Inventory & Monitoring Program

Pacific Island Network

Monitoring Plan

Supporting Documents:
Vital Signs
Complete List with Priorities

30 September 2004

Pacific Island Network (PACN)

Territory of Guam
War in the Pacific National Historical Park (WAPA)

Commonwealth of the Northern Mariana Islands
American Memorial Park, Saipan (AMME)

Territory of American Samoa
National Park of American Samoa (NPSA)

State of Hawaii
USS Arizona Memorial, Oahu (USAR)
Kalaupapa National Historical Park, Molokai (KALA)
Haleakala National Park, Maui (HALE)
Ala Kahakai National Historic Trail, Hawaii (ALKA)
Puukohola Heiau National Historic Site, Hawaii (PUHE)
Kaloko-Honokohau National Historical Park, Hawaii (KAHO)
Puuhonua o Honaunau National Historical Park, Hawaii (PUHO)
Hawaii Volcanoes National Park, Hawaii (HAVO)

The following is a list of all the Vital Signs considered during preparation of the Pacific Island Network monitoring plan. Priorities and ranks established by parks are also presented, for further details see the complete Network Monitoring Plan at http://science.nature.nps.gov/im/units/pacn/monitoring/plan/2004/.

Level 1	Level 2	Level 3	Vital Sign	Network Rank	Justification	Monitoring Questions	Monitoring Methods	Measures and Metrics	AMME_Score	WAPA_Score	NPSA_Score	USAR_Score	KALA_Score	HALE_Score	ALKA_Score	PUHE_Score	KAHO_Score	PUHO_Score	HAVO_Score	AMME_Rank	WAPA_Rank	NPSA_Rank	USAR_Rank	KALA_Rank	HALE_Rank	ALKA_Rank	PUHE_Rank	KAHO_Rank	PUHO_Rank	HAVO_Rank
Air and Climate	Air Quality	Air contaminants	Air contaminants	40	HAPs (hazardous air pollutants), are compounds known or suspected to cause cancer or other serious health effects and adverse environmental effects. GHGs (Greenhouse gases) have long-lasting regional or global effects on climate. Sources of HAPs and GHGs may be natural or anthropogenic. Changes to atmospheric deposition loads can significantly affect biogeochemical cycling and in this way affect ecosystem development and processes. In class I parks monitoring is mandatory under the PSD program.	How are atmospheric particulate species and concentrations changing? How much do anthropogenic vs. volcanic vs. other natural sources contribute? How much is deposited? What is the influence on the biogeochemical cycle?	filters, real time analyzers, continuous or periodic monitoring depending on species information desired	concentrations of HAPs, GHGs (CO2, O3 and others), trace species, deposition estimates, particle size analyses: pm10, pm 2.5	2.4	2.1	1.5	3	2.4	3.2	2.4	2.4	2.4	2.4	2.4	M	M	L	H	M	H	M	M	M	M	M
		Visibility and particulate matter	Solar radiation	46	Solar radiation, in particular PAR and UV wavelengths, affect physiological processes in plants and algae. It also affects physiological processes and behavior in terrestrial and marine fauna. Increases in UV wavelengths, as expected with growing air pollution and climate change are a particular concern since they can cause severe damage to both plant and animal cells.	How are solar radiation inputs, UV-B, photosynthetically active radiation (PAR), or other wavelengths, fluxes changing?	pyranometers, PAR sensors, UVB radiometers, etc., satellite data	upwelling & downwelling, direct & diffused; total, PAR, UVA, UVB, radiation budgets	2.3	2.5	1.5	2.3	3.2	2.3	2.3	2.3	2.3	2.3	2	M	M	L	M	H	L	M	M	M	M	L
			Visibility and particulate matter	39	Under the PSD (Prevention of Significant Deterioration) program the NPS is required to monitor visibility and work to prevent any future, or remedy any existing, impairments of visibility in Class 1 areas.	Is sight distance/quality reduced? Is light extinction affected?	Aerosol filters, cameras, nephelometer	sight distance (extinction coefficient), particulate concentration	1.6	2	1	2.7	2.4	3.5	2.7	2.7	2.4	2.8	3.1	L	M	L	M	M	H	M	M	M	M	7
		Wet and dry deposition	Wet and dry deposition	49	Atmospheric deposition estimates will further our understanding of the cycling of nutrients through ecosystems. A particular concern is acid deposition since it has been shown to stress plant growth, negatively affect aquatic resources and reduce soil productivity. Sources of acidic species in rain may be natural or anthropogenic.	What are the concentrations of important nutrients and toxins? How much is deposited? How much do anthropogenic vs. volcanic vs. other natural sources contribute?	Precipitation samples, fog water samples	precipitation & fog chemistry, concentrations/deposition estimates of major nutrients, toxins and trace species	1.6	1.7	1.5	2.8	2.5	2.4	2.2	2.2	2.5	2.2	2.9	L	L	L	M	M	L	L	L	M	L	M
	Weather and Climate	Weather and Climate	Weather/Climate	8	Weather monitoring serves to: 1. inform visitors of extreme weather conditions that may pose a health and safety risk. 2. predict the likelihood of brush fires. 3. provide baseline data (NPS-I&M guidelines) to characterize ecosystems 4. provide supportive information to other studies (hydrology/ground water/stream flow, mass wasting, etc) 5. provide data for climate mapping 6. provide indicators of changing climatic conditions. A long term meteorological monitoring program is essential to characterize the climate and to evaluate the influence of climate or climate change on ecosystems	What are current conditions? What are the different microclimates in the parks? What are ranges of weather parameters for each park? Are they changing (look at multiple scales)? How frequent & intense are extreme weather events, and what are temporal & spatial trends?	weather stations (RAWS, COOP, NPS-ARD), fog monitors, fuel sticks, soil moisture/temp sensors, wetness sensors, satellite data, lidar data, climate modeling, mapping, historical records	Wind, temperature, precipitation, relative humidity, fog immersion time, fuel moist/temp, soil moisture/temp, TWI, solar radiation, wetness, extreme events (cyclones, droughts, floods), ENSO, PDO	3.1	2.8	3	3.3	3.6	4	3.3	3.3	3.3	3.1	3.3	7	H	7	4	H	1	5	5	H	M	5
Biological Integrity	At-risk Biota	T&E species and communities	Rare, threatened & endangered species	7	Threatened and endangered species are an important aspect of biodiversity. Parks are mandated (Endangered Species Act, NPS Management Policies) to monitor their condition and implement conservation activities to further their recovery.	Are the numbers of Threatened, Endangered, and Species-of-Concern species represented in each park increasing, decreasing, or steady?	Presence/absence surveys, with periodic inventory for new T, E, S o-C species. Consider including "rare" species as well.	presence/absence.	3.5	2.3	2.8	3.5	3.6	3.2	3.5	3.5	4	3.2	3.5	3	M	H	2	H	H	4	4	1	H	3
			Rare, threatened & endangered marine animals	13	Threatened and endangered species are an important aspect of biodiversity. Parks are mandated (Endangered Species Act, Marine Mammal Protection Act, NPS Management Policies) to monitor their condition and implement conservation activities to further their recovery.	What are trends in distribution & abundance of protected marine species or selected species of concern? What are the trends in recruitment, growth & survival rates for those species selected? Are changes and trends deleterious, and can we control or reduce threats to these populations?	Population surveys, transects, quadrats, mapping, marine mammal surveys, periodic telemetry	Abundance, demography (where appropriate), distribution, recruitment, growth, survival. Prevalence of disease, pathogens, other population threats. Qualitative data including general health	2	2.1	2.8	3.4	4	2.5	2.8	2.8	4	3.8	3.2	M	M	H	3	1	M	M	M	1	2	6

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Biological Integrity	Focal Species or Communities	At-risk Biota	T&E species and communities	Rare, threatened & endangered terrestrial invertebrate populations	12	Threatened and endangered species are an important aspect of biodiversity. Rare invertebrates frequently exhibit characters that are unique for their group and thus evolutionarily significant on a global scale. Parks are mandated (Endangered Species Act) to monitor their condition and implement conservation activities to further their recovery. Those designated Species of Concern and other rare species also form a major part of the natural resources parks are mandated to protect.	What are trends in distribution, abundance, other population characteristics, and habitat? Are threats changing? If so are changes deleterious, and can we control or reduce threats to these populations?	Population surveys (including demographics), transects, plots, mapping	Abundance, density, demographics (size/age, structure, reproduction, recruitment, etc), distribution, documentation of other population threats	2	1.8	3.4	2.6	3.5	3.8	3.2	3.2	3.8	3.2	3	M	L	5	M	H	2	6	6	2	H	M
		Amphibians and Reptiles	Terrestrial Herpetofauna	67	Some species are sensitive to environmental changes, both natural and anthropogenic, and can act as indicators of specific changes. Because the parks are required to maintain populations of native species, monitoring the growth, distribution and reproductive dynamics of more sensitive species provides an early warning for the welfare of the target species as well as that of associated species.	Are distribution, abundance, other population characteristics, or habitat changing? Determine population levels over time.	Population surveys. A variety of standardized techniques (depending on target species) -- pitfall traps, baited traps, etc.	Abundance / density, distribution	1.4	2.2	2.8	NA	NA	NA	NA	NA	NA	NA	NA	L	M	H	NA	NA	NA	NA	NA	NA	NA	NA
		Aquatic vegetation	Freshwater plants and algae	44	Alien aquatic plant and algal species composition & productivity can serve as important indicators of ecosystem health (e.g., algal blooms indicate high levels of nutrients and may cause fish kills). Aquatic plants and algae are at the base of the food chain and their composition & productivity significantly influence aquatic animal communities.	What species are present? What are rates of production? What is the proportion of native vs. alien species contributing to productivity? Are there long-term changes in communities of aquatic primary producers? Where are algal blooms present? Includes benthic & planktonic species.	Periodic benthic quadrat sampling and/or plankton tows (depending on habitat).	trends in cover, density, diversity over time, distribution, species composition & biomass	2.6	1.7	2.1	NA	2.6	3	2.6	2.6	3	2.3	2	M	L	M	NA	M	M	M	M	H	M	L
		Cave biota	Cave communities	55	The cave fauna forms a largely self-contained ecosystem composed of unique species independently derived from surface ancestors. Cave ecosystems are emerging as highly vulnerable to environmental stressors. Especially sensitive or keystone species can be used as indicators to track habitat quality in caves.	What are trends in distribution, abundance, other population characteristics, and habitat quality? Are threats changing?	Population surveys, mapping; root type and abundance	Abundance, density, demographics, distribution, diversity, evenness, richness of natives and aliens	NA	2.8	1	NA	2.5	3	2.5	2.5	1.4	2.8	2.5	NA	H	L	NA	M	M	M	M	L	M	M
		Fishes	Focal marine fish species	25	Changes in population parameters of some species, such as butterfly fish or damselfish, may serve as early warning indicators of environmental stress or change so that counteractive management strategies may occur. Parks are required to maintain native species. Many of these species may be of interest to parks, particularly if they are a target for fisheries.	What are the trends in abundance and distribution of selected focal marine fish species? And if applicable/selected, what are the size/age classes?	Transects, mapping, population characteristics (demographics) of target species	Abundance, distribution, demography (size/age class frequency), qualitative data including general health and color morph	1.7	3.2	3.1	3.4	3	2.8	2.8	2.8	3.8	3.3	1	L	5	6	3	M	M	M	M	2	H	L
		Fishes	Marine fish communities	24	Fish serve a variety of ecological functions that affect ecosystem productivity and sustainability. Fish assemblages can act as indicators of general reef health and provide an early warning of environmental stress and potentially ecosystem change.	What are the trends in community composition & distribution in selected communities?	Transects, distance sampling, timed swim counts	Relative abundance, demographics, diversity	2.2	2.9	3.8	3.4	3.3	2.3	2.5	2.5	3.8	3.3	1	M	7	2	3	H	L	M	M	2	H	L
		Freshwater communities	Focal freshwater animal species	31	Some species are sensitive to environmental change processes, both natural and anthropogenic, and can act as indicators of specific changes. The parks are required to maintain populations of native species; several freshwater animals are also listed as threatened or endangered. Monitoring the growth, distribution, and reproductive dynamics of more sensitive species provides information that may act as an early warning for the welfare of the target species as well as that of associated species.	Is species present? If so, what are trends in population numbers, reproduction, distribution and density? Includes shrimp, fish, molluscs and insects.	Periodic quadrat netting/trapping, larval drift netting, visual transect censuses, mapping.	presence/absence, trends in abundance of different size/age classes, distribution and density	2	1.7	2.1	NA	3.3	3.8	3	3	3.3	3	2.8	M	L	M	NA	H	2	M	M	H	M	M

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Biological Integrity	Focal Species or Communities	Freshwater communities	Freshwater animal communities	19	Properties of faunal assemblages and populations may be important indicators of environmental change because fauna serve a great diversity of ecological functions that affect ecosystem productivity, resilience, and sustainability. Aquatic fauna also are desirable subjects for long-term ecological monitoring because they have public appeal, and changes in the park's fauna are likely to garner a high level of public interest and generate support for corrective or remedial management actions.	What species are present? Are there long-term changes in native fish and aquatic invertebrate communities (composition, species richness, presence of aliens, etc.)?	Population surveys, periodic quadrat netting/trapping, visual transect censuses, plots, mapping.	Trends in community diversity, density over time, abundance, demographics, distribution	2.8	2.8	2.1	NA	3.6	2.8	3.6	3.6	3.6	3.6	2.3	10	H	M	NA	H	M	3	3	H	3	L
		Intertidal communities	Intertidal community	18	Intertidal species are adapted to survive extreme environmental conditions however they are very vulnerable to effects from coastal land-use & development. Assemblages may be important indicators of environmental change. Tidepools serve as nurseries for important coral reef species. Most PACN parks contain an intertidal zone, either adjacent to or within their boundary. The intertidal region also has cultural significance for many Pacific Islands.	Are there long-term changes in selected communities' composition, distribution and cover? Are changes in community composition correlated with shoreline change?	Population surveys, transects, quadrats, mapping	Abundance and trends of selected assemblages or groups, evenness, richness, distribution, assemblages of foundation species, substrate type	2.5	2.5	2.2	3	3.6	2.8	3	3	3.5	3.8	2	M	M	M	H	H	M	M	M	H	2	L
		Marine communities	Benthic marine invertebrate community	25	Coral reefs create favorable habitat for many organisms becoming centers of biodiversity therefore community dynamics are important indicators of environmental change. Many pieces of legislation pertain to coral reef conservation. The Coral Reef Conservation Act (2000) was created to preserve, sustain, and restore the condition of coral reef ecosystems, while promoting wise management and sustainable use of these valuable marine resources.	Are there long-term changes in benthic community diversity (abundance and composition) and distribution of selected communities? What are the community dynamics? Includes both sessile & motile organisms.	Transects, quadrats (including photo, video)	Species composition & counts, percent cover of species, diversity, density/abundance, rugosity, coral growth rates	2	3	3.8	2.2	3.6	2.2	2.5	2.5	3.5	3.6	2	M	6	2	L	H	L	M	M	H	3	L
			Focal marine plant and algal species	22	Marine primary producers are important species and are sensitive to changes in environmental processes, both natural and anthropogenic and can act as indicators of specific change. There is ample scientific evidence showing phase shifts from coral to algal dominated communities associated with specific measurable environmental perturbations. Seagrass helps to reduce shoreline erosion and mangroves act as filtrating communities for coral reefs. Likewise parks are required to maintain populations of native species. Monitoring the growth, distribution, and reproductive dynamics of more sensitive species provides information that may act as an early warning for the welfare of the target species as well as that of associated species.	What are the trends in cover and frequency/density of selected focal marine algae and vascular plant species (including mangroves and seagrass)?	Transects, quadrats, species sampling for select turf species, crustose corallines and frondose algal species	Frequency for solitary algae, cover by species, demographics, recruitment, reproduction, growth rates. Qualitative data including general health.	2.4	3	2.5	3.4	3.6	2.5	2.5	2.5	3.5	3.3	2.2	M	6	M	3	H	M	M	M	H	H	L
			Marine algae and vascular plants	25	Algae and vascular plants are important components of different marine ecosystems (coral, seagreass, mangrove, macroalgae). Since they offer important nursery habitat, changes in these communities could have effects on the diverse assemblages they support. Parks are required to maintain many of these sensitive native species, some of which are protected under coral reef & wetlands legislation.	Are there long-term changes in selected communities' composition, distribution, cover? Examples of communities include macroalgae, seagrass and mangrove communities.	Transects, quadrats (photo, video), mapping	Distribution, species composition & diversity, density, biomass, shoot density (seagrass)	2.2	3	2.5	3.4	3	2.5	2.5	2.5	3.8	3.3	2.2	M	6	M	3	M	M	M	M	2	H	L
		Marine invertebrates	Focal marine invertebrate species	14	Monitoring population dynamics of sensitive species may act as an indictor of general population health and as early warning of environmental change. When subject to population outbreaks some invertebrate species can cause significant biological disturbances to coral reef ecosystems. Parks are required to maintain many of these native populations. Some of these species are important to monitor if they are also harvested. Many mandates exist for the protection of coral reefs.	What are trends in abundance, distribution of selected focal coral and/or invertebrate species? If applicable/selected what are the trends in reproductive indexes, growth, survival and recruitment of selected species?	Population surveys, transects, quadrats (photo and/or video), mapping	frequency/density (number per unit area), distribution, growth rates, survival, recruitment rate, reproductive index. Qualitative data, including general health	2.1	3	3.1	3.6	3.8	2.5	2.7	2.7	3.5	3.5	2.2	M	6	6	1	2	M	M	M	H	4	L

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Biological Integrity	Focal Species or Communities	Terrestrial communities	Focal terrestrial vertebrate species	50	Properties of faunal assemblages and populations may be important indicators of environmental change because fauna serve a great diversity of ecological functions that affect ecosystem productivity, resilience, and sustainability (Walker 1992, Risser 1995, Marcot et al. 1998). For example, apex seabird predators can be good indicators for monitoring. Terrestrial fauna also are desirable subjects for long-term ecological monitoring because they have widespread public appeal, and changes in the park's fauna are likely to garner a high level of public interest and generate support for corrective or remedial management actions.	Are selected native vertebrate communities or guilds changing? This includes changes in abundance of selected species (determined from population surveys), and/or changes in the identity and number of species present in the community or guild of interest (determined from presence/absence monitoring).	Population surveys, presence/absence surveys. Periodic inventories focused on picking up new species records (especially T, E, S-o-C species, and seabird colonies) and/or locations.	Within defined areas or specified communities: abundance and trends of selected vertebrate species or groups, species richness	2.9	1.5	2	2	2.6	3.8	2.6	NA	2	NA	3	9	L	M	L	M	2	M	NA	L	NA	M
			Forest birds and bats	32	Some species are sensitive to environmental changes processes, both natural and anthropogenic, and can act as indicators of specific changes. Because the parks are required to maintain populations of native species, monitoring the growth, distribution, and reproductive dynamics of more sensitive species provides an early warning for the welfare of the target species as well as that of associated species.	Are the demographics of selected native, endemic, or focal forest bird and bat species changing? If so, are changes deleterious, and can we control or reduce threats to these populations?	Population surveys, including demographic measures (size/age structure, reproduction, recruitment, etc.) and prevalence of disease, pathogens, and/or population threats. (Different methods for forest birds, raptors, bats, and fruit bats)	Population demographics, density, distribution. Prevalence of disease, pathogens, other population threats.	3.6	NA	3.7	NA	3.8	3.6	2	2	1.5	3.2	3.5	2	NA	3	NA	2	3	L	L	L	H	3
			Terrestrial animals	58	Habitat restoration is primarily done by re-establishing the plant community native to an area, but an ecosystem cannot be considered restored if native animals continue to be absent. Although there are many plant restoration projects, none are being monitored for recolonization by native animals. Existing plant monitoring plots can be used for animals as well.	What is the response of native vertebrate and invertebrate populations to habitat restoration, including alien control, outplanting, and seed-sowing activities? Which native species are recolonizing restored areas? Which ones are not?	Population surveys, transects, plots (monitoring of areas where seeds have been broadcast and native species outplanted), mapping	Abundance, density, size classes, vigor, species composition, seedling recruitment, growth rates, Cover, animal reproductive success, animal population size, animal population growth rates, survivorship, distribution, diversity, evenness, richness	NA	NA	1.8	1.8	3.4	3.2	1.8	1.8	1.5	1.8	2.6	NA	NA	L	L	H	H	L	L	L	L	M
		Terrestrial invertebrates	Terrestrial invertebrate focal species	27	Some species are sensitive to environmental change processes, both natural and anthropogenic, and can act as indicators of specific or general changes. Likewise, the parks are required to maintain populations of native species. Monitoring the growth, distribution, and reproductive dynamics of more sensitive species provides information that may act as an early warning for the welfare of the target species as well as that of associated species of both insects and plants. Sampling of many key groups can be done rapidly and efficiently and protocols already exist.	What are trends in distribution and abundance of invertebrate indicator or focal species? What are trends in distribution, abundance, and diversity of speciose groups within parks and across landscapes? Are species being locally extirpated or going extinct? What are effects of management on focal species?	Population surveys, transects, plots, mapping	Abundance, density, demographics, distribution, diversity, evenness, richness	2	2	2.3	3	3.6	3.6	3	3	2.2	3	3	M	M	M	H	H	3	M	M	M	M	M
		Vegetation communities	Focal terrestrial plant communities	9	As a result of stressors such as invasive species or habitat fragmentation, entire native communities or assemblages may be depleted or locally extirpated. Early detection of changes in these communities will aid managers in threat mitigation, restoration and protection of habitat for rare and endangered species. Protection of Endangered and Threatened Species and their habitats is mandated by the Endangered Species Act.	Are there detectable changes in selected communities of interest? What is the relative abundance of native and non native species of vascular or non-vascular plants in communities of interest? What plant species and natural communities are rare in the parks? How do native plants respond to management activities? What are impacts of severe weather events on communities & focal species?	Transects, permanent plots, mapping, remote sensing, tagging.	Presence/ absence, abundance of focal species and groups; diversity indices both within and across plant communities; Changes in structure, density, cover, recruitment, flower & seed production and trends in selected focal groups of plant species.	3.2	3.2	4	2	3.8	3.8	2.6	2.6	3.3	3.6	3.4	6	5	1	L	2	2	M	M	H	3	4

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Biological Integrity	Focal Species or Communities	Vegetation communities	Focal terrestrial plant species	3	Species that are highly sensitive to environmental variation act as indicators of natural and anthropogenic changes that may impact entire communities; their decline could serve as an early warning of ecosystem degradation . Threatened and Endangered species are an important aspect of biodiversity and parks are mandated (Endangered Species Act) to monitor their condition and implement recovery activities	What are the distribution, abundance, and demographics of Threatened, Endangered, Rare, and focal native vascular and non-vascular plant species? Is the overall number of rare plant species increasing or decreasing? Are plant populations reproducing at sustaining levels? Is pollination, seed bank, seed set, and seedling recruitment adequate to maintain populations?	Mapping, plots, counts in size classes. Soil cores and subplots for seed banks. Flower and fruit monitoring at focal plant populations. Genetic analysis of focal species samples.	Phenology, survival, soil seed bank, population structure, distribution, density, reproduction. Genetic similarity of individuals in populations.	3.2	2.9	2.9	3.2	4	3.8	3.8	3.8	3.8	3.8	3.8	6	7	8	5	1	2	2	2	2	2	1
		Wetland communities	Wetland and riparian plant communities	18	The riparian community controls the amount of light reaching the water surface, and strongly influences nutrient cycling and transport, organic matter input, bank stability and stream channel morphology, and subsurface water flow into streams & wetlands. Historically in the PACN, low-lying wetland, riparian, and coastal areas were the first to be altered by human activities; so plant communities in these areas have often been significantly altered. Understanding changes in populations of wetland species is important for their restoration or maintenance.	What species are present? What are rates of production? What is the proportion of native vs. alien species contributing to productivity? What are rates of riparian input (leaf litter, etc.) into aquatic habitat? Are there long-term changes in wetland & riparian plant communities?	Periodic transects & plot surveys, mapping, litter traps, surface water sampliig	trends in cover, density, size classes, litterfall, diversity over time, distribution, demographics, species composition, litter volume per species	3.6	2.4	1.2	3.2	3.5	2	3.5	3.5	3.5	3.5	2	2	M	L	5	H	L	4	4	H	4	L
	Infestations and Diseases	Animal diseases	Freshwater animal disease	59	Parasite and disease levels indicate health of aquatic populations. Introduced fish in Hawaii have been shown to carry parasites such as leeches or diseases which may be transferred to native stream fish. These introduced parasite species often have greater impacts on native Hawaiian fish than native parasites do, due to differences in their life cycles. This is an issue of unknown magnitude on the other islands in the PACN.	What is the incidence and level of disease in populations of freshwater animals?	Visual surveys of possibly affected populations, opportunistic collections of dead animals, tissue samples from non-native vector species	disease/parasite occurrence & frequency	1.2	1.2	1	NA	2.3	2.5	2.3	2.3	2.3	2.8	2.3	L	L	L	NA	L	M	M	M	M	M	L
			Marine animal disease	35	Disease can directly kill or weaken organisms impairing their ability to survive other stressors. Disease can interfere with reproduction, growth and other organismal functions.	What are the prevalences and levels (how severe), and trends in known causes of morbidity and mortality in targeted population? Where cause-effect is clearly established, are these affecting the populations? For targeted potential (incipient) causes of... (not including bleaching)	Known causes: specimen and/or carcass collection (may include telemetry to recovery carcasses), host or vector surveys/sampling; surveys of affected popns to determine popn status and impacts. Potential causes: Surveys in high risk sites; education.	Disease or threat prevalence, level, or presence/ absence; distribution and numbers of host and/or vector species involved; abundance or density of affected population. Stage of disease/infestation, host condition.	1.5	2.1	3.6	2.6	2.6	2	2.6	2.6	3.2	3.3	2	L	M	4	M	M	L	M	M	H	H	L
			Terrestrial vertebrate disease	41	Disease can directly kill or weaken organisms impairing their ability to survive other stressors. Disease also can interfere with reproduction, growth and other organismal functions. Avian disease is a serious limiting factor for several species of native Hawaiian forest birds and is thought to have contributed to historic extinction of additional species.	What are the prevalences and levels (how severe), and trends in known causes of morbidity and mortality in targeted populations? Where cause-effect is clearly established, are these affecting the populations? If so, are changes deleterious, and can we control or reduce threats to these populations? For targeted potential (incipient) causes of mortality and morbidity: are these present in popn or geographic area of concern? Are they present in other popns or in locations outside the immediate area of concern? If so, what are rates and directions of spread?	Known causes: specimen and/or carcass collection (may include telemetry to recovery carcasses), host or vector surveys/sampling; surveys of affected popns to determine popn status and impacts. Potential causes: Surveys high risk sites; passive surveys	Disease or threat prevalence, level, or pres/absence; distribution and numbers of host and/or vector species; abundance, density and demographics of affected popn. Potential causes: pres/absence; distribution, ID, and numbers of host and/or vector spp	1.2	1.9	2.6	1.8	3.2	3.5	1.8	1.8	3.8	1.8	3	L	L	M	L	H	H	L	L	2	L	M

Level 1	Level 2	Level 3	Vital Sign	Network Rank	Justification	Monitoring Questions	Monitoring Methods	Measures and Metrics	AMME_Score	WAPA_Score	NPSA_Score	USAR_Score	KALA_Score	HALE_Score	ALKA_Score	PUHE_Score	KAHO_Score	PUHO_Score	HAVO_Score	AMME_Rank	WAPA_Rank	NPSA_Rank	USAR_Rank	KALA_Rank	HALE_Rank	ALKA_Rank	PUHE_Rank	KAHO_Rank	PUHO_Rank	HAVO_Rank
Biological Integrity	Infestations and Diseases	Plant diseases	Terrestrial plant disease	55	Plant disease can cause direct mortality or make natural vegetation more susceptible to threats from other stressors. Disease interferes with reproduction, growth and other organismal functions. Understanding of normal rates of infestation, spread, and severity of established diseases helps in identifying events that require management action	What are the incidences and levels of plant pathogen and disease (including native, established alien, and incipient alien disease) in populations? Are diseases/pathogens affecting populations within the park? What are trends in disease/pathogens including rate and direction of spread? What are the causes of disease and mortality in selected plant populations?	Transects, plots, population surveys, Surveys in high risk sites; rapid assessment of extent of infestations passive surveillance; education, outreach, public reporting, and follow-up.	Presence-absence, identification & distribution of targeted "blacklist" species & other novel (previously undetected) invasives ; presence/absences and population dynamics of host and/or vector species	1.2	1.8	2	2	2	3.1	2	2	2	2.6	2.3	L	L	M	L	L	M	L	L	L	M	L
	Invasive Species	Both plants and animals	Exotic marine species-status and trends	27	Marine invasives species are receiving increasing scientific and public attention. There are now severe outbreaks of some species on some Pacific reefs. These species, their ecological consequences and possible means of control are subjects of very active research. The magnitude and geographic extent of this problem is not adequately known.	What are the trends in the incidence and level of infestation of alien/invasive species?	Population surveys, transects, quadrats, mapping	Presence/absence, trends in abundance, distribution and density, demography?, lab taxonomy?	2.1	1.8	2.6	3.5	2.7	2.3	3.5	3.5	3.2	3.3	2.2	M	L	M	2	M	L	4	4	H	H	L
		Invasive/Exotic animals	Exotic aquatic animals early detection	29	The establishment of different invasive animals has different consequences for native communities, depending on such factors as the invasive species' behavior and feeding and habitat preferences. Introduction of invasive aquatic species which occupy different ecological niches than natives can also have indirect effects, such as introduction of parasites or alteration of habitat. Assessing the threat posed by incipient invasive species and detecting their presence are important monitoring functions for Pacific Island parks to insure proactive and cost-effective management; the Invasive Species Act of 1996 mandates federal agencies to manage these species.	Is species present nearby? If so, what is the present extent and nature of occurrence? What are potential pathways for dispersal?	Periodic sampling of freshwater habitats outside of parks (quadrat netting/trapping, visual transect censuses, mapping), including identified pathways of dispersal.	presence/absence, trends in abundance, distribution and density	2.1	2.6	2.1	3	3	3.6	3	3	2.7	3	2	M	M	M	H	M	3	M	M	M	M	L
			Exotic aquatic animals status and trends	36	Invasive aquatic animals can predate upon or compete for food with natives, alter habitat, or spread disease. An example of this is the introduction of water surface-feeding topminnows, which have a profound predatory impact on native aquatic insect larvae, in contrast to bottom-feeding native gobies (Englund 1999). The Invasive Species Act of 1996 mandates federal agencies to manage these species	What is the present extent of occurrence? Are there changes in extent over time?	Periodic quadrat netting/trapping, visual transect censuses, mapping.	presence/absence, trends in abundance, distribution and density	1.8	1.8	2.1	NA	3.6	3.3	3	3	3.3	3	2	L	L	M	NA	H	H	M	M	H	M	L
			Exotic invertebrates-status and trends	54	The establishment of different invasive animals has different consequences for native communities, depending on such factors as the invasive species' behavior and feeding and habitat preferences. Invasive aquatic species can either predate upon or compete for food with natives. Introduction of invasive aquatic species which occupy different ecological niches than natives can have indirect effects, such as introduction of parasites or alteration of habitat.	Are native plant and animal species' abundance or distribution changing in response to predatory or omnivorous invasives, or in response to efforts to control these invasives? What are trends in predatory and omnivorous invasive species populations?	Treatment and control transects, plots, or sites using appropriate methods to assess both invasive and native organisms of interest (VCP, transects, etc.); surveys for predators using appropriate methods to estimate population size and distribution.	Plants: species composition, population and/or community structure. Animals: abundance or density, possibly presence/absence, and/or other measures of critical life stages impacted by predators. Predators: population indices, presence/absence	1.5	1.5	3.1	1.8	1.8	3.8	1.8	1.8	1.8	1.8	2.4	L	L	6	L	L	2	L	L	L	L	M
			Exotic invertebrates-status and trends	52	Single invasive species (e.g. ants) have the potential to radically alter both native insect diversity and overall ecosystem function, by disrupting natural pollination and decomposition regimes. Monitoring range expansion and abundance of aliens provides vital information for making decisions on control and documents effects on native habitats. Many species are invasive elsewhere and monitoring protocols have been developed	What are the abundance, distribution, and seasonal and year-to-year variations in populations? What are trends in impact? How effective is control? What is impact of invertebrate pests on historic & culturally significant sites?	Population surveys, transects, plots, mapping, periodic surveys of structures	Abundance, density, demographics, distribution of aliens and native indicator species, infestation rates/damage	2	2	1.9	1.8	2	3.6	1.8	1.8	2.1	1.8	2.6	M	M	M	L	L	3	L	L	L	L	M

Level 1	Level 2	Level 3	Vital Sign	Network Rank	Justification	Monitoring Questions	Monitoring Methods	Measures and Metrics	AMME_Score	WAPA_Score	NPSA_Score	USAR_Score	KALA_Score	HALE_Score	ALKA_Score	PUHE_Score	KAHO_Score	PUHO_Score	HAVO_Score	AMME_Rank	WAPA_Rank	NPSA_Rank	USAR_Rank	KALA_Rank	HALE_Rank	ALKA_Rank	PUHE_Rank	KAHO_Rank	PUHO_Rank	HAVO_Rank
Biological Integrity	Invasive Species	Invasive/Exotic animals	Exotic terrestrial invertebrates-early detection	15	Alien species invasions are much easier to control at an early stage than after they have become widespread. Preventing alien establishment and extirpating beachhead populations is especially important with invertebrates: without active monitoring, by the time they are detected the population is usually large and it is too late for the species to be effectively eradicated or contained	What potential high-impact species have breached the border-protection system and have potential to reach the park? What is the nature and extent of infestation? Is eradication/containment feasible and where should efforts be focused? Which species are present in park? What is the nature and extent of infestation? Where should efforts be focused? What are potential impacts?	Active monitoring (transects, plots,light trapping, etc.) in high-risk sites;rapid assessment of extent of infestation; mapping of new discoveries; education, outreach, and public reporting, follow-up on reports	Identification & distribution of targeted 'blacklist' and other novel (previously undetected) invasives. Presence/absence, distribution, rapid assessment of extent of infestation	2.1	2.9	2.3	2.4	3.8	3.8	3	3	2.5	3	3.4	M	7	M	M	2	2	M	M	M	M	4
			Exotic terrestrial vertebtates-early detection	11	Alien species invasions can impact native animals by predation; competition; facilitating the introduction of alien diseases and parasites; and displacing food supply, roost sites or other important habitat components. Invasive species may be even more damaging to native species and ecosystems on a global scale than the loss and degradation of habitats.	What potential high-impact species have breached the border-protection system and have potential to reach the park? What is the nature and extent of infestation? Is eradication/containment feasible and where should efforts be focused? What are potential impacts? Is species present in park? If so, what is the nature and extent of infestation? Are native plant and animal species' abundance or distribution changing in response to the invasive or its control? What are the pathways and points of entry?	Detection: survey high-risk sites; follow up reports; education and outreach (public reporting). Impacts and reponse to treatment: treatment and control transects, plots, or sites using appropriate methods to assess both invasive and native species	ID & distribution of targeted 'blacklist' and other novel (previously undetected) invasives. Presence/ absence; predator population indices and mapping; rapid assessment of infestation extent. Native plants: species composition, population status	2.1	2.9	2.3	3	3.8	3.8	3	3	3.5	3	3.4	M	7	M	H	2	2	M	M	H	M	4
			Exotic ungulates-status and trends	39	Ecological damage from exitic invasive species includes impacts to native flora and fauna, natural disturbance regimes, and ecosystem functions. Invasive species especially jeopardize the sustainability of threatened and endangered species and may cause loss of more common species.	What are the relative abundance, distribution, and population trends of feral ungulates? Are native plant and animal species' abundance or distribution changing in response to feral ungulates, or in response to efforts to control feral ungulates?	Treatment and control transects, plots, or sites using appropriate methods to assess both invasive and native organisms of interest (VCP, transects, etc.); surveys for predators to estimate population size and distribution. Treatment trials	Plants: species composition, population and/or community structure. Animals: VCP, abundance or density, possibly presence/absence, and/or other measures of critical life stages impacted by predators. Predators: population indices, pres/absence	NA	2.8	3	NA	3.8	3.8	2	2	1.5	3.1	2.9	NA	H	7	NA	2	2	L	L	L	M	M
		Invasive/Exotic plants	Exotic aquatic plants-early detection	28	Alien plant and algal species can serve as important indicators of ecosystem health. Invasive plant and algal species can impede water flow (filamentous algae and grasses), increase sediment deposition (mangrove and grasses), change patterns of organic matter input (fruit-bearing or nitrogen fixing plants), exclude native plants, and provide an inferior food source for aquatic herbivores. Assessing the threat posed by incipient invasive species and detecting their presence are important monitoring functions for Pacific Island parks to insure proactive and cost-effective management; the Invasive Species Act of 1996 mandates federal agencies to manage these species.	Is species present nearby? If so, what is the present extent and nature of occurrence? What are potential pathways for dispersal?	Periodic sampling of freshwater habitats outside of parks (transects & surveys, mapping), including identified pathways of dispersal.	presence/absence, trends in abundance, distribution and density	2.1	2.1	1.2	3.2	3.8	3.3	3.2	3.2	3.5	3	2	M	M	L	5	2	H	6	6	H	M	L
			Exotic aquatic plants-status and trends	21	Alien plant and algal species can serve as important indicators of ecosystem health. Invasive plant and algal species can impede water flow (filamentous algae and grasses), increase sediment deposition (mangrove and grasses), change patterns of organic matter input (fruit-bearing or nitrogen fixing plants), exclude native plants, and provide an inferior food source for aquatic herbivores. The Invasive Species Act of 1996 mandates federal agencies to manage these species	What is the present extent of occurrence? Are there changes in extent over time?	Periodic transects & plot surveys, mapping.	presence/absence, trends in abundance, distribution and density	3.6	3	1.2	3.2	3	2.6	3.2	3.2	3.8	2.7	2	2	6	L	5	M	M	6	6	2	M	L

Level 1	Level 2	Level 3	Vital Sign	Network Rank	Justification	Monitoring Questions	Monitoring Methods	Measures and Metrics	AMME_Score	WAPA_Score	NPSA_Score	USAR_Score	KALA_Score	HALE_Score	ALKA_Score	PUHE_Score	KAHO_Score	PUHO_Score	HAVO_Score	AMME_Rank	WAPA_Rank	NPSA_Rank	USAR_Rank	KALA_Rank	HALE_Rank	ALKA_Rank	PUHE_Rank	KAHO_Rank	PUHO_Rank	HAVO_Rank
Biological Integrity	Invasive Species	Invasive/Exotic plants	Exotic terrestrial plants- early detection	4	Early detection of incipient alien species of plants & fungi allows for proactive and cost-effective management. Eradication projects are likely to be more effective if invasive species are detected early. Identification of characteristics of high impact invasives (habit, taxonomic group, dispersal method) will aid in identification of other potential invaders.	What potential high-impact species have breached the border-protection system and have potential to reach the park? What is the mode of dispersal through which the species entered the park? What is the nature and extent of infestation? Is eradication/containment feasible and where should efforts be focused?	Shared surveillance by multiple agencies and public, including follow-up on reports; surveys in high-risk sites inside and outside parks (eg. roadsides, trails, ports, disturbed sites). Observations of seed dispersers and collection of seed rain info	Presence/ absence, assessment of extent of infestation. Density and size class of impacted native plant populations. Species composition of affected native communities. Species composition of seedbanks. ID and distibution of targeted "blacklist" species	2.1	3.4	3.6	3.2	3.8	3.8	3.8	3.8	3.8	3.8	3.4	M	4	4	5	2	2	2	2	2	2	4
			Exotic terrestrial plants-status and trends	1	In Pacific Island Parks, alien plant species have altered many ecosystems of cultural landscapes by displacement of native species, habitat fragmentation and disruption of ecosystem processes. Monitoring established alien plants allows park managers to improve strategies to control or eradicate them and restore natural vegetation	What is the distribution and abundance of established alien plants (including mosses)? What is the rate of spread of alien plants? What is the relative abundance of native and invasive species? What are the impacts on native species of vascular and nonvascular plants? What is the potential of alien plant species to invade and dominate communities?	Mapping, transects, plots, counts in size classes. Soil cores and subplots for seed banks.	Distribution mapping, frequency, cover, density and population structure of alien and native species. Species composition of seedbanks.	3.6	3.6	3.8	3.4	4	3.6	4	4	4	4	3.6	2	3	2	3	1	3	1	1	1	1	2
Ecosystem Pattern and Processes	Fire	Fire and fuel dynamics	Fire dynamics	47	Fire impacts all aspects of ecosystems at a landscape level including: Conversion of vegetation types, Wildlife and food resources, nutrient cycles, water quality/quantity. Plant communities vary in their response to, and recovery from fire. Improved understanding of fire dynamics will aid in Fire Management programs and Resources Management planning.	What is current or recent fire regime? What is extent & intensity of fires? What are current natural and anthropogenic ignition sources ? What are the impacts of fire on landscape pattern and patch viability? What are the implications to plant community composition and structure resulting from fire? What are impacts to threatened, endangered and SOC species of plants? What are impacts of fire to vertebrate and invertebrate groups?	Transects, plots, histories, mapping. Erosion pins and sediment collectors for erosion monitoring. For Community Level questions: Transects, plots, population surveys of focal plant, vertebrate and invertebrate species.	Change in vegetation structure, erosion, or nutrient loss following fire, landscape history. For Community Level Questions: Change in vegetation structure, cover, density, vigor, size classes, recruitment rates, growth rates, species composition, presence	NA	2.9	NA	NA	2.6	3.6	2.6	2.6	2.6	2.6	2.6	NA	7	NA	NA	M	3	M	M	M	M	M
	Land Cover / Land Use	Land cover / Land use	Land use patterns	5	Alerations in land use and its intensity of use may contribute to and be indicative of pollution of water and air resources, fragment habitat, alteration of migratory patterns of birds, increase soil erosion, and the introduction exotic invasive species.	What areas are most at risk due to conflicting adjacent changes in land use (e.g. ranching, urbanization)? What land use changes are occuring within and adjacent to the park? (trends in use types) What are the predicted impacts of land use changes on park values? Are there detectable changes w/in park due to land use.	Aerial photography, mapping, plots	change detection maps, area & distribution of change	2.6	2.2	3.7	3.6	3.6	3.6	3.6	3.6	4	3.6	3.1	M	M	3	1	H	3	3	3	1	3	7
			Marine landscape pattern	33	Disturbances, either of natural or of human origin impact all aspects of ecosystems at a landscape level. These impacts can include habitat, successional stages, structural differentiation, water quality/quantity yields, wildlife variety and quantity, and scenic variability. A memorandum to the Secretary from the Solicitor's office outlines the Secretary's duty to protect parks from activities on non-NPS lands adjacent to parks.	Are the distributions of large scale habitat types (inside and immediately outside the parks) changing over time (i.e. lagoons, algal/coral reef cover)? Is reef erosion/accretion or bleaching occurring?	Habitat mapping	Distribution, relative abundance, cover by type, rugosity	2	2.5	2.8	2.5	3.8	2.5	2.5	2.5	3.2	3.3	1	M	M	H	M	2	M	M	M	H	H	L

Level 1	Level 2	Level 3	Vital Sign	Network Rank	Justification	Monitoring Questions	Monitoring Methods	Measures and Metrics	AMME_Score	WAPA_Score	NPSA_Score	USAR_Score	KALA_Score	HALE_Score	ALKA_Score	PUHE_Score	KAHO_Score	PUHO_Score	HAVO_Score	AMME_Rank	WAPA_Rank	NPSA_Rank	USAR_Rank	KALA_Rank	HALE_Rank	ALKA_Rank	PUHE_Rank	KAHO_Rank	PUHO_Rank	HAVO_Rank
Ecosystem Pattern and Processes	Land Cover / Land Use	Land cover / Land use	Terrestrial landscape pattern	42	The character of a landscape's pattern (patch size, distribution, shape, dispersion, connection, etc.) influences the distribution, abundance, and movement of plants and animals (see review by Franklin and Forman, 1987). Fragmentation has been called the greatest worldwide threat to forest wildlife (Rosenburg and Raphael, 1986) and the primary cause of species extinction (Wilcox and Murphy, 1985).	How are the distributions of plant communities and land cover inside and immediately outside the Parks changing over time? Are fragments or patches of natural vegetation, or ecotone areas, changing in size or persisting over time?	Mapping, repeat imaging, transects, plots, histories, Where possible use traditional land divisions such as ahupua'a for monitoring units	Spatial statistics, Vegetation type	2.1	2.1	1.8	1.8	3.8	3.5	1.8	1.8	2.6	2.3	2.6	M	M	L	L	2	H	L	L	M	M	M
			Wilderness use	65	Monitoring of 'wilderness character' is mandated by the Wilderness Act.	Are wilderness areas / character being unacceptably changed?	Limits of acceptable change. Nature, magnitude, and source of impacts	Limits of Acceptable Change (LAC)	NA	NA	NA	NA	NA	3.8	NA	NA	NA	NA	2.2	NA	NA	NA	NA	NA	2	NA	NA	NA	NA	L
	Lightscape	Lightscapes	Lightscapes	41	Light pollution can negatively impact visitor experience as well as biological resources.	Are natural light/dark cycles maintained as appropriate (eg no inappropriate shading, etc)? Is artificial light appropriately shielded? Is artificial light restricted to basic human safety needs only? What is impact on night sky from artificial light sources outside the park?	above ground (aerial or satellite) vs on ground measurements (photographs) count of artificial light sources within park, calibrated/repeatable.	Light intensity, spatial distribution, temporal frequency, color. Baseline not greater than 10% deviation.	2.3	1.8	1.4	2.5	2.5	3.2	2.5	2.5	2.2	2.7	2.8	M	L	L	M	M	H	M	M	M	M	M
	Nutrient Dynamics	Nutrient cycling	Nutrient cycling	37	Nutrient cycles are essential ecosystem processes and the linkages to decomposition are complex and important. The carbon cycle is an essential ecosystem process, with insects, animals, saprophytes, pathogens and fire all play important roles in nutrient cycles. Nutrient cycles link the biotic and abiotic components of an ecosystem through a constant change of materials. As such, these cycles may be considered an integrating variable, since they occur across scales and involve the atmosphere, biosphere, lithosphere, and hydrosphere. While nutrients may be transported great distances in water or air, the key transformations that make these elements available to plants (and so to animals) are driven by soil microbes, as are the reactions that release the elements back to air or water, to repeat the cycle. In most cases, well established ecosystems have very "tight" nutrient cycles that conserve key nutrients. Human activities such as forest harvesting, fire suppression, disease introduction and/or control may disrupt these cycles leading to reduced availability of nutrients	How are processes changing over time (source, directions, levels of flow)?	monitoring plots	Aquatic senescence, Coral growth-CaCO3 deposition, Forest productivity (litter rain, incremental growth), Key constituents (N, K, CaCO3)	2.7	2.2	2.3	2.6	2.6	2.6	2.6	2.6	2.8	2.3	2.4	M	M	M	M	M	M	M	M	M	M	M
	Soundscape	Soundscapes	Soundscapes	39	Noise pollution can come from a variety of sources. Anthropogenic: aircraft, automobiles, other visitors, and activities external to the park can create noise, natural sources can be lost (native bird calls, running water), or alien species can introduce noise.	What type of alien sounds are present in respective management zones? What are sound levels? Are alien sounds appropriate to management zone? Are naturally present sounds maintained at appropriate frequencies, occurrence, db levels? Are we exceeding an acceptable level of sound?	point/plot sampling	frequency (hz), frequency (time), Sound durations, Sound levels, sound source identification, spatial distribution	1.4	1.6	1.2	2.7	2.4	2.7	2.7	2.7	4	2.8	2.7	L	L	L	M	M	M	M	M	1	M	M
Geology and Soils	Geomorphology	Coastal / oceanographic features and processes	Shoreline Change	26	Change in shoreline morphology affect both coastal and marine resourcse, such as wetlands, tidepools, coral reefs, and seagrass beds.	Where are shorelines advancing, retreating, or stable, and what is the rate of change?	historical shoreline analysis (air photos, T-sheets), beach profiles, tide gauge data to examine local sea-level trends, field observations and measurements	human development/infrastructure, substrate composition, shoreline aspect/position/slope, sea level, nearshore physical oceanography, historical shoreline analysis, amount of change (m) over the time span between measurements (years).	2.3	1.7	1.3	3.3	3.3	3.2	3.3	3.3	3.3	3.8	2	M	L	L	4	H	H	5	5	H	2	L

Level 1	Level 2	Level 3	Vital Sign	Network Rank	Justification	Monitoring Questions	Monitoring Methods	Measures and Metrics	AMME_Score	WAPA_Score	NPSA_Score	USAR_Score	KALA_Score	HALE_Score	ALKA_Score	PUHE_Score	KAHO_Score	PUHO_Score	HAVO_Score	AMME_Rank	WAPA_Rank	NPSA_Rank	USAR_Rank	KALA_Rank	HALE_Rank	ALKA_Rank	PUHE_Rank	KAHO_Rank	PUHO_Rank	HAVO_Rank
Geology and Soils	Geomorphology	Stream / river channel characteristics	Stream and river channel dynamics and geomorphology	60	Changes in stream morphology are highly indicative of land-use change. Native Pacific stream species are sensitive to habitat change, and alien species often prefer altered conditions.	Is erosion occurring? Are flow channels changing? Are substrate types changing?	mapping of streambed topology & substrate	bank depth, sinuosity, stream cross-section, stream gradient, substrate size	2.1	1.8	1.3	2.6	2.6	2.3	2.3	2.3	NA	1	NA	M	L	L	M	M	L	M	M	NA	L	NA
		Windblown features and processes	Dunes	66	Affect resource / habitat as well as recreational (terrestrial & marine uses)	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 regime	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.8	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	L
	Soil Quality	Soil function and dynamics	Biological Soil Crusts	64	Biological soil crusts are fragile communities important in controlling erosion and chemical processes in arid ecosystems.	Where are soil crusts broken, 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	NA	NA	NA	NA	2.5	3.3	2.5	NA	NA	NA	2.3	NA	NA	NA	NA	M	H	M	NA	NA	NA	L
			Erosion and Deposition	29	Erosion and sedimentation are directly indicative of soil disturbance and provide a good indicator of the rate or extent of land use change. When suspended in water, fine sediments increase turbidity, decrease light penetration, and alter primary productivity. In some cases excessive sediment accumulation can alter the hydrologic regime.	What are causes and locations of soil erosion, what are rates of change, what is land use and human impact?	erosion pins deployed together and integrated over watershed, sediment collectors, mapping, sediment fingerprinting	Areal distribution of rate of soil loss (mapping), transport out of watershed	2.1	3.6	1.7	2.8	3.1	3.3	2.8	2.8	2.6	3.3	2	M	3	L	M	M	H	M	M	M	H	L
			Soil structure and chemistry	44	Integrate a large number of factors and represent a sensitive early warning of change. Soil carbon can be related to productivity changes, soil chemistry, and community changes which in turn relate to a wide number of the stressors.	Are physical soil properties changing? Are soil buffering and filtering qualities changing? What are soil communities, and are they changing?	Soil sampling and analysis	DOC, grain size, moisture content, parent material, percent organic matter, permeability, POC, cations, pH, soil composition, Total Nitrogen & Total Carbon, 'bacteria, fungal/microrhizzal, worms/nematodes/arthropods, bulk density	2.1	2.1	2.3	2.4	2.4	3.1	2.4	2.4	1.8	2.1	2.4	M	M	M	M	M	M	M	M	L	L	M
	Subsurface Geologic Processes	Caves / karst features and processes	Cave habitat	51	Environmental conditions in caves and lava tubes are easily disturbed by human activity. However, caves and lava tubes are often important traditional cultural sites in Hawaii (and elsewhere?).	How do natural/human induced impacts affect environmental cave conditions (temp, humidity, light, etc.)? How do human activity & cultural practices impact cave systems above ground (outside) and inside?	Station/plot data, photo points (repeat photography)	litterfall, Species distribution & abundance, human use levels, temperature, humidity, ground compaction, etc.	NA	2.9	1.3	NA	2.2	2.8	2.8	2.8	1.2	2.8	3	NA	7	L	NA	L	M	M	M	L	M	M
			Cave system topography	63	Caves are protected geophysical resources under Hawaii State Law (embarrasingly not familiar w/Territorial statutes).	What are patterns of mineral accretion? Where & when are collapse/skylight formation or enlargement occurring? Are changes in karst systems leading to potential bedrock collapse, well yield disparities, poor groundwater quality, soil instability?	geologic mapping, periodic measurement of physical parameters and feature types, remote sensing, surface water chemistry, groundwater discharge patterns	dimensions, feature size, extent, baseline mapping, groundwater flow/quality	NA	2.2	1.3	NA	1.5	2.8	1.5	1.5	1.4	1.8	1.8	NA	M	L	NA	L	M	L	L	L	L	L
		Seismic activity	Seismic activity	56	Non-volcanic seismicity is a hazard.	Can we identify trends and predict hazards?	Seismometers (local and global)	tilt meters, seismometers, dilatometers (pressure gauges), EDM (Electronic Distance Measuring)	1.4	1.7	1.3	2.2	2.8	2.8	2.2	2.2	1.4	2.2	2.2	L	L	L	L	M	M	L	L	L	L	L

Level 1	Level 2	Level 3	Vital Sign	Network Rank	Justification	Monitoring Questions	Monitoring Methods	Measures and Metrics	AMME_Score	WAPA_Score	NPSA_Score	USAR_Score	KALA_Score	HALE_Score	ALKA_Score	PUHE_Score	KAHO_Score	PUHO_Score	HAVO_Score	AMME_Rank	WAPA_Rank	NPSA_Rank	USAR_Rank	KALA_Rank	HALE_Rank	ALKA_Rank	PUHE_Rank	KAHO_Rank	PUHO_Rank	HAVO_Rank
Geology and Soils	Subsurface Geologic Processes	Volcanic features and processes	Lava flows	61	Volcanic activity is a hazard.	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	NA	NA	NA	NA	NA	2.6	2.5	2.5	1.4	2.2	2.8	NA	NA	NA	NA	NA	M	M	M	L	L	M
			Mass wasting	57	Mass geologic wasting is a hazard.	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	NA	1.5	1.9	NA	3.1	2.8	2.5	2.5	1.4	1.9	2.2	NA	L	M	NA	M	M	M	M	L	L	L
			Volcanic ground deformation	62	Volcanic activity is a hazard.	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	GPS, subsurface temp, tilt meters	NA	NA	NA	NA	NA	2	2.5	2.5	1.4	2.2	2.7	NA	NA	NA	NA	NA	L	M	M	L	L	M
Human Use	Consumptive use	Consumptive use	Consumptive uses of National Park natural resources	43	Removal of natural resources can affect the ability of the resource to replenish itself and potentially affect other species in the biological system. Thus, the need to monitor how many species are removed and what effect the removal has on the population dynamics.	What are trends in harvest, including illegal species? Is human harvest changing distribution, abundance or other population characteristics? Can there be a balance between management goals or sustaining population numbers and culturally important species?	Transects, plots, systematic monitoring and/or population surveys of harvested species, creel surveys	collection statistics (quantity, age/size), species composition, counts by class	2.2	1.9	2.7	1.4	3.8	2.5	1.7	1.7	3	2.8	2.2	M	L	M	L	2	M	L	L	H	M	L
			Fisheries Harvest	38	In the Pacific, a wide diversity of marine species are fished for consumptive uses and fishing has well documented, significant impacts on ecosystem structure and function, and on the condition of resources. Fishing is increasingly documented as being the principal threat to Pacific coral reefs and other marine ecosystems worldwide. Currently fishing is allowed in PACN parks following established state/territorial regulations.	What are the trends in the harvest of fisheries species? Harvest includes legal and illegal take.	Systematic monitoring of fishing in park on species and harvest of shellfish and other inverts in coastal areas, creel surveys	CPUE (control & harvested population), collection statistics (quantity, age/size), composition	1.9	2.8	3.8	1.4	3.6	1	2	2	3.8	3.3	2	L	H	2	L	H	L	L	L	2	H	L
	Cultural Landscapes	Cultural Landscapes	Viewscapes	45	Class 1 parks have designated viewsheds.	Are landscapes/seascapes changing in and surrounding the park? If so, how?	historical photos (periodic photography from fixed points)	qualitative, % of change, presence/absence	NA	NA	1.6	2.5	2.5	3.2	2.5	2.5	2.9	3.3	2.4	NA	NA	L	M	M	H	M	M	M	H	M
	Point-Source Human Effects	Point-source human effects	Litter and debris	30	Litter and debris can be physically harmful to animals and plants, particularly by entanglement. Presence of litter dimishes visitor experience. International Convention for the Prevention of Pollution from Ships (MARPOL) 1973, 1978: Controls five types of pollution caused by ships: oil and oil products, noxious liquids carried in bulk, harmful packaged substances, sewage and garbage.	What are levels of litter within parks? Where is littering/ dumping of trash taking place? (e.g. terrestrial, open ocean) Where are areas of marine debris deposition?	surveys of activity & locations, identify spatial distribution, document/characterize source	quantity presence / absence, type & size	2.7	2.7	1.7	3.6	3	3.3	3	3	3.5	2.2	1	M	M	L	1	M	H	M	M	H	L	L
	Visitor and Recreation Use	Visitor usage	Marine visitor impact	48	Depending on severity, mechanical damage (either directly to the organism or an associated abiotic substrate/structure) can injure or kill organisms, reduce their ability to compete, or raise their susceptibility to disease or other mortality sources. Mechanical damage can have cascading ecological effects through a community when abiotic (e.g. cobbles, boulders, overhangs) or biotic (e.g. coral reef, macroalgae) structures that serve as important microhabitat are moved or destroyed.	Are use levels of marine recreational activities changing? What are the trends in observable damage to marine environments as a result of marine recreational use? Including damage from groundings/anchor damage, trampling, debris/damage from fishing, campers & cultural practices.	Mapping for anchor damage, timed visitor counts, periodic surveys of transects and/or quadrats (for damage assessments)	Visitor density (including dive hours), measure of damage (e.g. distribution & amount of severity of anchor damage, amount of lead sinkers, fishing line or net entangled on bottom, number of broken corals level/degree of trampling, water films)	1.6	2.5	2.4	NA	2.8	2	2.5	2.5	3	3.1	1.3	L	M	M	NA	M	L	M	M	H	M	L

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Human Use	Visitor and Recreation Use	Visitor usage	Terrestrial visitor usage	16	Human impacts can include habitat, successional stages, structural differentiation, nutrient cycles, forage availability, water quality/quantity yields, successional pathways, wildlife variety and quantity, carbon balances, and scenic variability. Human actions can significantly alter the extent, intensity, duration and periodicity of disturbance events e.g. excessive grazing over a number of years, permanent vehicle traffic routes through sensitive sites, annual spraying pesticides, removing vegetation altering snow accumulation and runoff timing, etc. Human actions can lead to disturbance rates that outstrip the ability of biological systems to respond and/or recover from the resulting changes. Human activity or interventions in the environment must take into account the recovery ability of ecosystems and normal patterns of disturbance at the landscape scale to assure that any proposed disturbance will be within normal recovery capabilities of the system.	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, quantify use levels	3	1.9	1.4	3	3.8	3.3	3.3	3.3	3.3	3.8	2	8	L	L	H	2	H	5	5	H	2	L
Water	Hydrology	Groundwater dynamics	Groundwater dynamics	34	Groundwater may be the significant water source for certain riparian systems, wetlands, and municipal water supplies (sole-source aquifers). An understanding of water table levels is required for predicting the effects of natural and human-induced hydrological changes (e.g., sea level rise, drought conditions, municipal groundwater withdrawal) and the fate of contaminants.	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, salinity, seepage	2.7	1.2	1.3	2.6	3.8	2.6	2.6	2.6	3.6	3.6	1.8	M	L	L	M	2	M	M	M	H	3	L
			Wetland hydrology	31	An understanding of wetland hydrology is required for predicting the effects of natural and human-induced hydrological changes (e.g., sea level rise, drought conditions, municipal groundwater withdrawal) and the fate of contaminants on wetland systems. The NPS is required to protect wetlands under E.O. 11990	What are freshwater/saltwater recharge rates? What is habitat extent and distribution? What are temporal trends in recharge rates and habitat extent? What are groundwater levels, residence times, infiltration, permeability, and evaporation in wetlands? What is the relationship between groundwater and wetlands in anchialine pools? Includes wetlands, anchialine	measure salinity, residence time, mapping, samples from wells	plant cover/ species present & extent, pool size, extent, depth & salinity, rainfall, sediment loads, pH, tidal fluctuation	3.4	1.6	1	NA	3	3.1	3.2	3.2	3.5	3	3	4	L	L	NA	M	M	6	6	H	M	M
		Marine hydrology	Marine Hydrography	23	An understanding of marine hydrology is importint in predicting the effects of storms and high wave events on marine resources.	What is the natural variability? What are temporal trends? What are the frequency, magnitude and distribution of marine inundation events, what park resources are subject to inundation during tsunamis, and large storms or big wave events?	tide gauge, ADCP, GIS, buoy data, satellite data, seismic networks, field mapping of water and debris lines (both horizontal incursion and vertical elevation)after an event, photograph damage and changes to park resources	maximum signal wave height, relative sea level, tide fluctuations, sea & storm surge levels, erosion/deposition	2	2.6	2.8	3.4	3.8	2.5	2.8	2.8	2.8	3.5	2.2	M	M	H	3	2	M	M	M	M	4	L
		Surface water dynamics	Stream flow	53	Hydrologic changes affect aquatic life, recreation, and aesthetics. Pacific Island streams typically have frequent and unpredictable periods of high flow associated with rainfall. These flooding events can be hazardous to human life, but are important to the maintenance of habitat for native species; invasive species often prefer streams with altered hydrological regimes	What are usual rates & range of flow? What is timing & magnitude of floods or low-flow events? What is the spatial distribution of the flow in question? What are base flow volume and seasonal trends?	gauges, sampling at permanent sites, flow regionalization	discharge / recharge over space & time, diversion patterns, flood timing / magnitude	1.2	2.1	1.8	2.6	3.6	3.5	2.6	2.6	NA	1.2	NA	L	M	L	M	H	H	M	M	NA	L	NA

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Water	Hydrology	Surface water dynamics	Water diversion and withdrawal	43	Diversion of surface water for agriculture and industry and withdrawal of groundwater for human consumption is one of the most significant stressors to freshwater biota on Pacific Islands. Water diversion reduces base flow in streams, thereby decreasing habitat availability, flow velocity, and channel size, and dampening the natural hydrologic regime. Diversion also lowers the water table, which shrinks wetlands, and may cause them to disappear. The degree of water diversion varies from island to island and park to park. The NPS is required to protect wetlands under E.O. 11990.	What proportion of water is being made unavailable for aquatic biota and designated uses? Includes both groundwater and surface water.	gages, wells, sampling at permanent sites	relative quantity of water being diverted, seasonal, spatial & temporal diversion patterns	2.9	NA	1	NA	3.8	2.8	3	3	3.6	2.7	NA	9	NA	L	NA	2	M	M	M	H	M	NA
	Water Quality	Aquatic macroinvertebrates and algae	Aquatic macroinvertebrates and algae	17	Aquatic organisms, especially non-mobile ones, provide a time-integrated record of water quality at a site. However, this area needs more research in the Pacific before this vital sign can be applied.	Are changes in benthic invertebrate & algal communities indicative of impaired water quality?	Periodic benthic quadrat sampling (sediment & sessile organisms).	species richness, composition, biomass, presence/absence of indicator species	1.4	2.5	2.8	3.4	3.6	2.8	2.8	2.8	3.8	3.6	2.5	L	M	H	3	H	M	M	M	2	3	M
		Microorganisms	Water Quality - Biological Condition	20	Microbial content can indicate impacts to water resources due to human and animal wastes and storm water runoff from urbanized and agricultural landscapes.	What are the range and variance of microbial water quality parameters? What are the temporal and spatial trends?	water sampling from dedicated monitoring wells in addition to supply wells	bacteria, viruses, protozoans, biological oxygen demand	3.2	3.4	2.5	2.8	2.8	3	2.8	2.8	3.5	2.8	2	6	4	M	M	M	M	M	M	H	M	L
		Toxics	Toxics and Contaminants	6	Toxics and contaminants reaching water resources negatively affect aquatic biota, human health, and local economics. Early detection is important to offset impacts from off-site pollution.	What are the range and variance of toxics and contaminants in surface water? What are the temporal and spatial trends?	water sampling, sediment sampling, animal tissue sampling, [GW: monitoring & supply wells, fat bags (SPMDs)]	chemical oxygen demand, heavy metals, herbicides, organics, pesticides, bioassays	3.3	3	2.3	3.6	3.8	3.8	3.8	3.8	3.8	3.6	2	5	6	M	1	2	2	2	2	2	3	L
		Water chemistry	Water quality core parameters	2	These parameters provide required minimum baseline data for water quality assessment that will be used throughout the National Park Service. Total nitrogen, total phosphorous, chlorophyll a, and depth were added due to their ecological significance in the Pacific Network.	What are the range and variance of the network core water quality parameters? What are the temporal and spatial trends?	in-situ measurements and collection of samples at established sites including controls	temperature, pH, salinity (sp. cond.), dissolved oxygen, PAR, total nitrogen, total phosphorous, chlorophyll a, depth	3.8	4	4	2.8	4	3	3.8	3.8	3.8	3.6	2.6	1	1	1	M	1	M	2	2	2	3	M
			Water quality supplemental parameters	10	These parameters provide important details for characterizing water resources, identifying potential stressors, and detecting changes early.	What are the range and variance of the supplemental water quality parameters? What are the temporal and spatial trends?	in-situ measurements and collection of samples at established sites including controls	inorganic nutrients (NO2/NO3, PO4, NH4), suspended sediments/turbidity/secchi disk, alkalinity, anions, cations, redox, total organic carbon, chlorophyll b, chlorophyll c	3.5	3.8	3	3	3.2	3	3.2	3.2	3.8	3.6	2	3	2	7	H	H	M	6	6	2	3	L