



Pacific Island Network, Inventory & Monitoring Program Vital Signs Workshop Review Materials

Background

The National Park Service, Inventory & Monitoring Program, Pacific Island Network (PACN) consists of 11 parks: War in The Pacific National Historical Park in Guam, American Memorial Park in the Commonwealth of the Northern Mariana Islands, National Park of American Samoa in American Samoa, USS Arizona Memorial (Oahu), Kalaupapa National Historical Park (Molokai), Haleakala National Park (Maui), Ala Kahakai National Historic Trail (Hawaii), Puukohola Heiau National Historic Site (Hawaii), Kaloko-Honokohau National Historical Park (Hawaii), Pu`uhonua O Honaunau National Historical Park (Hawaii), Hawaii Volcanoes National Park (Hawaii).

We are preparing a long-term natural resource monitoring plan for these parks. The following materials are a brief (17 page) summary of these materials. We would appreciate your reading this *prior* to the Vital Signs Workshop on 16-18 March, such that discussions can focus on soliciting suggestions for improving our monitoring plan. Most of the materials below are only brief excerpts; you will likely need to reference the complete version of the monitoring plan, appendices, etc. which is available at:

http://www.nature.nps.gov/im/units/pacn/monitoring/plan/vs04/review_materials.htm

- **Where:** East-West Center (Imin Conference Center), University of Hawaii-Manoa
- **When:** 16, 17, & 18 March 2004
- **Purpose:** Obtain peer review of existing monitoring plan and Vital Sign identification and prioritization by park managers and subject experts from within and outside of the NPS.

Meeting Goals/Outcomes

- (Peer) Review of the monitoring program: summary of current ecological understanding, monitoring goals, desired future conditions, and conceptual models
- Comments and suggestions for improvements upon the choice of and prioritization of Vital Signs (indicators) recommended for monitoring
- Identify existing sampling (monitoring) methodology and identify or recommend needs for the development of new protocols with high-priority indicators
- Recommendations for partnerships to accomplish monitoring priorities

Agenda: & other logistical details available at:

<http://www.nature.nps.gov/im/units/pacn/monitoring/plan/vs04/>

Attendance: Participants have been invited for specific days. Please note that we are limited by room size; thus, we are asking individuals to attend specific sessions and not attend others. We anticipate that *every* seat will be occupied on Tuesday morning, and ask that you not attend Tuesday morning unless we identified that session in your previously emailed invitation. *Please review your invitation to determine which sessions you were asked to attend.*

PRE-MEETING REVIEW MATERIALS

- 1) Summary of ecological understanding
- 2) Monitoring program goals & objectives
- 3) Monitoring strategies
- 4) Conceptual models
- 5) Criteria for Vital Sign ranking
- 6) Proposed Vital Signs & Priorities

1. Summary of Ecological Understanding (copied from park lists at:

<http://www.nature.nps.gov/im/units/pacn/resources/>)

Important natural resources and focal species or processes	
<p>War in the Pacific NHP (WAPA) Unique Ecosystems</p> <ul style="list-style-type: none"> ● Coral reef ● Sea grass beds ● Limestone forest remnants ● Savannah grasslands 	<p>American Memorial Park (AMME)</p> <ul style="list-style-type: none"> ● Wetlands/mangroves within and adjacent to the park (particularly the inland mangrove wetland, unique in all the Marianas) ● Endangered bird species ● Coral Reefs (not within park) ● Nearshore marine water quality (not within park)
<p>National Park of American Samoa (NPSA) Marine</p> <ul style="list-style-type: none"> ● Indo-Pacific Coral Reef Ecosystem ● Pristine Waters ● Coral Diversity and Density ● Coral Reef Fishes ● Sea Turtles ● Humpback Whales <p>Terrestrial</p> <ul style="list-style-type: none"> ● Mixed Paleotropical Rainforest ● Forest Pollinators (flying foxes and land birds) ● Charismatic Invertebrates (coconut crabs and land snails) ● Seabirds ● Rare Species 	<p>USS Arizona Memorial (USAR) The primary resource in USAR is the sunken WWII ship, the USS Arizona that entombs over 1000 soldiers. The hull of the sunken vessel has come to serve as habitat and substrate for many marine species.</p> <ul style="list-style-type: none"> ● Encrusting biofoul, including barnacles, oysters & corals and algae ● Green sea turtles observed resting on hull & monk seals observed swimming in the vicinity of the sunken vessel's hull (rare) ● Several highly urbanized streams flow into Pearl Harbor
<p>Kalaupapa NHP (KALA)</p> <ul style="list-style-type: none"> ● Rare plant communities and species ● Rare insect species (incl. pollinators) ● Unique crater lake ● Protected offshore islets ● Endangered monk seal pupping site 	<p>Haleakala NP (HALE) Haleakala NP resources include several unique ecosystems that provide very contrasting environmental conditions</p> <ul style="list-style-type: none"> ● Unique Ecosystems: Rainforests, high elevation bogs and lakes, alpine and subalpine ecosystems ● Rare and Endangered Plant Species ● Rare and Endangered Birds: Hawaiian Goose, Hawaiian Petrel, 5 species of Hawaiian Honeycreepers. ● Rare and Endangered Mammals: hawaiian monk seal and hawaiian hoary bat ● Rare and Endangered Fish: oopu ● Rare and Endangered Insects and Spiders ● Scenic Values: Haleakala crater vistas, Haleakala crater wilderness areas, Makahiku falls, Pilikea Stream, Pools of Oheo
<p>Ala Kahakai NHT (ALKA)</p> <ul style="list-style-type: none"> ● Threatened, Endangered, & native species ● Beaches ● Coastal strand communities ● Mineral resources ● Ethnobotanical resources ● Streams, wetlands, fish ponds, and anchialine pools ● Potable ground water and precipitation ● Caves ● Viewscapes ● Soundscapes 	<p>Puukohola Heiau NHP (PUHE) Focal Species</p> <ul style="list-style-type: none"> ● Pre-European plants ● Small mammals ● Green Sea turtles <p>Significant Resources</p> <ul style="list-style-type: none"> ● Water resources ● Wildlife habitat

Important natural resources and focal species or processes	
<p>Kaloko-Honokohau NHP (KAHO)</p> <ul style="list-style-type: none"> ● Native species, including threatened, endangered, and candidate species ● Anchialine pools ● Kaloko fishpond ● `Aimakapa fishpond & wetland ● Coral reef community & coastal resources 	<p>Puuhonua O Honaunau NHP (PUHO)</p> <ul style="list-style-type: none"> ● Coastal resources ● Rare plants in cliff refugia ● Anchialine pools ● Wetlands ● Native species
<p>Hawaii Volcanoes NP (HAVO) Hawaii Volcanoes National Park is best known for its geological processes and volcanic activity but it also has a wide variety of biologically unique and significant resources. Unique and Significant Ecosystems</p> <ul style="list-style-type: none"> ● Rainforest ● Mesic Forest ● Early successional lava flows and lava flow/kipuka mosaics <p>Rare and Endangered Species</p> <ul style="list-style-type: none"> ● 22 threatened and endangered plant species, 5 candidates for T & E status, 22 species of concern, and 40 rare plant species. ● Hawaiian Hoary Bat, Hawaiian Hawk, Nene, Dark-rumped petrel, Band-rumped storm petrel and the Hawksbill turtle. <p>Geologic processes and volcanic activity</p> <ul style="list-style-type: none"> ● World Heritage Site 	

Known stressors that may cause changes in park resources	
<p>War in the Pacific NHP (WAPA) Marine</p> <ul style="list-style-type: none"> ● Marine ● Fisheries <ul style="list-style-type: none"> ○ Ecological impact of fisheries not known ○ Debris, lost gear ○ Reef trampling ● Sedimentation effect on coral reefs ● Pollution, contaminants & ordinance <p>Terrestrial</p> <ul style="list-style-type: none"> ● Fires on savannah increase erosion and marine sediment load ● Adjacent land use and development encroaching on park units <p>Invasive and Alien species</p> <ul style="list-style-type: none"> ● Marine impact not known, baseline inventories needed ● Tangantangan, mission grass, and other invasive plants ● feral pigs, cats, and dogs and Philippine deer 	<p>American Memorial Park (AMME) Both manmade and natural threats and stressors could potentially impact AMME:</p> <ul style="list-style-type: none"> ● Typhoons ● Volcanic Activity ● Earthquakes and Tsunami ● Illegal dumping ● Effluent and Runoff from nearby hotels (spillway from Hilton) ● Abandoned equipment ● Puerto Rico Dump, Tanapag Lagoon (not within park) <p>Threats to significant park resources</p> <ul style="list-style-type: none"> ● Coral Reefs - watershed development, tourism, marina, invasion of alien algae species, overfishing, poor-quality water from nearby dump. ● Wetlands - encroaching development, illegal dumping, water quality, chemical contamination from previous dumping at Puerto Rico dumpsite
<p>National Park of American Samoa (NPSA)</p> <ul style="list-style-type: none"> ● Global Warming ● Overfishing ● Alien/Invasive Species ● Hurricanes ● Population Growth ● Expansion of Agricultural Plantations 	<p>USS Arizona Memorial (USAR)</p> <ul style="list-style-type: none"> ● Collapse of the ship and possible contamination by discharge of large amounts of oil, thus the importance for continuation of monitoring its decay rate. ● Alien and invasive species: Pearl Harbor has been documented by the Bernice P. Bishop Museum as an entry point to the remainder of the Hawaiian Islands ● Litter from tourists and nearby streams with large rainfall and run-off. ● Uphill run-off and pollution contributing to sedimentation

Known stressors that may cause changes in park resources	
<p>Kalaupapa NHP (KALA)</p> <ul style="list-style-type: none"> ● Feral ungulates ● Invasive species (rats, invertebrates, fish) ● Climate change ● Water diversion 	<p>Haleakala NP (HALE)</p> <p>Alien Species</p> <ul style="list-style-type: none"> ● Invasive Plant and Animals ● Small Mammals/Introduced predators ● Large Mammals/Ungulates ● Birds, especially competition by alien species, with native forest birds and invertebrates. ● Invertebrates ● Disease <p>Visitor Impacts</p> <ul style="list-style-type: none"> ● Developing Park Infrastructure ● Increasing park visitation ● Trampling of rare plant species ● Introduction of weed species ● Release of unwanted pets <p>Adjacent landowners</p> <ul style="list-style-type: none"> ● Expansion of Kahului Airport ● Invasive species on neighboring lands.
<p>Ala Kahakai NHT (ALKA)</p> <ul style="list-style-type: none"> ● Erosion ● Pollution ● Alien species ● Coastal habitat destruction ● Overharvesting ● Removal of sand ● Harbor operations ● Unexploded ordinance and military hazards ● Natural events ● Motorized vehicles ● Light pollution 	<p>Puukohola Heiau NHP (PUHE)</p> <p>Human threats</p> <ul style="list-style-type: none"> ● Development (resorts, golf courses, military) ● Marina Development ● Fishing / collecting in park waters ● General visitor use <p>Alien Plants</p> <ul style="list-style-type: none"> ● Kiawe (<i>Prosopis pallida</i>) ● Buffelgrass (<i>Cenchrus ciliaris</i>) ● Fountain grass (<i>Pennisetum setaceum</i>) ● Puncture vine (<i>Tribulus terrestris</i>) ● Sacramento bur (<i>Triumfetta semitriloba</i>) ● Numerous other alien plant species <p>Other threats</p> <ul style="list-style-type: none"> ● Tsunami ● Stream flood events ● Wildfire ● Erosion ● Air quality
<p>Kaloko-Honokohau NHP (KAHO)</p> <ul style="list-style-type: none"> ● Proximity of development ● Groundwater supply & contamination ● Air quality ● Alien predators (mongoose, cats, dogs) ● Alien fish in anchialine pools ● Invasive plants & algae in pools, fishponds, and on the coral reef ● Invasive land plants ● Fishing pressure and use of monofilament gill nets ● Visitor use impacts, e.g., scuba diving 	<p>Puuhonua O Honaunau NHP (PUHO)</p> <ul style="list-style-type: none"> ● Erosion ● Park maintenance ● Invasive species (plants and animals) ● Surrounding land use ● Marine recreation ● Harvesting activities ● Sea level rise, storms, and tsunami

Known stressors that may cause changes in park resources
<p>Hawaii Volcanoes NP (HAVO)</p> <p>Alien species</p> <ul style="list-style-type: none"> ● Invasive plant species ● Small mammals ● Avian diseases ● Introduced birds and invertebrates <p>Fire</p> <ul style="list-style-type: none"> ● Wildfires caused either by humans, lava flows or lightening <p>Geologic Hazards</p> <ul style="list-style-type: none"> ● Lava flows <p>Adjacent Landowners</p> <ul style="list-style-type: none"> ● Grazing on neighboring ranches ● Lack of management on surrounding natural areas and invasive species build up <p>Visitors</p> <ul style="list-style-type: none"> ● Trampling of rare plant species ● Introduction of weed species ● Release of unwanted pets

Important management issues	
<p>War in the Pacific NHP (WAPA)</p> <ul style="list-style-type: none"> ● Fishing effort not known & suspected commercial fisheries within park boundaries (studies currently underway) ● Adjacent land use and development encroaching on park boundaries ● Erosion (by fire), upstream sediment load, and sedimentation on coral reefs (studies currently underway) 	<p>American Memorial Park (AMME)</p> <p>The focus of natural resources management issues at AMME lies in control and removal of invasive species and in management of wetland areas.</p> <ul style="list-style-type: none"> ● Inventory and monitoring of wetland areas in and adjacent to the park ● Evaluation of impact of pollution from lands adjacent to the park
<p>National Park of American Samoa (NPSA)</p> <ul style="list-style-type: none"> ● Alien/Invasive Species ● Forest Pollinators (flying foxes and land birds) ● Agricultural Plantations ● Water Quality ● Fish Abundance ● Coral Bleaching and Disease 	<p>USS Arizona Memorial (USAR)</p> <p>Continued Monitoring</p> <ul style="list-style-type: none"> ● Decay rate of sunken vessel ● Baseline environmental data of marine environment surrounding vessel ● Spills and leak detection ● Bioufoul community
<p>Kalaupapa NHP (KALA)</p> <ul style="list-style-type: none"> ● Feral ungulates ● Rare plants & communities ● Fresh and marine water quality ● Invertebrate species diversity ● Seal & sea turtle nesting beaches 	<p>Haleakala NP (HALE)</p> <p>Management issues at Haleakala emphasize identification and mitigation of threats in order to preserve and protect park resources.</p> <ul style="list-style-type: none"> ● Control of invasive alien plant species ● Control of feral animals ● Control of predatory mammals ● Introduced bird and invertebrate populations ● Visitor impacts ● Reduce noise from helicopter around Haleakala crater area ● Restoration of native plants ● Restore endangered vertebrate and invertebrate populations ● Limited funding and staff

Important management issues	
<p>Ala Kahakai NHT (ALKA)</p> <ul style="list-style-type: none"> ● Development (including land tenure and access concerns) ● Visitor impacts ● Human health and safety ● Community awareness and participation ● Protocols for community based monitoring ● Ecological sustainability ● Coastal habitat restoration (fishponds, wetlands, strand, etc.) ● Alien species ● Natural events 	<p>Puukohola Heiau NHP (PUHE)</p> <ul style="list-style-type: none"> ● Preserve Hawaiian culture and land use ● Preserve native vegetation / control alien species <p>More information is needed on:</p> <ul style="list-style-type: none"> ● Assessment of wildlife use in the park ● Anchialine pond inventory
<p>Kaloko-Honokohau NHP (KAHO)</p> <ul style="list-style-type: none"> ● Groundwater quality and quantity ● Water quality of anchialine pools, ponds, and marine waters ● Development of surrounding and adjacent lands ● Predator control ● Invasive plant control ● Native plant restoration ● Management of endangered species populations ● Need for understanding of groundwater dynamics ● Limited funding & staff 	<p>Puuhonua O Honaunau NHP (PUHO)</p> <ul style="list-style-type: none"> ● Erosion due to storm surge, sea-level rise, and visitor traffic ● Invasive plant control ● Predator control ● Degradation of fish ponds and anchialine pools ● Location of park headquarters, maintenance area, and waste treatment facilities in coastal inundation zone ● Limited funding and staff
<p>Hawaii Volcanoes NP (HAVO)</p> <p>The Resource Management issues which are of greatest concern at Hawaii Volcanoes National Park include the following</p> <p>Invasive Species</p> <ul style="list-style-type: none"> ● Identification and control of incipient alien species inside the park and those outside the park threatening to invade the park and alter park ecosystems. ● Tools to control alien invertebrates such as wasps and aliens vertebrates such as small mammals, and mouflon sheep <p>Loss of Biodiversity</p> <ul style="list-style-type: none"> ● Stabilization of selected T&E and Species of Special Concern and full recovery of flagship species. ● Restoration of biodiversity in recovering or restored park ecosystems through reintroduction or augmentation programs. ● Control of disturbance sources including feral ungulates and fire and key alien plant species to allow natural recovery of native ecosystems, particularly in relatively intact, priority areas of the park. ● Restoration or rehabilitation of park ecosystems highly altered by invasive species through alien species control and outplanting programs. ● Maintenance of soundscapes, lightscapes, and wilderness qualities including ecological integrity and biodiversity. <p>Management Need</p> <ul style="list-style-type: none"> ● Staffing needs for alien species control, restoration, and monitoring program are currently inadequate, with only a small percentage of park managed. 	

2. Monitoring Program Goals & Objectives (copied from PACN Monitoring Plan, Chapter 1, section E)

Monitoring is a central component of natural resource stewardship in the NPS, and in conjunction with natural resource inventories, management, and research, provides the information needed for effective, science-based managerial decision-making and resource protection. Natural resource inventories, monitoring, and research are closely-related activities needed for effective science-based management of park resources, and the terms are sometimes confused. In general, monitoring is the tool used to identify whether or not a change occurred and research is the tool to determine what caused the change. While it is often hoped that ecological monitoring can help to explain complex relationships in ecological systems, such understanding often requires a more focused research investment.

1. Monitoring Goals

Monitoring program goals for the PACN were adopted directly from the national I&M Program goals, with the addition of a 6th goal addressing shared natural and cultural values (in *italics* below).

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

This sixth goal, related to resources that share cultural and natural value, will permit the network to more fully develop Vital Signs monitoring that address human activities and cultural practices as identified in the ecological organization outlined previously. It will also help us develop a monitoring program that meets the legal considerations and other mandates (also identified previously) that PACN parks must address.

2. Monitoring Objectives

In many respects, monitoring goals, objectives, and Vital Signs (see Chapter 3), represent the process the network has used to focus the monitoring program. We have identified broad monitoring objectives to help ensure that a full spectrum of ecological and management issues are identified. Subsequent chapters of this monitoring plan will continue to refine this focus through evaluation and selection of explicit objectives for individual Vital Signs, methods, metrics, and analytical techniques. In the interim, the objectives identified below will be refined and focused with feedback received, yet remain broad enough to help facilitate partnerships in accomplishing monitoring.

Formulation of monitoring objectives has been an iterative process: articulating objectives from suites of proposed Vital Signs, adjusting to reflect the categories outlined above, and adding objectives or questions that otherwise seemed to be missing. Our monitoring objectives, organized according to the network's framework for ecological organization, are available for review in the complete monitoring plan (http://www.nature.nps.gov/im/units/pacn/monitoring/plan/vs04/review_materials.htm).

3. Monitoring Strategies (copied from PACN Monitoring Plan, Chapter 1, section F)

A suite of Vital Signs which integrates multiple attributes of ecosystem composition, structure, and function, while representing several spatial and temporal scales (Holling 1986), is an efficient strategy for monitoring. The PACN monitoring program must also address the interaction of stressors from multiple sources, which occur at a various spatial and temporal scales. Anticipating future natural resource information needs is a daunting task, and past experience has shown that many of the most valuable uses of monitoring information were not anticipated in planning efforts. While not every park will identify nor need the same Vital Signs, monitoring that can be coordinated across multiple parks should be to gain logistical and financial economies, scientific synergy, and allow for multi-park or regional analyses, which would not otherwise be possible. Two overlapping broad strategies address such concerns: 1) ecosystem health-based monitoring and 2) issue-oriented monitoring.

1. Ecosystem Health-Based Monitoring

Ecosystem health or landscape-based monitoring integrates current scientific understanding of ecological structure, function, and composition, known anthropogenic impacts, and essential habitats. It focuses on assessing the ecosystem response to natural and anthropogenic inputs, both the stressors themselves and the resulting impacts on park ecosystems. This is essentially a landscape ecology approach to monitoring, investigating the arrangement of living organisms and ecosystems and the way they interact with each other and change over time. Monitoring of ecosystem health helps meet current natural resource information needs, while providing basic trend information that will help address future, as yet unknown, concerns. Such a broad, ecosystem health-based monitoring program emphasizes:

- Community composition and change.
- Systems, processes, and functions.
- Levels of ecological organization or structure.

Most PACN parks do not have existing ecosystem health-based monitoring. The network monitoring program will focus on this monitoring through formally identifying and prioritizing Vital Signs that address ecosystem health, monitoring a subset of ecosystem health components across the network, using the ecological organization outlined previously to help identify gaps and overlap in the ecological characteristics of Vital Signs, and facilitating additional park-based monitoring.

2. Issue-Oriented Monitoring

Issue-oriented monitoring addresses specific and immediate concerns that park managers face. Examples in the PACN include monitoring of threatened and endangered species, fishpond and anchialine pond water and habitat quality, invasive species, and outplanting or restoration effectiveness. While such issue-oriented monitoring may often overlap with ecosystem health-based approaches, it is intended to address specific, immediate, and known concerns.

Most PACN parks already have implemented (either themselves or through partnerships) monitoring that helps address some of the most significant park issues. The network monitoring program will help parks further this monitoring through formally identifying and prioritizing these issues, monitoring a subset of issues common to the network or to groups of parks, and facilitating additional park-based monitoring.

Worth noting is a hybrid concept in the differentiation of 'ecosystem health-based' and 'issue-oriented' monitoring strategies, watershed-based monitoring. The watershed is a key geographic unit in many PACN parks, as a watershed-based view of land management emphasizes the interconnections of ecosystems across the island landscape, from uplands to reef and near-shore marine habitats. Locally, watershed-based management is a traditional cultural means of land and resource management, at least in Hawaii, and thus is an excellent tool for community involvement and interaction. Watershed-based management programs in large geographic areas are often difficult for reasons of scale, whereas Pacific Island watersheds tend to be much smaller, and often fewer stakeholders are involved because land is often proportionately owned by fewer individuals. Applying the logic of ecosystem health-based monitoring within a watershed (using the ecological organization outlined previously to help identify gaps in the ecological characteristics of Vital Signs), will help facilitate linking these 2 strategies.

4. Conceptual Models

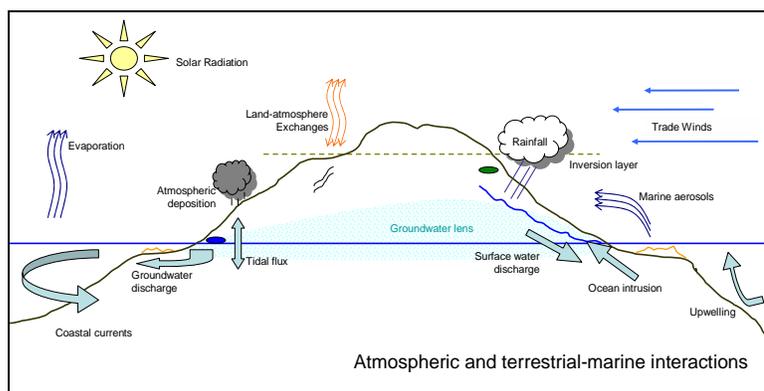
Conceptual models represent current knowledge of the processes occurring in systems, and as such, are able to illustrate system dynamics, identify the bounds and scope of the systems of interest, and provide a framework for testing hypotheses about how they function. They represent the current best understanding of system dynamics, and should be refined as our understanding of ecosystem processes increases. The conceptual ecological model ties the parks in the Pacific Island network together by illustrating their common similarities. The PACN parks share a suite of characteristics that make them unique within the NPS, as well as highly threatened ecologically.

Conceptual models have been prepared for a variety of aspects of Pacific Island Network ecology. These are available for review in the complete monitoring plan. The general approach used for currently existing models was to present an overview of geographic variation within the network, and then use a hierarchical model structure to focus on levels of increasing scale needed for Vital Signs monitoring. A model of ecosystem sustainability provides overarching cohesion of ecological structure. The ecosystem sustainability model incorporates many of the ecological characteristics identified in the table below.

Organization of ecological characteristics

Ecological Characteristic	Vital Sign Category
A. Human activities & cultural practices	C. Biotic Integrity (continued)
1) Soundscapes 2) Viewscapes / Lightscapes 3) Land Use 4) Use & Activities 5) Management Zones	2) Terrestrial Ecosystems a) Vegetation i) Landscape ii) Community iii) Population b) Consumers i) Community ii) Population c) Cave Systems
B. Physical and Chemical Conditions	3) Marine Ecosystems
1) Climate & Air Quality 2) Soil, Water, & Nutrient Dynamics 3) Water Quality 4) Geology a) Hazards b) Landforms	a) Benthic i) Landscape ii) Community iii) Population b) Water column (motile species) i) Community ii) Population c) Intertidal i) Community ii) Population
C. Biotic Integrity	
1) Freshwater Ecosystems a) Producers b) Consumers i) Community ii) Population	

Several specific models have been developed to date, at different levels of scale. Models applicable network-wide include: 1) ecosystem types found on an idealized Pacific island, 2) a generalized model of Pacific Island stressors, and 3) a model of island atmospheric, terrestrial, and marine interactions (figure below).



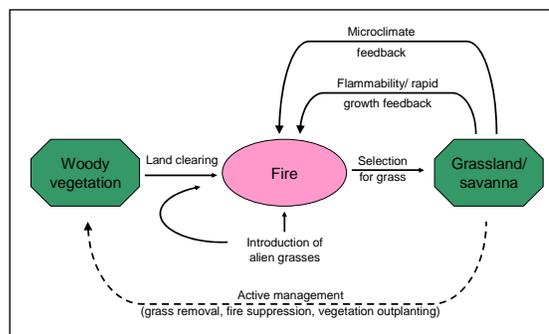
Atmospheric, terrestrial, and marine interactions. Shows key linkages between the atmosphere and marine, freshwater, and terrestrial ecosystems.

At the next level of scale, models of ecosystem function have been developed. Presently, a general terrestrial biological system model, a general marine biological system model, and a more specific stream biology ecosystem model have been completed. The table below outlines a potential hierarchy for constructing additional models as part of a completed monitoring plan. Models consist of illustrations and explanatory text, and are being developed for specific systems as need arises, in order to clarify the prioritization of Vital Signs.

Ecosystems located within or immediately adjacent to PACN parks, with brief descriptions and parks in which they are found. Resources of ALKA have not been inventoried.

Ecosystem Type	Description	Parks
Alpine & subalpine	High altitude, very low rainfall (above inversion layer). Scrubland and aeolian alpine desert.	HALE, HAVO
Forest		
Wet forest	Rain forest & mesic forest below inversion layer, cloud forest at inversion layer.	WAPA, NPSA, KALA, HALE, HAVO
Dry forest	Dryland forest, both coastal & montane.	HALE, KALA, KAHO, PUHO, HAVO
Scrubland & grassland	Mid- and low-altitude scrubland and grassland.	WAPA, HALE, PUHE, KAHO, PUHO, HAVO, ALKA?
Freshwater		
Stream	Flowing-water systems, includes sources, riparian areas, and estuaries. Both perennial and intermittent streams.	NPSA, WAPA, KALA, HALE
Wetland	Montane bogs at high elevation, lakes, coastal wetlands and mangrove forest, anchialine ponds, man-made enclosed fishponds, upland & coastal seeps and springs.	AMME, WAPA, KALA, HALE, PUHE, KAHO, PUHO, HAVO, ALKA?
Marine		
Coral reef	Coral communities measured from shoreline to pelagic zone.	AMME, WAPA, NPSA, USAR, KALA, HALE, PUHE, KAHO, PUHO, HAVO
Seagrass	Seagrass beds are located at Guam, Saipan, and Samoa parks.	AMME, WAPA, NPSA
Coastal	Includes sea cliffs, limestone and basalt rocky shores, sand and cobble beaches, and strand vegetation communities.	all parks
Subterranean	Cave and lava tube ecosystems.	WAPA, HALE, KAHO, HAVO, ALKA?

Additional models of more restricted topics present our understanding of selected ecosystem processes and components. They show in detail specific processes at or below the ecosystem level, such as the life histories and habitat uses of focal species, the effect of alien grasses and fire on community succession (figure at right), or water quality. These process/component models are useful for elaborating on subjects which were simplified in depiction of the ecosystem models. They will be constructed at the workgroup and park levels as the Inventory & Monitoring Program begins to identify possible Vital Signs.



Conceptual illustration of alien grass invasion and fire frequency (modified from D'Antonio & Vitousek 1992).

5. Criteria for Vital Sign Ranking (copied from PACN Monitoring Plan, Chapter 3)

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 elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes). Because of the need to maximize the use and relevance of monitoring results for making management decisions, vital signs selected by parks may include elements that were selected because they have important human values (e.g., harvested or charismatic species) or because of some known or hypothesized threat or stressor/response relationship with a particular park resource.

Within the definition outlined above, we identified Vital Signs that addressed the following broad categories:

- Ecosystem drivers that fundamentally affect park ecosystems.
- Stressors or threats and their ecological effects.
- Focal resources of parks.
- Key properties and processes of ecosystem integrity.

A. Identifying, Organizing, and Refining Vital Signs

Vital Signs were initially identified by the various topical working groups in 2003. These initial Vital Signs were differentiated by formulating a monitoring question or questions, articulating related management goal(s), and suggesting methods of measurement for each Vital Sign.

The initial Vital Signs were refined at several points, and the ecological organization and monitoring objectives outlined in Chapter 1, Sections C & E were used to structure the Vital Signs. The process of organizing Vital Signs and reviewing monitoring objectives helped identify areas of overlap as well as gaps in the initial list of Vital Signs, and appropriate additions or deletions were made

B. Vital Sign Priorities

Vital Signs were initially ranked by each park based on 4 individual criteria (ecological significance, management significance, legal mandate, and cost-effectiveness). Within each Vital Sign, the rankings for the individual criteria were weighted 30% ecological significance, 30% management significance, 20% legal mandate, and 20% cost-effectiveness (Table 3.1). When combined, these weighted priorities provide an overall rank for each Vital Sign (both across all 11 parks in the network, and for only those parks responding to a specific Vital Sign). For details about this prioritization approach see the PACN monitoring plan (http://www.nature.nps.gov/im/units/pacn/monitoring/plan/vs04/review_materials.htm), <http://science.nature.nps.gov/im/monitor/docs/CriteriaExamples.doc>, <http://science.nature.nps.gov/im/monitor/docs/PrioritizationExample.doc>, and the following publication.

Andreasen, J.K., O'Neill, R.V., Noss, R., and Slosser, N.C. 2001. Considerations for the development of a terrestrial index of ecological integrity. *Ecological Indicators*, 1: 21-35.

6. Proposed Vital Signs and Priorities (copied from PACN Monitoring Plan, Chapter 3)

With park staff ranking individual Vital Signs, priorities for the PACN reflect park staff understanding of each Vital Sign's management significance, ecological significance, legal/policy mandate, and cost effectiveness and feasibility. The criteria identified above are somewhat lengthy and required a significant time investment when ranking, many Vital Signs were in draft form at the time. The rankings identified are therefore tentative, and the network rankings are presented in this document as they reflect the combined input of park staff. Actual selection of Vital Signs will reflect a practical combination of inputs, including individual park priorities, using these rankings as a starting point for discussion. Figure 3.1 presents a visual schematic of how park, network, and regional or NPS-wide Vital Signs priorities may actually be reflected in implementation.

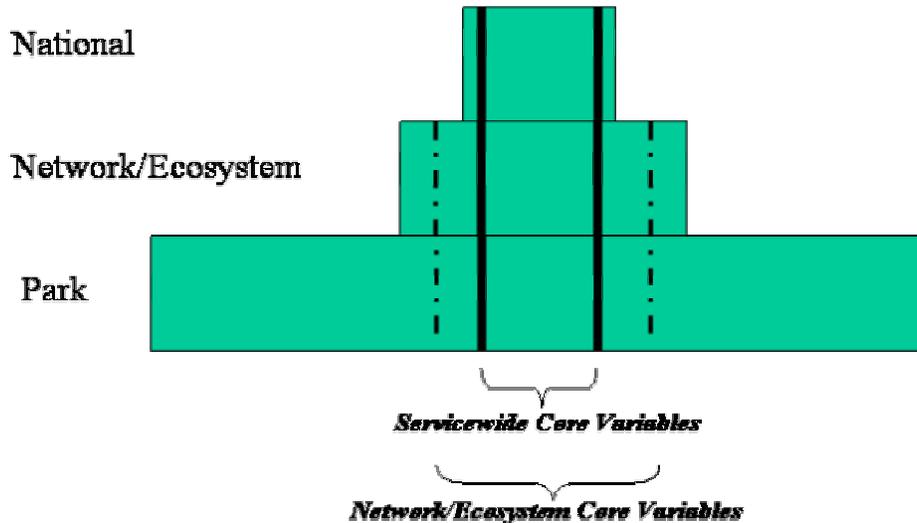


Figure 3.1. Schematic of Vital Sign priorities and implementation at park, network, and regional or NPS-wide levels.

Results of park prioritization of Vital Signs will be made available at the workshop on 16-18 March 2004. Proposed Vital Signs are below.

Table 3.2. PACN Vital Signs.

