PARK VITAL SIGNS/CONCEPTUAL MODEL SCOPING WORKSHOP

Point Reyes NS and Golden Gate NRA

July 17-18, 2002

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This document summarizes the process used and the products gained from a Vital Signs Monitoring Workshop conducted by Point Reyes National Seashore, Golden Gate National Recreation Area, and the park units administered by Golden Gate - Fort Point National Historic Area, Muir Woods National Monument, and the Presidio of San Francisco. The workshop was designed to review the proposed vital signs indicators selected through previous workshops, the underlying assumptions about ecosystem function, and the conceptual model about how they interconnect. Key points from discussion, work group discoveries and suggestions are included in this summary.

Introduction

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS's) ability to manage park resources "unimpaired for the enjoyment of future generations". NPS park managers are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions. They must provide scientifically credible information to select and defend management actions and fulfill legal mandates.

In response to these challenges, the NPS has identified 270 parks with significant natural resources for which inventories will be completed and long-term ecological monitoring will occur. The intent of the NPS monitoring program is to track a subset of park resources and processes, known as "vital signs", that are determined to be the most significant indicators of ecological condition for specific resources that are of greatest concern to each park.

Steps to develop a monitoring program

The NPS Inventory and Monitoring (I&M) Program grouped the 270 parks into 32 vital sign networks linked by geography and shared natural resource characteristics. Each network of parks is required to design an integrated monitoring program that addresses the Service-wide monitoring goals listed above and that is tailored to meet the high-priority monitoring needs of the parks. The basic approach to designing a monitoring program should follow the five basic steps recommended by the service-wide I&M program:

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

Point Reyes/Golden Gate workshop process and participants

A two-day workshop was held in lower Ft. Mason in July 2002. The 39 participants included predominantly NPS employees with resource specialties from the five parks. Other invitees included people from other agencies, universities, organizations or individuals working on projects in the parks.

During the first day, many participants were asked to present 3-5 minute-long summaries about the projects that they worked on. Then participants divided into smaller work groups of 5-12 to accomplish the first two steps of the workshop. During the second day, presentations were made about the management needs and issues in both parks. The "straw-dog" conceptual model was presented. Then the same groups formed to evaluate, revise and add to the descriptions. In the afternoon, the groups reviewed the indicators, but we didn't have time to rank them during the workshop. After the workshop using a ranking process through emails, we developed the ranking criteria for the indicators.

Workshop goals

The objective of the workshop was to revise and improve portions of the 2002 Point Reyes/Golden Gate Draft Monitoring Plan to meet NPS service-wide directions by taking the following steps:

1. Review significant natural resources.
2. Review stresses to the natural resources.
3. Review the "straw-dog" conceptual model with interconnections between stressors and resources.
4. Review/prioritize vital signs indicators.

Background

In the past, the parks separately developed I&M projects for single species or groups, such as rare plants, salmonids, pinnipeds, migratory raptors, and exotic plants. GOGA developed an ecological monitoring program in coastal scrub and grassland habitats in 1988 (Howell 1992).

In 1993, resource management staffs from PORE/GOGA parks decided to develop an I&M program. They decided to work closely with the Channel Islands prototype program since they had similar ecosystems and had prior monitoring experience. Monitoring elements that were initiated included the rocky intertidal, pinniped, landbird, owl, and salmonid monitoring. A vegetation map was initiated for all parks in 1995. A draft inventory and monitoring plan (1996) was developed at the end of this process, but it was only partially implemented due to lack of funding.

With the initiation of the Natural Resource Challenge, the Monitoring Plan was resurrected for review and modification during this workshop. Several events occurred that might affect recommendations made in 1996.

The NPS **Natural Resource Challenge** was implemented to improve how the NPS manages the natural resources under its care. It is an Action Plan that calls for

substantially increasing funding for the I&M program, exotic plant management teams, and learning centers. The Plan includes gathering baseline data on resource conditions, strengthening partnerships with the scientific community, and sharing knowledge. The I&M program developed specific standards for both inventories and vital signs monitoring that participating parks must meet. These standards were not in place when the Point Reyes/Golden Gate parks first developed their long-term monitoring indicators.

The Point Reyes/Golden Gate parks are a major part of the San Francisco Bay Area Network (SFAN). The SFAN was selected as one of the first three Networks in the region to obtain I&M program funds because of need, capacity and existing efforts. In 2000 using I&M funding, this Network began to complete inventories of natural resources for which information was lacking. Therefore, there is new information available to guide the parks since the initial workshops. These natural resource **baseline inventories** (NPS-75) allow us to account for park resources and represent "core" sets of information park managers need to effectively protect park resources.

SFAN parks developed an Inventory Study Plan that was implemented in FY2000. The first projects that were supported included completing vegetation mapping for GOGA and PORE and initiating a map for PINN and JOMU, data mining, and a small mammal inventory. An assessment of the herbarium was also initiated. In FY2001, the rare plant inventory started. The bat inventory and coastal inventory began in FY2002.

Service-wide vital signs monitoring goals

Despite differences that exist among parks, five service-wide goals for vital signs monitoring have been established for the 270 NPS park units with significant natural resources. The goal is to design an integrated monitoring program to:

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

Park monitoring goals and objectives

The first step in developing a monitoring plan is to form monitoring goals that describe why the parks want to monitor. These were developed in 1996 based on the I&M service-wide goals (NPS-75), the NPS mission, the Vail Agenda and the parks enabling legislation.

The goal of the Point Reyes and Golden Gate parks is to develop and institute a natural resource monitoring program, which will:

1. determine present and future ecosystem health,
2. establish empirical limits of resource variation,
3. provide early diagnosis of abnormal condition, and
4. identify potential agents of abnormal anthropogenic change.

The objectives of the park monitoring program are based on the monitoring goals, both service-wide goals and park goals. The following two objectives were developed in 1996:

1. to detect change and quantify trends in resource condition, and
2. to provide a rational, scientific basis for management decisions.

Definition of terms

Indicators are also called vital signs or attributes. They are any measurable feature of the environment that provides insights into changes in the state of the ecosystem. They are intended to track changes in a subset of park resources and processes of greatest concern to the parks. They may occur at any level of organization from landscape, community, population or genetic scales and also either structural (organization and pattern of the ecosystem) or functional (ecological processes).

Ecological effects are the physical, chemical and biological responses to processes and stresses.

Stressors are physical, chemical or biological perterbations to a system that are foreign to that system. Examples include resource extraction, air pollution, fire suppression, and invasive species introductions.

Natural ecosystem processes are the major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts and floods) that have large scale influences. Process examples include succession, deposition/accretion of soils, and marine currents.

Boundary of area of concern

The legislative boundaries of the coastal parks of central California extend from Tomales Point, Marin County, on the northern edge south to Milagro Ridge, San Mateo County. The total acreage for all parks is around 150,000 acres. This includes 71,068 acres in PORE, 75,398 acres in GOGA, 554 acres in MUWO, 29 acres in FOPO, and 1,480 acres in PRES. Within the legislative boundary of PORE are 4,970 acres of inholdings of state, federal and commercial enclaves, and 8,000 acres of designated wilderness. The PORE and GOGA boundary extends one-quarter of a mile offshore and includes all of Tomales Bay.

There are two boundary limits, an inner core which is more protected and an outer limit. The core is composed of areas within NPS boundaries, state parks, and adjacent watersheds. The outer limit is delineated by the broader boundary of the Central California Biosphere Reserve, of which the parks are members; three National Marine Sanctuaries; and the mouth and center of San Francisco Bay. Monitoring in the core area should be expanded to take into account upper and lower reaches of watersheds, which extend beyond the legislative boundaries of the parks. The outer limit of the boundary was developed for widely ranging species and headwaters of streams.

Conceptual model

A conceptual model is a visual or narrative summary that describes the important components of an ecosystem and the interactions among them. Development of a conceptual model helps in understanding how the physical, chemical and biological elements of a monitoring program interact and promotes integration and communication among scientists and managers from different disciplines. Conceptual model development is an iterative and interactive process. Models are expected to change as a network's monitoring program develops and as ecological linkages are better understood.

The PORE/GOGA parks developed a schematic model with a supporting narrative. The high biodiversity due to the moderate Mediterranean climate, topographic variation, convergent oceanic currents, and overlapping ecological regions made it challenging to divide the ecosystems into something that made sense. For conceptual purposes, the ecosystems were divided into four types – marine, terrestrial, wetland, and abiotic. The dominant ecosystem drivers, anthropogenic stressors, and broad-scale indicators were also represented in each model.

In order to review the schematic model, the underlying knowledge and assumptions had to be checked. The workshop participants reviewed the significant resources, natural processes and stresses as a single group. Participants divided by discipline into smaller work groups to review each schematic model and proposed indicators.

STRAW DOG CONCEPTUAL MODEL
Golden Gate NRA and Point Reyes NS
Assumptions or Current Knowledge for the Model

The first step was to document the significant resources that were being conserved for future generations. Legislation and executive orders were used as the first cut in listing significant resources for these park units.

The purpose of Golden Gate NRA as part of the "parks to the people" program:

> "in order to preserve certain areas of Marin and San Francisco Counties, possessing outstanding natural, historic, scenic and recreational values, and in order to provide for the maintenance of needed recreational open space necessary to urban environment and planning…" (1972 enabling legislation)

The purpose of Muir Woods:

> "to protect the grove of coast redwoods because 'the trees are of scientific value because of the primeval character of the forest, the age and size of the trees (and) their location near centers of population and instruction." (1905 enabling legislation)

The purpose of PORE:

> "… to save and preserve for the purpose of public recreation, benefit and inspiration, a portion of the diminishing seashore of the United States that remains undeveloped." (1962 enabling legislation)

The group expanded the list and grouped it by functionality. The summary is included below in alphabetic order in Table 1:

Table 1: Significant natural resources

1. Clean air
2. Clean and sufficient water
3. Dark night sky
4. Endemic species and their habitat
5. Geomorphic condition and function
6. Inspiration as part of visitor experience
7. Migratory species support systems
8. Natural soundscape
9. Natural functioning ecosystem
10. Special ecological regions
11. Threatened and endangered species and their habitats
12. Unique soils, geology and sensitive plant communities
13. Viewsheds
14. Wilderness

When the resources of all of the parks are combined, the parks in this Network become an awesome resource:

- one of the largest coastal preserves in the U.S. (over 100,000 acres)
- superlative north Pacific coast landscapes
- important scientific resources
- one of six most significant in the nation for biodiversity
- nearly 60 federal or state listed threatened and endangered species utilize the parks as residents or seasonal migrants
- one of the best birding areas in the U.S. (480 recorded species)
- eleven species of seabirds breed within the parks
- over 80 waterbird and shorebird species were identified during the 1997-99 inventories
- one of eleven mainland breeding areas for northern elephant seals in the world
- 20% of the breeding population of harbor seals in California
- highest density of spotted owls throughout its range
- highest density of red-legged frogs throughout its range

The next step was to identify and document the natural processes. The group began by checking the natural ecological processes first. Processes were assumed to be natural and operate within a normal range of variation.

Table 2. Major natural processes

- catastrophic events (fire from natural ignitions, floods, earthquakes, mass wasting, waves, wind)
- climate (decadal patterns and greater)
- dispersal (seeds, pollen, animals) needing connectivity
- disturbance
- edge effects
- environmental engineering (trampling, burrowing, grazing)
- evolution (affects endemism and genetic diversity)
- landscape/ patch dynamics
- nutrient cycles
- predator/ prey dynamics
- succession
- trophic interactions through the food web

Stressors were thought to be anthropogenic, to potentially have deleterious effects to park resources, and to accelerate rates of change. Processes may be accelerated or modified by anthropogenic causes. There were thought to be eight major sources of stressors to the resources – development, farming, fishing, unnaturally caused fire ignitions, park

operations, pollutants, over 150-years of ranching, and recreation. Most stressors were related to change in land use.

Table 3. Major stressors

- traffic and combustion engines causing air pollution and noise
- increased nutrients from fertilizer use and ranching
- erosion increasing sedimentation in streams and creeks
- lights decreasing dark night sky
- habitat fragmentation disrupting migration and dispersal
- changed fire regimes causing vegetation community structure and composition changes
- trampling from humans and ranching causing soil compaction and erosion
- increased urban to parkland edge
- global warming
- changes in nutrient cycles from fertilizers and pollutants resulting from increased development
- wildlife behavior changes from increased urban interactions and loss of habitat
- loss of viewsheds due to increased patchiness and development
- increased avenues of entry for exotic species
- increased avenues of entry for disease
- increased plastic litter that can be ingested or can entangle
- increased direct take and removal of resources, especially marine resources through fishing

The summary of the processes and stressors affecting the parks in this workshop is also included in Worksheet 1 on page 13.

Both marine and terrestrial ecosystems overlapped with wetland ecosystems, so the workshop participants decided to define the **boundaries** of the wetland group. No areas bounding the Pacific Ocean were included in the wetland group. The wetland group included entire stream reaches until they flowed into bays/estuaries. All freshwater ponds and impoundment's were included in the wetland group. The Cowardin definition of a "wetland" using the vegetation parameter was also used for the purposes of this discussion.

The participants reviewed the current knowledge and assumptions for which the conceptual model is based. They thought that identifying the knowledge gaps would be helpful to future reviewers, so these were included. All three groups where able to discuss the interconnections between stresses and resources leading to monitoring questions/indicators.

METEOROLOGY AND CLIMATE

The San Francisco Bay Area Network parks are in the Mediterranean climate zone. The moderate climate offers long growing seasons and supports diverse plant and animal communities. The majority of rainfall occurs during the winter months. There is a high variability in winds but dominant winds are from the northeast during the spring and summer, and from the south and west in the winter. The coastal areas are characterized by fog, precipitation, and steep gradients. Terrestrial areas have pockets of marine-influenced microclimates with intense variation in rainfall and fog, both spatially and temporally (seasonal, annual, long-term, decadal).

There are spatial gaps in both current and legacy meteorological data.

GEOLOGY AND GEOMORPHOLOGY

Elevation across the parks ranges from sea level to 3,300 feet above mean sea level. There is varied topography. Slopes range from almost flat marine terraces and alluvial deposits to steep canyons along some creeks, providing dramatic topography and, therefore, habitat heterogeneity.

The San Andreas Fault, the dominant geological force in the area, is a source of natural disturbance in the form of seismic activity resulting from the interaction of the Pacific and Continental Plates. This geologic activity restructures ecosystems offering unusual habitat for endemics and species at the edge of their range. Geology and soil types are diverse.

There are gaps in knowledge about soil biotic components (mycrorhyzae, invertebrates). A soil map for San Mateo lands is needed.

WATER RESOURCES

Many aquatic resources are significant in an ecological and economical context. Aquatic resources include streams, bays, estuaries, lagoons, lakes, reservoirs, freshwater and estuarine marshes, seeps and bogs. The combinations of marine and freshwater systems support a variety of threatened and endangered species. Four Areas of Special Biological Significance, state designated, have been established within the legislative boundaries of the San Francisco Bay Area parks. These include the Point Reyes headlands, Bird Rock, Double Point, and Tomales Point. The areas were chosen based primarily on habitat quality. Commercial operations include a significant herring fishery, rockfish fishery, and aquaculture operations, ranching and agriculture.

The hydrologic systems are very flashy, with high runoff in the wet winter, and very low to intermittent flow dominating summer conditions. In response to the flashy hydrologic conditions and the highly active geologic processes associated with the San Andreas Fault, stream channels are typically dynamic.

Watershed conditions vary from coastal wetlands in wilderness areas to urbanized watersheds, some of which are managed as a public water supply. Watersheds are

relatively small ranging from the 9 sq.mi. Redwood Creek watershed in GOGA/MUWO to the approximately 88 sq.mi. Lagunitas Creek watershed in PORE/GOGA.

Knowledge about how and where the sediment load affects water quality and biota in flowing water is lacking. Research is needed to document sediment load at erosion sources, stream bank erosion rates and sediment fate/transport through the system. Cross-section mapping of selected channel locations is also desirable. Groundwater quantity and quality issues are also complex. Both need to be tied to withdrawals and connectivity to surface waters.

OCEANOGRAPHY

The convergence of oceanic currents rising from the abyssal plain over a steep submarine cliff makes the marine and coastal shoreline habitats complex and diverse. The California coast around Point Reyes is one of only five areas of eastern boundary upwelling currents worldwide. In addition, a plume of warmer, freshwater exiting the San Francisco Bay extends out into the Gulf of the Farallones. The nutrient rich waters support an abundant and diverse fauna. More than one-third of the world's cetacean species occurs in these waters. Significant haulout areas for five species of pinnipeds are used year round.

There are gaps in knowledge about bathymetry, seabed classification, physical nearshore oceanography, sea level change and paleo resources. There is not enough knowledge about the sources of offshore oil, both natural from seeps and anthropogenic from ships and spills.

HABITATS AND COMMUNITIES

According to the habitat classifications by Bailey 1995 (*Description of Ecoregions of the United States*), the PORE/GOGA parks are located within two biomes. The area south of the Golden Gate Bridge (PRES, FOPO, and GOGA) is within the California Coastal Chaparral Forest and Shrub Province, and the Marin County hills north of the Bridge (PORE, GOGA, and MUWO) are within the California Coastal Step and Redwood Forest province.

Park staff grouped twenty-six micro-clusters (super alliances/assemblages) from the vegetation maps. These clusters were further clumped for a coarser scale view. Major habitat clusters include the redwood, Douglas fir-tanoak, coast live oak, chaparral, and grassland series. Workshop participants assume that the high variability and amount of urban edge produces unique communities and redirects wildlife corridors.

Gaps in knowledge occur for invertebrates (macro and micro), for wide ranging vertebrates, reptiles, amphibians, and for rarer species where relative abundance and distribution are desired. Vascular plant inventories at PORE are probably at the 90% level, but they are not complete at GOGA. There are data gaps for non-vascular plants and invasive species. The terrestrial group thought that research was needed on minimum viable populations and population viability analysis for recovery planning.

EFFECTS OF STRESSORS AT DIFFERENT SCALES

It was assumed that the effects of stressors occur at different scales. The landscape scale was defined by the terrestrial group as being greater than a community, thus having multiple vegetative structures, patches and communities. The overall distribution of populations and habitats can be viewed at the landscape level. Effects at this scale could change patch dynamics, connectivity (migration and dispersal corridors), metapopulation dynamics, increased soil nutrients and decreased soil quality, distribution and quantity of edge, groundwater and surface water degradation, loss of vegetation communities and changes in disturbance (fire, flood, mass wasting) frequency, intensity and location.

At the community scale, there are other effects including changes in animal and vegetation species composition (richness, diversity, dominants). There are also changes in trophic interactions, soil composition and soil biotic components. Ecological interdependence (symbiotic, parasitic) may be affected. There may be losses and additions of species. Microclimates may change.

At the population scale, impacts may come from disease and evolution. Impacts to animal species may be to reproduction, mortality, behavior, dispersal, movement, activity pattern, age structure and genetic/phenotypic plasticity (resiliency). Impacts to plant species are similar and could affect reproduction, mortality, dispersal and resiliency. Effects may change local abundance and small-scale distribution and habitat selection.

In order to see both significant resources and stresses/processes that cause change at the same time, a spreadsheet was developed. "Worksheet 1 – Effects of Stressors". It contains the significant resources down the left side and the sources of the stresses at the top. This was an attempt to identify the specific stress and connect it to the source(s) and the resource. Four stresses are listed at the bottom of the worksheet because they were significant enough in themselves and couldn't be tied to a single resource.

PORE/GOGA WORKSHOP - WORKSHEET 1. 7/17-18/02

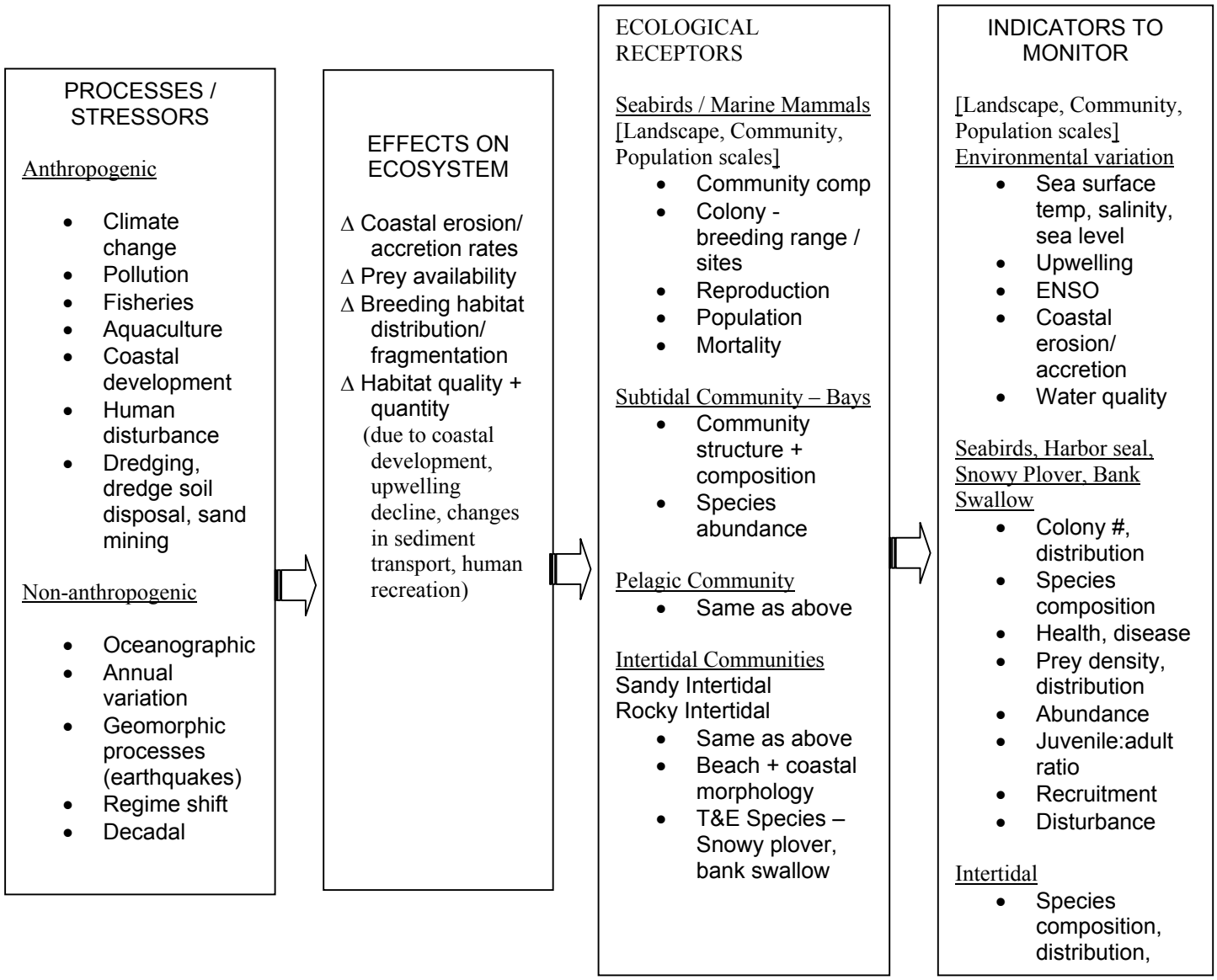
Stresses and Processes

Stressors:

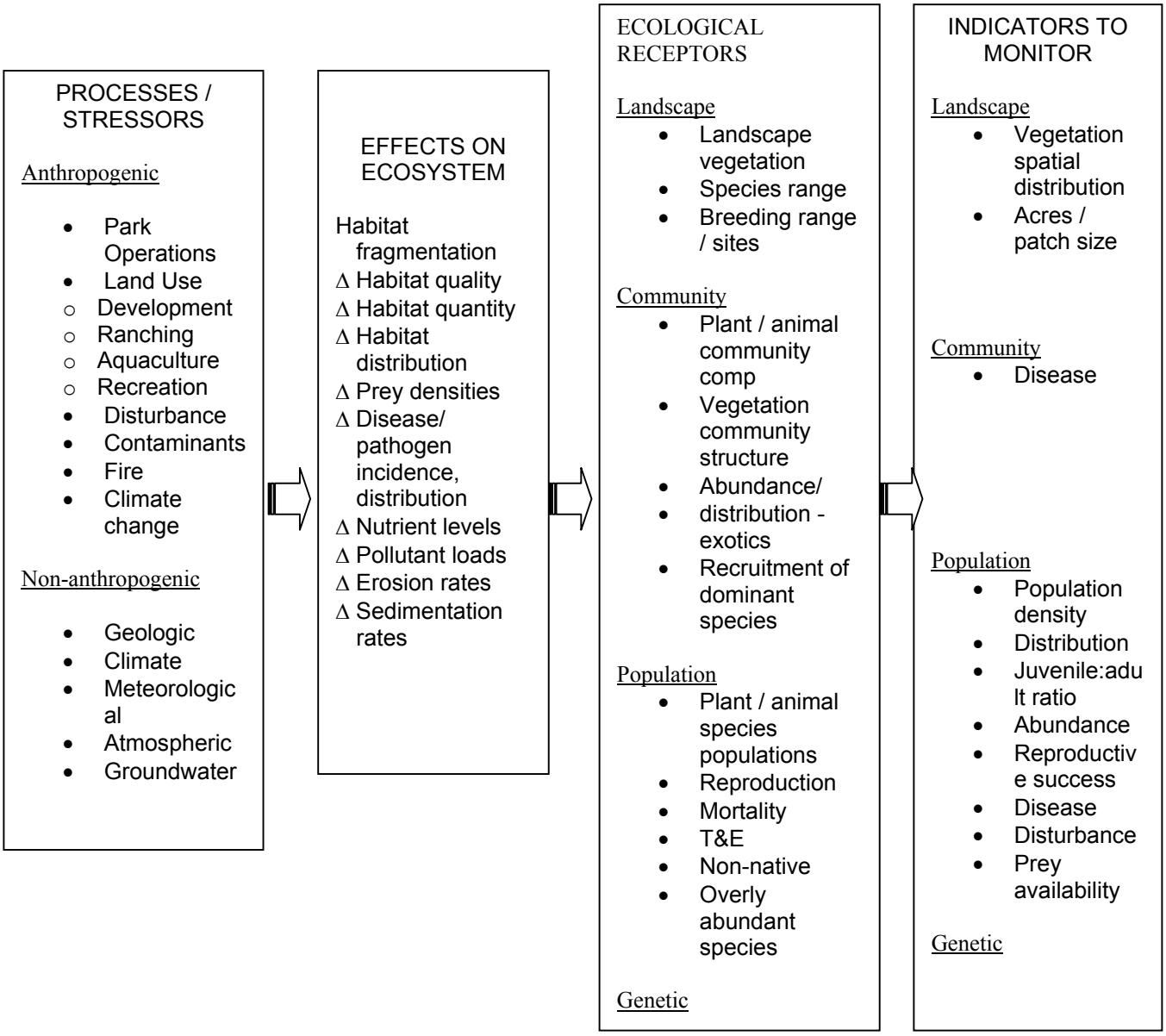
	Development	Farming	Fire	Fishing/ Aquaculture	Park Operations	Pollutants	Ranching	Recreation
Significant Resources								
Clean air	X	X	X		X	X	X	X
Clean water	X	X	X	X	X		X	X
Dark sky	X			X	X		X	X
Endemics & their habitat	X	X	X	X	X		X	X
Migratory species support systems	X	X		X	X		X	X
Natural soundscape	X			X	X			X
Naturally functioning ecosystem								
Connectivity	X	X	X		X		X	X
Dispersal	X	X	X	X			X	X
Disturbance (fire, erosion, seismic…)	X	X	X	X	X		X	X
Edge effects	X	X	X	X	X		X	X
Environmental engineering (trampling…)	X	X			X		X	X
Evolution (endemism & genetic diversity)		X		X		X		
Geology		X	X			X	X	
Hydrology	X	X		X	X	X	X	X
Landscape/patches	X	X	X		X		X	X
Meteorology						X		
Nutrient cycles	X	X	X		X	X	X	X
Predator/prey dynamics	X		X	X	X		X	X
Succession			X	X				
Trophic interactions			X	X		X		X
T&E species and habitats	X	X		X	X		X	X
Unique soil/geology w/plant communities	X	X	X		X		X	X
Viewsheds	X	X	X	X	X		X	X
Wilderness	X		X	X	X			X
Inspiration (visitor experience)	X	X	X	X	X			X
Stressors								
Exotic species	X	X	X	X	X		X	X
Disease	X				X		X	X
Litter (plastic)	X	X		X	X	X	X	X
Direct take and consumption			X	X	X		X	

The four schematic models that Sarah Allen and Daphne Hatch developed for the workshop based on the previous workshops were presented. They each contain the significant resources, the natural processes and stressors, and are based on the above knowledge and assumptions.

MARINE RESOURCES MODEL



TERRESTRIAL RESOURCES MODEL



PHYSICAL RESOURCES MODEL

STRESSORS

Anthropogenic

- Development (External and internal)
  - Roads, utilities
  - Buildings
  - Water withdrawals
  - Transportation
- Fire
- Farming
- Global climate change
- Hydrological changes (dams..)
- Park operations
- Past land use
- Pollution
- Ranching
- Recreation

Non-Anthropogenic

- Dispersal (seed, animals, pollen)
- Disturbance (fire, flood, drought, mass wasting…)
- Environmental engineering (trampling, burrowing, grazing)
- Evolution
- Nutrient cycles
- Plate tectonics
- Succession
- Weather (fog, El Nino)

SIGNIFICANT RESOURCES

- Biodiversity
- Clean air and water
- Dark sky
- Endemics and their habitats
- Migratory species support system
- Naturally functioning ecosystems
- Natural soundscape
- T&E species
- Unique soil/geologic types and their plant communities
- Viewsheds
- Wilderness

EFFECTS ON RESOURCES

Δ Air quality degradation
Δ Community composition/ structure
Δ Connectivity of habitats
Δ Exotic species/disease dispersal
Δ Fire frequency/intensity
Δ Habitat fragmentation
Δ Populations (reproduction, behavior, dispersal, genetic resiliency)
Δ Soil erosion – coastal & upland
Δ Water quality degradation

INDICATORS TO MONITOR

Physical resources

- Acid deposition
- Air quality (ozone, particulates, SO2, nitrates, visibility)
- Carbon dioxide emissions
- Dark night sky
- Natural sound
- Toxins (PCB, dioxin, mercury)
- Weather – temp, precip…

Water resources (see Aquatic grp)

Geologic resources

- Disturbance event (seismic frequency, fire, flood, mass wasting..)
- Erosion/accretion rates
- Land use
- Soil

Biotic resources

- Disease
- Invertebrate richness
- Landscape – vegetation distribution, connectivity, edge
- Plant community
  - distribution
  - composition (richness)
- Select non-native species
- Select T&E species/habitat

Wilderness values

WETLAND RESOURCES MODEL

PROCESSES / STRESSORS

Anthropogenic

- Contaminants
- Pollutants
- Dams
- Impoundments
- Dredge/ fill
- Development/
- Land use

(External and internal)

- Runoff
- Septic systems
- Water withdrawal
- Global climate change
- Nutrient enrichment
- Ranching
- Resource extraction
- Fisheries

Non-anthropogenic

- Climate cycles & variation
- Environmental engineering (trampling, burrowing, damming)
- Evolution
- Geomorphic distribution
- Hydrologic cycles
- Nutrient cycles
- Oceanic circulation & tides
- Plate tectonics
- Sediment distribution
- Sediment chemistry
- Water quality
- Water quantity

EFFECTS ON ECOSYSTEM

- Δ Coastal erosion/ accretion rates (shoreline change)
- Δ Community composition & structure
- Δ Connectivity of habitats
- Δ Exotic species/ disease dispersal
- Δ Floodwater retention
- Δ Habitat fragmentation
- Δ Habitat quality & quantity
- Δ Plant/animal species composition
- Δ Water quality degradation
- Δ Wetland function

ECOLOGICAL RECEPTORS

Landscape

- Species range & distribution
- Watershed hydrologic function

Community

- Composition
- Habitat distribution
- Structure

Population

- Distribution
- Reproduction

INDICATORS TO MONITOR

Landscape

- Habitat distribution
- Sea level rise/ shoreline change
- Watershed hydrologic function

Community (Watershed)

- Aquatic invertebrates
- Fish – salmonids
- Geomorphology
- Hydrologic function
- Riparian songbirds
- Waterbirds
- Water quality/quantity

Population

- Riparian songbird nest success
- T&E species
  - amphibians
  -
- Yellowthroat nesting sites

The models were thought to be fairly complete as is. The participants suggested that the next iteration of the schematics should have minor modifications. Participants thought that there was a strong connection and dependence of the biotic resources on the physical resources; therefore, information from the physical model should be woven into the biotic models leaving only three schematics. The schematics could be enhanced with the inclusion of the significant resources, perhaps grouped in a meaningful way. It was thought that a feedback loop was necessary from the vital signs indicators to the effects, since monitoring is supposed to assist in the mitigation of effects and general protection of resources. The groups spent some time trying to describe more specific effects and receptors of the stressors. The models will be updated for our next workshop.

Discussion of potential vital signs monitoring indicators.

MARINE GROUP (Rebecca Beavers, Ben Becker, Darren Fong, Stephanie Egan, Dale Roberts)
In order to systematically review all marine resources and stressors, this group combined marine resources into four functional/form categories. Each resource category had the same stressors and significant resources. The categories were sandy beach, rocky intertidal, bay/estuary and ocean (with the sub-groups of soft bottom and rocky bottom).

The group felt that it was important to monitor actual distribution and acreage of these habitat types. General vital signs indicators that were thought to be important but were addressed under separate indicators or by other groups included air quality, disease, disturbance, predator–prey interactions, recruitment and water quality.

In developing the potential vital signs indicators, the marine group used several criteria. Legal considerations included the enabling legislation and external regulations such as the Marine Mammal Protection Act, the Marine Sanctuaries Act, and the Endangered Species Act. Ecological importance of the potential indicator was critical. If there was a partnership opportunity with other organizations and a high feasibility of success in conducting the monitoring, the indicator was given greater consideration. The group was able to identify seven areas needing monitoring. They also identified why the monitoring was important and what attributes would be monitored. These areas are listed below.

1. Monitor and evaluate species community composition, distribution and abundance of rocky intertidal vertebrates and invertebrates. Intertidal invertebrate monitoring in the rocky intertidal zone is currently being conducted. The reasons for this monitoring are to assess climate change through sea level change; to assess the impact of human trampling; to detect invasive species, oil and hazardous materials spills, and impacts and incidence of disease; and to monitor ecological change on a community level. Rocky intertidal monitoring includes monitoring both intertidal assemblages at the landscape & community level, and individual species at the population level.

2. Monitor and evaluate nearshore subtidal conspicuous fishes and invertebrates.
   This monitoring has not yet started. The inventory is not yet complete. Nearshore monitoring will help assess the effectiveness of marine protected areas, overfishing, and presence and influence of invasive species. It will also detect the impacts and incidence of disease and monitor ecological change on a community level. It is anticipated that fish and invertebrate assemblages, particularly sport and commercial species, will be monitored using direct observation techniques, e.g. SCUBA or ROV.

3. Monitor and evaluate the distribution and size of habitat types.
   This type of monitoring will assist with evaluation of effects of climate change, especially sea level change. It will also detect invasive species, oil spill and other pollution events, and impacts and incidence of disease. In rocky intertidal areas, the monitoring will also assist in evaluating the impact of human trampling. Monitoring of ecological change will be done on a community level. Monitoring along the shoreline will use LIDAR and satellite imagery to detect change in habitat. Change in substrate types will be done through seabed classification.

4. Assess the effects of invasive species on communities.
   Invasive species tend to displace native species, particularly TES (threatened, endangered, and sensitive) species. Invasive species are generally undesirable and may hybridize with native species. The marine group thought it important to monitor presence/absence as well as distribution and abundance of species. Impacts will be monitored at the community level. The California State List was recommended as a source for candidate species.

5. Detect and evaluate change in physical oceanography and climatology.
   Physical oceanography and the climate are closely linked; therefore, the marine group put them together. Two examples of parameters to monitor were developed, although there may be more.
   a) Monitor change in sea level (linked to the habitat mapping indicator).
      Sea level was chosen as a potential indicator because sea level change has so many affects. Change can destroy or create habitats, drain or inundate wetlands, affect shoreline habitat, threaten public and private infrastructure, and create hazards to navigation. Attributes to monitor include sea level height, current patterns, and shifts in availability of various habitats. The use of LIDAR and CODAR may be extremely useful tools.
   b) El Nino Southern Oscillation (ENSO)
      The El Nino system affects food webs and species ranges. It can even lead to a greater incidence of heavy storms. Attributes to monitor include water temperature, upwelling intensity, and rainfall amounts. Habitat change can also be monitored, i.e., the loss of seal haul outs among others.

   NOTE: The NPS may not be the primary source for these data. NOAA and other institutions collect much of this information. The NPS can interpret these data on scales appropriate to I&M network and park issues.

6. Detect and evaluate change in water quality
   The good condition of water quality is the basis for all marine life. The quality of the water affects food webs, plant and animal populations and structure, and human recreational opportunities including swimming and fishing. It can even affect air quality as deep vents outgas hydrogen sulfide gases. Three parameters were thought to be important indicators. Chlorophyll A is a measure of phytoplankton blooms. The general species composition of phytoplankton is the base of the marine/estuarine food web. Presence of pathogenic bacteria, such as coliform bacteria, has enormous health consequences.

7. Monitor TES species

TERRESTRIAL GROUP (Dawn Adams, Marc Albert, Maria Alvarez, Erin Boydston, Peter Brastow, Tom Elliott, Natalie Gates, Amy Fesnock, Paul McLauglin, Barbara Moritsch, Judy Rocchio, Will Russell, Dave Schirokauer, Craig Scott, Jessica Shors, and Katrina Strathmann)
This group also decided on a method to help them sort through the diverse terrestrial resources in a systematic way. For their potential vital signs indicators, they grouped resources into five large categories: abiotic, natural disturbance, social/anthropogenic factors, vegetation and wildlife.

1. Abiotic resources
   Since the Aquatic group dealt with water quality, only three areas within this category were discussed for monitoring: air quality, soil and weather.
   a) Detect and assess degradation of air quality
      Five attributes of air quality were considered important for vital signs monitoring. For each of these attributes monitoring should include the total emission level and the distance and direction from the source.
      - Acid deposition could affect resource health, development of both plants and animals, and modify all other pollution sources. The source is primarily industrial.
      - Carbon dioxide emissions were considered important due to the contribution to global climate change and as one of the parameters with measurable standards in the Clean Air Act. Sources of carbon dioxide were thought to be from mobile sources (vehicles, lawn mowers), stationary sources (industry, power, oil refineries), and the general area (temperature inversion created smog).
      - Contaminants or toxins to monitor include PCB, dioxin, and mercury. Industrial and agricultural areas are the primary sources of contaminants.
      - Ozone, sulfur dioxide and nitrates were thought to come from park operations, development, and fire. They were considered important indicators due to the potential adverse effects on resources and to meeting standards in the Clean Air Act.
      - Particulates and visibility were also considered important indicators. In addition to general adverse affects to resources, particulates degrade the viewshed. Park operations, development and fire are the most important

sources of particulates. Viewsheds are significant resources in all parks and in the enabling legislation of most.

b) Detect and assess change in soils
Soils are critical to the formation of the structure and type of vegetation community, which in turn support particular wildlife communities. That interdependence makes soils a critical component to monitor, although not frequently (every 10+ years). Vital signs indicators were thought to be:
- Chemical composition including nutrients
- Soil macro and micro-biota (microryhizae)
- Soil distribution (map)
- Soil structure including compaction
- Soil texture including depth of topsoil and development rates

c) Detect and assess change in weather and climate
Like soil, weather determines the type of vegetation community that will succeed. Global climate change is affecting normal seasonal and decadal cycles of weather patterns to which the vegetation and wildlife have adapted. Vital signs monitoring should include temperature and rainfall at the local, regional and landscape scales.

2. Natural disturbance and resiliency.
The terrestrial group identified three types of natural disturbances with pulsed effects that create drastic and rapid changes to the ecosystem. Anthropogenic stresses modify these natural processes/disturbances and accelerate the rates and intensity of change. Long-term vital signs monitoring should include basic documentation of the disturbance: occurrence, size, aerial extent, intensity, and date. Monitoring should also include the response and resilience of the vegetative community to adapt to the disturbance.

a) Monitor change in fire regime
The fire regime, therefore fire adapted communities, has been drastically changed. Nearly every ignition is put out, even natural ignitions. Closeness of park resources to the urban interface makes human safety the top priority.

b) Monitor resiliency to flood

c) Monitor resiliency to geologic hazards (landslides, earthquakes, mass wasting)

3. Social/anthropogenic factors.
There were three resources important to visitor aesthetics that were also important to ecosystem function and condition.

a) Document and assess loss of dark night sky
Inclusion of this resource type is fairly new to our thinking. Effects of light pollution are not well understood. Bright lights may affect nocturnal wildlife such as bats and vegetative growth (photoperiodicity). From the human and scientific standpoint, there are very few areas for viewing and studying stars. Core areas of parks are important areas of dark night sky. The terrestrial group thought that it would be important to monitor both the total amount of light and the location of bright light sources.

b) Document and assess degradation of viewsheds
   Viewshed and superlative views are a significant resource in both parks. Degradation of viewsheds comes from air pollution, development, deforestation, and land use change. Important viewsheds include:
   - selected views of the ocean and shoreline
   - selected views of rolling hills and pastoral settings
   - selected views of coastal scrub

c) Monitor Wilderness values (PORE)
   Wilderness values include natural quiet, solitude, wonderment, wildlife viewing, lack of vehicles, and the opportunity to do orienteering and test physical prowess. Many wilderness values are also important outside the wilderness and are primary reasons people visit the parks. It is important to monitor selected values in order to maintain wilderness values for all visitors. The group decided that monitoring should include:
   - number of visitors using different areas of wilderness
   - number/location of social trails using remote sensing
   - natural quiet

Since animal behavior may be affected by stressors such as too much light and unpulsed/ random sounds, monitoring select animal behavior may prove important although time consuming.

4. Terrestrial vegetation resources
   Long-term monitoring of the terrestrial vegetation was divided by scale into landscape, community, and population level monitoring.

   a) Monitor and evaluate change in plant communities at the landscape scale
      The use of aerial photography was identified as a tool in monitoring plant community distribution on a landscape scale. The landscape scale was defined as containing multiple vegetative structures, patches, communities and was therefore greater than a single community. Topics and issues that could be examined at this scale included fire frequency, metapopulation dynamics, soil distribution, distribution and quantity of edge, disturbance, habitat fragmentation and connectivity.

   b) Monitor and evaluate change in plant community composition
      Plant community composition includes attributes such as richness, diversity and dominants. At this scale, other factors to consider and monitor included trophic interactions and change, loss of and addition of species, ecological interdependence (symbiosis, parasitism), and biotic components in soil and changes in it's composition. Changes in invertebrate communities were considered important to monitor. Microclimate changes may affect vegetation communities and change plant dominance and non-native plant invasions. Specific plant communities were considered unique or special; therefore should be monitored. These included serpentine soil communities and bishop pine communities. T&E habitat was thought to be important at the community scale.

   c) Monitor and evaluate change in plant species distribution or relative abundance
      Issues that could be examined at the population level included plant reproduction, mortality, dispersal and genetics. Three groups of plants were discussed:

keystone plants (bishop pine, coastal live oak, redwoods, lichens), non-native plants, and threatened and endangered plants. The group thought that it was important to monitor specific taxa at the population scale, but to consider effects to the ecosystem on the community scale.

d) Detect and assess the spread of plant disease. Sudden oak death has made this an important vital signs monitoring category. Monitoring should be proactive, therefore transects through oaks should be monitored at a regular frequency. In addition, the location and spread of disease should be monitored.

5. Terrestrial wildlife resources

Wildlife monitoring was also divided by scale.

a) Monitor and evaluate change in animal community distribution at the landscape scale

At the landscape scale, the most important stressor to monitor was the loss of corridors for connectivity and migration. The resultant fragmentation and isolation of larger megafauna may cause genetic bottlenecks. The use of vegetation maps and evaluation of the vertical component of vegetation structure may be helpful in this monitoring endeavor. Other issues were similar to those discussed under plants.

b) Monitor and evaluate change in animal community distribution

Species richness was considered important at the community scale. