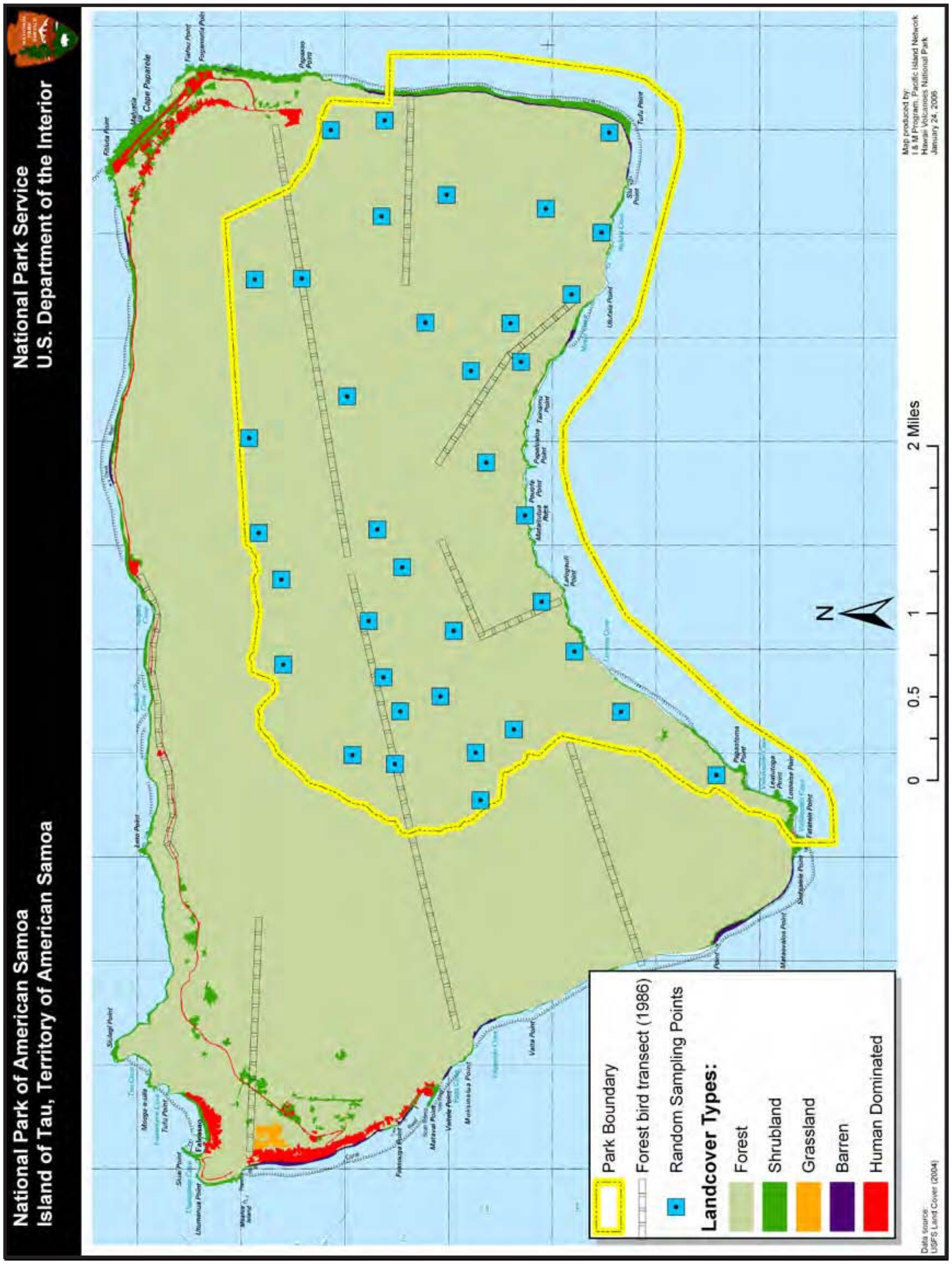
Seabirds—The Seabirds protocol will be monitored using a combination of transect-, list-, and index-based approaches. “Low elevation seabirds” will be monitored using transects, “Hawaiian petrels” using a list-based design, and “seabirds of special interest” using an index-based approach.

Transect-based monitoring will initially be implemented at NPSA, KALA, and KAHO. The sample frame for low elevation seabirds will consist of park shorelines, with individual birds within the frame being the sample units. Transect placement will be stratified by proximity to the shoreline, and will consist of a count of all birds sighted along transects. The single parameter monitored by this protocol is species and individual count using a stratified random design. Spatial and within-year temporal variance are both high. Low elevation seabird monitoring may be co-located with the Insectivorous and Frugivorous Bat monitoring protocol.

Hawaiian petrels will be monitored at HALE and HAVO using two complimentary list-based approaches, consisting of a list of known nesting sites and a list of potential locations. Spatial allocation will utilize a stratified random approach. Sample units will consist of grid squares, and the sample frame will be stratified into known colony sites and areas of potential colony location. This portion of the protocol will be co-visited with the Cave community and Insectivorous Bat protocols.

Seabirds of special interest will be monitored at NPSA, KALA, HALE, and HAVO using an index-based approach, therefore spatial allocation must utilize expert-based judgment. Birds will be monitored by radar detection or call counts. Seabird monitoring at NPSA may be co-located with the Frugivorous Bat protocol, and with the Insectivorous Bat protocol at the other three parks. Further details on monitoring design and co-visitation may be found in table 4.5.

Figure 4.6.
Map of proposed Landbirds sampling scheme on the Island of Tau, Manua group, National Park of American Samoa.



List-Based Sampling Design – Aquatic Ecosystems—To increase integration of the PACN program, Water quality as a list-based Vital Sign will be co-located and co-visited with two other aquatic monitoring programs: Groundwater dynamics and Freshwater animal communities.

Water Quality—This protocol will be implemented at all PACN parks. The PACN Water quality Vital Sign will utilize two sampling schemes: (a) list-based, and (b) index-based. The sampling frame for this sampling method consists of 4 strata: marine waters, streams, mixohaline waters, and groundwater wells within a park's water quality area of interest (appendix I). Sample units are random point samples allocated proportionately to the relative area of each resource type. The spatial allocation will be a GRTS design (temporal allocation will be annually independent for each stratum, with a target of 30-50 samples in American Samoa, Mariana Islands, and Hawaiian Islands). There will be several index sites for each park to monitor both status and trends in water quality parameters. Fiscal resource constraints may limit our efforts of focused sampling to 1 or 2 strata in a single geographic region per year. Thus, a period of approximately 6 years may elapse between status updates for a given geographic strata.

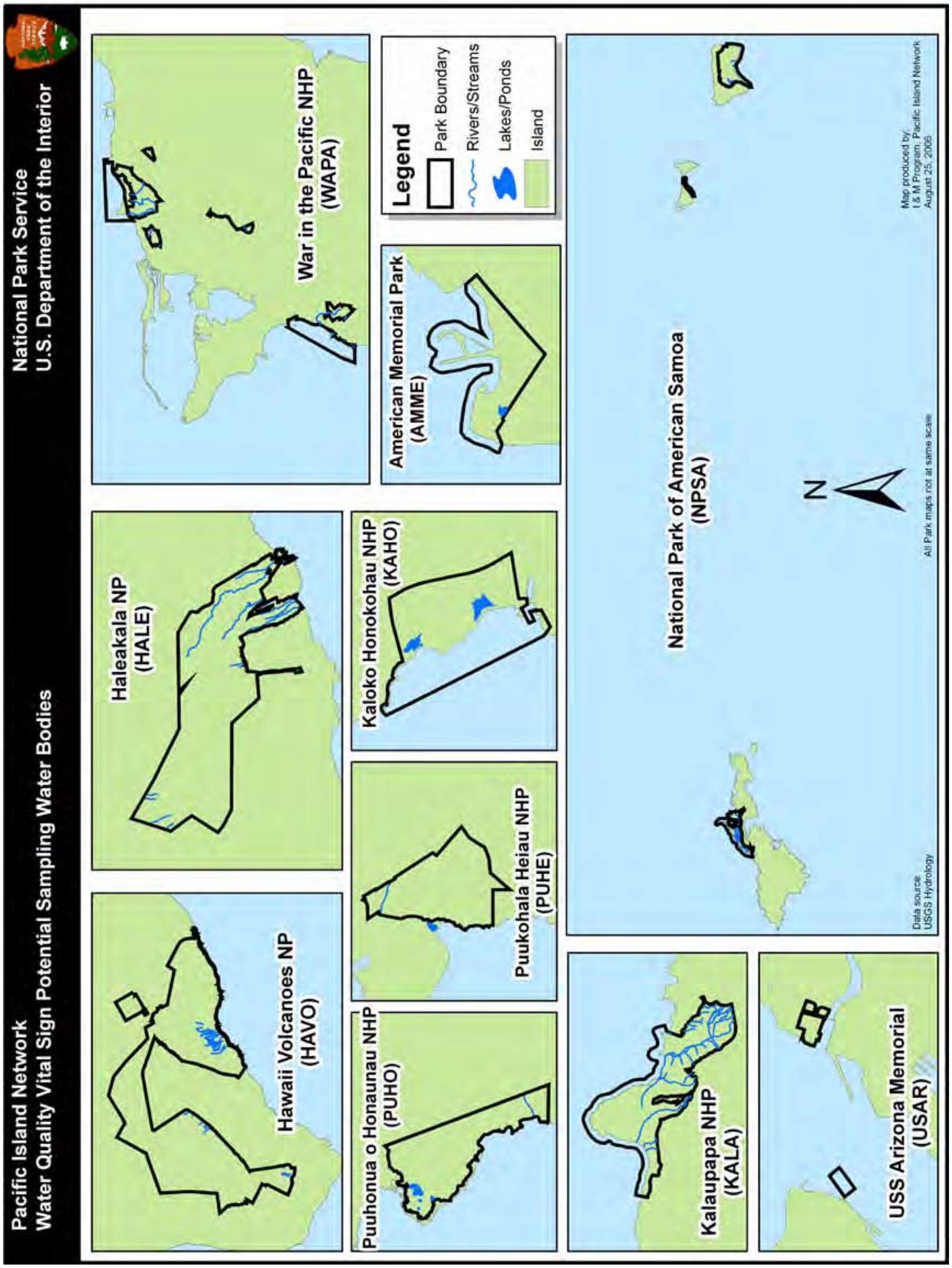
The other monitoring method for Water quality will consist of a series of automated, continuous data loggers deployed at index sites in conjunction with freshwater, marine, and groundwater monitoring protocols. Continuous sampling will focus on gathering trend information for integration with spatial status information. Instruments will be rotated among pre-established index sites. The sampling frame for the index-based component is the same as the GRTS sample frame, with site selection by professional judgment (e.g., watershed collector sites in streams, co-located with Benthic marine community Vital Sign monitoring in marine strata). Sample units are index sites addressing priority management areas and issues. The index sites will be annually rotated across the network in conjunction with GRTS sampling rotation discussed previously. This approach will permit characterization of temporal variability at multiple scales, including diel and seasonal cycles.

This combination of status (GRTS sampling) rotated in conjunction with trend (continuous, index site) monitoring provides a hybrid approach for addressing a broad suite of management issues. This hybrid approach also characterizes a specified target population (strata) on a broad spatial basis using a randomized GRTS approach, as well as refined temporal basis using continuous-recording index sites from within the same sample frame. Potential water bodies for monitoring within the PACN are presented in figure 4.7.

Groundwater Dynamics—The Groundwater dynamics protocol will initially be implemented at AMME, KALA, ALKA, and KAHO and co-located and co-visited with Water Quality. Groundwater dynamics will be monitored using a list-based design in several discrete groundwater wells, streams, springs, and wetlands. Sampling frames consist of a list of accessible wells within the water quality area of interest (see appendix I), and a list of streams and springs within the water quality area of interest. Regarding wells, given the limited number of monitoring wells available, the spatial allocation is being treated as a list-based design, with the intention of monitoring the entire list. The protocol will recommend additional monitoring well locations for future consideration. Whenever possible, wetlands and ponds will be randomly selected from a list using a GRTS spatial allocation. Parameters to be measured include: groundwater level, surface discharge, and conductivity/salinity. This protocol may be co-located and co-visited with Water quality monitoring. Further details on monitoring design and co-visitation may be found in table 4.5.

Freshwater Animal Communities—The Freshwater animals communities Vital Sign will initially be implemented at AMME, WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, and HAVO and will be co-located and co-visited with Water Quality. The sampling frame consists of a list of all accessible intermittent streams, anchialine pools, and ponds within a park. This protocol will be monitored using a

Figure 4.7.
PACN potential water quality sampling water bodies.



list-based design. The spatial allocation is stratified random sampling (SRS) for pools, perennial streams, and intermittent water bodies within and immediately adjacent to park boundaries. Sample units will consist of reaches within streams, and individual anchialine pools. Two methods that will be used include visual surveys and electro-shocking. The list-based sampling design for streams will use a GRTS design for reach selection. This protocol will be co-located with Water quality index-based monitoring. Further details on monitoring design and co-visitation may be found in table 4.5.

List-Based Sampling Design – Terrestrial Ecosystems

Climate—This protocol will be implemented at all PACN parks and monitored using a list-based design. The sample frame will consist of a list of automated weather stations, and monitoring will consist of a suite of continuously monitored measures. The spatial allocation will be existing climate stations. Spatial variance in data collection in each park can be modeled, and there is no issue of allocation of within-year temporal variance. No co-location or co-visitation opportunities are foreseen for this protocol.

Index-Based Sampling Design – Terrestrial Ecosystems—Index-based sampling for PACN Vital Signs monitoring will include: Bats (frugivorous and insectivorous), Cave community, Fish harvest, and Erosion and deposition. In terrestrial/aquatic ecosystems, Erosion and deposition may be co-located with Water quality and Benthic marine community Vital Signs. The terrestrial erosion component may be co-visited with Focal terrestrial plant communities.

Insectivorous Bats—Insectivorous bats will be monitored using an index-based design. The Hawaiian hoary bats protocol will initially be implemented at KALA, HALE, ALKA, PUHE, KAHO, PUHO, and HAVO. Bats will be monitored at mobile and fixed bat detection stations along roads and trails (in large parks), or throughout the park (at small parks). Locations of remote data collection stations for bat detections will be based on expert judgment. One parameter, individual count (# detections/unit time), will be monitored for this protocol. Spatial variance and within-year temporal variance are both high. Two sampling methods will be used: road and/or trail transect counts for active data collection and vista counts for remote echolocation monitoring stations.

Sites will be stratified for Hawaiian hoary bats based upon habitat. Co-visitation will occur with components of the Landbirds and Seabirds protocols. Further details on monitoring design and co-visitation may be found in table 4.5.

Frugivorous Bats—The fruit bats protocol will initially be implemented at NPSA. If inventory data suggests adequate populations are present at WAPA, then fruit bat monitoring will be implemented at WAPA as well. An index-based sample design will be used to monitor frugivorous bats (also called fruit bats or flying foxes) from vista points (figure 4.8), and a list-based design for roosting colonies. Both known colonies and individuals will be monitored, utilizing expert judgment for spatial allocation, and existing colonies. Only a single parameter of individual count will be monitored for this protocol. Spatial variance is high and within-year temporal variance is moderate. Two sampling methods will be used: colonial counts and vista counts. Measurement error for colonial counts is high, and measurement error for vistas is moderate.

Counts will consist of both colony-based emergence and activity counts, as well as solitary bats within sampling units. Sampling locations may change based upon both species' mobility, and roosting locations. Co-location will occur with the Seabirds protocol. Co-visitation will occur with the Seabirds (in NPSA), and Landbirds

Figure 4.8. Frugivorous bat surveys co-visited with Landbirds and Seabirds Vital signs monitoring, Tutuila Island, National Park of American Samoa.

protocols (matching both index designs). Further details on monitoring design and co-visitation may be found in table 4.5.

Cave Communities (phase 2)—An Index-Based Design will be used to monitor this protocol, which will initially be implemented at KALA, HALE, KAHO, PUHO, NPSA, WAPA and HAVO. The sample frame will include accessible caves with significant biological and/or cultural resources. Three types of monitoring will be conducted: (a) cave biological resources, (b) surface vegetation, and (c) other resources within caves (e.g., cultural or paleontological features).

This protocol has little potential for co-location, but will be co-visited with the Seabirds Vital Signs protocol. Further details on monitoring design and co-visitation may be found in tables 4.5.

Index-Based Sampling Design – Aquatic Ecosystems

Fish Harvest—The Fish harvest Vital Sign will be monitored using an index-based approach. It will initially be implemented at WAPA, NPSA, KALA, and KAHO. The sample frame includes park shorelines and marine waters, with a potential buffer area. Two parameters, catch per unit effort and fish length, will be monitored for this protocol. For spatial allocation, the sites to collect creel-survey data will be selected using scientific judgment. Both spatial and within-year temporal variance for each parameter are high. Two methods will be used: creel counts and participation surveys.

Figure 4.9. Monitoring of invasive plants is planned in Pacific Island Network Parks such as Hawaii Volcanoes National Park.

This protocol has little potential for co-location or co-visitation with other Vital Signs. Further details on monitoring design and co-visitation may be found in table 4.5

Erosion and Deposition (phase 2)—The erosion and deposition protocol will be monitored using an index-based approach for sampling design. This protocol will initially be implemented at WAPA, NPSA, USAR, KALA, HALE, and PUHE. Three types of monitoring will occur: terrestrial erosion monitoring, surface water/marine turbidity monitoring, and marine sedimentation monitoring. Spatial allocation will be identified from expert judgment of the terrestrial, surface water, and marine sites.

This protocol will be co-located and co-visited with Benthic marine, Focal terrestrial plant community, and Water quality monitoring. Further details on monitoring design and co-visitation may be found in table 4.5.

Buffer Zone Vital Sign Monitoring—Two of PACN Vital Signs are unusually grouped together by sampling location outside the PACN parks, rather than sampling design. Both Early detection of invasive plants and Invertebrates, and Landscape dynamics will collect data in the buffer zones of the PACN parks. Therefore, while Early detection is list, linear, and index-based, the census-based Landscape dynamics will be co-visited and potentially co-located with the Early detection monitoring team, for the purpose of ground-truthing the monitoring data.

Early Detection of Invasive Plants and Invertebrates (Linear, List, and Index-Based)—The Early detection of invasive plants protocol will be initially be implemented at AMME, WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, and HAVO. The sample frame will consist of nurseries, roads, and other dominant invasive species entry points (figure 4.9) on the islands where a park is based. Three sampling schemes will be utilized: (a) linear-based sampling, (b) list-based sampling, and

Table 4.5. Sample units and sampling designs for PACN Vital Signs.

Vital Sign	Sample Units		Sampling design	
	Sampling Frame	Within-Park Units	Within Park	Within Sample Unit
Climate	List from existing weather stations (more stations are expected in future)	Weather station	One or more weather stations per park, convenience sample. Criteria must be selected for multiple stations in a park (e.g., windward/leeward, elevation).	Continuous sampling
Groundwater dynamics	a) List from monitoring wells within/adjacent to parks b) List of streams and springs within/adjacent to parks	a) Monitoring wells b) Streams and springs	a) Complete list, or systematic sample b) All available sites	a) 2-3 measures/site visit b) 1 measure/site visit
Water quality	a) Lists of resources for 4 strata: marine, perennial streams, mixohaline (pools & ponds), groundwater b) Index site(s) from each strata: marine, perennial streams, mixohaline (pools & ponds), groundwater	a) Discrete point samples in strata: marine, perennial streams, mixohaline (pools & ponds), groundwater b) Continuous point samples	a) GRTS proportional to area of resource type. Never revisit b) Index-site instrument rotated by park and/or resource type	a) ~30 samples per strata b) Continuous sampling
Status and trends of established invasive plant species	a) 8 focal communities in parks b) Transport routes (transects, roads, trails, developed areas) c) Within park boundaries	a) Sampling units adjusted by habitat (small sites to 10 ha) b) 10-m segments of transects, 1-mi road segments, sites in developed areas c) 10-m segments of transects, 1-mi road segments, sites in developed areas	a) Stratified by sub-habitats, GRTS sample b) Exhaustive (canvass) c) Detection array, linear lattice	a) Varies by life form: trees- whole plot; shrubs & small forms- sub-plot; random panel, refresh new random subplots & revisit large plots b) No sub-sampling c) N/A
Early detection of invasive plants	a) Units that must be individually selected b) Units that can be randomly selected (list-based, linear-based)	a) Nurseries, stretches of road b) Road types (public-paved; public-unpaved, & private)	a) Index: selected by site; b) Sample within strata, stratified by risk	Survey within nursery, or road units
Benthic marine community	10-20 m strata in Marine realm with hard bottom	25-m transect (cover, disease rugosity); arrays along a 25-m transect (recruitment); discrete *Pocillopora spp* colony (growth)	SRS, Split Panel Design (1/2 fixed, 1/2 50% rotational) for cover, disease, rugosity, growth; SRS of 1/2 fixed transects (recruitment)	SRS of images; counts of recruitment, and disease; total growth of index corals; rugosity measurement per site
Marine fish	10-20 m strata in Marine realm with hard bottom	25 m x 5 m transect	Stratified by hard bottom habitat types; split panel design	Species, length, abundance per transect
Fish harvest	Park shoreline & marine waters (potentially plus buffer)	N/A	Potentially exhaustive sampling of marine areas	Effort- systematic sampling of # fishermen by gear type, stratified by day vs. night. Catch- opportunistic creel survey
Freshwater animal communities	a) List of all accessible streams b) List of all accessible streams, anchialine pools, and ponds	a) Quadrats within reaches (2 levels of units) b) Reaches within streams, anchialine pools, and ponds	GRTS for reaches, Anchialine pools, and ponds. Canvass pools in stream reaches	Random reaches within streams, random quadrats within reaches. Aquatic fauna: random quadrats within pools or net/trap samples
Focal terrestrial plant communities	8 focal communities in parks	By sampling units: Unit size adjusted by habitat (small discrete sites to10 ha)	Stratified by sub-habitats, GRTS sample	Varies by life form: Trees- whole plot, shrubs & small forms- sub-plot, random panel, refresh new random subplots & revisit large plots

Table 4.5. Sample units and sampling designs for PACN Vital Signs—*Continued*.

Vital Sign	Sample Units		Sampling design	
	Sampling Frame	Within-Park Units	Within Park	Within Sample Unit
Landbirds	Selected biomes of parks	Tracts (within a biome of a park)	Systematic sampling with random placement of the first sampling unit & systematic distribution of remaining sampling units; rotating panel design with membership panel and revisit panel specific to the membership: [1-0,2-4]	Transects, stations, search-area sites, mark-resight sites, or nest searching (within tracts)
Seabirds a) Hawaiian Petrel b) Species of special interest c) Low elevation surveys	a) Known nesting areas & potential habitat (list) b) Within-park sampling design c) Park shorelines (linear)	a) Grid squares b) Radar detection (individual birds), calling birds c) Individual birds	a) 2 strata: Known areas & potential areas b) Index sites c) Along-shore strata	a) Known: canvass or sample; Potential: sample (i.e., grid) b) Radar or call counts c) Count of all birds seen on transect
Bats a) Insectivorous bats b) Frugivorous bats	a) HALE, HAVO, and KALA: All accessible roads and trails, & other focal areas; PUHE, PUHO, and KAHO: park level b) NPSA: Focal coastal, road, and/or trail areas	a) Mobile and/or immobile bat detection stations b) Colony: Colonial species Individual: Both solitary & colonial species	a) Hawaiian hoary bats: sites allocated by expected habitat utilization with fixed, echolocation detection equipment. Other fixed sites selected to give better representation of park, survey using mobile detectors. Stratified: Forest, non-forest, ecotones. b) Within island: Direct colony counts and emergence counts at roosts (colonies); station counts at roosts and vistas (solitary species or individuals) Within sampling units: Count individual bats (solitary and colonial species).	a) Minutes of activity/ unit time will be recorded for each site. All sites will be visited monthly during year one and annually after determining those months with highest bat activity levels. Number of sites TBD. b) Count individual bats (both solitary & colonial species); locations may change due to resource availability
Landscape dynamics	Park plus buffer	4-m imagery cells	Census	Census
Erosion and deposition	a) Potentially same as vegetation b) Potentially same as water quality c) Potentially same as benthic marine	a) 3-5 soil samples b) Automated turbidity meter c) TBD	a) Potentially incorporate into vegetation design; index based b) Incorporate into WQ; stratify by proximity to point sources; index-based c) Potentially incorporate into benthic protocol; index based	a) TBD b) TBD c) TBD
Cave community	a) Selected accessible caves with resources b) Roots in caves, surface vegetation above caves c) Selected accessible caves with resources	a) Plots in caves b) Roots within caves, surface vegetation over cave footprint c) Caves	a) Plots & cave obligate species; index based b) Plots & cave for roots, surface vegetation transects over cave footprint; index based c) Opportunistic distribution, note change	a) Timed counts, bait counts, walk-through b) Photo documentation, relative cover of roots, root samples for ID c) Change in status, photo documentation, data loggers for human visits
Terrestrial invertebrate communities	Selected tracts within parks	Fixed transects within tracts	Random placement of bait stations; some sites index-based design	Bait stations along transects
Early detection of invasive invertebrates	a) Units that will be individually selected b) Units that can be randomly selected (list-based + index)	Index trap sites	a) Index: selected by site; b) Sample within strata, stratified by risk	Survey within units

(c) index sampling. Linear sampling will occur along road corridors that serve as vectors of invasive species introductions, and may spatially allocate by a stratified random sample, if necessary. The linear corridors may be stratified by road type: primary (public-paved), and secondary (public-unpaved), and private property roads (where accessibility is granted). Details of the early detection of invasive invertebrates will be determined in phase 2.

List-based sampling of Early Detection invasive plants will occur for plant distribution centers, including nurseries, botanical gardens, and retail stores where ornamentals can be purchased, in addition to other sites such as refuse dumps and supply yards. Stratified random sampling will be used near parks where the buffer zones around a park can be stratified as concentric rings within a pre-set buffer distance of the park. For the parks where the plant distribution centers and botanical gardens are minimal, an index-based approach will be used to hand-pick these sites, as well as ports of entry (e.g., marine vessels or airports) known to distribute ornamentals and/or other potential invasive plant species. This protocol will partially be co-located with the Status and trends of established invasive plants protocol, and be co-located and co-visited with the Landscape Dynamics protocol. Further details on monitoring design may be found in table 4.5.

Census-based Design

Landscape Dynamics—This protocol will initially be implemented at AMME, WAPA, NPSA, KALA, HALE, PUHE, KAHO, PUHO, USAR, and HAVO. Landscape dynamics will use a census approach with field sampling for training and accuracy assessment data. The sample frame consists of the park, in addition to a buffer area, and sample units consist of 4-m^2 imagery cells. Further details on monitoring design and co-visitation may be found in table 4.5.

Summary

Chapter 4 describes the sampling designs that will be used for the fourteen phase 1 (and four phase two) Vital Sign monitoring protocols that are being developed for the Pacific Island Network. In an effort to reduce program costs and increase efficiencies, we have found numerous opportunities for terrestrial and aquatic Vital Signs to be co-located and/or co-visited. These efforts should substantially reduce time, personnel, and travel costs for protocol implementation. In this chapter, we describe four general sampling approaches that will be used in our 11 national park system units: linear-based, list-based, index based, and a census, as well as specific spatial and temporal sampling designs. The information presented herein summarizes the results of work accomplished at several meetings over a three-year period. Many individuals contributed including: Inventory and Monitoring staff, other NPS staff, CESU Cooperators, as well as other agencies, Universities, NGOs, and professional biometricians, whose scientific expertise and quantitative skills contributed substantially to the PACN Vital Sign monitoring program.

"In an effort to reduce program costs and increase efficiencies, we have found numerous opportunities for terrestrial and aquatic Vital Signs to be co-located and/or co-visited."

Chapter 5. Monitoring Protocols

> *"Monitoring protocols are detailed study plans that explain how data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs. Protocols are necessary to ensure that changes detected by monitoring actually are occurring in nature and not simply a result of measurements taken by different people or in slightly different ways." (Oakley et al., 2003)*

The Pacific Island Network is developing 14 Vital Sign monitoring protocols that are planned for implementation during 2006-2011. Schedules for implementation are described in chapter 9. In general, the PACN protocols will be extensive documents, outlining well-defined objectives and detailing: (a) background research, (b) sampling design, (c) field, laboratory and data analysis methods, (d) data management, (e) QA/QC procedures, (f) reporting procedures, and (g) other Standard Operating Procedures (SOP) and materials that are protocol specific (figure 5.1). All PACN protocols will closely follow the national standards for long-term monitoring protocols as outlined by Oakley et al. (2003). Thus, each protocol will consist of three primary sections: (1) a protocol narrative, (2) a set of standard operating procedures, and (3) supplementary materials.

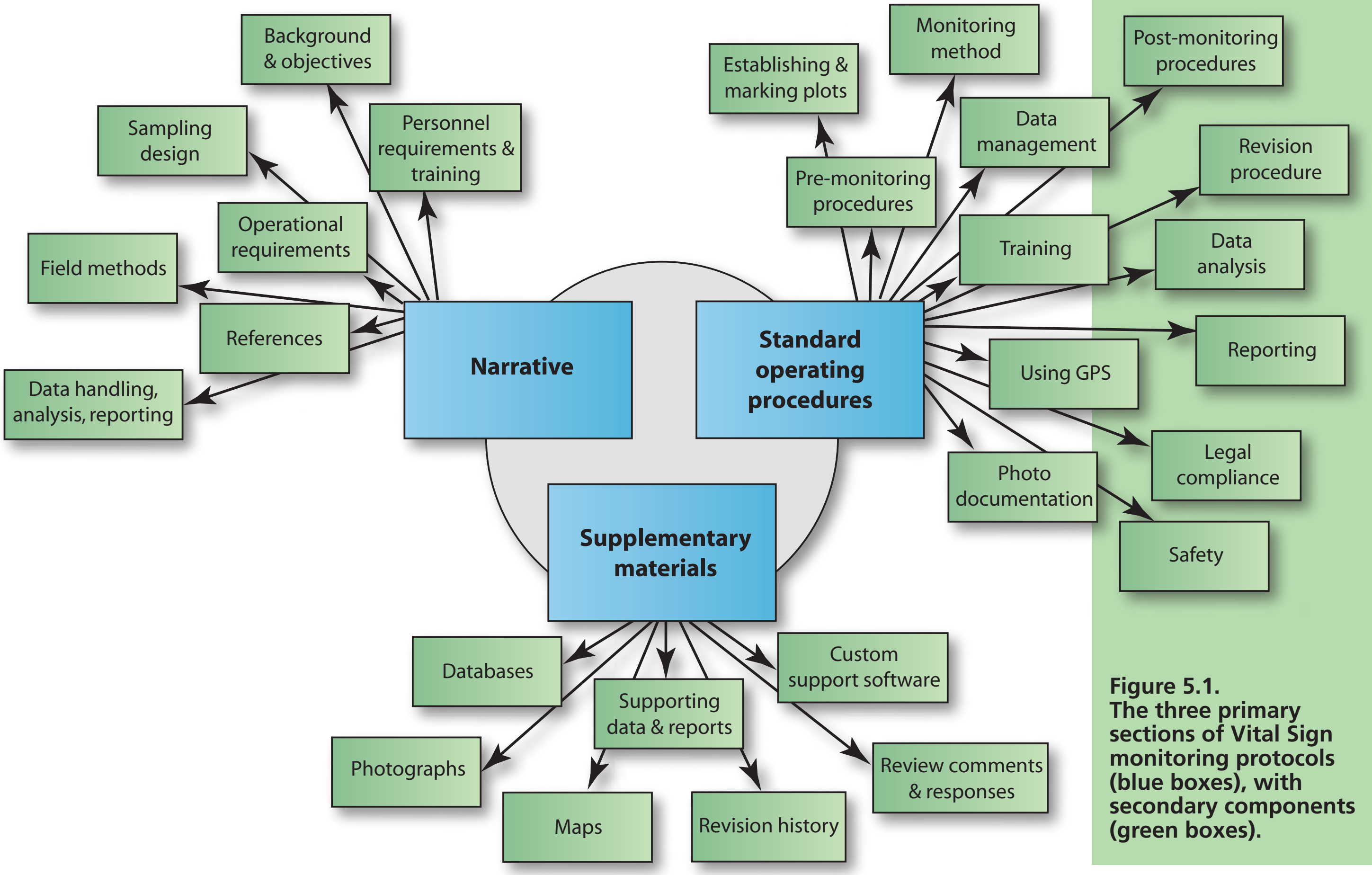
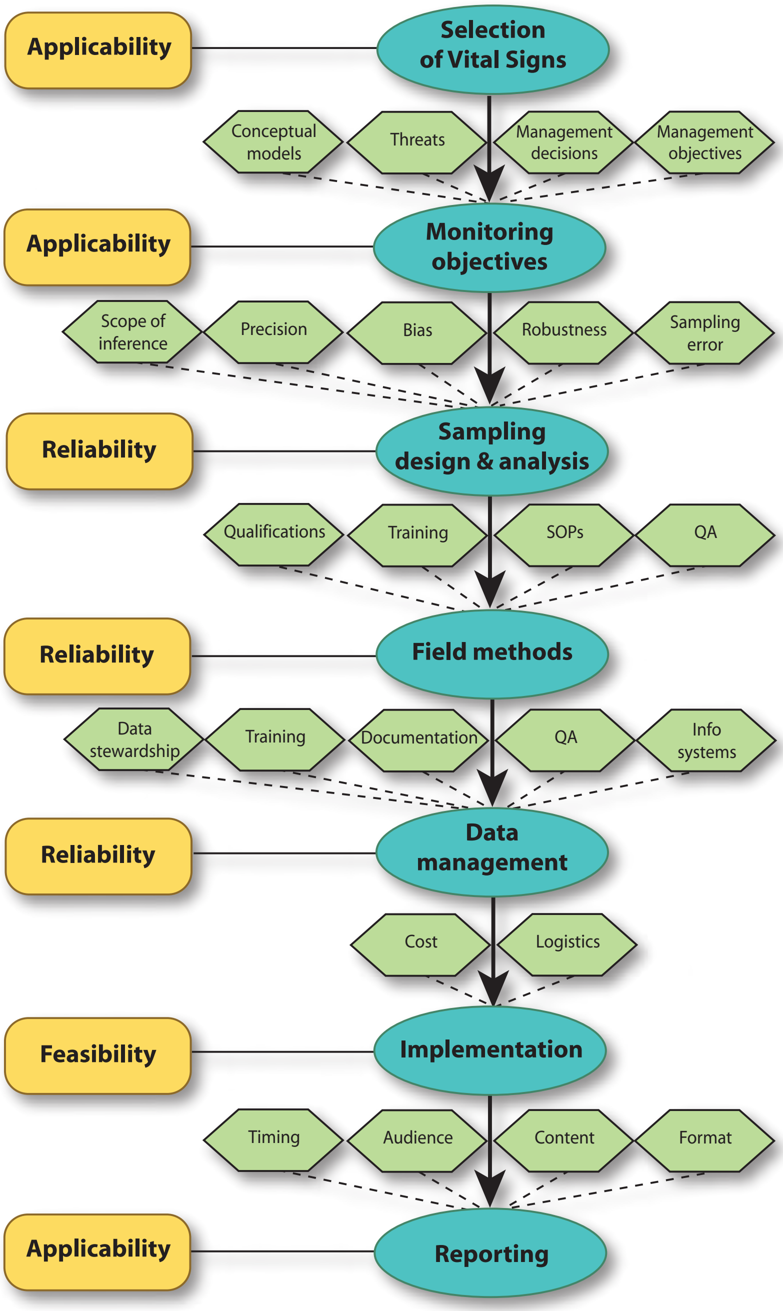


Figure 5.1. The three primary sections of Vital Sign monitoring protocols (blue boxes), with secondary components (green boxes).

Figure 5.2. Vital sign conceptual framework illustrating the importance of individual components to applicability, reliability, and feasibility for protocols.



As the PACN list of Vital Signs was refined, we emphasized applicability, feasibility, and reliability (i.e., scientific defensibility) of metrics to detect change. These elements have been addressed in previous monitoring plan chapters. Figure 5.2 illustrates how the pieces of the protocols contribute to major program components of applicability, reliability, and feasibility of our monitoring program.

Vital Sign Protocol Development Roles

To ensure a system of checks and balances regarding the roles of NPS staff and cooperators, we have defined five primary roles in protocol development, as described below. Individuals responsible for each protocol are identified in table 5.1.

Table 5.1. PACN protocol development roles and individuals involved.

Protocol	Principal Investigator	NPS Lead	I&M Project Manager	CESU Cooperator
Climate	Fritz Klasner (NPS)	TBD	Fritz Klasner	Karin Schlappa
Status & trends of established invasive plant species	Jim Jacobi (USGS-BRD) Linda Pratt (USGS-BRD)	Rhonda Loh Steve Anderson	Leslie HaySmith	Joan Yoshioka Alison Ainsworth
Water quality	Tahzay Jones (NPS)	Eric Brown	Tahzay Jones	Kimber DeVerse
Seabirds	Darcy Hu (NPS) David Duffy (CESU)	Cathleen Bailey	Leslie HaySmith	Gail Ackerman
Landscape dynamics	Melia Lane-Kamahele (NPS) Barbara Gibson (Univ. of Hawaii)	Sandy Margriter	Fritz Klasner	Page Else Viet Doan
Fish harvest	Jim Beets (UH)	Peter Craig	Tahzay Jones	Raychelle Daniel
Landbirds	Rick Camp (USGS-BRD) Thane Pratt (USGS-BRD)	Cathleen Bailey, Darcy Hu	Leslie HaySmith	N/A
Freshwater animal communities (perennial & intermittent streams & ponds)	Anne Brasher (USGS-WRD)	Tahzay Jones	Tahzay Jones	N/A
Bats (insectivorous & frugivorous)	Leslie HaySmith (NPS)	Darcy Hu	Leslie HaySmith	Gail Ackerman, Heather Fraser
Focal terrestrial plant communities	Jim Jacobi (USGS-BRD) Linda Pratt (USGS-BRD)	Rhonda Loh	Leslie HaySmith	Alison Ainsworth
Early detection of invasive plants	Lloyd Loope (USGS-BRD)	Steve Anderson	Leslie HaySmith	Joan Yoshioka
Benthic marine community	Eric Brown (NPS)	Dwayne Minton	Tahzay Jones	Raychelle Daniel
Marine fish	Jim Beets (UH) Alan Friedlander (NOAA)	Peter Craig	Tahzay Jones	Raychelle Daniel
Groundwater dynamics	Steve Anthony (USGS-WRD)	Tahzay Jones	Tahzay Jones	N/A
Erosion & deposition	TBD	Dwayne Minton	Fritz Klasner	Raychelle Daniel
Terrestrial invertebrate communities	David Foote (USGS-BRD)	TBD	Gordon Dicus	TBD
Cave community	Frank Howarth (Bishop Museum) Jadelyn Moniz Nakamura (NPS)	TBD	Gordon Dicus	TBD
Early detection of invasive invertebrates	Lloyd Loope (USGS-BRD)	Steve Anderson	Leslie HaySmith	TBD

Principal investigator (PI) - The PI takes overall responsibility for a Vital Sign in the network. He or she works with the network coordinator, PACN staff, and Technical Committee to ensure long-range perspectives for project design, data collection, data analyses, and reporting. Principal investigators oversee summarization and reporting of the monitoring data.

NPS lead - The staff member from a park or I&M who ensures that NPS-wide interests are maintained throughout monitoring development for each Vital Sign.

I&M project manager - I&M staff that are assigned to each protocol to steward the planning, development, budget, timeline, and implementation phase, in accordance with program guidelines. The I&M project manager may assume "contracting officer representative" duties.

CESU cooperator - The CESU staff member who assists with literature reviews, data mining, writing and editing of protocol development summaries, study plans, and protocols, including standard operating procedures. Other duties include coordinating meetings for protocol development, data management of protocols, and some data analysis.

Parks point of contact (PPOC) – The park staff member who coordinates the PIs and team visits for field reconnaissance to their parks. PPOC also review study plans and draft protocols with respect to plans for Vital Sign monitoring in their parks.

In addition to NPS leads, project managers, and PPOC who are formally involved in Vital Sign monitoring, many other staff members, ecologists, and natural resource managers provide assistance and information about their park, which is invaluable in preparing protocols and conducting monitoring in PACN parks. This collaboration for Vital Sign monitoring is particularly important, considering the geographic isolation and travel and logistics costs to conduct monitoring in the PACN.

"...collaboration for Vital Sign monitoring is particularly important, considering the geographic isolation and travel and logistics costs to conduct monitoring in the PACN."

Protocol Summary Information

Detailed protocol development summaries are presented in appendix L. Table 5.2 presents an abbreviated version of the justifications and objectives for each protocol and lists parks in which each of the 18 Vital Signs will be monitored. Implementation will occur in two phases over a 5-year period. Note that some Vital Signs will be implemented in both phase 1 and phase 2.

Table 5.2. Summary information for PACN Vital Sign monitoring protocols.

Vital Sign	Justification[a]	Vital Sign Monitoring Objectives[b]	Parks Planned for Implementation
Climate[I]	Climate is a major driver for terrestrial and marine ecosystems, affecting biotic and abiotic ecosystem attributes. In many of the PACN parks, basic weather/climate data collection is completely lacking or inadequate. Identification of climate variability and change, and its effect on natural resources, is complicated by the lack of baseline data.	Determine: Ia. Ranges of average (statistical mean) conditions for monthly, yearly, and seasonal measurements of core weather parameters on various spatial scales. Ib. Trends for core climate parameters on park, island, and network-wide scales. Ic. Long-term trends and spatial extent for other parameters (based on site-specific needs). IIa. Limits for extreme conditions for core weather parameters on various spatial scales. IIb. Frequency, spatial extent, duration of extreme weather events (droughts, tropical cyclones, El Nino cycles, PDO, changes in predominant wind patterns).	AMME, WAPA, NPSA, USAR, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO
Status and trends of established invasive plant species[I]	Alien species invasions reduce native plant diversity and abundance, and alter vegetation structure. At their worst, ecologically disruptive species are able to completely displace the native vegetation and alter ecosystem processes. Among the >4,600 alien species established in Hawaii, there are 100+ highly disruptive alien pest species. Over 105 species are identified as disruptive or potentially so in American Samoa; and 133 species identified as disruptive or potentially so in Micronesia.	Ia: Periodically compile information and develop lists of invasive non-native species in or adjacent to PACN parks. Ib: Prioritize non-native species to identify the most disruptive species threatening PACN parks. II: Determine distribution and abundance of disruptive non-native species along major corridors and randomly located belt transects spanning plant communities from 0 to 10,000 ft elevation (5 year intervals). III: For highly disruptive non-native species, determine the stand structure (number of individuals in different size classes), and record reproductive status in permanent plots.	AMME, WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO
Water quality[I]	The quality of surface waters, marine waters, and groundwater is critical to the functioning of aquatic and terrestrial ecosystems. Water resources in the PACN parks span a range of conditions from pristine to highly impaired water bodies. Both point and nonpoint sources impact waters at various locations. NPS management policies mandate that parks determine the quality of their water resources and strive to avoid anthropogenic pollution both within and outside of park boundaries.	Determine: I: Range and spatial variance of temperature, pH, conductivity, dissolved oxygen, flow/stage/level, PAR, total nitrogen, total phosphorous, and chlorophyll a in PACN surface water bodies and groundwater (annually). not in groundwater. II: Temporal and spatial trends for temperature, pH, conductivity, and dissolved oxygen in PACN surface water bodies and groundwater. If necessary, collect and analyze pilot field data to resolve knowledge gaps. III: Temporal water quality trends in individual park water bodies and document changes in land uses in watersheds; identify correlations.	AMME, WAPA, NPSA, USAR, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO

[a]. Justification is for entire Vital Sign, and is condensed. Justification for individual objectives is presented in protocol development summaries (appendix L).

[b]. Specific objectives presented here are condensed.

[I]. Implementation in phase 1.

[II]. Implementation in phase 2

Table 5.2. Summary information for PACN Vital Sign monitoring protocols—*Continued.*

Vital Sign	Justification[a]	Vital Sign Monitoring Objectives[b]	Parks Planned for Implementation
Seabirds[I]	Prior to human colonization, seabirds nested widely and in enormous numbers on all PACN islands. Today the group is marked by precipitous declines and extirpations on all inhabited islands. Any extant colonies are remnants in dire need of protection, active monitoring, and management. Rare, threatened, and endangered seabird species are of primary concern to PACN. Two species are federally listed: the Hawaiian petrel (Pterodroma sandwichensis, Uau) is endangered, and Newell's shearwater (Puffinis newelli, Ao) is threatened. Other rare species include band-rumped storm-petrel (Oceanodroma castro, Akeake), Tahiti petrel (Pterodroma rostrata), Herald's petrel (Pterodroma arminjoniana), and Polynesian storm-petrel (Nesofregetta fuliginosa).	Hawaiian petrel: Ia: Detect changes in distribution of colonies by searching suitable nesting habitat at intervals of every 5-10 years. Calculate density of colonies by locating active nests and delineating colony area. Ib: Determine numbers of active nests and annual fledging success. Other threatened and rare species: IIa: Determine seabird species presence and relative abundance by non-intrusive means such as radar and combined use of night vision and call recognition. IIb: Periodically (<annually) monitor reproductive success of all seabirds. Common, low-elevation seabirds: IIIa: Use repeated surveys along prescribed routes, or counts from fixed points, to assess changes in distribution and relative abundance of common seabirds. IIIb: In accessible colonies where human disturbance will not disrupt nesting, determine changes in colony density over time. I,II,IIIc: Compare numbers of active nests and fledging success for areas (times) with/without predator control.	NPSA, KALA, HALE, KAHO, PUHO,HAVO
Landscape dynamics[I]	Land use and land cover change have become a central component in current strategies for managing natural resources and monitoring environmental change. Remote sensing and Geographic Information Systems (GIS) are providing new tools for advanced ecosystem management.	I: Map existing land cover in small parks at1:24,000 scale (or better) using high resolution imagery. For larger parks Landsat Imagery may be used to key in on focal changing areas for analysis with higher resolution imagery. IIa: Map land use/land cover for PACN parks every 10 years and use GIS to analyze land use changes. IIb: Map the distribution and density of infrastructure (roads and developments) at the wildland-urban interface of PACN parks every 5 years.	AMME, WAPA, NPSA, USAR, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO
Fish harvest[I]	In PACN parks, a wide variety of coral reef fish, invertebrates and algae are harvested annually in either traditional, artisanal, recreational, or subsistence fisheries. The impact of a seemingly small but persistent level of daily fishing activity can be substantial. Fishing has well-documented significant impacts on reef ecosystem structure and function, and on the condition of fish populations.	I. Determine annual composition, sizes, catch-per-unit-effort, and quantities (by weight, and numbers where possible) of park-specific targeted coral reef fishes and invertebrates (shellfish, octopus, lobster, sea urchins and palolo polychaetes) harvested in park waters. Use standardized catch and effort surveys consisting of fishermen interviews or "creel surveys", and participation surveys.	WAPA, NPSA, KALA, KAHO

[a]. Justification is for entire Vital Sign, and is condensed. Justification for individual objectives is presented in protocol development summaries (appendix L).

[b]. Specific objectives presented here are condensed.

[I]. Implementation in phase 1.

[II]. Implementation in phase 2

Table 5.2. Summary information for PACN Vital Sign monitoring protocols—*Continued*.

Vital Sign	Justification[a]	Vital Sign Monitoring Objectives[b]	Parks Planned for Implementation
Land birds[I]	Birds are the principal, and sometimes only, terrestrial vertebrates on islands. Pacific islands' avifauna is composed overwhelmingly of endemic species. Human settlement of Pacific islands has brought about extinction of a large proportion of the original avifauna, and many of the surviving species are greatly reduced. However, hope remains for Pacific island birds in situations where they can escape alien threats (e.g., high elevation rainforests), can be assisted by human management of ecosystems, or can ultimately adapt to novel pressures.	Ia: Determine distribution and density of all non-threatened native and most non-native land bird species. Ib: Determine distribution and estimate reproductive success and annual survival for birds of special interest, including T&E species, species of concern, and species that require more precise monitoring than is provided by count surveys. Ic: Document all observations of rare or elusive birds and newly arrived invasive bird species. II: Monitor changes in native and non-native forest bird species abundance and composition relative to forest restoration (alien plant and animal control) and reforestation actions.	AMME, NPSA, KALA, HALE, HAVO
Freshwater animal communities[I]	Due to the isolation of the Pacific islands, there is a high level of endemicity in the small number of native species found in the diverse array of freshwater/brackish habitats in the PACN. Several freshwater animals are listed as candidate endangered species or species of concern. Throughout the region, exotic species introductions and habitat destruction are significant threats to native animal populations. PACN parks protect some of their last remaining habitats.	Ia: Determine long-term trends in composition and diversity of selected fish and invertebrates in selected freshwater and mixohaline communities. Ib: Determine trends in distribution and abundance of selected fish and invertebrate populations in selected stream and lentic habitats. II: Improve understanding of relationships between freshwater or brackish water animal communities and their habitat by correlating physical/chemical habitat measures with changes in distribution and abundance of fish and invertebrates.	WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO
Bats[I]	The Hawaiian hoary bat (Lasiurus cinereus semotus), is found throughout the Hawaiian Islands. Large fruit bats, or flying foxes, are ecologically important pollinators and seed dispersers. Flying foxes are subjected to hunting, habitat loss, climatic disturbances, and predation, leading to population declines. Lack of knowledge of status, distribution, and habitat needs, coupled with conflicting and vague population estimates, makes long-term monitoring critical to the survival of bat species in the PACN.	Insectivorous: I: Determine presence, distribution, and relative activity levels of hoary bats in national parks of the Hawaiian Islands. II: Determine foraging habitats associated with insectivorous bats in national parks of Hawaii. Frugivorous: I: Determine long-term trends (10-20 years) in population size (i.e., relative abundance) and distribution of flying foxes (WAPA monitoring contingent upon inventory results). II: Determine roosting and foraging habitats associated with flying foxes in and near the national parks (WAPA monitoring contingent upon inventory results).	WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO

[a]. Justification is for entire Vital Sign, and is condensed. Justification for individual objectives is presented in protocol development summaries (appendix L).

[b]. Specific objectives presented here are condensed.

[I]. Implementation in phase 1.

[II]. Implementation in phase 2

Table 5.2. Summary information for PACN Vital Sign monitoring protocols—*Continued.*

Vital Sign	Justification[a]	Vital Sign Monitoring Objectives[b]	Parks Planned for Implementation
Focal terrestrial plant communities[I]	The central reasons for monitoring terrestrial plant communities are: (a) they are key indicators of ecosystem health, (b) they reflect the dynamic between invasive plant species and native species, (c) they indicate management needs and effectiveness. Monitoring key characteristics (e.g., species composition, community structure) of focal plant communities informs managers of changing conditions that may require management action and provides feedback on the effectiveness of those actions in protecting important plant community resources.	I: Determine changes at 5-10 year intervals in vascular plant species presence/absence, cover, and density and woody species density by height or diameter classes in focal plant communities. II: Compile species lists and location data from previous plant inventories, existing databases, ongoing surveys, and mapping projects. III: Determine long-term trends in the distribution and abundance of selected rare, threatened, endangered, and other focal plant species within selected native plant communities. IV: Determine size class distribution (stand structure) of focal plant species populations within the five major native plant communities. V: Determine long-term trends in the abundance and stand structure of focal plant species populations in selected native plant communities with or without (or before and after) management intervention.	AMME, WAPA, NPSA, KALA, HALE, KAHO, HAVO
Early detection of invasive plants[I]	Invasive alien species pose an enormous threat to the world's biological diversity. Hawaii has the most severe non-native species problem of any state in the United States, and other Pacific islands are comparably vulnerable. Early detection of targeted ecosystem modifying/displacing alien species will provide data needed to prioritize rapid response to prevent invasions and subsequent damage to national park resources.	Ia: Develop a list of targeted known invasive plant species potentially posing threats to a park by causing major ecological or economic problems if they were to become established. Ib: Develop and implement an optimal search and reporting strategy based on sampling to efficiently cover large areas. Ic: Working with partners, refine knowledge of dispersal pathways and search high-risk sites (nurseries, botanical gardens) for targeted incipient populations of invasive plants. II. Determine management actions for eradication of priority invasive plant species, based on life history attributes (especially its seed bank), dispersal modes, invasion corridors, vectors of spread, invasibility of areas, and number and size of known locations.	AMME, WAPA, NPSA, KALA, HALE, ALKA, PUHE, KAHO, PUHO, HAVO
Benthic marine community[I,II]	The benthic marine communities in the PACN parks comprise rich and diverse biota including algae, corals, and thousands of other invertebrates. Nearshore or shallow-water benthic marine communities in the PACN include coral reefs, mangrove stands, sea grass beds, and intertidal habitats. Given multiple existing threats to coral reefs and resources therein, and limited funds, monitoring of this Vital Sign will focus at present on coral reef communities.	Determine (annual surveys) trends in: Ia: Abundance of sessile marine benthic macroinvertebrate and macroalgal assemblages at randomly selected sites stratified by habitat along a 10-20 m isobath. Ib: Benthic small-scale topography or rugosity at randomly selected, fixed stations stratified by habitat or reef zone (e.g., reef flat, reef slope). IIa: Hard coral recruitment rate to uniform artificial surfaces at selected sites on the fore reef along a 10-20 m isobath. IIb: Growth and survival rates of randomly selected coral colonies of a common Pacific species (Pocillopora sp.) found in all parks and growing at similar depths. IIc: Incidence and severity of coral and algal disease and bleaching.	WAPA, NPSA, KALA, KAHO

[a]. Justification is for entire Vital Sign, and is condensed. Justification for individual objectives is presented in protocol development summaries (appendix L).

[b]. Specific objectives presented here are condensed.

[I]. Implementation in phase 1.

[II]. Implementation in phase 2

Table 5.2. Summary information for PACN Vital Sign monitoring protocols—*Continued.*

Vital Sign	Justification[a]	Vital Sign Monitoring Objectives[b]	Parks Planned for Implementation
Marine fish[I,II]	Fish are a major component of the coral reef ecosystem, including 500-900 species in PACN parks depending on geographic location. Fish assemblages or selected species can act as indicators of general reef health and provide a warning of environmental stress and potential ecosystem change.	I. Determine the density and biomass of the defined component* of the reef fish assemblage at randomly selected sites. II. Determine the distribution of fishes in each park. *visible diurnal component of the coral reef fish fauna.	WAPA, NPSA, KALA, KAHO
Groundwater dynamics[I,II]	Groundwater levels impact significant resources including wetlands, anchialine pool systems, springs and seeps, and municipal/agricultural water supplies. Due to the high permeability of substrate on Guam, Saipan, and Hawaii, there is high infiltration to groundwater. The potential for seawater intrusion to the freshwater lens is a primary limiting factor of Pacific island groundwater resources. Long-term groundwater monitoring data can be used to establish trends, develop models to predict future conditions, and potentially detect groundwater-supply problems for dependent ecosystems.	Determine: I. Areal and vertical distribution of salinity levels in the PACN park units (monthly). IIa: Groundwater levels in park units and surrounding areas (monthly). IIb: Surface-water discharges from streams and springs (monthly). IIc: Rainfall in park units and surrounding areas (frequency TBD). IIIa: Current and proposed distribution and rates of groundwater withdrawals in park units and surrounding areas. IIIb: Effect of land-use changes on infiltration capacity and the recharge component of the water budget.	AMME, KALA, KAHO, ALKA
Erosion and deposition[II]	Erosion and sedimentation are directly indicative of soil disturbance and movement and represent a significant threat to terrestrial, aquatic, and marine resources. In the PACN, soils occur in limited quantities (very thin or no soil in many locations) and have variable quality. Loss of soil through erosion can result in conversion or loss of entire vegetation communities. When suspended in water, fine sediments increase turbidity, decrease light penetration, and alter primary productivity. Sediments also settle on the bottom and smother benthic organisms such as corals.	I: Annually assess soil depth, quality (organic matter, pH, infiltration, aggregate stability, soil crusts), and loss/accretion at randomly selected monitoring sites stratified across rainfall and slope gradients in PACN parks. IIa: Seasonally (wet/dry season) measure water column turbidity at randomly selected marine and freshwater monitoring sites. IIb: Seasonally (wet/dry season) measure sediment collection rate and determine percent contribution and total load of terrestrial soils in marine and freshwater sediments at randomly selected, fixed monitoring sites.	WAPA, NPSA, USAR, KALA, HALE, PUHE

[a]. Justification is for entire Vital Sign, and is condensed. Justification for individual objectives is presented in protocol development summaries (appendix L).

[b]. Specific objectives presented here are condensed.

[I]. Implementation in phase 1.

[II]. Implementation in phase 2

Table 5.2. Summary information for PACN Vital Sign monitoring protocols—*Continued*.

Vital Sign	Justification[a]	Vital Sign Monitoring Objectives[b]	Parks Planned for Implementation
Early detection of invasive invertebrates[I]	Invasive alien species pose an enormous threat to the world's biological diversity, believed by most authorities to rank second only to land-use change. Hawaii has the most severe non-native species problem of any state in the United States, and other Pacific islands are comparably susceptible. Available strategies include prevention, early detection and rapid response with eradication or containment, and biological control. Early detection lends itself well to the goals of the NPS PACN monitoring program, especially the goal of heading off incipient problems before it is too late.	Ia: Develop a list of targeted known invasive invertebrate species (primarily ants, wood-boring beetles, and yellowjackets) that potentially pose threats to a park by causing major ecological or economic problems if they were to become established. Ib: Develop and implement an optimal search and reporting strategy for targets to efficiently cover highest risk sites and large areas. Ic: Working with partners, refine knowledge of dispersal pathways and search high-risk sites (port areas, industrial areas, nurseries) for targeted incipient populations. II. Determine management actions for eradication of highest priority invertebrate threats, based on life history attributes, dispersal modes, likely rate of spread, invasibility of surrounding areas, and number and size of known locations.	NPSA, KALA, HALE
Terrestrial invertebrate communities[II]	The terrestrial invertebrate fauna of the PACN is extraordinarily diverse and serves as a model for the evolution of island biotas worldwide. These species also play important functional roles in nutrient cycling, pollination, and as prey for endemic birds and bats. Invertebrates have been generally poorly inventoried and under-monitored in PACN national parks. However, taxonomically well-characterized endemic taxa (e.g., snails, picture-wing Drosophila, and native bees) are readily monitored.	Ia: Quarterly determine the relative abundance of terrestrial insects and other macroinvertebrate assemblages at bait stations along transects, stratified in representative wet, mesic, and coastal habitats. Ib: Annually conduct focal searches to detect rare or at-risk invertebrate taxa. IIa: Annually measure the relative abundance of native and alien terrestrial invertebrate species in paired treatment and non-treatment resource management sites. IIb: Seasonally (bimonthly) measure the population size and distribution of invasive predacious social insects, including ants and wasps.	AMME, WAPA, NPSA, KALA, HALE, PUHE, KAHO, PUHO, HAVO

[a]. Justification is for entire Vital Sign, and is condensed. Justification for individual objectives is presented in protocol development summaries (appendix L).

[b]. Specific objectives presented here are condensed.

[I]. Implementation in phase 1.

[II]. Implementation in phase 2

Table 5.2. **Summary information for PACN Vital Sign monitoring protocols**—*Continued*.

Vital Sign	Justification[a]	Vital Sign Monitoring Objectives[b]	Parks Planned for Implementation
Cave community[II]	Caves are particularly sensitive to physical disturbance and changes in the outside environment. Key reasons for monitoring cave habitat at PACN parks are: (1) Caves contain pre-contact Hawaiian ruins and artifacts which provide a wealth of information on early Hawaiian use and adaptation to the landscape, (2) Caves contain geologic information that may hold keys to understanding the formation and history of the islands, and (3) The living ecosystem in park caves harbor endemic, cave-adapted organisms.	Ia: Compile information and develop lists of known caves and cave resources within the PACN parks. Ib: Prioritize the list to identify caves with significant and vulnerable resources. Ic: Select candidate caves with significant resources for long-term monitoring. Monitor long term trends in: IIa: Cave arthropod diversity and relative abundance. IIb: The health of the cave ecosystem (distribution, abundance, breakage of tree root patches). IIc: The integrity of cultural and geological resources.	WAPA, NPSA, HALE, KAHO, PUHO, HAVO

[a]. Justification is for entire Vital Sign, and is condensed. Justification for individual objectives is presented in protocol development summaries (appendix L).

[b]. Specific objectives presented here are condensed.

[I]. Implementation in phase 1.

[II]. Implementation in phase 2

Summary

The Pacific Island Network is carefully planning the development and subsequent implementation of its monitoring protocols. By following national Inventory and Monitoring program guidance, we will produce protocols that articulate three important themes: applicability, reliability (i.e., scientific defensibility), and feasibility. Each protocol will consist of three primary sections: (1) a protocol narrative, (2) a set of standard operating procedures, and (3) supplementary materials, which are outlined by Oakley et al (1993). During protocol development and Vital Sign monitoring we will work closely the network Technical Committee, NPS leads, parks point of contacts and other park staff, as well as HPI-CESU cooperators.

Chapter 6. Data Management

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

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

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

Data Management Goals

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

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

> *"The data management mission of the Pacific Island Network is to provide data and information resources that are organized, available, useful, compliant, and secure."*

sets into modern formats and improve the quality and documentation of these datasets or other data originating from outside the Inventory and Monitoring program

- Objective – Work with partner agencies and institutions to promote the sharing and development of data, software applications, and analyses

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

Data Management Priorities—The priorities for network data management efforts are to:

* Produce and curate high-quality, well-documented data originating with the I&M program

* Assist with data management for current projects, legacy data, and data originating outside the I&M program that complement program objectives

* Help ensure good data management practices for park-based natural resource projects that are just beginning to be developed and implemented

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

Data Stewardship Roles and Responsibilities

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

Stewardship of data and information assets requires that knowledgeable individuals from scientific, administrative, and technological disciplines work in concert to ensure that data are collected using appropriate methods, and

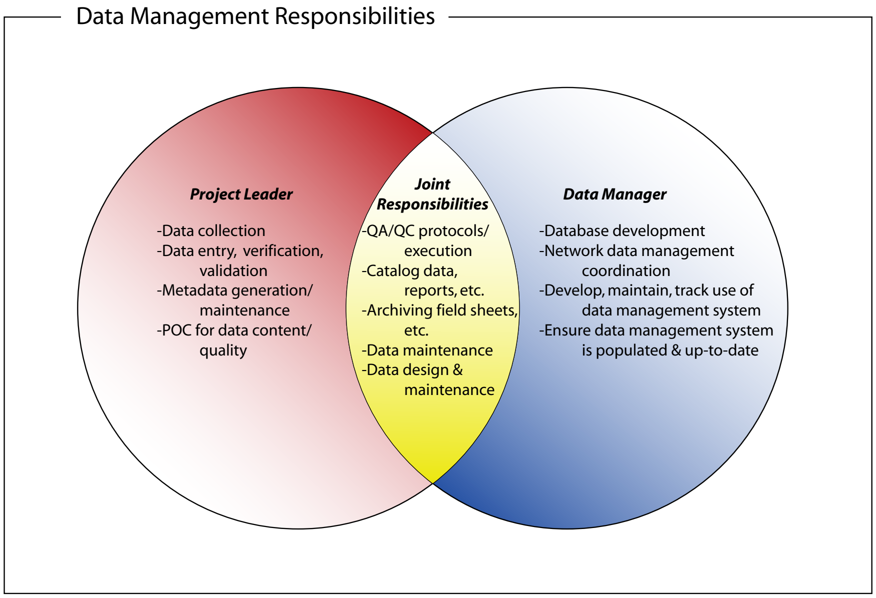


Figure 6.1. Core data management responsibilities for a project leader and the data manager.

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

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

"Datasets and the presentations of these data must be credible, representative, and available for current and future needs."

that resulting datasets, reports, maps, models, and other derived products are well managed. Datasets and the presentations of these data must be credible, representative, and available for current and future needs. Stewardship responsibilities apply to all personnel who handle, view, or manage data (table 6.2). Vital Sign monitoring protocols will describe more detailed, project-specific data stewardship roles and responsibilities.

Data and Information Workflow

Understanding the life cycle of data throughout a project will help to manage the staffing resources necessary to complete and support quality data. PACN projects include short-term data collection, analysis, and reporting efforts, such as inventories, and long-term efforts such as Vital Sign monitoring, as well as efforts external to the I&M program that generate data of interest to PACN. Short- and long-term projects share workflow characteristics and both generate products that must be managed and made

Table 6.2. **Programmatic roles and responsibilities for data stewardship.**

Role	Data Stewardship Responsibilities
Project crew member	Collect, record, and verify data
Project leader/principal investigator	Direct project operations. Communicate data management requirements and protocols to project staff, data manager, and GIS specialist(s). Responsible for data verification, validation, and documentation, and for submission of products and deliverables.
Data/GIS manager (project)	Develop and manage GIS data and metadata in standard file formats
Data/GIS specialist (network or region)	Process and manage data
Statistician/biometrician (project or network)	Analyze data and/or consult on analysis
Park research coordinator (park)	Facilitate data acquisition by external researchers; communicate NPS requirements to permit holders
Park resource specialist	Validate and make decisions about data
Curator (park or region)	Oversee all aspects of specimen acquisition, documentation, and preservation; manage park collections
Network data manager	Ensure inventory and monitoring data are organized, useful, compliant, secure, and available
Network ecologist	Integrate science in park and network activities
Network coordinator	Coordinate and oversee all network activities
GIS manager (region)	Support park management objectives with GIS and resource information management
Information technology specialist (region)	Provide IT support for hardware, software, networking
I&M data manager (national)	Provide servicewide database availability and support
End users (managers, scientists, interpreters, public)	Inform the scope and direction of science information needs and activities; interpret information and apply to decisions

available. The workflow of project management can be divided into five primary stages (figure 6.2), each of which entails a set of project management and data management tasks.

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

1. Planning and approval- In this stage, many of the preliminary decisions are made regarding project scope and objectives. In addition, funding sources, permits, and compliance are addressed. Primary responsibility rests with project leaders and program administrators. It is important that data managers remain informed of projects in this stage, especially as timelines for deliverables are finalized. Contracts, agreements, and permits should include standard descriptions for formats, specifications, and timelines for project deliverables.

2. Design and testing- During the design stage, details are worked out regarding data acquisition, processing, analysis, reporting, and availability. Applicable SOPs, guidance documents, and training materials are collected and/or developed. The project leader is responsible for development and testing of methods, sampling design, field forms, database design requirements, and SOP for data collection and processing. Regular communication between the project leader, the network data manager, and the regional GIS specialist will establish good data management throughout the project. An important part of such collaboration is the development of the data models and data dictionaries, which define in detail the parameters to be collected and allow the project leader, data manager, and GIS specialist to construct the project database application(s).

3. Implementation- During the implementation stage, data are acquired, processed, error-checked, and documented. This stage is also when products such as reports, maps, GIS themes, and other products are developed and delivered. The project leader oversees all aspects of implementation from logistics planning to data acquisition, report preparation, and final delivery. Throughout this stage, data management staff fills a facilitation role by providing training and support for database applications, GIS, GPS, and other data processing applications; facilitating data summarization, validation, and analysis; and assisting with the technical aspects of documentation and product development.

4. Product integration- During this stage, data products and other deliverables are integrated into national and network databases, metadata records are finalized and posted in clearinghouses, and products are distributed or made available to intended audiences. Another aspect of integration is merging data from a work-

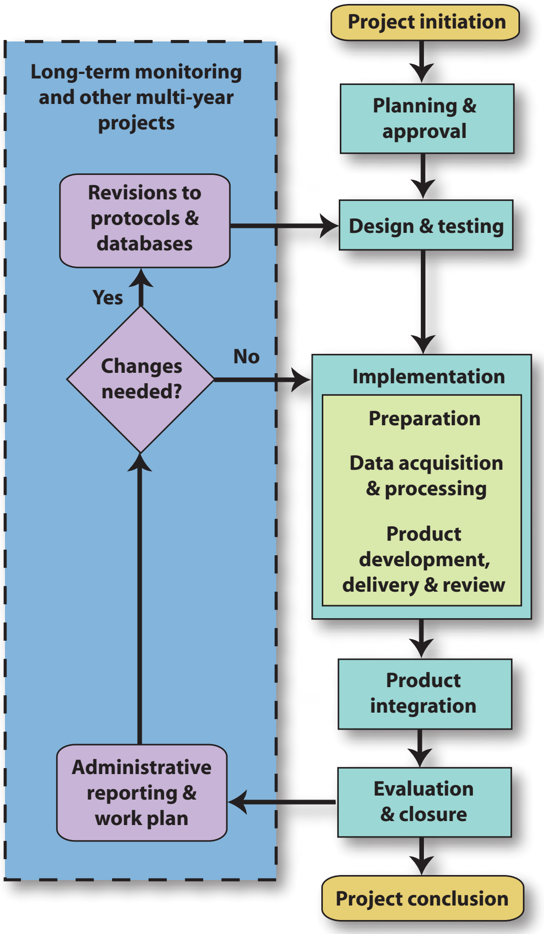


Figure 6.2. Project work flow with the five primary project stages shown in green boxes.

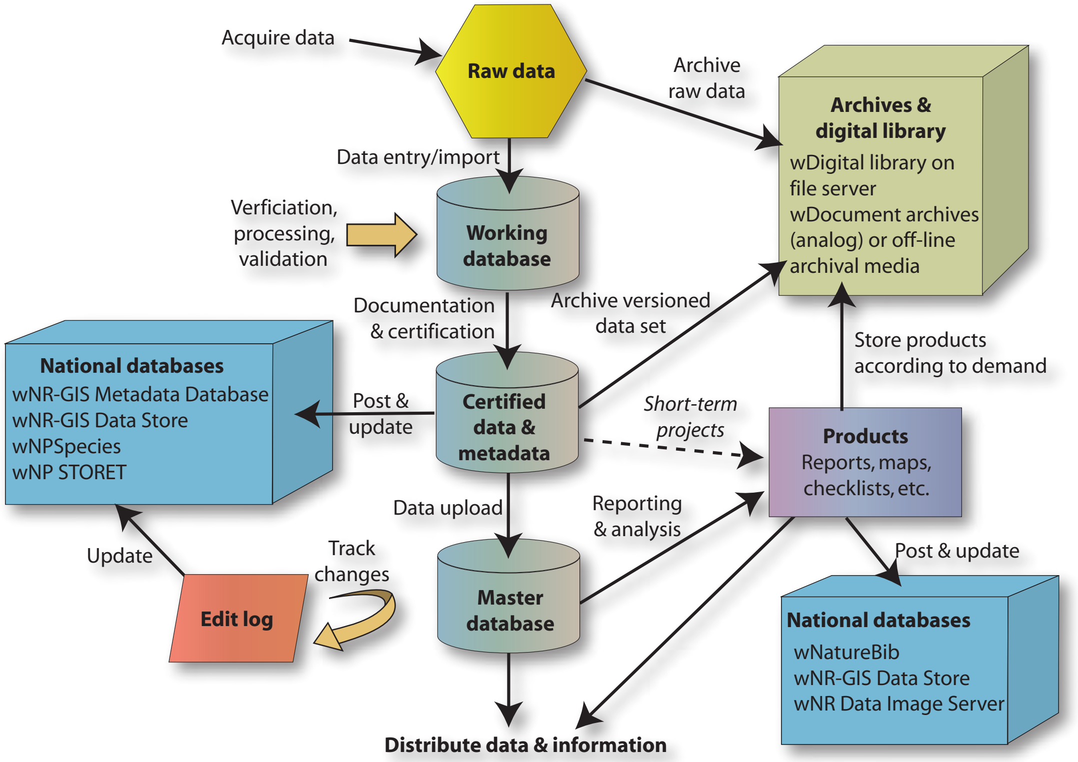
ing database to a master database maintained on the network server. This step occurs only after the annual working dataset has been validated and certified by the project leader. Certain projects may also have additional integration needs, such as when working jointly with other agencies sharing a common database.

5. Evaluation and closure- Upon project closure, network records and project-tracking tools are updated to reflect the status of the project and its associated deliverables. For long-term monitoring and other cyclic projects, this stage occurs at the end of each field season, and leads to an annual review of the project. For non-cyclic projects, this stage represents project completion. Program administrators, project leaders, and data managers will work together to assess how well the project met its objectives, and determine possible improvements in methodology, implementation, and formatting of the resulting information. For monitoring protocols, careful documentation of all changes is required. Changes to methods, SOPs, and other procedures are maintained in a tracking table associated with each document. Major revisions may require additional peer review.

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

- Raw data – Analog data recorded by hand on hard-copy forms and digital files from handheld computers, GPS receivers, telemetry data loggers, etc.
- Working database – A project-specific database for entering and processing data for the current season (or other logical time period); this may be the

Figure 6.3. Diagram of project data life cycle.



only database for short-term projects with no need to distinguish current season data from the full set of validated data

- Certified data and metadata – Completed data and documentation for short-term projects, or one season of completed data for long-term monitoring projects; certification is a confirmation by the project leader that the data have passed all quality assurance requirements and are complete and ready for distribution; metadata records include the detailed information about project data needed for its proper use and interpretation
- Master database – Project-specific database for storing the full set of validated project data; current season data from working database(s) must pass all quality assurance steps prior to upload into this master project database
- Reports and data products – Information that is derived from certified project data
- Edit log – A means of tracking changes to certified data
- National databases and repositories – Applications and repositories maintained at the national level, primarily for the purpose of integration among national park system units and for sharing information among NPS staff, cooperators, and the public
- Digital libraries and archiving – All certified digital files associated with a project are stored on file servers at the network level, including data backups; archiving of all project hard-copy items is accomplished at the park level by cultural resources staff, with coordination from both the project leader and PACN staff

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

Infrastructure and System Architecture

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

The infrastructure supports these required functions:

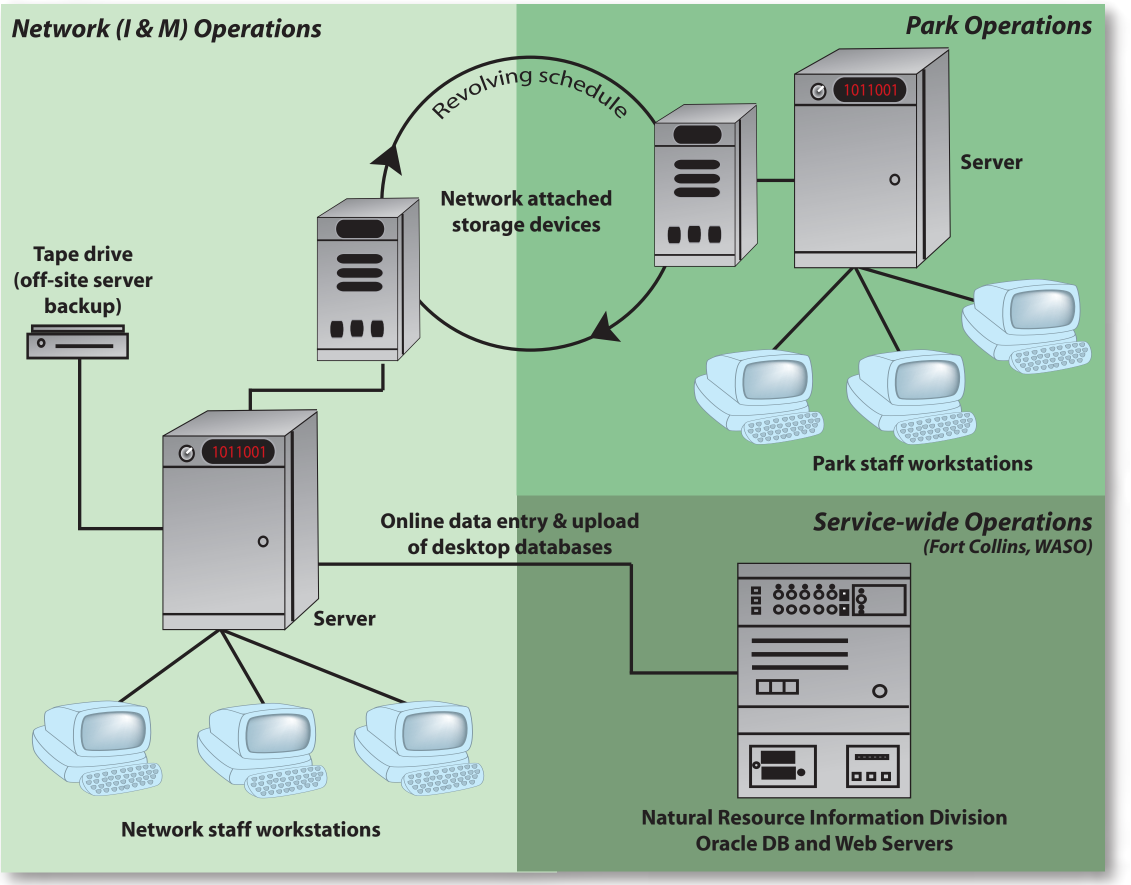
- Provides a central repository for master datasets
- Provides controlled subsets of data for local computing
- Provides a means for uploading and downloading data for both NPS and the public
- Supports desktop and internet applications
- Provides security, stability, and backups of digital data products

PACN offices are located at Hawaii Volcanoes National Park, and the PACN information system architecture consists of file and database servers maintained at the servicewide, network, and park level, with access by staff workstations provided through the regional wide-area network (figure 6.4). This system allows for park and PACN staff sharing of working files, PACN archiving of products and metadata, posting of products and metadata to national clearinghouses, and secure data backups.

Database Design Strategies

For PACN inventory projects and Vital Sign monitoring projects, the project leader and the

Figure 6.4. Schematic representing the layout and connectivity of IT resources. Most of the PACN natural resource information system is maintained on servers at the Servicewide and network levels.



data manager will work together to develop conceptual and logical data models to:

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

Each database must ultimately meet the needs of the project leaders and network staff. Considerations for these needs may include interactions with other agencies and ease of use, maintenance, integration, and customization.

Data management elements or principles common to more than one Vital Sign protocol will, to the greatest extent practical, be standardized so as to enhance overall data integrity and the comparability of data across the network.

Acquiring and Processing Data

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

- Program data – produced by projects that are initiated (funded) by and/or involve the I&M program (e.g., natural resource inventories and Vital Signs monitoring projects)
- Non-program legacy/existing data – produced by NPS entities without the involvement of the I&M program (e.g., park or regional projects)

- Non-program external data – produced by agencies or institutions other than the NPS (e.g., weather and water quality data)

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

Ensuring Data Quality

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

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

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

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

Data Documentation

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

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

Data documentation will be available and searchable in conjunction with related data and reports via the PACN website as well as the national I&M program's NR-GIS Metadata and Data Store, a searchable online application for managing and sharing natural resource and GIS metadata and data generated by the NPS.

Data Analysis and Reporting

Providing meaningful results from data summary and analysis is a cornerstone of the I&M program and characterizes the network's data management mission to provide useful information for managers and scientists. Each moni-

"Providing meaningful results from data summary and analysis is a cornerstone of the I&M program and characterizes the network's data management mission to provide useful information for managers and scientists."

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

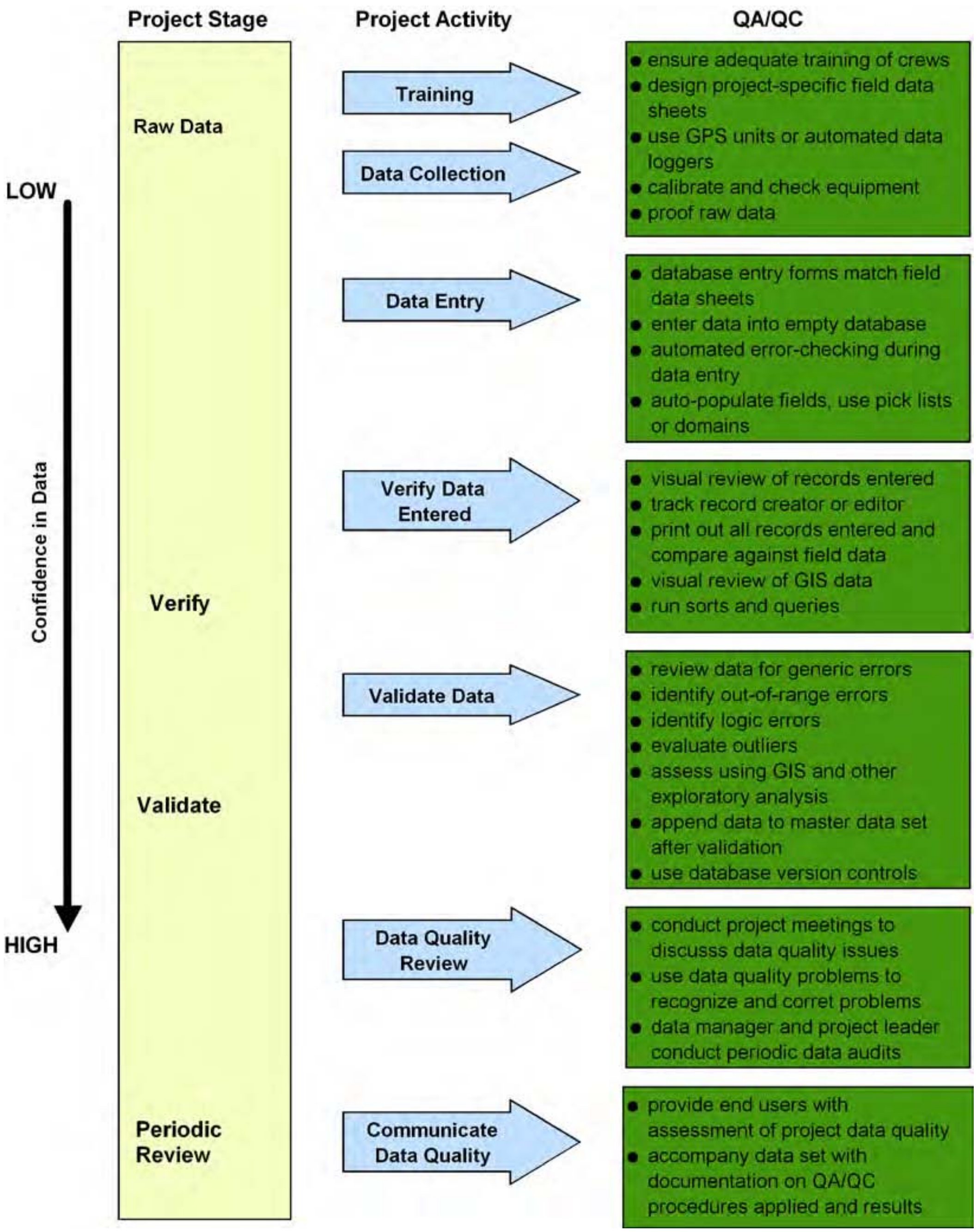


Figure 6.5. Schematic of the Quality Assurance/ Quality Control procedures to be carried out during the project stages associated with the typical data life cycle.

Data Dissemination

The PACN data dissemination strategy aims to ensure that:

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

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

- Links to public data products from PACN public website
- NR-GIS Metadata and Data Store, an online application for managing and sharing natural resource and GIS meta-

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

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

data and data (distribution instructions for each dataset will be provided in the respective metadata)

- Servicewide databases, such as NPSTORET for water quality data, NPSpecies for species biodiversity data, and NatureBib for bibliographic data
- Regional, network, or park data servers for providing datasets in a read-only format
- External repositories such as the University of Hawaii, US Geological Survey, US Forest Service, Bishop Museum, Western Regional Climatic Center, and many others
- FTP sites, CDs, DVDs, or hard drives, as appropriate

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

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

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

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

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

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

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

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

Digital Data Maintenance, Storage, and Archiving

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

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

Primary data maintenance occurs on the PACN file server and on Servicewide servers maintained by NPS staff and cooperators at the Washington Area Support Office in Fort Collins, Colorado. PACN staff are responsible for keeping data and information current on PACN and Servicewide servers, and depend on national and regional IT staff for assistance with regular data backups. PACN staff will ensure that the latest versions of primary data are available in conventional formats reflecting common data usages in the resource management community.

Project data are electronically archived as standalone products that include:

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

Non-digital Data Archiving and Records Management

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

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

Water Quality Data

All water quality data collected by the PACN will be managed according to guidelines from the NPS Water Resources Division. This includes using the NPSTORET desktop database application at the parks to help manage data entry, documentation, and transfer. PACN I&M data management staff will implement and maintain a desktop copy of NPSTORET and transfer its contents at least annually to NPS Water Resource Division for upload to the STORET database (figure 6.6). Although WRD's data dissemination needs dictate a monthly schedule for uploads to their data warehouse, PACN data collection and summation activities will likely be on an annual schedule requiring data uploads to the master WRD database only once a year.

> *"PACN staff will ensure that the latest versions of primary data are available in conventional formats reflecting common data usages in the resource management community."*

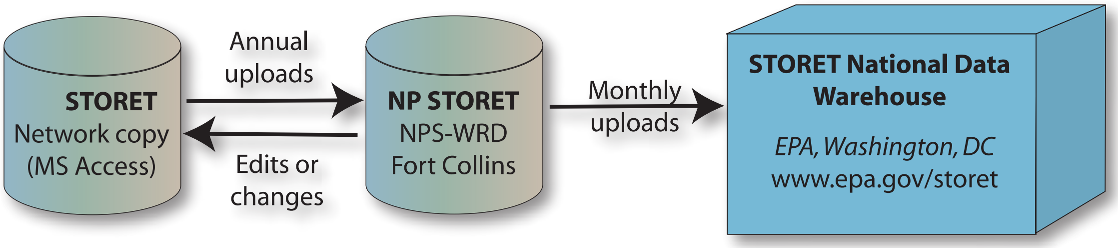


Figure 6.6. Data flow diagram for water quality data.

"The overarching goal of our data management strategy is to provide timely and usable scientific information about the status and trends of park resources to park managers."

Implementation

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

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

Summary

The overarching goal of our data management strategy is to provide timely and usable scientific information about the status and trends of park resources to park managers. The success of our program hinges upon our ability to produce, manage, and deliver this information to its intended audience. Our strategy aims to ensure the quality, interpretability, security, longevity, and availability of our natural resource data. In implementing our data management strategy we will strive for the following:

- Confidence in the security and availability of natural resource data and related information
- Easy access to most information, and appropriate safeguards for sensitive information
- Awareness of the intended use and limitations of each dataset
- Infrastructure and documentation that encourages data exploration
- Compatibility of datasets for exploration and analysis at larger scales and across disciplines
- Implementation of standards and procedures that facilitate information management, and that reinforce good habits among staff at all levels of project implementation
- A proper balance between the standards needed to ensure quality and usability, and the flexibility to meet specific needs and encourage innovation

The PACN Data Management Plan outlines how we intend to implement a data management strategy and maintain an infrastructure that will meet the data and information needs of our Inventory and Monitoring program. This plan reflects our commitment to establishing and maintaining a robust data management system to ensure the availability and usability of high-quality natural resource information.

Chapter 7. Data Analysis and Reporting

The six monitoring goals of the Pacific Island Network require communication of relevant, timely, and reliable monitoring results and related information to park managers, administrators, and the public. Consistent, diverse, and effective communications facilitate a smooth transition between the five steps in the cycle of adaptive management for natural resources (figure 7.1). Because the I&M program places a strong emphasis on information management, we must interpret and communicate monitoring results, as well as synthesize and analyze the information for appropriate audiences.

Figure 7.1. The five steps in the adaptive management cycle.

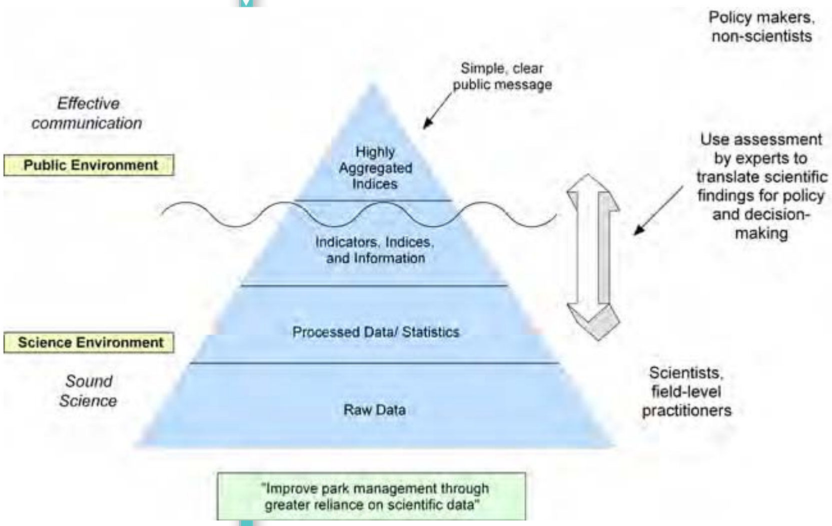
The broad-based, scientifically sound information obtained through natural resource monitoring has multiple applications for management decision-making, research, education, and promoting understanding of park resources. The primary audience for the results of Vital Signs monitoring are park managers. Monitoring results provide superintendents, park resource chiefs, and other managers with the data they need to make and defend management decisions and to work with others for the benefit of park resources. However, other key audiences for monitoring results include: park planners, interpreters, researchers and other scientific collaborators, the general public, Congress, and the President's Office of Management and Budget (OMB). To be most effective, monitoring data must be analyzed, interpreted, and provided at regular intervals to each of these key audiences in a format they can use. This means that there must be several different scales of analysis, and the same information needs to be packaged and distributed in different formats to the different key audiences.

Scientific data indicating the status and trends in the condition of park resources, which is needed to better manage the parks, will come

Figure 7.2. Data collection, analysis, and reporting of beach profile monitoring at American Memorial Park, Saipan.

from many sources. In addition to new field data collected (figure 7.2) through the I&M program, data will come from other park projects and programs, other agencies, and from the general scientific community . To the extent that staffing and funding are available, the network monitoring program will collaborate and coordinate with these other data collection and analysis efforts, and will promote the integration and synthesis of data across projects, programs, and disciplines (figure 7.3).

Figure 7.3. Transformation of scientific data toward effective communication for various audiences.



Analysis of Monitoring Data

Appropriate analysis of monitoring data is directly linked to the monitoring objectives, the spatial and temporal aspects of the sampling design used, the intended audiences, and management uses of the data. Analysis methods need to be considered when the objectives are identified and the sampling design is selected. Each monitoring protocol (chapter 5) will contain detailed information on analytical tools and approaches for data analysis and interpretation, including the rationale for a particular approach, advantages and limitations of each procedure, and standard operating procedures for each prescribed analysis.

Data analysis is the process by which observations of the environment are turned into meaningful information. Thus, data analysis includes quality assurance and control efforts that occur in field settings, during exploratory analysis and data interpretation, as well as when compiling reports. In this chapter we outline the general strategy the PACN will use for analysis of Vital Sign monitoring data.

PACN Analytical Strategies—In this monitoring plan, we identify two steps for analysis of PACN Vital Sign monitoring data: (1) data characterization (i.e., outliers, mean or median values, and other descriptive statistics), and (2) identification of the range of temporal and spatial variability and trends (MacCluskie & Oakley 2004). This range may include establishment of a normal range of variation and identifying valid data that falls outside these expected bounds. Establishing a range of normal variation may take years for many Vital Signs, and be both spatially and temporally scale-dependent. These two steps are included in data management and data stewardship strategies which are discussed in the PACN Data Management Plan.

Analytical Approaches for PACN Vital Signs—Several analytical approaches are anticipated for the PACN given the diversity of Vital Signs and associated management issues. Details on analyses will be provided in individual Vital Sign protocols. The approaches anticipated include: (a) integrative approaches such as diversity indices or multivariate analyses; (b) Bayesian, or probability distributions using pre-existing knowledge and accumulated monitoring data; (c) model development and testing, such as targeted searches for invasive species based on modeled habitat and dispersal patterns; and (d) hypothesis testing. It is important to note that individual or a combination of analytical approaches will be used with Vital Sign analyses.

Four basic levels of analysis will be common to the PACN monitoring data: (1) sample unit level, (2) sample frame and sample design level, (3) trend assessment level, and (4) data synthesis. The sample unit level addresses whether finite or infinite populations are included, and clarifies relative, absolute, or index response variables for individual monitoring locations. This facilitates clear data collection and data management which will produce comparable and scientifically valid data throughout the monitoring protocol.

The sample frame and sample design level of analysis provides within-year status estimates for an individual park. The sample frame and

Table 7.1. Four approaches to analyzing monitoring data.

Level of Analysis	Description	Responsible party
Sample Unit Level	Calculation of individual sample unit statistics from monitoring data (e.g., multiple sample locations along transects). Step 1: (characterization): Measures of mean, median, variation, and other basic statistics. Graphical presentation of data. Step 2: (range of variation): Establish historical or expected range of values, relationship to regulatory levels, and confidence intervals. Vital Sign Specific: Indices or other site-specific metrics may be developed.	Data management staff produce unit level summaries under the supervision of the protocol principal investigator, network coordinator, network data manager, and network ecologists*. Variables and procedures are specified in the monitoring protocol.
Sample Frame and Sample Design Level (Status Determination)	Integration of sample unit data across each park's sample frame to determine ecological status on a temporal basis. Step 1: Integration of sample unit summarization results across each park's entire sample frame. Step 2: Integration of sample unit variation results across the sample frame with additional refinement of spatial pattern analyses. Vital Sign Specific: Sample design and target population will guide selection of appropriate methods.	The protocol principal investigator, network coordinator, and network ecologists* share responsibility for frame level analyses. This entails consultation and assistance with partners, cooperators, subject matter experts, and regulatory agencies to conduct analysis and interpret results.
Trend Assessment Level	Evaluation of Vital Sign trends over time. Typically, regression will be among the methods used. Step 1: Integration of each park's sample frame summarization over time. Step 2: Integration of each park's sample frame variation results over time. Include establishing direction and rate of change that may be used to provide early warning. Confidence intervals for trends will be established. Vital Sign Specific: Parametric and nonparametric statistics and models will be used. Trend assessment will include accounting for influences of drivers and stressors.	The protocol principal investigator, network coordinator, and network ecologists* share responsibility for sample frame level analyses. This entails consultation and assistance from partners, cooperators, subject matter experts, and regulatory agencies to conduct analysis and interpret results. Comparison with other relevant long-term research and monitoring will aid interpretation.
Synthesis	Examination of patterns within and across Vital Signs and ecological factors to gain broad insight on ecological processes and integrity. Includes qualitative and quantitative comparison, additional data exploration, and development of predictive model based approaches.	The network coordinator and network ecologists* are the lead analysts, working with subject matter experts, partners, cooperators, and others to conduct analyses and assist with interpreting results. Integration with research and experimental work throughout the region is critical.

*Includes network quantitative ecologist.

"Monitoring program products should include a diversity of formats (i.e., written, oral, website, and informal) to reach the varied audiences in the PACN."

sample design level also identifies the spatial and temporal allocation of samples, such as the revisit scheme. The long-term trend assessment level of analysis integrates sample unit and sample frame data, where typically regression is used to identify the slope or trend over time. Finally, the synthesis level of analysis examines patterns within and across Vital Signs to gain broad insight into ecological processes and integrity. Each Vital Sign protocol identifies the sample design and analytical methods (table 7.1) with synthesis addressed at a network level rather than within individual Vital Signs.

Data analysis will be addressed in each Vital Sign monitoring protocol including: (a) adequate resources devoted to data analysis; (b) timely data analysis and feedback to field, operational, and management personnel; (c) analytical methods appropriate to sampling design using quantitative and qualitative principles; and (d) a discussion of adaptive analytical methods, documented in Vital Sign protocols and SOPs. An overview of analytical approaches for each PACN Vital Sign protocol under preparation is shown in table 7.2.

Communicating & Reporting

A well-communicated monitoring program will enhance resource protection and stewardship, and foster a stronger monitoring program and more effective resource management. All monitoring program elements are relevant to communication strategies including goals and objectives of the monitoring program and specific Vital Signs, administration, implementation, data management, data analysis, reporting, and outreach. To effectively reach the diverse audiences of the monitoring program, the PACN will adopt a variety of media tailored to each group. Clearly targeted audiences and communication venues are critical to reaching broad groups, and generating interest and concern toward resource protection and stewardship.

The network must emphasize prompt data analysis and communication on a regular schedule. A consistent schedule will ensure stronger communication between field scientists, data analysts, park interpretation staff, managers, planners, and others. A clear communication strategy will include both quality control and quality assurance issues that arise with delays in communication processes. Additionally, prompt and timely analysis, reporting, and communication of monitoring data and information are essential for effective adaptive management.

Reporting of Monitoring Results—Monitoring program products should include a diversity of formats (i.e., written, oral, website, and informal) to reach the varied audiences in the PACN. The dominant audiences for monitoring products and information are the resource managers and superintendents of each network park, along with other NPS managers who utilize status and trends information when making management decisions. Table 7.3 identifies schedules for reporting PACN monitoring results. Other target audiences include federal and state agencies, scientists, educators, and the general public.

The network recognizes that funding and time must be available to support these reports, meetings, and scientific symposia. Products that are produced by the network for dissemination to the parks and public must comply with applicable laws, be available on the internet, adhere to NPS Inventory and Monitoring program report format guidance, and include brief summaries with findings in the reports. Table 7.4 identifies product type, purpose, targeted audience, responsible party, production frequency, and review process in more detail.

The various approaches and products we plan to use to disseminate the results of the monitoring program and to make the data and information more available and useful to our key audiences are organized into the following seven categories and described in the following sections:

1. Annual reports for specific protocols and projects
2. Annual briefings to park managers
3. Analysis and synthesis reports
4. Protocol and program reviews
5. Scientific journal articles, book chapters, and presentations at scientific meetings
6. Internet and intranet websites
7. Interpretation and outreach

Table 7.2. Summary of analytical approaches for each PACN Vital Sign protocol.

Vital Sign protocol	Data analysis approach	Frequency of analysis	Responsible party for data analysis
Climate	Sample Unit level: Summaries and range-of-variation of monitoring variables (i.e., temperature and precipitation) at individual monitoring stations. Sample Frame level: Status analysis of individual variables (i.e., trade-wind and precipitation patterns) and indices (e.g., ENSO) at a park, regional (island group), and network level. Trend Assessment level: Trend analysis of individual station-based (unit level) variables and sample frame level status of both variables and indicators (i.e., drought and climate normals).	Annual summaries of individual station-based variables, annual sample frame-level analyses of status (both design- and model-based), and annual and decadal design- and model-based analyses of trends.	PACN ecologist
Groundwater dynamics	Sample Unit level: Salinity and water level in individual monitoring wells and anchialine ponds and discharge rates in seeps and springs. Sample Frame level: Groundwater models integrating geologic data with unit level measurements. Sample frame determined by variation at fixed points (wells). Trend Assessment level: Trends in individual (unit level) monitoring sites such as salinity and water level, with sample frame level trends in modeled groundwater levels and salinity.	Annual analysis of monthly sampling data for unit level trends, and modeled sample frame level seasonal and annual spatial patterns and temporal trends.	USGS-WRD cooperator/ partner; PACN aquatic ecologist
Water quality	Sample Unit level: Range-of-variation in core water quality variables of pH, temperature, salinity, dissolved oxygen, chlorophyll a, and nutrients (N and P) at randomly selected and fixed (continuously recorded) sites. Sample Frame level: Spatial distribution (mapping) of unit level parameters. Similar techniques as employed in EPA National Coastal Assessment (NCA) by park, island, and island group (Hawaii, American Samoa, Northern Mariana Islands). Trend Assessment level: Trend and rate of change at continuously monitored sites.	Annual analysis of continuously recorded sites for both within and multi-year trends. Decadal scale analysis of trends from geostatistical characterization and from probability-based monitoring.	PACN aquatic ecologist
Status and trends of established invasive plant species	Sample Unit level: Presence / absence of targeted species in specific park areas, and where spatial and temporal sampling efforts will be conducted. Sample Frame level: Species density, habitat range, and invasion fronts of targeted species as estimated within a sample frame consisting of corridors (transects, trails, and roads). Increased sampling effort along inferred invasion fronts. Trend Assessment level: Multi-year change in species density, extent, and habitat range, with emphasis on tracking change in invasion fronts and changes in multi-species invasion relationships.	Annual synthesis of plant species at unit and sample frame level, more frequent analyses of species with high rate of spread or high impact on native species.	USGS-BRD cooperator/ partner; PACN ecologist

Table 7.2. Summary of analytical approaches for each PACN Vital Sign protocol—*Continued*.

Vital Sign protocol	Data analysis approach	Frequency of analysis	Responsible party for data analysis
Early detection of invasive plants and Early detection of invasive invertebrates	Sample Unit level: Documented detection of targeted invasive species in units defined by duration and area of search effort. When in conjunction with random or systematic sample design, includes areas that are potentially susceptible to invasion and areas that are considered to be invasion free. Sample Frame level: Spatial layout targeted at geographic areas at risk for invasion by new species at scale of island regions, entire islands, and island groups. When in conjunction with random or systematic sample design, includes areas potentially susceptible to invasion and areas considered to be invasion free. Risk estimates based on presence/absence and search effort considered to be more appropriate than probabilistic estimates of abundance or status. Trend Assessment level: Annual and inter-annual variation in targeted species detection rates and geographic (map) distribution.	Annual reporting of documented casual reports and planned surveys.	USGS-BRD cooperator/ partner; PACN ecologist
Benthic marine community	Sample Unit level: Summaries and range-of-variation for annual % benthic cover by transect, rugosity ratios, recruitment rate by site, and growth rates by site. Spatial unit consists of fixed points along transect. Sample Frame level: Annual status of % benthic cover, rugosity ratios, recruitment rates, and growth rates for area of interest (e.g., entire park like KAHO, individual islands in NPSA, or individual units in WAPA). Spatial layout consists of transects on selected depth contours within accessible marine areas, but with no stratification. Statistical inference within spatial layout to be determined. Trend Assessment level: Multi-year change in % benthic cover, rugosity ratios, recruitment rates, and growth rates for both unit level data (transects/sites) and sample frame level areas of interest.	Annually, within six months of field data collection for each of the three levels.	NPS marine ecologist, PACN aquatic ecologist
Marine fish	Sample Unit level: Species richness and abundance by transect. Counts of species (or lowest selected taxon level) in units of known lengths along 25-m x 5-m strip transects. Sample Frame level: Annual status of species richness and abundance by park. Same spatial layout and inference as benthic marine protocol. Trend Assessment level: Year-to-year change in species abundance and distribution on individual transects and at sample frame level.	Annually, within three months of field data collection.	NPS marine ecologist, PACN aquatic ecologist

Table 7.2. **Summary of analytical approaches for each PACN Vital Sign protocol—*Continued*.**

Vital Sign protocol	Data analysis approach	Frequency of analysis	Responsible party for data analysis
Freshwater animal communities	Unit level: Summary and range-of-variation determined with monitoring parameters (density, abundance, and species composition) in quadrats of known area. Sample Frame level: Status analysis of individual unit-level parameters, within and between pool complexes, as well as longitudinal species distribution in each stream. Statistical inference within spatial layout to be determined. Trend Assessment level: Trend analysis of unit-level parameters and total species abundance in pool complexes or along stream reaches.	Annual (or after each sampling season) summaries of unit and sample frame-level analyses; annual (or after each sampling season) trend assessments.	USGS-WRD cooperator/ partner; PACN aquatic ecologist
Focal terrestrial plant communities	Sample Unit level: Summary and range-of-variation for species diversity and composition at monitoring plots, and abundance and density for targeted species at monitoring plots. Sample Frame level: Distribution (spatial and frequency) of community types, and distribution and gradient analysis of sample unit level variables by physical habitat type. Spatial layout and inference within layout to be determined. Trend Assessment level: Change in species diversity and composition at both unit level (monitoring plots) and in sample frame distribution. Change detection maps for distribution and gradient analyses by physical habitat type.	Annually, with multi-year and decadal comparisons for less frequently visited plots.	USGS-BRD cooperator/ partner; PACN ecologist
Landbirds	Sample Unit level: Summary and range-of-variation in plot and transects for species presence/absence and abundance, and correlation with habitat variables. Sample Frame level: Statistical inference within spatial layout to be determined. Correlation with habitat variables and documenting species distribution. Trend Assessment level: Trend in species presence/absence and abundance at individual sites, abundance across a given habitat, and changes in distribution (range expansion or contraction).	Annual for sites monitored, although individual sites may not be visited every year.	USGS-BRD cooperator/ partner; PACN ecologist
Seabirds	Sample Unit level: Range-of-variation and frequency distribution of active nesting burrows in monitoring plots; both random and targeted areas. Sample Frame level: Estimation of total nesting activity in known areas and identification of other similar habitats that may also contain active nesting burrows. Spatial layout and inference within layout to be determined. Trend Assessment level: Annual variation in total nesting activity in known areas and summary for park(s) and species.	Annual analysis post-breeding season.	PWR-HNL science advisor

Table 7.2. Summary of analytical approaches for each PACN Vital Sign protocol—*Continued*.

Vital Sign protocol	Data analysis approach	Frequency of analysis	Responsible party for data analysis
Bats	Sample Unit level: Range-of-variation and frequency distribution of detection using bat detectors (sound frequency), emergence counts, and individual counts. Unit of search effort to be determined. Sample Frame level: Estimation of species distribution and abundance (including density). Spatial layout and inference within layout to be determined. Trend Assessment level: Change in abundance and distribution by habitat.	Annual, post summer monitoring season for unit, sample frame, and trend levels.	PACN network coordinator/ ecologist
Landscape dynamics	Sample Unit level: Remote sensing image analysis which addresses pixel-by-pixel characterization, although unit-level emphasis typically focused on field-validation sites. Sample Frame level: Image analysis of remote sensing data addressing entire park; mapping land use and dynamic feature boundaries. Trend Assessment level: Change detection mapping, trend in land use density (development levels), and mapping of features such as invasive species fronts.	Decadal mapping of individual parks and affected region, annual narrative descriptive summary of change to facilitate decadal mapping and identifying rapidly changing areas.	PWRH cartographer, PACN geographer, PACN ecologist
Erosion and deposition	Sample Unit level: Soil and sediment depth, and soil type and benthic cover type at existing monitoring sites. Sample Frame level: Landscape dynamic and benthic cover types correlated with monitoring soil and sediment depth, and soil type and benthic cover type plot data to permit extrapolation across the landscape. Trend Assessment level: Loss and accretion rates at monitoring sites and scaled across landscape using landscape dynamic maps and benthic marine cover types.	Annual unit level monitoring of soil and sediment depth and trend assessment of unit level data. Also soil type and benthic cover type, with decadal (or other frequency as determined by landscape dynamics Vital Sign), sample frame level and trend assessments.	PACN ecologist and aquatic ecologist
Cave community	Sample Unit level: Summary and range-of-variation for physical parameters (i.e., temperature and moisture), human impacts (i.e., soil compaction and damage), and species presence / absence as well as abundance. Sample Frame level: Qualitative characterization of status in parks, and integrating the unit levels of physical, human impact, and species indices. Trend Assessment level: Site specific characterization of trends in physical and species parameters, with documentation of rate of human impact occurrence.	Annual synthesis of continuous data on physical parameters, 5-10 year analysis of human impact and species indices where monitoring activity has potential for impacts.	Bishop Museum cooperator; and NPS archaeologist

Table 7.2. Summary of analytical approaches for each PACN Vital Sign protocol—*Continued*.

Vital Sign protocol	Data analysis approach	Frequency of analysis	Responsible party for data analysis
Terrestrial invertebrate communities	Sample Unit level: Range-of-variation and summary of species diversity and abundance of target species. Sample Frame level: Variability and abundance across habitat types. Trend Assessment level: Year-to-year variability and trends at unit level monitoring stations and sample frame level assessments.	Annual where monitoring frequency permits, decadal at a minimum for less frequently monitored parks/sites.	USGS-BRD cooperator/partner; and PACN ecologist
Fish harvest	Sample Unit level: Visual and creel surveys to document effort, gear type, catch per unit effort. Sample Frame level: Park summary details of parameters. Trend Assessment level: Document change parameters and overall synthesis to park (sample frame) level changes.	Annual visual surveys and 5 year creel surveys.	NPS marine ecologist, PACN aquatic ecologist

Table 7.3. Schedule for recurrent reporting of PACN monitoring results to NPS staff.

Type	Purpose	Primary audience	Frequency	Primary presenter(s)
Technical Committee (administrative meeting)	Provide an update on network activities and findings; receive feedback from Technical Committee on resource issues and monitoring program	Park resource staff, partners from other agencies	Semi-annually	Network coordinator, ecologists, data manager, protocol managers
Board of Directors (administrative meeting)	Update park management and network managers on PACN operations; present draft budget and workplan; obtain feedback and guidance on administrative and programmatic issues, and park planning needs	Superintendents, PWR regional program manager, PWR science advisor(s)	Semi-annually	Network coordinator, ecologists, data manager
Protected area managers briefing / park science fair (results synthesis)	Communicate highlights and potential management action items, with 1-2 page briefing statements for each protocol	Park resource staff; network staff; agency and academia scientists; other federal, state, and territorial protected area managers, discipline specialists, interpretive staff	Annually, perhaps in conjunction with Board of Directors administrative meetings	Network coordinator, ecologists, and other scientists involved in parks monitoring
Park staff meetings (results synthesis)	Communicate network mission and results to a non-technical audience; receive feedback on resource and monitoring issues in park operations	All park staff, volunteers, and partners, especially those not typically encountered in I&M program operations	Annually, for each network park	Network coordinator, ecologists, data manager, biological technicians, CESU cooperators
Park trainings and orientations	Communicate inventory and monitoring (Vital Sign) results for further distribution to public	Park interpretive and outreach staff	Annually or as requested	Network coordinator, ecologists, data manager, biological technicians, CESU cooperators

Annual Reports for Specific Protocols and Projects—The primary purposes of annual reports for specific protocols and projects are to:

- summarize and archive annual data and document monitoring activities for the year;
- describe current condition of the resource;
- document changes in monitoring protocols; and,
- increase communication between the parks and network.

The primary audiences for these reports are park superintendents and resource managers, network staff, park-based scientists, and collaborating scientists. Most annual reports will receive peer review at the network level, although a few may require review by subject matter experts with universities or other agencies. Many of our monitoring protocols involve data collection each year, and those protocols will generate an annual report each year (table 7.4). However, some sampling regimes do not involve sampling every year. Those projects will produce "annual" reports only when there are significant monitoring activities to document. Wherever possible, annual reports will be based on automated data summarization routines built into the database for each protocol. The automation of data summaries and annual reports will facilitate the network's ability to manage multiple projects and to produce reports with consistent content from year to year at timely intervals. For analyses beyond simple data summaries, data will first be exported to external statistical software.

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 a "Science briefing for park managers" (possibly in conjunction with a Board of Director's meeting) in which network staff, park scientists, USGS scientists, collaborators from academia, and others involved in monitoring the parks' natural resources will provide managers with a briefing on the highlights and potential management action items for each particular protocol or discipline. These briefings may include specialists from the air quality program, fire ecology program, and collaborators from other programs and agencies to provide managers with an overview of the status and trends in natural resources for their parks. Unlike the typical science presentation that is intended for the scientific community, someone representing each protocol, program, or project will be asked to identify key findings or "highlights" from the past year's work, and to identify potential management action items. The scientists will be encouraged to prepare 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 compiled into an annual 'Status and Trends Report' for the network. In the process of briefing the managers, the various scientists involved with the monitoring program will learn about other protocols and projects, and the process will facilitate better coordination and communication, while promoting integration and synthesis across disciplines.

Analysis and Synthesis Reports—The role of analysis and synthesis reports is to:

- determine patterns/trends in condition of resources being monitored;
- discover new characteristics of resources and correlations among resources being monitored;
- analyze data to determine amount of change that can be detected by this type and level of sampling;
- provide context: interpret data for the park within a multi-park, regional, or national context;
- recommend resource management changes (feedback for adaptive management).

The primary audiences for these reports are park superintendents and other resource managers, network staff, park-based scientists, and collaborating scientists. These reports will receive external peer review by at least

"Periodic formal reviews of individual protocols and the overall monitoring program are an important component of the overall quality assurance and peer review process."

three subject-matter experts, including a statistician. Analysis and synthesis 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 analysis, more in depth than that of the annual report, requires several seasons of sampling data. Therefore, these reports are usually written at intervals of every three to five years for resources sampled annually, unless there is a pressing need for the information to address a particular issue. For resources sampled less frequently, or which have a particularly low rate of change, intervals between reports may be longer. An overview of anticipated PACN analysis and synthesis reports is presented in table 7.4.

It is important that results from all monitoring projects within and across all parks be integrated across disciplines in order to interpret changes to park resources. This will be accomplished with a network synthesis report produced at three to five year intervals.

Protocol and Program Reviews—Periodic formal reviews of individual protocols and the overall monitoring program are an important component of the overall quality assurance and peer review process. A review of each protocol will be conducted before the first five year analysis and synthesis report and in conjunction with future analysis and synthesis reports as needed, but at least at 10-year intervals. Because protocols must be reviewed in light of the data they produce, it is most efficient to review protocols coincident with synthesis reports. Features of these protocol reviews include:

- A USGS scientist, outside contractor, or academic is enlisted to analyze data, and evaluate results of the monitoring protocol (e.g., power analyses of the data) and report findings.
- Subject-matter experts/peers are invited to review the analysis and synthesis report, power analysis, and protocol.
- Subject-matter experts/peers are invited to a workshop to discuss the protocol, results of the data analysis and evaluation, whether or not the protocol is meeting its specific objectives and is able to detect a level of change that is meaningful, and to recommend improvements to the protocol.
- The protocol P.I., network coordinator, or contractor writes a report summarizing the workshop. The report is reviewed and edited by the participants, and then the final report is posted on the network's website. Copies of the report are sent to NPS regional and WASO program offices.

The network coordinator will initiate the network monitoring program review. The purpose of these reviews is to have the program evaluated by highly qualified professionals. Features include:

- Network staff and collaborators provide a summary of the program and activity to date including a summary of results and outcomes of any protocol reviews.
- Scientific review panel obtains input from Board of Directors, network staff, park scientists, and others. Panel holds a workshop to discuss the program and whether it is meeting its goals and expectations. Review panel makes recommendations for improving the effectiveness and value of the monitoring program.

Network coordinator develops a strategy with the PACN Technical Committee and Board of Directors as to which of the review panel's recommendations to implement.

Topics to be addressed during the program review include program efficacy, accountability, scientific rigor, contribution to adaptive park management and larger scientific endeavors, outreach, partnerships, data management procedures, and products. These reviews cover monitoring results over a longer period of time, as well as program structure and function to determine whether the program is achieving its objectives, and also whether the list of objectives is still relevant, realistic, and sufficient.

Scientific Journal Articles, Book Chapters, and Presentations at Scientific Meetings—The publication of scientific journal articles and book chapters is done primarily to communicate advances in knowledge, and is an important and widely-acknowledged means of quality assurance and quality control. 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. Network staff, park scientists, and collaborators will also periodically present their findings at professional symposia, conferences, and workshops as a means of communicating the latest findings with peers, identifying emerging issues, and generating new ideas.

All journal articles, book chapters, and other written reports will be listed in the network's Annual Administrative Report and Work Plan that is provided to network staff, Technical Committee, Board of Directors, and regional and national offices each year. Additionally, all scientific journal articles, book chapters, and written reports will be entered into the NatureBib bibliographic database maintained by the network.

Internet and Intranet Websites—Internet and (restricted) intranet websites are a key tool for promoting communication, coordination, and collaboration among the many people, programs, and agencies involved in the network monitoring program and the general public. 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/pacn

Documents to be posted to the network website include the PACN 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 as documents 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 materials which require restricted access can be shared within the program.

Interpretation and Outreach—The National Park Advisory Board, in their July 2001 report "Rethinking the National Parks for the 21st Century", wrote that "A sophisticated knowledge of resources and their condition is essential. The Service must gain this knowledge through extensive collaboration with other agencies and academia, and its findings must be communicated to the public. For it is the broader public that will decide the fate of these resources." In keeping with this statement and the vision statement of the PACN Board of Directors, the network will make a concerted effort, working with park interpreters and others, to ensure that the results of natural resource monitoring are made available to the interested public. To increase integration with the parks, the PACN I&M program is fostering cross-program coordination through environmental education and outreach activities with park employees, the public, and select community groups (figure 7.4). The PACN views interpretation divisions as particularly vital to this effort, as interpretive rangers are a major conduit of natural resource information from the parks to the public.

We will develop an internal science communications and outreach plan in FY 2007 to build

Figure 7.4 Bat researchers conducting outreach in Fagatele Village, Tutuila Island, National Park of American Samoa.

linkages with interpretation programs in all 11 PACN units. As part of this plan (initiated in FY 2006), the I&M science communications specialist, network coordinator, and program ecologists will meet with the interpretation divisions of all network parks during FY 2006-2007. These meetings will enhance mutual understanding of goals, identify needs for interpretive material, and generate joint outreach activities. One product of these meetings will be the development of a specific plan to integrate the Vital Signs monitoring program and scientific results as educational tools within each park.

The PACN staff is already working with chiefs of interpretation, staff interpreters, and others to convey information in interesting and understandable formats to various audiences (figure 8.4). Some examples of program integration already implemented are: a brown-bag lunch series with interpretation division staff, presentations at all-employees meetings in the parks and at public outreach programs (e.g., HAVO's "After-Dark-in-the-Park"), and informational newsletters distributed to regional and PACN park staff, as well as other agencies, university affiliates, and other entities. Other specific examples of how the PACN could integrate with outreach programs in network parks include:

- Participate in ranger and volunteer interpreter training in network parks by giving an overview of the I&M program, as well as providing specific scientific materials for interpreters and the public. For example, the I&M program has produced resource bulletins on several natural resource subjects, including bats and invasive species, that can be distributed to staff and the public. These bulletins provide information on natural history of species and conservation needs, such as species location documentation and identification of invasive plant locations.
- Participate in national park and community fairs and festivals with I&M exhibits. (Figure 7.5)
- Produce an interpretative program with park interpretation staff highlighting select public-interest natural resources, such as imperiled Hawaiian forest birds, or producing a bird species checklist for general use.
- Meet annually with park staff in a scientific forum to provide updates on network activities and identify opportunities for collaboration.
- Produce an I&M brochure for distribution at conferences and to the general public.
- Develop an outreach / environmental education plan targeting local community interests and values, as well as soliciting input and developing environmental education materials for use in schools, universities, national parks, and community-group activities.
- Work with Vital Signs protocol teams to develop and integrate each protocol's education and outreach component with parks, community groups, and educational institutions.

Figure 7.5. I&M staff and volunteers with interpretation and outreach display for cultural festival at Puukohola Heiau National Historic Site.

Table 7.4. Summary of anticipated Pacific Island Network reports, grouped by type and frequency.

Type of report	Purpose of report	Targeted audience	Initiated by	Frequency of reporting	Review process
Annual reports for specific protocols and projects					
Vital Sign monitoring protocol reports	Documents and archives annual monitoring activities and data, describes current resource conditions and 3 core analysis results, documents data management activities, documents changes in monitoring protocol, and communicates monitoring efforts to resource managers. During protocol development stages, report will emphasize progress made and challenges encountered.	Park resource staff, PACN staff, external scientists, partners	Protocol manager, network coordinator, ecologists, data manager	Annually	Peer review at network level
Non-technical summary of Vital Sign monitoring protocol reports	Prepared concurrently with "Vital Sign monitoring protocol reports" above, but highlights key points for non-technical audiences	Superintendents, NPS interpreters, public, partners	Network coordinator, science outreach staff (CESU), & interpretive divisions	Annually, compiled each spring	Peer review at network level
Annual briefings to park managers					
PACN Technical Committee and Board of Directors meetings (administrative meetings)	Review and summarize information on PACN Vital Signs, refine interpretation and presentation of information, identify emerging issues, assist with park planning, and generate new ideas	Superintendents, park resource staff, network staff	Network coordinator	Annually (integrated into existing meetings)	Meeting presentation is a form of peer review
Protected area managers briefing / park science fair (results synthesis)	Communicate highlights and potential management action items, with 1-2 page briefing statements for each protocol	Park resource staff, network staff, scientists, other federal, state, and territorial protected area managers, discipline specialists, interpretive staff	Network coordinator, PACN ecologists, and scientists involved in monitoring	Annually, in conjunction with Board of Directors administrative meetings	Peer review by network and monitoring staff
Analysis and synthesis reports					
Trend analysis and synthesis report	Describes and interprets patterns / trends of monitored Vital Signs resources, identifies correlations among monitored resources, identifies relationships between drivers / stressors and responses at various scales, recommends changes to management of resources (adaptive management feedback). Analysis and reporting will occur at multiple scales, including park, multi-park, and network / region.	Park resource managers, PACN staff, external scientists, partners	Protocol managers and network coordinator, ecologists, biological technicians, CESU cooperators	3-5 year intervals for all Vital Signs	Peer review at the network level and region

Table 7.4. **Summary of anticipated Pacific Island Network reports, grouped by type and frequency**—*Continued.*

Type of report	Purpose of report	Targeted audience	Initiated by	Frequency of reporting	Review process
Non-technical summary of trend analysis and synthesis report	Prepared concurrently with "trend analysis and synthesis report" above, but highlights key points for non-technical audiences	Superintendents, NPS interpreters, public, partners	Network coordinator, science outreach staff (CESU), and park interpretation divisions	Commensurate with reporting activity of "Trend Analysis and Synthesis Report"	Peer review at the network level
"Status and trends" (state of the parks) report for the PACN Vital Signs program	Describes current condition of park resources, reports trends and highlights of monitoring activities, identifies resource issues of concern, explores future directions	Superintendents, park resource managers, network and monitoring program staff, external scientists, partners, public	Network coordinator, ecologists	Annually, published each spring for preceding calendar year	Peer review at network level
PACN contribution to NPS-wide "state of the parks" report	Describes current conditions of park resources, reports interesting trends and highlights of monitoring activities, identifies resource issues of concern, explores future directions	Congress, budget office, NPS leadership, superintendents, general public	Compiled by the Washington Area Support Office (WASO) from data provided by networks	Annually	Peer review at national level
Protocol and program reviews					
Program review report	Periodic formal review of operations and results, including the effectiveness of communications to audiences, the use of results in adaptive management decision-making, and success at engaging external scientists through data sharing, or in designs of resource-monitoring studies	Superintendents, park resource managers, PACN staff, Servicewide program managers, external scientists, partners	Network coordinator, ecologists, data manager	5-year intervals, in accordance with PACN charter	Peer review at regional and national level, PACN Board of Directors, Technical Committee
Protocol review reports	Documents where protocol procedures fall short or exceed expectations, recommends necessary changes, documents changes since last protocol review report; and documents overall quality of protocol, focusing on protocol objectives, implementation, effectiveness, and data management	Superintendents, park resource staff, PACN staff, Servicewide program managers, external scientists, partners	Protocol managers, network coordinator, ecologists	Within 1-3 years of implementation, 5-year intervals thereafter	Peer review at network and regional level
Annual administrative report and work plan	Account for funds and FTEs expended. Describe objectives, tasks, accomplishments, products of the monitoring effort. Improves communication within park, network, and region.	Superintendents, Technical Committee, network staff, program managers, Congressional reporting	Network coordinator, ecologists, data manager	Annually, due early November	Reviewed and approved by BOD, regional I&M coordinator, and Servicewide program manager

Table 7.4. Summary of anticipated Pacific Island Network reports, grouped by type and frequency—*Continued.*

Type of report	Purpose of report	Targeted audience	Initiated by	Frequency of reporting	Review process
Scientific journal articles, book chapters, and presentations at scientific meetings					
Scientific journal articles and book chapters	Documents and communicates advances in knowledge, provides a broader perspective on quality assurance and peer review	External scientists, park resource managers, and professional staff	Protocol scientists, network coordinator, ecologists, data manager	Variable	Peer review according to journal or book standards
Other symposia, conferences, and workshops	Review and summarize information on PACN Vital Signs, help identify emerging issues and generate new ideas	External scientists, professional staff, and park resource managers	Network coordinator, ecologists, data manager, protocol scientists, CESU cooperators	Variable. Opportunities include professional conferences, NPS Pacific West Region meetings, and regional and national professional meetings	Peer review at network level; may also be peer reviewed if written papers are published
Internet and intranet websites					
Web-based media	Centralized repository of all final reports to ensure products are easily accessible in commonly-used electronic formats; other synthesized information on the PACN	Superintendents, park resource staff, PACN & NPS staff, Servicewide program managers, external scientists, partners, students, public	Network coordinator, ecologists, data manager	As media is completed	Peer review at network level to NPS web standards; and finalized, reviewed products
Interpretation and outreach					
Interpretive meetings	Interactive meetings with park interpretive staff to discuss key monitoring program findings as well as underlying data; discuss potential significance for management, further monitoring, additional research potential, and for outreach	Park interpretive staff, environmental educators, PACN staff	Network coordinator, ecologists, data manager, protocol scientists, biological technicians, CESU cooperators	Variable by park, at least annual when possible	Peer review by network staff
Park staff meetings (results synthesis)	Communicate network mission and results to a non-technical audience, receive feedback on resource and monitoring issues in park operations	All park staff, volunteers, and partners, especially those not typically encountered in I&M program operations	Network coordinator, ecologists, data manager, protocol scientists, biological technicians, CESU cooperators	Annually for each network park	Peer review by network staff
PACN newsletter	Review and summarize network activities and findings of general interest; describe the role and purpose of the network to non-technical audiences	Park staff, agency partners, cooperators, academia, informed public	Ecologists, CESU cooperators	Quarterly (email and web distribution)	Peer review by network staff and outside experts when necessary

“The communication and reporting plan for the PACN incorporates a diverse strategy to address our multiple audiences.”

Summary

The Pacific Island Network emphasizes providing park management with timely monitoring results that are synthesized with regards to monitoring goals and Vital Sign objectives. The PACN network will emphasize planning for data analysis and reporting throughout all facets of the monitoring program. Two data analysis outcomes are emphasized for PACN: (1) annual status summarization, and (2) long-term trend assessment. Expanding upon these two data analyses and management components, the network identified a hierarchy of four analytical strategies for Vital Signs: (1) sample unit level, (2) sample frame level, (3) trend assessment level, and (4) synthesis of results.

The communication and reporting plan for the PACN incorporates a diverse strategy to address our multiple audiences. The reports of the PACN emphasize communicating results of the program to the Board of Directors, Technical Committee, and other park staff, followed by other agencies, institutions, and the general public. This communication strategy will document long-term monitoring activities and facilitate program improvement, while validating the scientific integrity of the I&M program in the parks. These reports and products have been grouped into seven categories for our diverse audiences with the varied communication needs including: (1) annual reports for specific protocols and projects, (2) annual briefings to park managers, (3) analysis and synthesis reports, (4) protocol and program reviews, (5) scientific journal articles, book chapters, and presentations at scientific meetings, (6) Internet and Intranet websites, and (7) interpretation and outreach.

Chapter 8. Administration and Implementation of the Monitoring Program

To develop and implement a large-scale monitoring program in the 11 Pacific island national parks, a significant effort in planning and administration is required. This planning effort includes communication and decision-making between national, regional, network, and park levels. Furthermore, planning for long-term monitoring, as described in this chapter, requires: a staffing plan, integration of network functions with park operations, identification of key partnerships, established field procedures, and a periodic review process for the program.

PACN Administrative Structure and Function

The PACN charter (appendix P), signed in March 2001, describes the basic practices used to plan, organize, manage, evaluate, and modify the efforts of the PACN. The charter established the Board of Directors as the network's governing body and a Technical Committee to provide technical assistance and advice to the BOD. Amendments to the charter recognized the Ala Kahakai National Historic Trail as part of the PACN in December 2002 and designated the point of contact for the PACN databases in December 2003.

The Board of Directors for the PACN includes superintendents from each national park system unit in the network, plus additional ex-officio members with non-voting status (table 8.1). The charter specifies that one superintendent serves as the chairperson of the BOD on a rotating three-year basis and that all decisions are made by consensus. The BOD also provides overall direction for the PACN by reviewing and approving annual accomplishment reports, work plans, and budget.

The Technical Committee is composed of natural and cultural resource specialists and other key staff from each PACN park, USGS partners, science advisors, and I&M staff (table 8.2). The Technical Committee provides the BOD with information about park resources, participates in the development and evaluation of Vital Signs protocols, and reviews progress reports. The network coordinator chairs the TC and acts as liaison to the board.

The network is transitioning from inventories and planning for long-term monitoring to Vital Sign protocol development and implementation. In this process, the BOD will re-evaluate the network's administrative structure to ensure that the BOD and network information needs are continually met.

Table 8.1. PACN Board of Directors.

Title	Current Member	Voting	Advisor
Superintendent: AMME & WAPA	Sarah Creachbaum	X	
Superintendent: NPSA	Roger Moder	X	
Superintendent: USAR	Doug Lentz	X	
Superintendent: KALA	Tom Workman	X	
Superintendent: HALE	Marilyn Parris	X	
Superintendent: ALKA	Aric Arakaki	X	
Superintendent: PUHE	Daniel Kawaiaea	X	
Superintendent: KAHO & PUHO	Geri Bell	X	
Superintendent: HAVO	Cindy Orlando	X	
Pacific Area Director	Frank Hays	X	
PWR Coordinator	Penny Latham		X
PWR-HNL Science Advisor	Darcy Hu		X
Network Coordinator	Leslie HaySmith		X

PACN Staffing Plan

The PACN staffing plan is intended to assist the network with the professional expertise and scientific guidance needed to implement a scientifically credible monitoring program. Through diverse expertise, the staffing plan addresses critical long-term monitoring issues which are reflected in the network Vital Signs.

The proposed network staffing plan consists of eleven NPS positions which comprise a combination of permanent, permanent subject-to-furlough, term, and seasonal positions. These positions include a network coordinator/ecologist, four professional ecologists, two biotechnicians, a data manager, a database programmer (term), an administrative technician, and a GIS specialist (the latter two are <1.0 FTE). In addition to the above NPS/I&M positions, the network has proposed to allocate 1.0 FTE toward 6 parks, to cover staff time for field assistance in monitoring. The time allocation will cover eight weeks for field monitoring assistance in each of these parks (HAVO, HALE, KALA, AMME, WAPA, NPSA) for all of the Vital Signs monitoring. At the remaining five parks I&M PACN staff will conduct all of the monitoring, because small park staffs already have significant collateral duties. The other positions are Hawaii-Pacific Islands Cooperative Ecosystems Studies Unit (HPI-CESU) cooperators. Collectively, these positions meet the network's need for broad subject matter expertise in several areas, institutionalize professional data management practices, provide qualified field personnel, and ensure proper administration of the I&M program (figure 8.1).

Table 8.3 lists the primary responsibilities of these positions, the duty station, and time allocations. NPS term positions consist of a standard one to four year time period. CESU cooperator positions may change as program needs change.

Table 8.2. PACN Technical Committee (as of June 2006).

Name	Park	Scientific Discipline	Management Discipline
Leslie HaySmith[a]	I&M	Terrestrial ecology	Network coordinator
Doug Lentz[a]	USAR/PIN	NA	Board liaison
Darcy Hu	Network	Terrestrial flora and fauna	PWRH science Advisor
Larry Basch	Network	Marine ecology	PWRH-Coral Reef Program Science advisor
Tavita Togia	NPSA	Natural resources	Natural resource specialist
Dwayne Minton	WAPA & AMME	Marine sciences	Natural resource specialist
Guy Hughes	KALA	Wildlife biology	Natural resource management
Steve Anderson	HALE	Vegetation	Natural resource specialist
Linda Pratt[b]	USGS/BRD (HAVO)	Botany	Natural resource management
Rhonda Loh	HAVO	Vegetation	Natural resource management
TBD	PUHO	Archaeology	Cultural resources
Sallie Beavers	KAHO	Marine ecology	Natural resources
Stephen Anthony[b]	USGS WRD (Honolulu)	Aquatic (groundwater, water quality)	Natural resources

[a]. Not a voting member.

[b]. USGS agency scientist; all others are NPS staff.

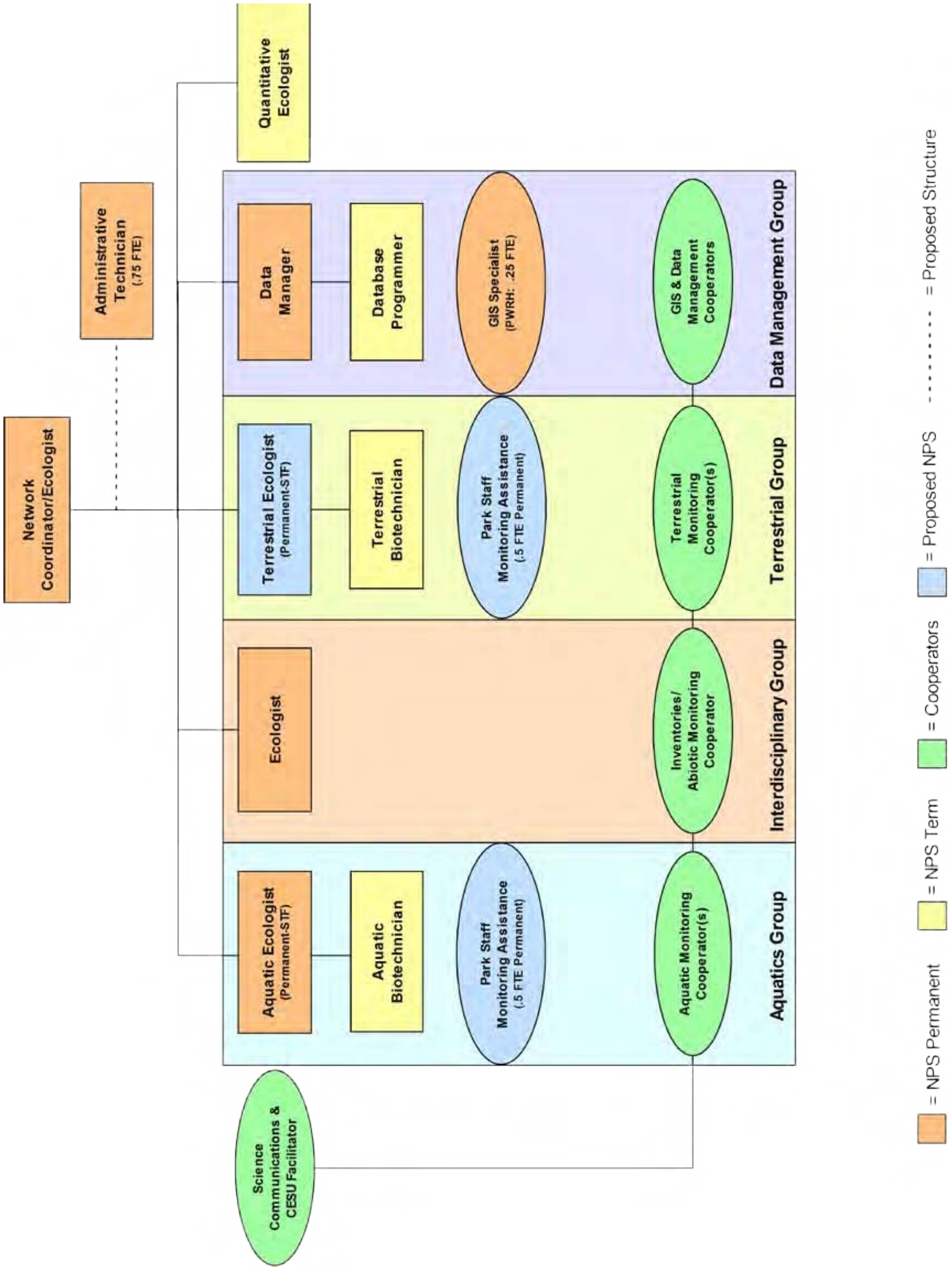


Figure 8.1. Proposed PACN organization chart.

Table 8.3. PACN staff and their duties.

Position	Duty Station	Primary Duties	% of Time
		NPS Permanent Positions	
Network coordinator/ ecologist (GS-12)	HAVO	Provides direction and manages overall planning and implementation of the PACN I&M program, including communications with network parks, the Board of Directors, Technical Committee, Scientific Review Panel, PWR regional coordinator, and agency or CESU cooperators; administers/oversees program budget and coordinates development of monitoring plan	35
		Oversees protocol development and implementation to ensure scientific integrity of sampling design, data analysis, summary, and reporting; as ecological duties inter-mingle, oversees biological protocols; serves as principal investigator on selected projects	30
		Supervises PACN professional level positions and provides general oversight and accountability for the program	15
		Ensures scientific and program information is communicated to parks and partners in useful formats, working with interpretation and other divisions	10
		Coordinates and oversees I&M partnerships	10
Ecologist (GS-11)	HAVO	Provides guidance, oversight, and management of I&M projects, particularly physical Vital Signs, including data analysis, summary and reporting, data validation and verification; serves as NPS lead on relevant protocols under development, works extensively with monitoring plan and protocol documents	25
		Works with administrative components of program including budget, task agreements, and contracts	25
		Oversees and provides input to program and select protocol projects on data management, data programming, and adherence to I&M policies on data management	25
		Works with program professionals to provide information to parks and partners in useful formats, including web-design and other written communications	10
		Provides oversight to selected I&M projects and liaises with CESU cooperators on projects	10
		Initiates and coordinates I&M partnerships	5
Aquatic ecologist (GS-11, Subject to furlough)	HAVO	Coordinates all aspects of aquatic I&M projects, including aquatic projects sampling design and pilot testing, data collection and analysis, project documentation and metadata management, data validation and verification, and preparation and dissemination of Vital Sign protocols, project summaries, and reports	35
		Serves as the primary network expert for aquatic resources issues and provides guidance, oversight, and management of aquatic I&M projects	25
		Works with program professionals to provide information to parks and partners in useful formats for aquatic related projects	20
		Initiates and coordinates aquatic related I&M partnerships	10
		Primary liaison for CESU technicians working on aquatic I&M partnerships	10

Table 8.3. **PACN staff and their duties—*Continued*.**

Position	Duty Station	Primary Duties	% of Time
Data manager (GS-11)	HAVO	Ensures project data conforms with program standards and serves as lead in data archiving, security, and dissemination; database development; and overall QA/QC for the I&M program by working with protocol PIs and NPS leads to develop data entry forms, project QA/QC procedures, and automated reports	50
		Supervises data management staff and provides oversight and supervision for data management activities; provides oversight to CESU cooperators in parks and for data management	25
		Coordinates and implements data management partnerships	15
		Collaborates with PWRH GIS specialist to maintain standards for data and associated metadata, and ensures GIS information is provided to network parks and partners in useful formats	10
GIS specialist (GS-11)	HAVO	Coordinates the dissemination of I&M-generated GIS information with clearinghouses; works closely with I&M data manager and other data management staff (supervised by PWR-Honolulu office; funded 0.25 by PACN I&M)	25
Administrative technician (GS-7)	PWR-HNL	Provides administrative support for NPS staff, including working with I&M budget, travel, purchasing, and other program support needs (supervised by PWR-Honolulu science advisor; funded 0.75 by PACN I&M)	75
NPS Term Positions			
Quantitative ecologist (GS-11)	HAVO	Serves as subject matter expert for protocol sampling designs and analytical methods by providing input on within-park and between-park sampling designs for Vital Signs monitoring, and assures continuity between monitoring projects such as co-location and co-visitation, whenever possible; serves a dominant role in development and writing of Vital Signs protocols	100
Database programmer (GS-9)	HAVO	Performs database design and data management with protocol PIs, NPS leads, and park staff conducting I&M-related work; works closely with the data manager	60
		Conducts data archiving and dissemination, assists with QA/QC procedures for I&M metadata and datasets	40
Aquatic biotechnician (GS-5/7)	KAHO	Serves as field biotechnician on aquatic-based Vital Signs monitoring projects in all PACN parks (Water quality, Groundwater dynamics, Benthic marine, Marine fish, Fish harvest, and Freshwater animal communities); works closely with aquatic ecologist; works with I&M ecologists, PIs, and NPS leads to collect monitoring data, including water quality, document methods, verify and correct data values, and document procedures and deviations from protocols; assists in preparation and writing of monitoring protocols; performs data management duties on aquatic projects	30
		Conducts data entry and verification, including performing regular data transfer and backup.	20

Table 8.3. PACN staff and their duties—*Continued.*

Position	Duty Station	Primary Duties	% of Time
Terrestrial biotechnician (GS-5/7)	TBD	Serves as field biotechnician on terrestrial-based Vital Signs monitoring projects in all PACN parks (3 Plants-related protocols, Landbirds, Seabirds, Bats, Climate, Landscape dynamics, Terrestrial invertebrates, and Caves); works closely with I&M network coordinator, ecologists, terrestrial ecologists, PIs, and NPS leads to collect monitoring data, document methods, verify and correct data values, and document procedures and deviations from protocols; performs other data management duties on terrestrial projects, and assists with writing of monitoring protocols	100
Proposed NPS Positions			
Terrestrial ecologist (Perm-STF, GS-7/9)	HAVO	Serves as project coordinator and planner for terrestrial-based Vital Sign monitoring in PACN parks (3 Plants-related protocols, Landbirds, Seabirds, Bats, Climate, Landscape dynamics, Terrestrial invertebrates, and Caves); serves as lead coordinator and ecologist for terrestrial ecology components of the program protocols; coordinates monitoring implementation in all parks where terrestrial projects will occur and works closely with I&M ecologists, PIs, and NPS leads; this includes site-specific field scientific issues, logistical monitoring issues, schedules with I&M and park-staff who assist with monitoring, and leading field crews; works closely with PACN network coordinator/ecologist, quantitative ecologist, and other staff, as well as CESU cooperators in planning, and assists with writing of monitoring protocols; ensures data management duties are maintained	100
Parks staff monitoring assistance (GS variable)*	HAVO HALE KALA NPSA WAPA AMME	Provides park-specific and on-site monitoring field assistance with terrestrial and aquatic related monitoring projects; works closely with Vital Signs monitoring teams when teams are conducting monitoring in parks; advises on field sampling, logistics, and management concerns; may assist with preparation and or reviews of park-specific components of monitoring protocols; total allocation for each park is 8 weeks per year for planning field data collection, data analysis, management, and reporting.	23
CESU Cooperators			
Science communications/CESU facilitator*	HAVO	Provides administrative support and supervision for the CESU cooperators, including management of the CESU budget and administration of the HPI-CESU task agreement between NPS and University of Hawai`i at Manoa	50
		Works closely with various PACN park divisions, partners, and communities to communicate I&M activities and scientific findings through outreach programs, preparation of newsletter and other publications, and other outreach venues; works closely with network park interpretation specialists	25
		Provides technical support for PIs and NPS leads to develop and support the implementation of the education outreach sections of the monitoring protocols	25

Table 8.3. PACN staff and their duties—*Continued*.

Position	Duty Station	Primary Duties	% of Time
Inventories Coordinator/ abiotic monitoring facilitator	HAVO	Works with I&M ecologists, PIs and NPS leads to collect data on abiotic protocols including climate data (from field or existing sources), document methods, verify and correct data values, and document procedures and deviations from protocols; position liaison with I&M staff; conducts data entry and verification, including performing regular data transfer and backup; works on planning, preparation, and writing phases of climate monitoring protocol	60
		Works with network coordinator, I&M ecologists, and parks staff to develop a long-term inventory strategy, and oversees all inventory reports to publication	40
Aquatic monitoring cooperators	TBD	Works on development of aquatic-related protocols; works with I&M ecologists, PIs and NPS leads to collect aquatic projects data (Benthic marine communities, Marine fish, Fish harvest, Water quality, Freshwater animals, and Groundwater dynamics); documents methods, verifies and corrects data values, and documents procedures and deviations from protocols; assists with preparation and writing of monitoring protocols	70
		Conducts data entry and verification, including performing regular data transfer and backup	30
Terrestrial monitoring cooperators	TBD	Works on development of terrestrial-related protocols; works during implementation stages with I&M ecologists, PIs and NPS leads to collect terrestrial projects data (3 **Plants-related protocols, Landbirds, Seabirds, Bats, Climate, Landscape dynamics, Terrestrial invertebrates, and Caves**); documents methods, verifies and corrects data values, and documents procedures and deviations from protocols; assists with preparation and writing of monitoring protocols	70
		Conducts data entry and verification, including performing regular data transfer and backup	30
Data management assistant	HAVO	Provides technical support for database design and data management with protocol PIs, NPS leads, and park staff conducting I&M-related work; works closely with the data manager and database programmer	60
		Assists with metadata creation and GIS/GPS support for I&M projects	40
GIS specialist	HAVO	Develops GIS spatial data layers for 18 Vital Signs long-term Vital Signs monitoring projects; coordinates with I&M ecologists, PIs, and NPS leads in developing spatial layers for long-term monitoring, which includes protocol development and implementation, once monitoring data is available; works closely with I&M data manager and PWRH GIS specialist	100

“The PACN depends on substantial involvement of numerous park staff, and agency partners to execute the program.”

Information Exchange within the Pacific Island Network

In addition to positions in the staffing plan, the PACN depends on substantial involvement of numerous park staff, and agency partners to execute the program. The staffing plan in figure 8.1 provides for staff to conduct field monitoring through a combination of NPS permanent, subject-to-furlough, term, and seasonal positions, along with assistance by CESU cooperators. Therefore, the needs for Vital Signs monitoring that remains are dominantly travel and equipment costs. This staffing plan helps address a long-held concern by parks’ staff, regarding how monitoring will be accomplished, since many park staff are already working on numerous collateral duties. We elaborate on the some of the advantages and disadvantages of various staffing plan approaches in table 8.4. Based on the network’s experience to date, we anticipate that a combination of three or more of the staffing approaches described in table 8.4 will be employed during operational monitoring. Final staffing decisions will be made by the PACN Board of Directors.

In addition to working closely with the BOD, TC, and parks staff, I&M works extensively with Pacific West Regional offices, the NPS Washington Area Support Office, and network IT and regional GIS staff. This information exchange ensures continuity and adherence to the program mission and guidance, and it allows for broad technical support.

I&M staff will also guide and administer the monitoring protocol development teams. Since the PACN staffing plan combines permanent, subject-to-furlough, term/seasonal, park staff assistance, and CESU cooperator positions, the plan is fiscally conservative, while allowing staffing flexibility as the program matures. Figure 8.2 provides a more comprehensive schematic of the network staff and their interactions with other entities, including recommendations for a scientific review panel to work closely with the TC.

In accordance with the language in the PACN charter, the Technical Committee can establish finite-term sub-committees to address various issues, including soliciting scientific advice from internal and/or outside scientists. One of these

Table 8.4. Additional staffing approaches for accomplishing PACN monitoring tasks.

Approach	Program element addressed	Advantages	Disadvantages
Permanent professional positions	Program administration, planning, data analysis and interpretation	Consistency, technical knowledge, accountability	Long term commitment of funds, NPS administrative costs
Permanent technician positions	Data collection, data entry	Consistency, direct supervision by core staff	Long term commitment of funds, NPS administrative costs
Seasonal technician positions	Data collection, data entry	Direct supervision by core staff, flexibility	Turnover will increase training needs and decrease consistency, NPS administrative costs
Contractors/ Cooperators	Data collection, data entry, analysis and interpretation	Flexibility, technical knowledge	Turnover will increase training needs and decrease consistency, non-supervision by NPS core staff
Multi-year graduate and undergraduate interns	Data collection, data entry, analysis and interpretation	Low cost, flexibility, integration with agency and research partners, technical knowledge	Lack of consistency

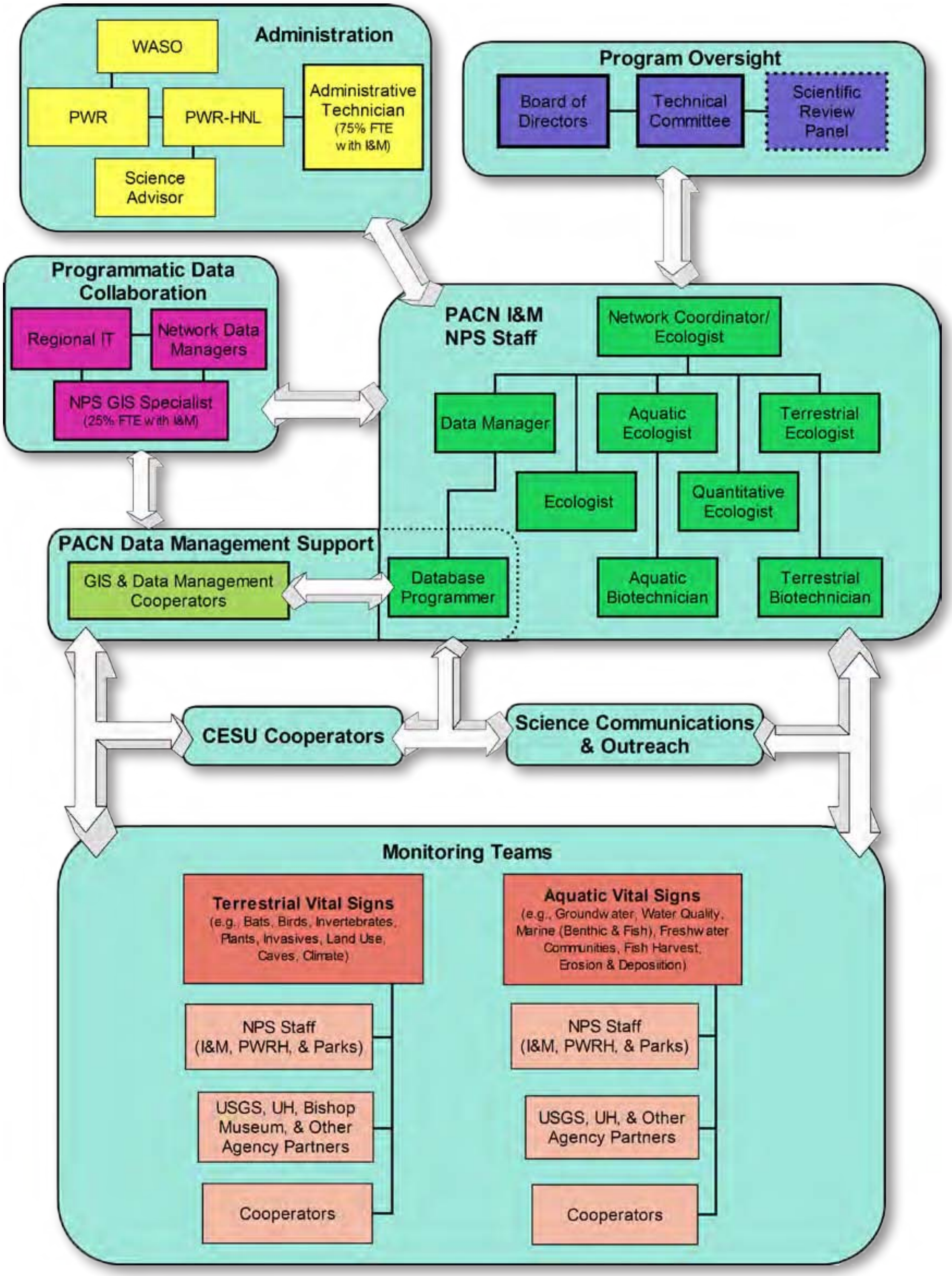


Figure 8.2. Interactions between Pacific Island Network staff, cooperators, and national and regional offices.

“One of the keys to monitoring success is adequate integration of I&M with other park programs. . . and with non-NPS partners.”

sub-committees, the Scientific Review Panel (SRP), can offer relatively unbiased reviews of Vital Signs protocols throughout the development process and into the implementation phase for PACN parks. Scientific Review Panel members will be selected through recommendations generated by PACN I&M, reviewed and approved by the TC, with final approval given by the BOD. The TC will review and approve the SRP recommendations of Vital Sign protocols before they go to the BOD. Specific roles of the SRP are listed in table 8.5.

Inventory and Monitoring Partnerships and Program Integration

One of the keys to monitoring success is adequate integration of I&M with other park programs, including interpretation and outreach efforts, park resource operations, and with non-NPS partners. Figure 8.3 illustrates the manner that I&M can serve as a catalyst for integration of Vital Signs monitoring programs and individual parks. In addition, the Vital Signs development and implementation phases must allow for adequate planning through the park divisions and permitting processes, which include compliance with the National Environmental Policy Act (NEPA) and National Historic Preservation Act (NHPA) for monitoring projects.

Integration with Park Operations—To better integrate with park operations, the network has assigned an NPS lead and an I&M project manager to work closely with each principal investigator in developing monitoring protocols. The NPS leads are responsible for contacting parks and exchanging information about protocols under development, particularly where these may impact or interact with ongoing park operations. Additionally, the PACN I&M program has conducted meetings with staff at each network park to explain the I&M program, identify their needs, and acquire additional staff knowledge on historical changes of our Vital Signs. These meetings enhance the network’s ability to work collaboratively with select park divisions, better understand the scope of work conducted by those divisions, and identify how the PACN I&M program can collaborate on various activities to enhance respective goals (figure 8.3). Additional integration is facilitated through the network’s Board of Directors and the Technical Committee, who bring pertinent activities and concerns of network parks to the attention of the I&M program, and vice versa. Furthermore, the information that I&M will provide through numerous reporting mechanisms (chapter 7), will facilitate more open and frequent communications between network parks.

Partnerships and Integration with other Programs—Partnerships with universities, NGO’s and other organizations make use of expertise inside and outside of the NPS. Numerous partners have been involved in inventories of PACN park resources and development of monitoring protocols (appendix B). Due to the iterative process in developing the I&M program, the Pacific Island Network will solicit more partners as protocol development progresses. Furthermore, the PACN recognizes the importance of integrating our Vital Signs monitoring with other federal, state, and commonwealth agency programs. The USGS Biological Resources and Water Resources Divisions, as well as the NPS Pacific Islands Coral Reef program are working closely with the PACN on inventory projects and on development of Vital Signs monitoring. The network will further identify ways to work with the USGS-BRD and WRD, the USDA Forest Service (USFS), DOI Fish and Wildlife Service (USFWS), and state, territorial, or commonwealth natural resource programs. In addition, PACN works closely with the Hawaii-Pacific Islands CESU on cooperative agreements for inventories and monitoring.

Program Review and Management

Adaptive Management—The PACN monitoring plan is an active and iterative document with an adaptive modification process based on monitoring results, budget, program reviews, and other factors. For example, while monitoring protocols are being developed, the costs for monitoring are only estimates. Therefore, once monitoring data are available, decisions must be refined regarding sampling design, numbers and locations of permanent plots, and other critical implementation issues. Once completed, these protocols may be revised to accommodate new methodologies or analyses, based on monitoring results. For example, if response variables

Table 8.5 Roles of the scientific review panel in the Pacific Island Network monitoring programs.

1. Review study plans of Vital Signs protocols focusing on: scientific feasibility of objectives, methodologies, sampling schemes, and budget adequacy for scientific methods proposed
2. Review draft protocols for network application before being sent for external peer review
3. Evaluate and provide input on long-term VS monitoring after implementation. This evaluation addresses: (a) scientific issues (e.g., species or ecosystem applications, methodologies, ecological sampling problems), (b) VS data-based results, and (c) trends analysis results
4. Provide advice to the Technical Committee who makes recommendations to the BOD

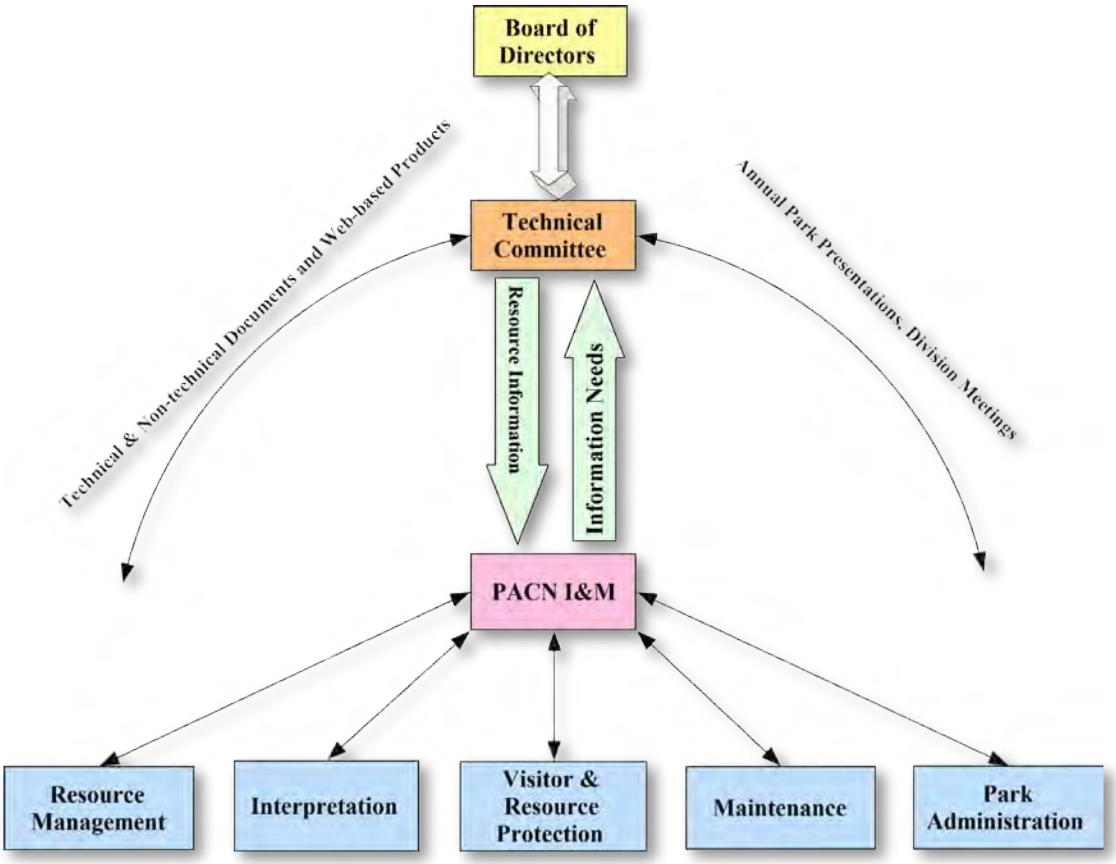


Figure 8.3. Integration of the PACN Vital Signs program into park operations.

have more variability than originally planned in sampling layout, more samples may be necessary to reach stated statistical confidence levels. This could lead to cost inflation, which would impact other monitoring activities.

Long-term monitoring is most valuable when implemented consistently over time. Therefore, the early development phases of the I&M program should be viewed as a window for making adjustments, while minimizing impacts of changes. In the current PACN schedule (chapter 9), a program benchmark will be reached in late 2008 when final monitoring protocols are implemented. A program review is planned for 2009, which will provide an opportunity for program adjustment, following adaptive management strategies.

Program Review Process—The Inventory and Monitoring program has developed a multi-level review process (table 8.6) that evaluates many facets of the program. For example, the Annual Administrative Report and Work Plan (AARWP) provides the Technical Committee and Board of Directors with an opportunity to review what has occurred in the prior year and what is planned for the next year. This annual program evaluation will be particularly important during the next three to five years, as actual monitoring of Vital Signs is implemented.

The PACN will incorporate a second level review for the program, represented in an annual report/symposium to the Technical Committee and Board of Directors. This report will be conducted as a one or two-day symposium, which includes technical presentations on results and status of monitoring projects. A TC meeting to discuss scientific presentations as progress reports and evaluate the scientific and operational merit of the work will follow the symposia. Results and decisions from this symposium review will be presented to the Board of Directors for endorsement. This format is used by National Science Foundation Long-term Ecological Research sites, and is effective in keeping a program appropriately focused. The first report to the Technical Committee will be held in spring 2007, after the first season of program implementation.

A 5-year program review will also be incorporated as a third level of evaluation. This review

Table 8.6. Review process for the PACN monitoring program.

Review	Scheduling	Who conducts review	Intent of the review
Annual Administrative Report and Work Plan	Annual	Technical Committee and Board of Directors	Provide yearly accountability for the program; report on accomplishments and explain goals and projects for the next fiscal year
Report to the Technical Committee	Biannual	All parties collecting data for the network, other invited experts as needed, representatives of the TC and BOD	Provide technical details on results and status of monitoring data within the program; evaluate if goals are being met appropriately and if focus of program is consistent with goals; evaluate if operations of program are working in concert with other aspects of program
5-year Program Review	Every 5 years	All parties collecting data for the network, other invited experts as needed, representatives of the TC and BOD	Provide synthesis of data collected by program and evaluate the utility to park management; evaluate administration and operations of the program; make recommendations for improvement of all aspects of the program

is an expanded version of the Report to the Technical Committee symposium/review, focusing on salient results from data collected and their relevance to park management. The review will include data presentation and syntheses followed by discussion and evaluation by the Technical Committee. Decisions to phase out projects or to adjust the program focus may be recommended to the Board of Directors. A separate workgroup will evaluate program administration and operations based on goals and objectives as determined by the TC and endorsed by the BOD.

All reviews should focus on program implementation and how effectively the PACN achieves programmatic goals. I&M program implementation also includes the collection, management, quality assurance and quality control, analysis, summarization, and reporting of data. Likewise, implementation of the program also includes integration of monitoring information, collaboration with park operations and partners, and information dissemination and outreach.

Summary

The Pacific Island Network Inventory and Monitoring program is planning to implement the I&M program through numerous mechanisms including: adequate governing structure and staffing; close collaboration and exchange between PACN parks, WASO, PWRH, and cooperators; science communications and outreach; partnerships; and three levels of program review. We will work closely with our Board of Directors and Technical Committee to finalize staffing and ensure protocol credibility. Through a staffing arrangement that incorporates a team approach, we are strategically planning to employ a combination of permanent and non-permanent NPS positions, parks staff, and CESU cooperators to balance and augment skills needed by the program, yet heed potential fiscal constraints. The Pacific Island Network is already beginning to integrate with divisions in all 11 PACN parks, to expand science communications and outreach. We will also be expanding our partnership outreach to augment monitoring activities and collaboration by working closely with other federal, state, and county agencies, and NGOs that are already conducting monitoring in or near the PACN national parks. To facilitate effective and critical review of our monitoring program, we will engage in a three-level review process, which is locally based with the Technical Committee and Board of Directors, in addition to a WASO review. In summary, we believe that through the administration and implementation plan presented in this chapter, we can effectively implement our monitoring program over the coming decades.

“Implementation of the program also includes integration of monitoring information, collaboration with park operations and partners, and information dissemination and outreach.”

Chapter 9. Schedule

"*The transition from planning and development to implemented monitoring signals an important milestone in the monitoring program.*"

A strategic monitoring plan will only be successful if a schedule is identified early in the planning processes. Scheduling allows the network to balance short- and long-term planning requirements and ensure timely implementation, data analysis, and reporting. Various schedules address timing and frequency of monitoring protocols and peer reviews for the 11 PACN parks. These schedules will help the network adaptively develop staffing plans, budgets, and plan work needs for NPS staff and CESU cooperators.

Protocol Schedule

Fourteen monitoring protocols are scheduled for development in phase 1 as discussed in chapters 4 and 5 of this monitoring plan. Upon successful implementation of the initial 14 phase 1 monitoring protocols, we will begin the second phase of implementation, which includes four Vital Signs. In this chapter we describe the protocol development plan and key tasks that must be addressed for each protocol over the next five years (table 9.1). All protocols implemented with partial or full Inventory and Monitoring program funding must be written according to rigorous standards (Oakley et al. 2003) and be formally reviewed. Some Vital Signs monitoring will entail coordination with government and state agencies already collecting data (e.g., water quality parameters). Others will require detailed scoping, adaptive data collection efforts, and determination of analytical methods.

In table 9.2, we outline the planned implementation schedule for phase 1 monitoring protocols under development. This table identifies which parks protocol development and implementation will occur, as well as noting for which parks monitoring (not in current protocols) may be expanded in the future. For each protocol in the table, a protocol development summary is available in appendix L.

Monitoring Schedule

The transition from planning and development to implemented monitoring signals an important milestone in the monitoring program. Implementation includes all aspects of monitoring operations such as data collection, data management, analysis, and reporting. For the PACN program, monitoring officially begins in 2006 with the implementation of the benthic marine community monitoring protocol. Vital Signs monitoring will increase incrementally as monitoring protocols are completed and approved for implementation by the Pacific West Regional Office and the I&M program's peer review process (table 9.3).

In table 9.4, we depict the frequency and timing of sampling for eight phase 1 Vital Signs for which protocol development was initiated in 2005 and 2006. While some data will be collected continuously (e.g., climate data), other data will be collected over several days in one season (e.g., freshwater animals). This table demonstrates that our field efforts are not entirely weighted to one season but are distributed throughout the calendar year due to consistent seasons in the islands, yet variability in select parameters (e.g., rain). In many cases, field efforts for a protocol will also be geographically staggered throughout the year (e.g., sampling in southern hemisphere parks October - December, and in northern hemisphere parks April - July).

Development and testing of phase 1 monitoring protocols continues through 2009. Appendix N portrays the phased approach to the development and implementation of phase 1 PACN monitoring protocols. Protocol development is complex and includes: refining and testing methods, preliminary data collection, analyses of preliminary data to determine adequate sample size, and refinement of sampling based on these analyses. Preliminary or enhanced data collection for some protocols will occur during the field season following submission of draft protocols for review.

Table 9.1. Development tasks for phase 1 and phase 2 Vital Signs monitoring protocols.

Vital Sign	Key issues to be addressed in development stage	Target year for protocol completion
Benthic marine community[a]	A number of existing methods to monitor benthic marine communities are readily available. Many commonly used monitoring methods lack statistical power or may need modification to function at PACN parks. A comprehensive review of these methods, and thorough testing and evaluation of methods and sampling design is necessary.	2007
Early detection of invasive plants[a]	Several methods for detecting distribution and abundance of newly invasive plant species have been tested for invasion corridors/pathways. These protocols will be reviewed based on detection rates vs. cost, and will largely form the basis for the invasive species protocol.	
Focal terrestrial plant communities	Procedures for plant community and focal and RTE plant species monitoring are established and will be reviewed and evaluated. The work focuses on drafting the sampling design, preparing a database, and developing SOPs.	
Landbirds	Standard approaches to monitoring land birds in Pacific islands and protocols for bird survey methodologies already exist. Work will consist primarily of designing sampling schemes tailored to each park and its avifauna.	
Water quality	Development of new techniques or protocols is not needed. Protocol development will utilize a combination of previously defined spatial and temporal sampling designs. Work will focus on tailoring the established protocol and sampling design to the specific resource type and the individual park.	
Status and trends of established invasive plant species	Work focuses on compiling and prioritizing invasive species for each PACN park based on a review of current lists, reviewing and evaluating existing exotic plant monitoring protocols, and developing a sampling design based on them. The National Invasive Species Program will be asked to review this protocol.	
Landscape dynamics	Available information concerning land use or landscape change conducted within or adjacent to PACN parks will be considered prior to initiating any new work. Land cover/land use maps and protocols have been developed by the NOAA C-CAP/ USGS for Landsat imagery and are currently being developed for IKONOS, and will be adapted for PACN parks. We will collaborate with other networks conducting similar protocols.	

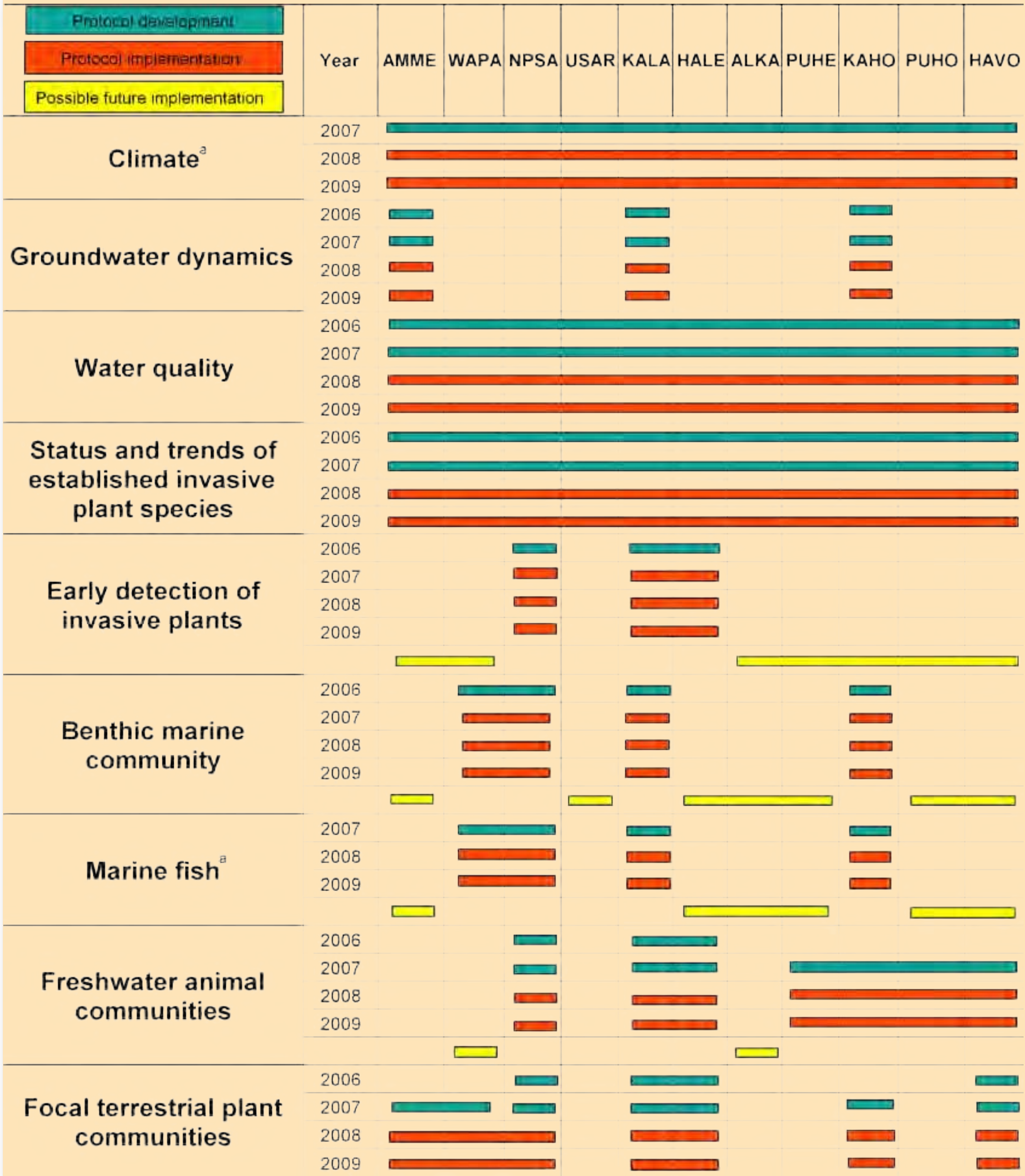
[a]. A second phase of protocol implementation will be established in 2008 – 2010 for these protocols.

Table 9.1. **Development tasks for phase 1 and phase 2 Vital Signs monitoring protocols—*Continued*.**

Vital Sign	Key issues to be addressed in development stage	Target year for protocol completion
Climate	Climate monitoring will rely primarily on historic and active weather monitoring efforts in and near PACN parks, and other agencies' protocols. If parameters or stations are lacking, additional sensors may be added to existing stations or new long-term stations will be added.	2008
Groundwater dynamics[a]	The USGS Pacific Islands Water Science Center currently conducts groundwater monitoring using well-defined procedures. The primary task will be to document the questions being asked and to determine an appropriate network design and sampling frequency to answer the questions.	
Freshwater animal communities	Several sampling methods have been established for animal communities in PACN streams and will be evaluated for this protocol. SOPs will be created for each sampling method, along with standard criteria to be used to determine which method to use at each site. Crustacean trap and release methods are currently being refined for anchialine pool shrimp, and the utility of other sampling methods will be evaluated for the different mixohaline habitats.	
Seabirds	Protocols to monitor the Hawaiian petrel have been developed at HALE and HAVO. These protocols will be evaluated and modified to ensure monitoring is comparable between the two parks. Initial intensive inventories for additional species of interest are needed to gather basic information on presence/absence, seasonality, and gross distribution. The focus of work will be on developing sampling methods and designing a database.	
Bats	Methodologies for monitoring insectivorous bats are established, while several count techniques have been successful in assessing the distribution and abundance of frugivorous bats. These methods need to be reviewed and field evaluated to develop a successful long-term monitoring program for PACN. Pilot surveys will help to determine the status of insectivorous bats on Molokai and Maui, and to test sample sites and methods for fruit bats. The work focuses on establishing standardized survey methods, designing sampling methods, and developing a database.	
Marine fish	There are a number of existing methods to monitor coral reef fish. Initial tasks will be to review and summarize existing reef fish monitoring methods, evaluate the literature comparing specific techniques, assess their applicability to our current monitoring needs, and then tentatively select and test methods.	
Fish harvest	Fisheries data are routinely conducted by fisheries agencies around the world. Work will focus on analyzing existing NPSA and WAPA fisheries data, the review of existing literature, developing study design, and developing a database.	2009
Early detection of invasive invertebrates[a]	Several methods for detecting distribution and abundance of newly invasive invertebrate species have been tested for invasion corridors/pathways. These protocols will be reviewed based on detection rates vs. cost, and will largely form the basis for the invasive species protocol.	
Cave community[a]	Existing methodology for detecting human intrusion in caves will be modified for the PACN. Established methods for sampling cave insects and vegetation will be incorporated into the protocol. Only a sample of known caves from each PACN park targeted for this protocol will be monitored; these must be selected prior to implementation.	
Terrestrial invertebrate communities[a]	Work focuses on developing sampling design and preparing database(s) and SOPs.	
Erosion & deposition[a]	A number of existing protocols are available in the literature and through appropriate agencies (e.g. NOAA, NRCS, USGS). Comprehensive review and field testing of these methods is needed to develop a sampling design for PACN.	

[a]. A second phase of protocol implementation will be established in 2008 – 2010 for these protocols.

Table 9.2. Phase 1 PACN Vital Sign implementation schedule for each park: 2006 – 2009*.



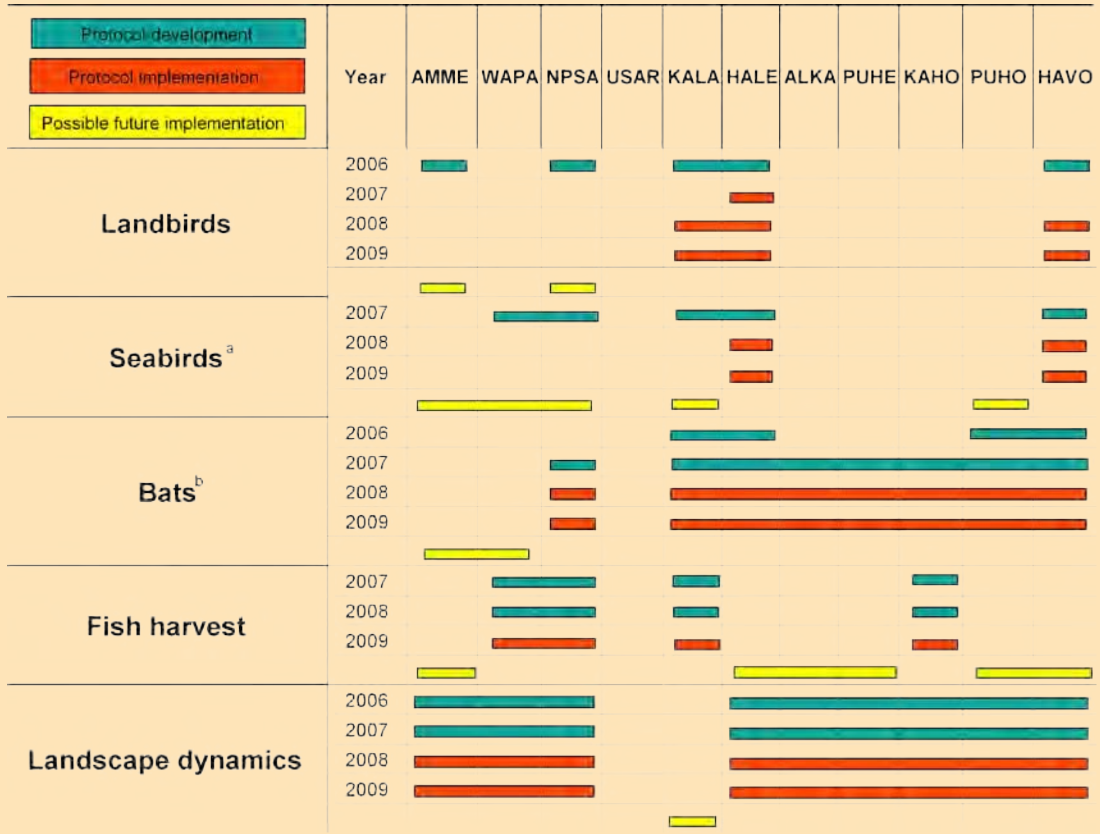
🟦 Protocol development 🟥 Protocol implementation 🟨 Possible future implementation	Year	AMME	WAPA	NPSA	USAR	KALA	HALE	ALKA	PUHE	KAHO	PUHO	HAVO
Climate[a]	2007	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	2008	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
	2009	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Groundwater dynamics	2006	🟦				🟦				🟦		
	2007	🟦				🟦				🟦		
	2008	🟥				🟥				🟥		
	2009	🟥				🟥				🟥		
Water quality	2006	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	2007	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	2008	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
	2009	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Status and trends of established invasive plant species	2006	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	2007	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	2008	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
	2009	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Early detection of invasive plants	2006			🟦		🟦	🟦					
	2007			🟥		🟥	🟥					
	2008			🟥		🟥	🟥					
	2009			🟥		🟥	🟥					
		🟨	🟨					🟨	🟨	🟨	🟨	🟨
Benthic marine community	2006		🟦	🟦		🟦				🟦		
	2007		🟥	🟥		🟥				🟥		
	2008		🟥	🟥		🟥				🟥		
	2009		🟥	🟥		🟥				🟥		
		🟨			🟨		🟨	🟨	🟨		🟨	🟨
Marine fish[a]	2007		🟦	🟦		🟦				🟦		
	2008		🟥	🟥		🟥				🟥		
	2009		🟥	🟥		🟥				🟥		
		🟨					🟨	🟨	🟨		🟨	🟨
Freshwater animal communities	2006			🟦		🟦	🟦					
	2007			🟦		🟦	🟦		🟦	🟦	🟦	🟦
	2008			🟥		🟥	🟥		🟥	🟥	🟥	🟥
	2009			🟥		🟥	🟥		🟥	🟥	🟥	🟥
			🟨					🟨				
Focal terrestrial plant communities	2006			🟦		🟦	🟦					🟦
	2007	🟦	🟦	🟦		🟦	🟦			🟦		🟦
	2008	🟥	🟥	🟥		🟥	🟥			🟥		🟥
	2009	🟥	🟥	🟥		🟥	🟥			🟥		🟥

[*] Projections in table to 2009, with the assumption that monitoring will continue indefinitely

[a]. Preliminary protocol development to begin in 2006.

[b]. Pilot data collection to begin in 2006.

Table 9.2. **Phase 1 PACN Vital Sign implementation schedule for each park: 2006 – 2009*—** *Continued.*



🟦 Protocol development
🟥 Protocol implementation
🟨 Possible future implementation

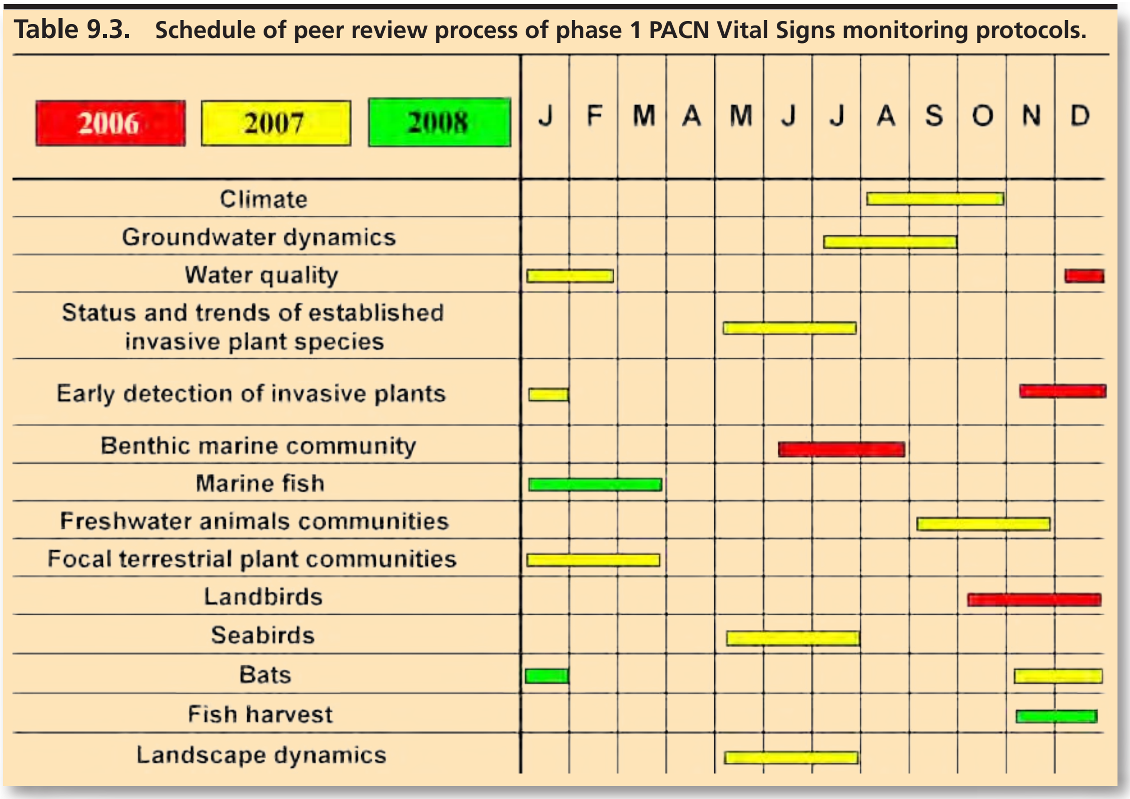
	Year	AMME	WAPA	NPSA	USAR	KALA	HALE	ALKA	PUHE	KAHO	PUHO	HAVO
Landbirds	2006	🟦		🟦		🟦	🟦					🟦
	2007						🟥					
	2008					🟥	🟥					🟥
	2009					🟥	🟥					🟥
		🟨		🟨								
Seabirds[a]	2007		🟦	🟦		🟦	🟦					🟦
	2008						🟥					🟥
	2009						🟥					🟥
		🟨	🟨	🟨		🟨					🟨	
Bats[b]	2006					🟦	🟦				🟦	🟦
	2007			🟦		🟦	🟦	🟦	🟦	🟦	🟦	🟦
	2008			🟥		🟥	🟥	🟥	🟥	🟥	🟥	🟥
	2009			🟥		🟥	🟥	🟥	🟥	🟥	🟥	🟥
		🟨	🟨									
Fish harvest	2007		🟦	🟦		🟦				🟦		
	2008		🟦	🟦		🟦				🟦		
	2009		🟥	🟥		🟥				🟥		
		🟨					🟨	🟨	🟨		🟨	🟨
Landscape dynamics	2006	🟦	🟦	🟦			🟦	🟦	🟦	🟦	🟦	🟦
	2007	🟦	🟦	🟦			🟦	🟦	🟦	🟦	🟦	🟦
	2008	🟥	🟥	🟥			🟥	🟥	🟥	🟥	🟥	🟥
	2009	🟥	🟥	🟥			🟥	🟥	🟥	🟥	🟥	🟥
						🟨						

*Projections in table to 2009, with the assumption that monitoring will continue indefinitely

[a]. Preliminary protocol development to begin in 2006.

[b]. Pilot data collection to begin in 2006.

Table 9.3. Schedule of peer review process of phase 1 PACN Vital Signs monitoring protocols.



🟥 2006 🟨 2007 🟩 2008	J	F	M	A	M	J	J	A	S	O	N	D
Climate								🟨	🟨	🟨		
Groundwater dynamics							🟨	🟨	🟨			
Water quality	🟨	🟨										🟥
Status and trends of established invasive plant species					🟨	🟨	🟨					
Early detection of invasive plants	🟨										🟥	🟥
Benthic marine community						🟥	🟥	🟥				
Marine fish	🟩	🟩	🟩									
Freshwater animals communities									🟨	🟨	🟨	
Focal terrestrial plant communities	🟨	🟨	🟨									
Landbirds										🟥	🟥	🟥
Seabirds					🟨	🟨	🟨					
Bats	🟩										🟨	🟨
Fish harvest											🟩	🟩
Landscape dynamics					🟨	🟨	🟨					

The reporting of monitoring results will also be phased over time. As principal investigators and protocol teams collect data, the PIs and staff will prepare annual reports of activities and findings for each monitoring protocol. As data accumulate, protocol development teams will include comprehensive analysis and results synthesis in their annual reports. Once the fourth year of monitoring is completed, reports will include trend assessments within park units and network-level summaries and comparisons between parks. Additional details of planned reports are in chapter 7.

Other Important Planning Needs

In addition to data collected through monitoring the 14 phase 1 Vital Signs, results of park or partner sponsored monitoring programs will provide information that will enhance the Vital Signs monitoring program. Such monitoring should also be guided by protocols that are adequately documented and include a strategy for data stewardship and reporting. As network monitoring protocols are approved and implemented, effort will shift towards working with park staff and partners to update and/or revise high-priority existing park monitoring programs and to adequately document these in protocols.

Over the next five years, the network plans to provide technical assistance and support to park- and partner- sponsored monitoring programs for these activities, dependent on budgetary and staffing availability. The goal is an integrated approach to acquiring network Vital Signs and park- and partner-sponsored monitoring information (figure 9.1). The technical expertise of network staff can help to standardize procedures and establish quality control, data management, and reporting protocols. Most importantly, this strategy will allow parks to increase the quality of monitoring data that they produce and use. It will also help to promote coordination and communication of monitoring activities at the park and (where appropriate) network and regional levels, and will encourage broad participation in monitoring and the use of resulting data.

Table 9.4. Frequency and timing of sampling for PACN Vital Signs whose development will be initiated in 2006-2007.

Observers for the Benthic marine community Vital Sign will be trained during April/May[bc] and October/November[d]. Training for the Landbirds Vital Sign observers will occur in April[b] and October[c].

Vital Sign	Sample type/interval ** = two to three day sampling event ¤ = weekly	January	February	March	April	May	June	July	August	September	October	November	December
Groundwater dynamics	Spaced sampling events	**		**		**		**		**		**	
Status and trends of established invasive plant species	Annual + multi-annual sampling visits		¤			¤			¤			¤	
Early detection of invasive plants [a]	Annual + multi-annual sampling visits	¤			¤			¤			¤		
Benthic marine community	Annual surveys	¤[d]	¤[d]				¤[bc]	¤[bc]	¤[bc]				¤[d]
Freshwater animal communities	Biannual multi-day sampling visits			**	**					**	**		
Focal terrestrial plant communities	Annual + multi-annual sampling visits			¤[b]	¤[b]	¤[b]	¤[b]	¤[c]	¤[c]				
Landbirds	Annual surveys + more frequent monitoring				¤[b]						¤[c]		
Landscape dynamics	5 & 10 year review of available imagery	NA											

[a]. Timing of sampling dependent on personnel status. Sampling distributed throughout the year for different parks.

[b]. Hawaii national parks (statewide)

[c]. AMME/WAPA

[d]. NPSA

Figure 9.1. Traditional community fishing practice (hukilau) demonstrated at a Puuhonua o Honaunau National Historical Park cultural festival; one of many fishing practices potentially monitored by the Fish harvest protocol.

Summary

The Pacific Island Network has an ambitious protocol development and monitoring schedule, with 14 protocols to be developed and implemented for phase 1 Vital Sign monitoring within the next five years, and four phase 2 Vital Signs in the following three years. The program implementation schedule for 2007-2011 will require comprehensive planning and adequate staffing to stay on schedule. Inventory and Monitoring staff must collaborate and communicate closely with network parks, cooperators, and partners on Vital Sign protocol development, budgets, and schedules in order to submit protocols for peer review on time. However, with adequate planning, budget, and collaboration we anticipate full implementation of the Pacific Island Monitoring program. The planning outlined in this chapter will enable the network to adequately develop and fully implement Vital Signs monitoring.

Chapter 10. Budget

The PACN receives $1,570,100 from the NPS Inventory and Monitoring program for Vital Sign monitoring and $151,000 from the NPS Water Resources Division for water quality monitoring. Annual expenditures presented in the network budget match income amounts, yet do not reflect in-kind contributions of existing park and partnership efforts. Calculation of these tangible and intangible benefits to the I&M program from NPS, other state and government agencies, and additional partnerships will be included in program reports as identified in chapter 7.

Annual Vital Sign Monitoring Budget

The PACN, similar to other NPS Inventory and Monitoring networks, annually prepares an annual administrative report for the previous fiscal year, and a work plan for the upcoming fiscal year which is sent to the Washington Area Support Office. The categories identified in figure 10.1 mirror the categories used in the annual report and work plan which is presented to Congress on a Servicewide basis. The network has elected to phase in monitoring of Vital Signs, as discussed in chapters 3 and 9, by staggering protocol development and implementation over multiple years. The budgets presented in figure 10.1 represent the aggregate of this phased-in approach to Vital Signs monitoring.

Personnel costs are 42% of total expenses beginning in FY 2007 and increase to 49% by 2011. These cost increases are due to estimated annual pay and step increases (3.5% per year). These personnel expenditures include permanent staff (network coordinator, data manager, aquatic ecologist, terrestrial ecologist, ecologist, GIS specialist, administrative technician, and park staff assistance) as well as term, seasonal and temporary staff (database programmer, quantitative ecologist, aquatic biological technician, and terrestrial biological technician) which are funded by the PACN. Cost-sharing and partnership opportunities will be pursued as appropriate, such as joint funding of the aquatic biological technician with the coral reef program. The network assumes a conservative approach to permanent staffing through working with the Cooperative Ecosystems Studies Unit. The CESU can provide skilled cooperators who augment I&M and existing resource staff in parks by providing expertise in planning for ecological monitoring, science communications,

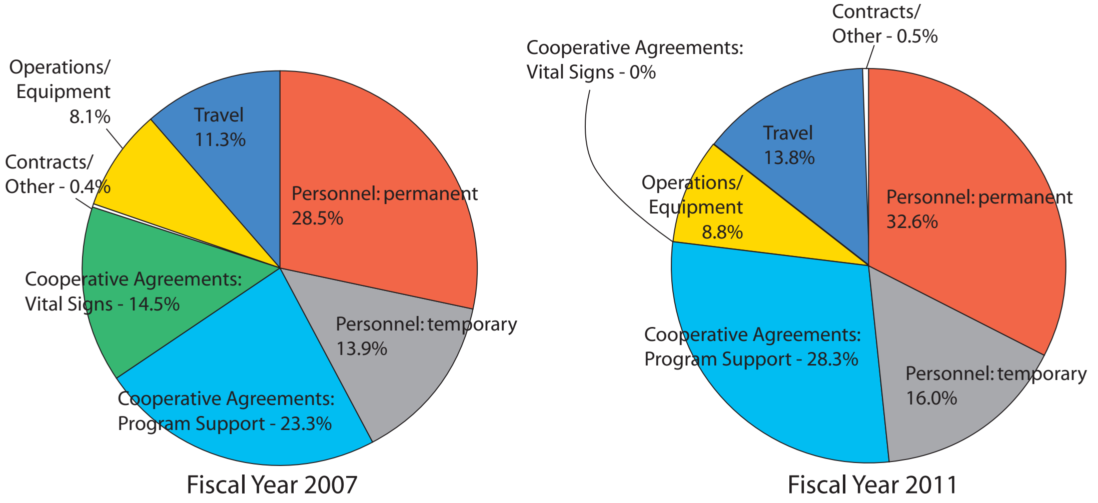


Figure 10.1. Comparison of the projected Pacific Island Network Vital Sign Monitoring program budgets in FY 2007 and FY 2011.

GIS, databases, and field monitoring, among other tasks. The ability to work with CESU cooperators gives us flexibility to increase, decrease, or reallocate human resources as program needs change in the early years of monitoring implementation.

Cooperative and interagency agreements are integral components of the PACN monitoring program. The PACN will obligate 38% for 2007 and 28% of the 2011 budgets to CESU, as well as other agency agreements. These cooperative agreements are displayed in two categories: (1) program support reflecting science communication, data management, and Vital Sign assistance (chapter 8), and (2) Vital Sign protocol development of selected Vital Signs.

Program costs such as building rent and office supplies are included in budget allocations. We anticipate that operations and equipment costs will gradually increase from 8% in 2007 to 9% in 2011 due to inflation, the need for expanded office space, and monitoring equipment replacement. Operations and equipment costs in the Pacific islands can be expensive due to environmental issues (e.g., cyclones, corrosion) and logistical considerations (e.g., increased shipping time and costs, storage considerations, and limited transportation options on remote islands). Likewise, travel costs between islands in the PACN are substantial, particularly between the island groups of Hawaii, American Samoa, and the Mariana Islands. The network is dependent upon commercial air, land, and sea transportation between most parks and to local and national meetings, trainings, and other venues. However, we anticipate that, through careful management, travel costs will only gradually increase from 11% in 2007 to 14% in 2011.

The remaining expenditure category of “contracts and other” will comprise a small portion of the budget. This category primarily includes General Services Administration (GSA) coordinated vehicle leases and helicopter rentals. We anticipate that 0.4% of funds will be allocated to this category in 2007 and 0.5% in 2011.

As Vital Sign monitoring protocols are approved and implemented, associated expenses shift from cooperative agreements (research and design of protocols) to personnel and travel (staff time and travel to implement monitoring). Approximately $249,100 will be available for cooperative agreements associated with Vital Signs development in 2007, which will decrease to $0 in 2011 (table 10.1).

Table 10.1. Proposed network expenditures for the Pacific Island Network Vital Signs monitoring program in the first five years of implementation.

Category	2007	2008	2009	2010	2011
Personnel: permanent	$489,500	$506,500	$524,500	$543,000	$561,600
Personnel: term, temporary, and seasonal	$240,000	$248,000	$257,000	$266,500	$275,000
Cooperative agreements: program support	$401,500	$422,000	$443,000	$465,000	$488,500
Cooperative Agreements: Vital Sign development	$249,100	$189,600	$128,600	$65,600	$0
Contracts and other	$6,000	$7,000	$7,500	$7,500	$8,000
Operations and equipment	$140,000	$143,000	$145,000	$148,000	$151,500
Travel	$195,000	$205,000	$215,000	$225,500	$237,000
Total	**$1,721,100**	**$1,721,100**	**$1,721,100**	**$1,721,100**	**$1,721,100**

Data Management Expenditures—National monitoring program guidance specifies that approximately 1/3 of the monitoring budget should be devoted to data management. Data management related expenses include NPS personnel (data manager, GIS specialist, and database programmer), cooperative agreement data management assistance, related equipment and supplies, and travel for NPS data management personnel. Individual Vital Sign data management budgets, and the portion of time that biological technicians and CESU cooperators dedicate to data management, are anticipated to be approximately 33% in accordance with Vital Sign protocol standards. Additional data management expenses, not included in this summary, will include analysis, reporting, and communications. The approximate data management expenditure proportions for FY 2007 ($565,500 out of the $1,721,100 total budget, or 33%) will continue through subsequent fiscal years.

Summary

The PACN annually receives $1,721,100 for Vital Sign and water quality monitoring. In the initial implementation phase of the I&M program, we will allocate approximately 28% of these funds for permanent personnel. Approximately 52% of the total funds will be obligated in cooperative agreements and limited-term personnel in 2007. Over subsequent years, we anticipate that expenditures for cooperative agreements will drop, while personnel and travel costs rise, reflecting the shift from vital sign development to implemented monitoring.

As part of our annual reporting and planning, financial allocations will be adjusted yearly after approval by the Board of Directors, with systematic program reviews and adjustments occurring at five-year intervals. These annual and five-year reviews will evaluate costs of Vital Sign monitoring, partnerships, and personnel in order to enhance long-term monitoring effectiveness. In addition, the PACN will pursue future partnership and leveraging opportunities to increase effectiveness and long-term alliances for monitoring in our national parks (figure 10.2).

Figure 10.2. A portion of the proposed alignment of the Ala Kahakai National Historic Trail. The trail requires extensive partnerships for monitoring success.

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Glossary

A

Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form employs management programs that are designed to experimentally compare selected policies or practices by implementing management actions explicitly designed to generate information useful for evaluating alternative hypotheses about the system being managed.

Aeolian: An ecological zone characterized by little or no photosynthetic productivity and having a food web supported by windblown organic matter. This zone occurs only on the islands of Hawaii and Maui in the PACN.

Ahupuaa: Traditional system of land division in the Hawaiian Islands, typically consisting of a watershed from mountaintop to nearshore marine habitat.

Amphidromy: Type of life history shared by most native Pacific island stream organisms, in which species migrate between fresh and salt water at two points in their life cycle: from fresh to salt as embryos and from salt to fresh as juveniles (Fitzsimons et al. 2002).

Anchialine: Anchialine pools or ponds are brackish land-locked bodies of water with underground connections to the ocean. Their salinity and volume varies in a delayed manner with the tides.

Area (sampling) frame: A sampling technique where the population or area to be surveyed is subdivided into geographic areas.

(Ecological) Attributes are any feature or process of the environment that can be measured or estimated and that may provide insight into the state of the ecosystem. Attributes are selected to represent the overall health of the system, known or hypothesized effects of stressors, or elements that have important human values. Examples include: diversity of native species, presence of alien species, and sediment in the water column. In PACN models, they are represented by an octagon.

B

Belt transect: A sampling technique that involves taking measurements along a long, two-dimensional sample area that has a length much greater than width. This is similar to the line transect method but gives information on abundance as well as presence or absence of the target. For example, a typical vegetation belt transect might involve recording all plants that occur in a sampling area 10 m wide and 500 m long, at 100 m intervals, forming consecutive quadrats.

Benthic: Pertaining to the bottom of a body of water, in the bottom sediments, or bottom-dwelling organisms.

Bog: A type of wetland that accumulates acidic peat, a deposit of dead plant material. In the PACN region, bogs can occur in both lower and upper elevation ecosystems and are most often dominated by herbaceous plant species.

Brackish: Having a combination of fresh and sea water, as occurs naturally in estuaries and anchialine pools.

C

Chamorro: The native Pacific island people of Guam.

Cloud forest: A generally wet, tropical, or subtropical montane forest characterized by a profusion of epiphytes and the regular emersion of the canopy in low-level clouds.

Coastal strand: Beach and very shallow coastal area dominated by shoreline processes, particularly wave processes.

Co-location: Refers to sampling the same physical units for multiple Vital Signs, which can result in simplified logistics, decreased travel costs, and decreased time spent in the field.

Composition is defined as the identity and variety of elements within an ecosystem, including species present and their population structure, abundance, and genetic diversity (Noss 1990).

Cover (of plants, land, or substrate): Refers to the percentage of ground covered by living or organic material (e.g., plants).

Co-visitation: Refers to sampling the same units for multiple Vital Signs on the same occasion, thus reducing travel and personnel costs.

Cultural landscape: A landscape created by people and their culture, which is the product of human interactions with nature and has cultural significance. Cultural landscapes include historic designated landscapes, historic vernacular landscapes, historic sites, and ethnographic landscapes.

D

Data dictionary: A file or document that defines the basic organization of a database. It is a repository of descriptive information about data and includes database elements and valid values used to describe datasets.

Data mining: Process of extracting useful information or knowledge from large data stores or sets. For the I&M program, this involves the entry of information into the Servicewide databases for existing data sets (Dataset Catalog), literature citations (NatureBib), and species occurrence information (NPSpecies).

(Ecosystem) Drivers are major external forces of change to ecosystems, both natural and anthropogenic, including state factors. Examples of drivers include storm frequency and sea level rise, fire cycles, climate, and hydrological cycles. In PACN models, they are represented by a rectangle.

Dry forest: Vegetation community characterized in the PACN region by greater than 25% tree cover and prevailing rainfall of less than 2,500 mm per year. Other factors such as topography, seasonality, and soil moisture regime contribute to the moisture regime within this forest type.

Dry grassland: Vegetation community characterized in the PACN region by greater than 40% grass cover and prevailing rainfall of less than 2,500 mm per year. Other factors such as topography, seasonality, and soil moisture regime contribute to the moisture regime within this forest type.

Dual frame: Statistical design that incorporates more than one sampling frame. For example, a list frame that contains known information about the targeted resources and an area frame where the population or area to be surveyed is subdivided into geographic areas. By combining the frames, researchers can make inferences about the data beyond the specific targeted resources.

E

Ecological effects are the physical, chemical, biological, or functional responses of ecosystem components to stressors. In ecosystem conceptual models, they are also the working hypotheses of the links between environmental stressors and ecological attributes. Ecosystem effects are represented by a diamond in PACN models.

Ecological 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. It implies the presence of appropriate species, populations and communities, the occurrence of ecological processes at appropriate rates and scales, and environmental conditions that support these taxa and processes.

Ecosystem: A community of organisms living in and interacting with a physical and chemical environment, which may be characterized by energy and matter flows between the different elements.

Ecotone: A transitional area between two (or more) ecological communities, which may have characteristics of both as a blended habitat or its own distinct characteristics reflected as a sharp boundary line.

Ethnographic: The qualitative description of specific cultures.

Exhaustive sampling: Sampling scheme that is a census of all sample units within the area of interest.

F

Fishponds: Brackish-water ponds constructed by early Hawaiians in coastal areas and used for farming of marine and estuarine fish species. Though most fishponds have fallen into disuse, they are culturally significant and continue to serve as habitat for many native species.

Focal species include those species that play significant functional roles in the maintenance of ecosystem structure, function, and composition (encompassing the concepts of keystone species, umbrella species, and ecosystem engineers) as well as those species that do not necessarily play significant functional roles but may be harvested, endemic, alien, or have protected status.

Function refers to how ecosystem parts interact with each other. Ecosystem functions include flow of nutrients or energy between ecosystem components and succession of biological communities after disturbance.

G

Generalized Random Tessellation Stratified (GRTS) Design: A relatively new, list-based, sampling design method which produces a spatially well-balanced random sample using restricted randomization algorithms (Stevens and Olsen 2004).

Guild: A group of species that use ecological resources in similar ways or have similar foraging strategies.

H

Heiau: A Hawaiian place of worship, including temples and shrines.

Hot spot: A fixed area below the earth's crust where magma rises from the mantle. As the crust moves over the hotspot, magma pushes through the mantle, creating volcanic eruptions that eventually form islands. The Hawaiian and Samoan Island chains were formed in this fashion.

Hurricane: see tropical cyclone.

I

Index-based sampling: Sampling scheme that collects information on areas or at points (index sites) that are hand-picked by lead investigators to yield adequate data on a particular vital sign.

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 2003). They 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.

Interactive controls are defined in the interactive-control ecosystem sustainability model as drivers that generally operate inside the bounds of ecosystems. They respond dynamically to each other and interact with ecosystem processes, but are constrained by state factors (Chapin et al. 1996). They include: disturbance regime, biological functional groups, soil or water resources and conditions, and regional and local climate.

(Temperature) Inversion: A characteristic feature of the latitudes in which the trade winds occur. Subsiding air in the Hadley cell warms as a result of compression. At the same time, air rising from the surface cools. At the meeting point of the two air masses warm air overlays cool air forming a temperature inversion.

K

Karst: Geologic topography characterized by rugged, irregular limestone erosion patterns with sinks, underground streams, and caverns.

Kipuka: Hawaiian term for an island of vegetation surrounded by lava.

L

Lava tubes: Natural conduits through which lava travels beneath the surface of a lava flow. The conduits cool, leaving a long, cave-like channel that may support unique cave-dwelling organisms.

Line transect: A sampling technique that involves taking measurements along a sample line lain out along the area of study. The line transect provides present or absence data and relative frequency information. For example, a typical line transects might involve recording the number of centimeters at the start and end points for all plant species and bare ground falling directly beneath the meter tape or the species or substrate directly under reference points at preset intervals along the tape or rope to determine the relative cover of each species.

List (sampling) frame: A sampling technique that incorporates known information about the targeted resources such as known nest sites, specific geomorphologic features, etc. Sampling these known units can provide valuable information about changes in those specific resources over time, but it will not allow inferences to be generalized to the rare resource as a whole. By combining list frame with other sampling frames (e.g. area frames) in a dual frame design, researchers are able to make inferences about the data beyond the specific targeted resources.

List-based sampling: Sampling scheme that constructs a list of sample units and either draws a probability sample from the list or attempts to census all units.

M

Matai: Traditional system of land management in the Samoan Islands.

Mauna: In Hawaiian, ‘mountain’.

(Ecological) Measures are the specific variables used to quantify the condition or state of an attribute (or Vital Sign). These are specified in definitive sampling protocols. One example is stream flow as an attribute, while discharge measurements in cubic feet per second are the measure. In PACN models, they are represented by a parallelogram.

Membership design: The way in which units in the population are selected to become members of a sampling panel.

Mesic forest: Moist forest characterized in the PACN region by prevailing rainfall of 1,200 to 2,500 mm per year. Other factors such as topography, seasonality, soil moisture regime, and fog drip contribute to the moisture regime within this forest type.

Metadata: Data describing other data, including: when the data was created, who created it, how it was created, and where it is stored.

Mixohaline: Brackish; mixed fresh and salt waters.

Monitoring: The collection and analysis of repeated observations or measurements over a long period of time to document changes in status and trends in ecological parameters.

N

Nearshore marine: A coastal zone extending seaward from the shoreline to the depth of maximum light penetration (about 10 m).

Nonparametric statistics: The branch of statistics dealing with variables without making assumptions about the form or the parameters of their distribution; normal distribution curves cannot be drawn.

P

Panel: A group of sample units that are always sampled during the same sampling occasion or time period. A sample unit may be a member of two or more different panels.

Parametric statistics: The branch of statistics dealing with one or more variables, or parameters, which can be varied to elicit different results. It is a group of statistical procedures used to test data that are normally distributed.

Parent material: The primary material from which soil is formed, generally bedrock or sediment.

Passerine birds: Birds of the order Passeriformes, typically called perching birds or less accurately, “songbirds.” They are distinguished by the orientation of their four grasping toes. Warblers, finches, and sparrows are typical passerines.

Pelagic zone: The zone located in the open sea, away from the sea bottom.

Population: In sampling terminology, the total collection of units from which a sample will be drawn.

Probability sample: A sample chosen using some type of random draw.

R

Responses: Measurements taken on sample units.

Restricted randomization algorithm: An algorithm used to produce a sample that is well balanced, yet randomly selected.

Revisit design: The temporal sampling schedule that specifies the pattern of visits through time to all panels.

Rotating panel design: Monitoring design that entails repeat sampling of sites or units each year over a set cycle period, after which the cycle is repeated. Rotating panel designs may allow for visiting a subset of sites every year, revisiting some sites on longer cycles, and incorporating new sites each year along with the revisit schedule.

Rugosity: Measure of the roughness of a surface. Provides an index of potential habitat or hiding places for marine organisms.

S

Sample: The subset of units from the population for which we collect responses.

Sample frame: The defined area of the target population from which one draws a sample. Ideally, the sample frame is identical to the target population.

Sample units: The smallest entities of a target population upon which measurements are taken. In some studies, sample units will be discrete entities such as stream segments, ponds, lakes, etc. In other studies, sample units will be standardized areas such as transects, plots, or pixels in an image.

Scalar (ecological processes): A variable quantity that cannot be resolved into components and can only be described in terms of magnitude, such as time, temperature, and speed.

Simple random sample: Sampling method in which n units are selected from a population of size N via a random process, such that every sample unit has the same probability of being included in the sample.

Spatial variance: Statistical measure of variation in horizontal or vertical space such as distribution, distance, direction, or area occupied by individuals/populations.

Stand structure: The number of individuals in different size classes within a stand which can be described by species, vertical or horizontal spatial patterns, size or age of individuals, or a combination of these.

State factors as defined in the interactive-control ecosystem sustainability model are variables with independent variation which function as ultimate controls on ecosystem structure and function (Chapin et al. 1996). They are considered ecosystem drivers. They are major forces of change in ecosystems, and may be affected by human activity. State factors include: time since disturbance, potential biota, parent material or water supply, topography, and global climate.

Stratified sampling: A sampling technique in which the population of interest is divided according to a common characteristic or attribute (stratum), commonly used when the population is heterogeneous or dissimilar. Stratified sampling may be used to reduce cost per observation, estimate population parameters for each sub-population, and increase accuracy of sampling within strata.

Subalpine shrubland: Vegetation community characterized in the PACN region by greater than 40% shrub cover which occurs between 1,700 and 3,000 m in elevation.

Systematic sample: Sampling method in which one subject is typically selected at random and subsequent subjects are selected according to a systematic pattern.

(Environmental) Stressors are physical, chemical, or biological perturbations to a system that may be either foreign or natural to the system, but applied at an excessive or deficient level (Barrett et al. 1976). Stressors often move the ecosystem away from desired future conditions through forcing change in ecosystem composition, function, or structure. Examples include: air pollution, water pollution, water withdrawal, pesticide use, land-use change, and introduction of invasive terrestrial, marine, and aquatic species. Stressors act together with drivers to influence ecosystem attributes. In PACN models, they are represented by an oval.

Structure is the physical organization or spatial patterns of organisms and habitats (i.e., the arrangement of species in space). Structure can be seen at widely divergent spatial scales, from the micro-scale structure in a patch of moss growing on a stream boulder to the landscape-scale three-dimensional profile of a coral reef system as measured from sandy shore to outer reef.

T

Transect-based sampling: Sampling scheme that draws a probability sample based upon a set of permanent transects.

Tropical cyclone: For simplicity, we use the term topical cyclone in this report for the entire PACN region to refer to storms with sustained wind speeds above 63 knots/hr even though the terminology varies by geographic region.

Typhoon: see tropical cyclone.

V

Viewscape: An area of particular scenic, historic, or cultural value, generally visible from a fixed vantage point or series of points, which is deemed worthy of preservation. Also called viewshed.

Viewshed: See viewscape.

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

Vog: Photochemical haze from volcanic emissions, “Volcanic Smog”.

W

Wet forest: Vegetation community characterized in the PACN region by prevailing rainfall of more than 2,500 mm per year. Other factors such as topography, seasonality, soil moisture regime, and fog drip contribute to the moisture regime within this forest type. Includes rain forest and cloud forest.

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