Ecological Characteristic	Vital Sign Category	Monitoring Objectives	VS Id#	Vital Sign	Monitoring Question(s)	Monitoring Method	Metrics
Human activities & cultural practices	Soundscapes	Monitor sound sources, frequencies, occurrence, and levels	H1	Alien, Natural, Human Soundscapes	Are alien species sounds appropriate to management zone? Are naturally present sounds maintained at appropriate frequencies, occurrence, db levels?	point/plot sampling	frequency (hz), frequency (time), Sound durations, Sound levels, sound source identification
		Viewscape / seascape appearance	H2	Viewsheds	Are landscapes/seascapes changing?	historical photos	qualitative
	Viewscape / Lightscape	Monitor light levels and characteristics of light/dark cycles	H3	Lightscape & Night sky	Are natural light/dark cycles maintained as appropriate (eg no inappropriate shading, etc)? Is artificial light restricted to basic human safety needs only?	above ground (aerial or satellite) vs on ground measurements (photographs)	Light intensity, spatial distribution, temporal frequency
		Monitor points of entry for invasive species	H4	Alien Invasive Species Points of Entry	What are points of entry for invasive species, ALL taxa? What species are being introduced--reaching the islands?	Point / port of entry monitoring	Number, identification of species detected / interdicted
	Land Use	Monitor water use adjacent to or upstream from park boundaries	H5	Water Use(s) Within & Surrounding Parks	Which resources are most at risk due to conflicting water uses (withdrawals, diversions, inputs)?	Stream gages, well monitoring/logs	Volume, rate
		Monitor land use adjacent to, or upstream of, park boundaries	H6	Land Use(s) Within & Surrounding Parks	What areas are most at risk due to conflicting adjacent changes in land use (e.g. ranching, urbanization)?	Aerial photography, mapping, plots	change detection maps
	Park Use & Activities	Monitor debris-trash occurrence in coastal, riparian, wetland, and lacustrine habitats; in or near high use areas	H7	Litter/debris	What are levels of litter within parks? Where is littering/ dumping of trash taking place? What are areas of marine debris deposition?	surveys of activity & locations	quantity present / removed
		Monitor patterns of park visitation, use & damage (terrestrial & marine)	H8	Marine Recreational Activities & Groundings/Anchor Damage	Are use levels changing? What are trends?	plots, transects, and surveys	density of fish line, density of lead sinkers on bottom, level/degree of trampling, percent broken coral, quantity of beach users, quantity of diver hours, water films
			H9	Footprint & Visitor Use Patterns	Are locations and/or intensity in use areas (visitor or management) changing? Are use levels associated w/detectable levels of resource change?	VERP program, repeated mapping of use areas, plot sampling	erosion, plant cover
			H10	Subsistence Farming/Agriculture	What areas are affected by subsistence farming and how are these practices modifying plant communities?	Mapping/gps perimeter of farmed areas, aerial photos	area covered by disturbance, Distribution
		Monitor incidence & occurrence of bioprospecting	H11	Bio-prospecting Harvest	Are harvest levels changing? What are trends? Is human harvest changing distribution, abundance, or other population characteristics? What are current trends (research activities) in bioprospecting.	Surveys in various targeted habitats: pharmaceutical plants, thermal pools, coral reefs, intertidal zones, etc. Quantification of research activity, harvest levels, and of targeted population characteristics.	harvest composition, harvest quantity, Research activity
		Monitor levels of take & harvest of harvested species (marine, freshwater, and terrestrial) or resources (coral, sand)	H12	Coral/Sand Mining Harvest	Are harvest levels changing? What are trends?	plots/transects and remote sensing	harvest composition, harvest quantity
			H13	Culturally Significant Plant Harvest	What impact does gathering of plant materials by humans have on harvested populations?	Transects, plots	Cover, demographics, density
			H14	Culturally Significant Vertebrate Species Harvest	Is human harvest changing distribution, abundance or other population characteristics? Can there be a balance between management goals of sustaining population numbers and culturally important species?	Systematic monitoring and/or population surveys of harvested species	collection statistics, counts by class, Creel counts
			H15	Reef Fisheries Harvest	Are harvest levels changing? What are trends? Is human harvest changing distribution, abundance, or other population characteristics? Harvest includes legal and illegal take.	Systematic monitoring of fishing and harvest of shellfish and other inverts in coastal areas; population characteristics of target species	catch per unit effort, collection statistics (quantity, age/size), composition, Creel counts, harvest quantity
		Management Zones	Monitor patterns and effects of use and management	H16	Management Zone uses	Are locations, extent and/or intensity in use areas (visitor or management) changing? Are use levels associated w/detectable levels of resource change?	mapping
	Monitor effects of management practices on wilderness character		H17	Wilderness Areas - HAVO, HALE, other Unofficial	Monitor to identify the need for, or effects of, management actions	Limits of acceptable change. Nature, magnitude, and source of impacts	Limits of Acceptable Change (LAC)
Physical / Chemical Environment	Climate & Air Quality	Monitor visibility	P1	Visibility	Is sight distance, extinction, and quality reduced?	Aerosol filters, cameras	sight distance (extinction coefficient), particulate concentration, turbidity
		Track rates of atmospheric deposition	P2	Atmospheric Deposition: Wet (direct & occult) and Dry	Document differences in Human vs. Volcanic vs. other natural sources	Station data	Total Hg & Hg concentration, Total N & N concentration, Total S & S concentration
		Track atmospheric concentrations of particulates and gases, levels of radiation--emphasizing those with known human health or environmental impacts	P3	Atmospheric Gases: Climate Change Indicators, Human Pollutants, Natural-Volcanic	How are atmospheric gas concentrations changing and are these changes having ecological or human health impacts? How does volcanic activity influence air quality?	Station data	Air toxics concentration/human, CO2 concentration/climate change, Nox concentration/humans, O3 concentration/humans, S concentration/volcanic
			P4	Marine Aerosols	How do marine aerosol levels vary over time and space?	station data	species, concentrations
			P5	Atmospheric Particulates: Climate Change Indicators, Human Pollutants, Natural-Volcanic	How are atmospheric particulate species and concentrations changing and are these changes having ecological or human health impacts?	Station data	Dust, Particle analyses/species: 10-2.5-1 micron cuts, species
			P6	Solar radiation	How are solar radiation inputs, UV-B, photosynthetically active radiation, or other wavelengths, fluxes changing?	UV-B monitoring (eg Brewer's), PAR sensors, total flux	upwelling / downwelling
		Monitor core weather/climate conditions within each park (on each island)	P7	Weather & Climate	What are ranges of climate parameters within each park? Are they changing?	Weather stations (RAWS, COOP, NPS-ARD).	fog, wind, temperature, solar radiation, soil moisture, relative humidity, fuel moist/temp, wetness, precip (direct & occult)
	Monitor frequency and intensity (severity) of extreme events (hurricanes, waves, winds, rain, etc.)	P8	Extreme events (weather & ocean)	What are impacts of extreme events? How often do they occur, and at what intensity? What are temporal trends?	NOAA, USGS, NWS	hurricane extent/intensities, ENSO extent/intensities, etc	
	Identify and monitor spatial patterns of climate, such as trade-wind inversion elevation, lifting condensation level, lapse rates, etc.	P9	Climate Representations - 2- & 3-dimensional	Provide baseline data to help evaluate stability and variability in climate affecting natural populations, processes, and large scale ecological drivers?	modeling or mapping	Lifting condensation Level, Temperature lapse rates, Trade-Wind Inversion, Cloud patterns (incl. radiation)	
	Soil, Water, & Nutrient Dynamics	Monitor physical ocean dynamics--ocean currents, sea level, tides/swell	P10	Ocean/Physical Dynamics: Currents, Sea Level, Tides/Swell	Is variation within normal range? What are temporal trends?	Tide Gauge, GIS, Buoy data, satellite data	buoy data, instrument data, Mapping velocity and direction, maximum signal wave height, satellite data, sea level, flood timing / magnitude, tide fluctuations
		Monitor cycles of nutrients and elements within soils and water--including carbonate (oceanic), nitrogen, and phosphorous	P11	Biogeochemical Cycles - Nutrient Cycling	How are fluctuations changing over time (source, directions, levels of flow)?	monitoring plots	Aquatic senescence, Coral growth-CaCO3 deposition, Forest productivity (litter rain, mineral growth), key constituents (N, K,

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Ecological Characteristic	Vital Sign Category	Monitoring Objectives	VS Id#	Vital Sign	Monitoring Question(s)	Monitoring Method	Metrics	
		Monitor soil erosion	P12	Soil Erosion	What are causes and locations of soil erosion?	erosion pins, sediment collectors, mapping	CaCO3) Rate of change?	
		Monitor soil quality trends (physical, toxics/contaminants, other biologic and nutrients)	P13	Soil Quality - Biological	Are soil communities changing?	Soil sampling and analysis	bacteria, fungal/microrhizal, worms/nematodes/arthropods	
			P14	Soil Quality- Chemical	Are soil buffering and filtering qualities changing?	Soil sampling and analysis	appropriate WQ measures, cations, pH, soil composition, Total Nitrogen & Total Carbon	
			P15	Soil Quality- Physical	Are physical soil properties changing?	Soil sampling and analysis	DOC, grain size, moisture content, parent material, percent organic matter, permeability, POC	
		Monitor condition and extent of soil crusts	P16	Soil Crust Change (Arid-Semi-arid habitats)	What are pressures/impacts on soil crusts, and how are they distributed in space and time?	soil and geologic mapping, remote sensing, periodic change analysis	distribution of soil crusts, pH, rainfall, substrate composition, volcanic aerosol composition, wind spd/dir	
		Monitor trends in surface water flow regimes	P17	Flowing surface water hydrology	What are usual rates & range of flow? What is timing & magnitude of floods or droughts? Is erosion occurring, or are flow channels changing?	gages, sampling at permanent sites	erosion, discharge / recharge, diversion patterns, flood timing / magnitude, withdrawal & consumption rates, stream cross-section, stream discharge, stream gradient	
		Monitor wetland (incl. anchialine ponds) water flow exchange dynamics, size, and distribution	P18	Wetlands (incl. anchialine pools) hydrology	What are freshwater/saltwater recharge rates? What is habitat extent? What are temporal trends in recharge rates and habitat extent?	measure salinity, residence time, mapping	erosion, flood timing/magnitude, flow, parent material/geomorphology, plant cover/ species present, pool size, depth & salinity, rainfall, sediment loads, stream cross-section, stream discharge, stream gradient	
		Monitor ground water flow rates and direction of movement (recharge)	P19	Groundwater dynamics	What are rates of subsurface flow? What is level of freshwater/saltwater mixing? What are flow patterns?	well, seep, & spring discharge measurements	discharge/recharge, injections (sewage), permeability, tide fluctuations, withdrawal & consumption rates	
	Water Quality	Monitor water quality core parameters	P20	Ground Water Quality Core parameters	Is variation within normal range? What are temporal trends?	water sampling from dedicated monitoring wells in addition to supply wells	temperature, pH, salinity (sp. cond.), Dissolved Oxygen,	
			P21	Marine Water Quality Core parameters	Is variation within normal range? What are temporal trends?	in-situ measurements and collection of samples at established sites including controls	temperature, pH, salinity (sp. cond.), Dissolved Oxygen, PAR	
			P22	Surface Water Quality Core parameters	Is variation within normal range? What are temporal trends?	in-situ measurements and collection of samples at established sites including controls	temperature, pH, salinity (sp. cond.), Dissolved Oxygen, PAR	
		Monitor supplemental water quality parameters	P23	Ground Water Quality Supplemental parameters	Is variation within normal range? What are temporal trends?	water sampling from dedicated monitoring wells in addition to supply wells	nutrients, total suspended solids/turbidity, chlorophyll A , alkalinity, anions, cations, redox, total organic carbon,	
			P24	Marine Water Quality Supplemental parameters	Is variation within normal range? What are temporal trends?	in-situ measurements and collection of samples at established sites including controls	nutrients, total suspended solids/turbidity, chlorophyll A , alkalinity, anions, cations, redox, total organic carbon,	
			P25	Surface Water Quality Supplemental parameters	Is variation within normal range? What are temporal trends?	in-situ measurements and collection of samples at established sites including controls	nutrients, total suspended solids/turbidity, chlorophyll A , alkalinity, anions, cations, redox, total organic carbon,	
		Monitor microbiological water quality parameters	P26	Ground Water Quality - Microbiology	Is variation within normal range? What are temporal trends?	water sampling from dedicated monitoring wells in addition to supply wells	bacteria, biological oxygen demand	
			P27	Marine Water Quality - Microbiology	Is variation within normal range? What are temporal trends?	collection of samples at established sites including controls	bacteria, biological oxygen demand	
			P28	Surface Water Quality - Microbiology	Is variation within normal range? What are temporal trends?	collection of samples at established sites including controls	bacteria, biological oxygen demand	
		Monitor toxic and contaminant levels in water	P29	Ground Water Quality - Toxics & contaminants	Is variation within normal range? What are temporal trends?	water sampling from dedicated monitoring wells in addition to supply wells	chemical oxygen demand, heavy metals, herbicides, organics, pesticides	
			P30	Marine Water Quality - Toxics & contaminants	Is variation within normal range? What are temporal trends?	water sampling, sediment sampling, animal tissue sampling	chemical oxygen demand, heavy metals, herbicides, organics, pesticides	
			P31	Surface Water Quality - Toxics & contaminants	Is variation within normal range? What are temporal trends?	water sampling, sediment sampling, animal tissue sampling	chemical oxygen demand, heavy metals, herbicides, organics, pesticides	
		Monitor biological invertebrate communities	P32	Marine Water Quality - macroinvertebrates	What are community dynamics of marine & estuarine sediment communities?	benthic community composition (transects, quadrats, traps, trawls, tows)	diversity, species richness, indicator species, recruitment	
			P33	Surface Water Quality - macroinvertebrates	What are community dynamics of benthic freshwater communities?	benthic community composition of standard sampling units	diversity, species richness, indicator species, recruitment	
		Geology	Hazards	Monitor surface volcanic activity (lava flows, eruption events & ground deformation)	P34	Volcanic Unrest - Ground Deformation	What role does volcanic activity and deformation play in maintaining public safety, park facilities, and how do they affect natural processes?	Dry and wet tilt meters, dilatometers, GPS
	P35				Volcanic Unrest - Lava Flows	What role do lava flows play in maintaining public safety, park facilities, and how do they affect natural processes?	Remote sensing, visual observation, tilt meters and dilatometers, GPS ground deformation	tube mapping, flow direction/magnitude, GPS
	Monitor volcanic & non-volcanic seismicity		P36	Seismicity of Non-Volcanic Origin	Can we identify trends and predict hazards?	Seismometers (local and global)	tilt meters, seismometers, dilatometers (pressure gauges), EDM (Electronic Distance Measuring)	
			P37	Seismicity of Volcanic Origin	Can we identify trends and predict hazards?	Seismometers (local and global)	tilt meters, seismometers, dilatometers (pressure gauges), EDM (Electronic Distance Measuring)	
	Monitor extent, location, and causes of mass wasting events (e.g. landslides)		P38	Mass Geologic Wasting	Can we predict slope failure hazards to protect habitats and human safety? Can we monitor or identify causes? What are temporal trends?	Rainfall and other climactic analyses (precursors and catalysts), stream gauges, remote sensing	soil saturation, soil/ground creep, substrate composition/permeability, substrate distribution	
	Landforms	Monitor shoreline dynamics	P39	Coastal Shoreline Change (erosion)	Where are shorelines advancing, retreating, or stable?	tide gauge, GPS, remote sensing, field	human development/infrastructure, substrate	

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Biotic Integrity	Terrestrial Ecosystems	Vegetation	Landscape		& accretion)		investigation, periodic change analysis	composition, shoreline aspect/position/slope, sea level, nearshore physical oceanography		
				Track dune locations and topography	P40	Dune Change (erosion & accretion)	Are drought & desertification influencing topsoil transport and seed/nutrient transport patterns?	remote sensing, field investigation, periodic change analysis	grain size & parent material, rainfall, soil crust development, substrate composition, substrate distribution, veg stabilization, wind spd/dir	
				Identify and monitor the extent of permafrost	P41	Permafrost on Big Island summits	Is extent of permafrost declining? Influence on ground subsidence, slope failure, etc?	Remote Sensing (ground penetrating radar), satellite thermal analysis, drilling	temperature, volcanic activity (heating), permafrost thickness, rainfall	
				Monitor karst and non-karst cave and lava tube habitat characteristics, topography, and extent	P42	Cave Environmental conditions	Are cave systems impacted and changing as a result of above ground changes or human activity & cultural practices? Are environmental conditions in caves changing (temp, humidity, light, etc.)?	Station/plot data	litterfall, Species distribution & abundance, human use levels, temperature, humidity, ground compaction, etc.	
					P43	Cave Geology: non-karst	What are patterns of mineral accretion? Where & when are collapse/skylight formation or enlargement occurring?	geologic mapping, periodic measurement of physical parameters and feature types	dimensions, feature size, extent	
			P44	Cave Geology: karst	Are changes in karst systems leading to potential bedrock collapse, well yield disparities, poor groundwater quality, soil instability?	Geologic mapping, remote sensing, surface water chemistry, groundwater discharge patterns	baseline mapping, groundwater flow/quality			
			Community	Landscape	Monitor patterns of distribution & extent of community types	T1	Soil and Pollen Landscape History	Are intact paleo landscapes being altered?	Mapping; Pollen and charcoal assemblages, soil horizons, etc.	Rate of change?
						T2	Ecozone Boundaries	Are locations of ecotones changing? Are the communities that comprise ecological boundary zones changing?	vegetation mapping, landscape photography, high spatial resolution plots	change detection maps
						T3	Landscape Fragments, Patch Size, Land Cover	How are the distributions of plant communities and land cover inside and immediately outside the Parks changing over time?	Mapping, repeat photography	FRAGSTAT statistics, Vegetation type
					Monitor fire regimes and effect on vegetation	T4	Fire Effects & Dynamics: Vegetation and Landscape Level	What is a natural fire frequency? What changes in plant community composition and structure result from fire? What are the biogeochemical effects of fire?	Transects, plots, histories	change in vegetation structure, Cover, density, erosion, nutrient loss, species composition
		Track insect and disease presence during forest dieback			T5	Forest Dieback	What percentage of trees in a populations is declining or dying? What proportion are dying by natural vs. non-native influences? What are temporal trends?	Transects, plots, population surveys	Plant cover, density, vigor, size classes, species composition, Density of herbivores relative to degree of dieback	
		Monitor community dynamics, structure, function, and composition		T6	Terrestrial Plant Biodiversity	Are there detectable short-term changes in selected native plant communities?	plots, transects	abundance, density, cover, Abundance and trends in selected focal groups of plant species		
				T7	Long-term Plant Succession	What are long-term trends in plant community composition and structure, regardless of management treatment or land use?	Transects, plots, mapping, remote sensing	Cover, density, vigor, size classes, growth rates, species composition		
				Monitor effects of management on native communities	T8	Recovery/Change of Native Vegetation with Alien Plant Control	What are trends in plant community composition and structure in response to alien plant control treatments?	Transects, plots	Cover, density, vigor, size classes, species composition, recruitment rates	
					T9	Recovery/Change of Native Vegetation with Feral Ungulate Control	What are trends in plant community composition and structure after removal or sustained control of feral ungulates? Are habitats damaged by alien ungulate species restorable?	Transects, plots. Monitor fenced areas where ungulates have been removed.	Cover, density, vigor, size classes, species composition	
					T10	Recovery/Change of Native Vegetation with Invasive Alien Invertebrate Control	Are native plant species recovering where invasive invertebrates are controlled? What are trends in plant community composition and structure following invasive invertebrate control?	Transects, plots	species composition, vigor, size classes, density, Cover, abundance & distribution of alien inverts & native pollinators, flower & seed production	
					T11	Invertebrate Biocontrol of Plants	What is the long-term impact/efficacy on populations of blackberry, passionflower, & other pests? Are non-target plants, especially natives, being affected?	Plots & transects for plants	Infestation rates	
				T12	Plant Pathogen Biocontrol of Plants	What is the impact/efficacy on populations of control target? Are non-target species being attacked?	Plots & transects	Infestation rates		
		Population	Monitor population size and distribution of native, endemic, or focal species, including response to restoration efforts. Where appropriate, measure demographics (size/age structure, reproduction, recruitment, etc.) of selected indicator species	T13	Native Plant Species Protection (T, E, S-o-C species)	What are the distribution, abundance, and demographics of threatened, endangered, and rare native plant species? Are plant populations reproducing at self-sustaining levels?	Mapping, plots, counts in size classes	phenology, survival, soil seed bank, population structure, Distribution, density, reproduction		
			Monitor disease incidence and impacts, especially on native species	T14	Established Plant Disease & Pathogens	What is the incidence and level of disease in populations? Are diseases/pathogens affecting populations? What are trends in disease/pathogen?				
				T15	Alien Incipient Plant Disease & Pathogens	Where are disease locations outside parks? What species are they affecting? What are rates and directions of spread? Identify existing disease/pathogen incidence, impact, and trends?				
			Monitor extent and response to treatment of established invasive species	T16	Established Alien Species - Plants	What is the distribution and abundance of established alien plants? What is the rate of spread of alien plants?	Mapping, transects, plots, counts in size classes	Distribution mapping, frequency		
Monitor occurrence of non-established (incipient) invasive species	T17		Alien Incipient Invasive Plants	Is species present, if so what is the nature and extent of infestation? What are the most effective strategies for detecting and preventing new invasives species? Where should efforts be focused? What are potential impacts?	Passive surveillance and follow-up; surveys in high-risk sites (eg. roadsides, trails, ports, disturbed sites)	Presence/ absence, rapid assessment of extent of infestation				
Consumers	Monitor community dynamics, structure, function, and composition	T18	Terrestrial Invertebrate Biodiversity	What are trends in distribution and abundance of hyper-diverse groups w/in parks?	Population surveys, transects, plots	Diversity, evenness, endemism				
		T19	Terrestrial Vertebrate (including off-shore islets refugia) Biodiversity	Are there long-term changes in selected native vertebrate communities?	Population surveys	Abundance and trends of selected vertebrate species or groups				
	Monitor effects of management on native communities	T20	Recovery/Change of Native Invertebrates Communities with Native Plant Restoration	What native species are recolonizing restored areas? Which ones are not?	Transects, plots	abundance, Presence, trends of selected species or groups				
		T21	Recovery/change of Native Wildlife and habitats (including wetlands) with restoration of native vegetation	What are trends in plant community composition and structure resulting from outplanting and seed-sowing activities? What is the response of native vertebrate and invertebrate populations to plant community restoration? What are priority plant species that should be restored?	Transects, plots (monitoring of areas where seeds have been broadcast and native species outplanted)	size classes, vigor, species composition, seedling recruitment, growth rates, Cover, animal reproductive success, animal popn size, animal popn growth rates, survivorship, density				
		T22	Invertebrate Biocontrol of Invertebrates	What is the impact of biocontrol agents on native moths, beetles, & parasitoids? What is the impact/efficacy on target populations?	Population surveys, rearing	Infestation rates				

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Ecological Characteristic	Vital Sign Category		Monitoring Objectives	VS Id#	Vital Sign	Monitoring Question(s)	Monitoring Method	Metrics			
			Monitor population size and distribution of native, endemic, or focal species, including response to restoration efforts. Where appropriate, measure demographics (size/age structure, reproduction, recruitment, etc.) of selected indicator species	T23	Forest Birds and Bats (includes T & E spp.)	Are distribution, abundance, other population characteristics, or habitat changing? Determine population levels over time.	Population surveys (forest bird methods differ from those for raptors or bats)	Abundance / density, distribution			
				T24	Herps (native)	Are distribution, abundance, other population characteristics, or habitat changing? Determine population levels over time.	Population surveys	Abundance / density, distribution			
				T25	Invertebrate Charismatic or Species of Concern	Are distribution, abundance, other population characteristics, or habitat changing? Determine population levels over time.	Population surveys	Abundance / density, demographics, distribution			
				T26	Seabirds (including T & E spp.)	Are distribution, abundance, other population characteristics, or habitat changing? Determine population levels over time.	Population surveys	Abundance / density, distribution			
				T27	Shorebirds and Waterbirds (including T & E spp.)	Are distribution, abundance, other population characteristics, or habitat changing? Determine population levels over time.	Population surveys	Abundance / density, distribution			
				T28	Terrestrial Invertebrates Associated with Habitat Quality	What are trends in invertebrate indicator species?	Population surveys	abundance, distribution, demographics			
				T29	Terrestrial Invertebrate Species Protection (T, E, S-o-C Species)	Are distribution, abundance, other population characteristics, or habitat changing?	Mapping, plots, population surveys	abundance, distribution, demographics			
			Monitor disease incidence and impacts, especially on native species	T30	Established Disease & Pathogens of Terrestrial Vertebrates	What is the incidence and level of disease in populations? Are diseases/pathogens affecting populations? What are trends in disease/pathogen?	Continue to monitor bird, bat, and herp populations (VCP, mist-netting)	incidence, Presence/ absence			
				T31	Alien Incipient Disease & Pathogens of Terrestrial Vertebrates	Where are disease locations outside parks? What species are they affecting? What are rates and directions of spread? Identify existing disease/pathogen incidence, impact, and trends	Surveys in high risk sites; passive surveillance,; education, outreach, public reporting, and follow-up	Presence/absence, rapid assessment of extent of infestations (distribution, identification and numbers of host and/or vector species involved)			
			Monitor extent and response to treatment of established invasive species	T32	Established Alien Species - Feral Ungulates	What are the relative abundance and population trends of feral ungulates? What are the impacts of feral ungulates? Is competition from invasive spp changing distribution, abundance, etc. of native spp.?	Animal activity transects	Index of ungulate damage (to both plants and animals as appropriate) index of erosion damage by ungulates, plant species recovery after removal of ungulates			
				T33	Established Alien Species - Invasive Terrestrial Invertebrate Pests of natural systems	How effective is control? What are the abundance, distribution, and seasonal and year-to-year variations in populations? What are trends in impact?	Transects, plots, population surveys	abundance, distribution, demographics			
				T34	Established Alien Species - Predatory Terrestrial Vertebrates	Are native plant and animal species abundance or distribution changing in response to predators or predator control? What are trends in invasive species populations?	Treatment and control Transects/plots (for plants); other methods appropriate for native vertebrates of interest (VCP, transects, etc.); population surveys for predators	Plants: species composition, population and/or community structure. Animals: VCP, transects, other methods to monitor critical life stages identified as impacted by predators. Predator population indices, presence/ absence			
				T35	Established Alien Species - Terrestrial Invertebrate Pests (agricultural)	Monitor population fluctuations to determine when additional control actions are needed	Population surveys	Infestation rates of native and alien fruits			
				T36	Established Alien Species - Terrestrial Invertebrate Pests (human structures)	Characterize extent of impact invertebrate pests are having on historical and other culturally significant structures?	Periodic sampling of structures	Infestation rates			
				Monitor occurrence of non-established (incipient) invasive species	T37	Alien Incipient Invasives - Predatory Terrestrial Vertebrate	Is species present, if so what is the nature and extent of infestation? What are the most effective strategies for detecting and preventing new invasives species? Where should efforts be focused? What are potential impacts?	Passive surveillance and follow-up on reports; education, outreach, and public reporting; surveys in high- risk sites	Predator population indices, presence/ absence, rapid assessment of extent of infestation		
			T38		Alien Incipient Invasives - Fungi	Is species present, if so what is the nature and extent of infestation? What are the most effective strategies for detecting and preventing new invasives species? Where should efforts be focused? What are potential impacts?	Passive surveillance and follow-up on reports; education, outreach, and public reporting; surveys in high- risk sites	distribution, Presence/ absence, rapid assessment of extent of infestation			
			T39		Alien Incipient Invasives - Terrestrial Invertebrates	Is species present, if so what is the nature and extent of infestation? What are the most effective strategies for detecting and preventing new invasives species? Where should efforts be focused? What are potential impacts?	Passive surveillance and follow-up on reports; education, outreach, and public reporting; surveys in high- risk sites	distribution, Presence/ absence, rapid assessment of extent of infestation			
			T40		Alien Incipient Invasives - Vertebrates	Is species present, if so what is the nature and extent of infestation? What are the most effective strategies for detecting and preventing new invasives species? Where should efforts be focused? What are potential impacts?	Passive surveillance and follow-up; surveys in high- risk sites	distribution, Presence/ absence, rapid assessment of extent of infestation			
				Cave Systems	Community	Monitor changes in cave communities	T41	Cave & lava tube communities	Are cave (biotic) communities changing? What are temporal trends?	Population surveys, root type and abundance	abundance, distribution, demographics
			Biotic Integrity	Freshwater Ecosystems	Producers	Monitor community composition, structure, and productivity	F1	Community dynamics of primary producers	What species & groups are present? What are normal rates of productivity? Where are algal blooms present?	periodic benthic sampling	abundance, distribution, demographics
Consumers	Community	Monitor community dynamics, structure, function, and composition			F2	Aquatic and Riparian Species (vertebrate and invertebrate) Biodiversity	Are there long-term changes in selected aquatic native communities?	population surveys, transects	Abundance and trends of selected species or groups		
		Monitor disease incidence and impacts, especially on native species			F3	Freshwater Animals Disease & Pathogen	What is the incidence and level of disease in populations? Are diseases/pathogens affecting populations? What are trends in disease/pathogen?	visual surveys of possibly affected populations	disease types, occurrence, tissue samples, vectors		
		Monitor population size and distribution of native, endemic, or focal species, including response to restoration efforts. Where appropriate, measure demographics (size/age structure, reproduction, recruitment, etc.) of selected indicator species			F4	Amphidromous Fauna Size-Age Structure, Reproduction and Recruitment	Is variation within normal range, why not? What are selected short- and long-term trends? Is recruitment at normal levels?	Size & age structure: transects, plots. Repro & recruit: downstream larval drift & upstream immigration.	abundance of size classes, recruitment and reproduction rates, species diversity		
		Monitor extent and response to treatment of established invasive species			F5	Established Alien Species - Predatory Freshwater (vertebrate and invertebrate)	What is the extent of present infestations? What is the impact of predatory invasive species on native species abundance and distribution? What are effective management strategies for invasive species removal?	Periodic sampling of freshwater habitats.	abundance, Distribution		
		Monitor occurrence of non-established (incipient) invasive species			F6	Alien Incipient Invasives - Predatory Freshwater (vertebrate and invertebrate)	Is species present, if so what is the nature and extent of infestation? What are the most effective strategies for detecting and preventing new invasives species? Where should efforts be focused? What are potential impacts?	Periodic sampling of freshwater habitats outside of parks	abundance, Distribution		

*Pacific Island Network, Monitoring Plan (Vital Signs Workshop) Review Materials
16-18 March 2004, East-West Center, University of Hawaii-Manoa*

Ecological Characteristic	Vital Sign Category		Monitoring Objectives	VS Id#	Vital Sign	Monitoring Question(s)	Monitoring Method	Metrics
Marine Ecosystems	Benthic	Land scape	Monitor patterns of distribution & extent of community types	M1	Coral Growth (erosion & accretion)	Is net accretion or erosion occurring? What are spatial patterns?	monitoring quadrats	coral growth and decline rates, water chemistry
				M2	Benthic Habitats	How are the distributions of benthic habitats/communities and coral/algal cover inside and immediately outside the Parks changing over time?	mapping, transects, quadrats	Rugosity, relative abundance, species diversity, indicator species
		Community	Monitor community dynamics, structure, function, and composition	M3	Benthic Marine Invertebrates and Algae Biodiversity	Are there long-term changes in composition of selected native communities?	Transects, quadrats (photo, video)	Cover by type, biomass, species diversity, relative abundance, counts
				M4	Subtidal - Hard Bottom (coral reef, colonized basalt, etc.)	Is variation within normal range? What are selected (community composition, distribution, physical structure) short- and long-term trends?	transects, quadrats (photo, video), mapping	cover by type, biomass, habitat type diversity, percent cover of species density
				M5	Subtidal - Soft Bottom (sand flat, seagrass bed)	Is variation within normal range? What are selected (community composition, distribution, physical structure) short- and long-term trends?	transects, quadrats, mapping	cover by type, biomass, habitat type diversity, percent cover of species density
		Population	Track community and population trends in harvested fisheries / collected species	M6	Benthic Reef Fisheries / Collected species (inverts: sea cucumbers, pololo worm, corals; etc)	What are effects (size/age cohort, demographics) of human harvest on fished or gathered species? What are the trends of trackable population parameters? If variance is observed, is it due to harvest? Is variance due to harvest levels?	Transects, quadrats	Counts, biomass, relative abundance
				M7	Benthic Marine Invertebrates and Algae	Is population variation within normal range (size/age cohort, demographics)? What are population trends?	transects, quadrats (photo, video), mapping	Counts, demographics, biomass, relative abundance, recruitment rate
			Monitor population size and distribution of native, endemic, or focal species, including response to restoration efforts. Where appropriate, measure demographics (size/age structure, reproduction, recruitment, etc.) of selected indicator species	M8	Coral Growth/Size and Age Structure, and Recruitment	Is variation within normal range (growth, size, and age structure)? What are selected short- and long-term trends?	transects, quadrats (photo, video), mapping	Cover by type, growth rates, recruitment rates, mortality, survivorship
				Monitor disease incidence and impacts, especially on native species	M9	Established Coral Disease & Pathogens (including bleaching)	What is the incidence and level of disease in populations? Are diseases/pathogens affecting populations? What are trends in disease/pathogen?	transects, quadrats (photo, video), mapping, incidence
			M10		Alien Incipient Coral Disease & Pathogens	Where are disease locations outside parks? What species are they affecting? What are rates and directions of spread? Identify existing disease/pathogen incidence, impact, and trends	Transects, quadrats (photo, video), mapping, incidence, modeling	Disease rates, occurrence, vectors, recruitment rates
			M11	Established Alien Species - Benthic Marine	Can we detect changing trends in alien and invasive species? What are effects of alien and invasive species on communities? What is response to treatment?	Transects, quadrats (photo, video), mapping	abundance, demography, distribution	
		M12	Alien Incipient Invasives - Benthic Marine	Is species present, if so what is the nature and extent of infestation? What are the most effective strategies for detecting and preventing new invasives species? Where should efforts be focused? What are potential impacts?	transects, quadrats, mapping	abundance, demography, distribution		
	Water column (mottle)	Community	Monitor community dynamics, structure, function, and composition	M13	Water Column Marine Vertebrates and Invertebrates Biodiversity	Are there long-term changes (community composition, distribution) in selected native communities?	telemetry, quadrats, transects, aerial surveys, tows, traps	Relative abundance, demographics, distribution, movement, diversity
		Population	Track community and population trends in harvested fisheries species	M14	Water Column Reef Fisheries	Is variation in community / population parameters due to harvest? What are effects of human harvest on fished or gathered species?	Transects, quadrat	Abundance, demography, size class, recruitment
				Monitor disease incidence and impacts, especially on native species	M15	Established Marine Animal (other than turtles) Disease & Pathogens	What is the incidence and level of disease in populations? Are diseases/pathogens affecting populations? What are trends in disease/pathogen?	Incidence, telemetry
			M16		Established Turtle Disease & Pathogens	What is the incidence and level of disease in populations? Are diseases/pathogens affecting populations? What are trends in disease/pathogen?	incidence, telemetry (mark-recapture)	disease types, occurrence, vectors
			M17	Established Alien Species - Water Column Marine	Can we detect changing trends in alien and invasive species? What are effects of alien and invasive species on communities? What is response to treatment?	Transects, quadrats	abundance, demography, distribution	
			Monitor extent and response to treatment of established invasive species	M18	Water Column Marine Invertebrates	Is variation within normal range? What are temporal trends?	Transects, quadrats, tows, traps	Abundance, size, demography, recruitment rates
				M19	Fish Growth/Size and Age Structure, and Recruitment	Is variation within normal range? What are selected short- and long-term trends?	transects, quadrats, photoquadrats, mapping	abundance of size classes, recruitment rates, species diversity
		M20	Marine Species Protection (T, E, S-o-C species)	Is variation within normal range? What are temporal trends?	telemetry, quadrats, transects, aerial surveys	abundance, demographics, distribution, movement		
		M21	Alien Incipient Invasives - Water Column Marine	Is species present, if so what is the nature and extent of infestation? What are the most effective strategies for detecting and preventing new invasives species? Where should efforts be focused? What are potential impacts?	Transects, quadrats, tows, traps	abundance, demography, distribution		
	Intertidal	Community	Monitor community dynamics, structure, function, and composition	M22	Intertidal Biodiversity - Vertebrates, Invertebrates, and Algae	Are there long-term changes in selected native communities, distribution, cover?	Population surveys, transects, quadrats	Abundance and trends of selected species or groups, evenness, richness
				M23	Intertidal - Hard Bottom	Is variation within normal range? What are selected (community composition, distribution, physical structure, habitat extent) short- and long-term trends?	transects, quadrats	cover by type, habitat type diversity, percent cover of species density
				M24	Intertidal - Soft Bottom (sand beach, mudflat, mangrove)	Is variation within normal range? What are selected (community composition, distribution, physical structure, habitat extent) short- and long-term trends?	transects, quadrats, mapping	cover by type, habitat type diversity, percent cover of species density
		Population	Track community and population trends in harvested fisheries collected species	M25	Intertidal Reef Fisheries / Collected species (limu, opihi, crabs, fish, etc.)	What are effects of human harvest on fished or gathered species? What are trends in harvested species?	Transects, quadrats, mapping, traps, biomass, percent cover	Demographics, size, recruitment, distribution
				M26	Intertidal Marine Invertebrates, Fish, and Algae	Is variation within normal range? What are the long / short term trends?	population surveys, quadrats, transects, traps, tows	abundance, distribution, evenness, demography, recruitment
			Monitor extent and response to treatment of established invasive species	M27	Established Alien Species - Intertidal Marine	Can we detect changing trends in alien and invasive species? What are effects of alien and invasive species on communities? What is response to treatment?	population surveys, quadrats, transects, traps, tows	abundance, demography, distribution
				M28	Alien Incipient Invasives - Intertidal Marine	Is species present, if so what is the nature and extent of infestation? What are the most effective strategies for detecting and preventing new invasives species? Where should efforts be focused? What are potential impacts?	Transects, quadrats, mapping, vectors, traps	abundance, demography, distribution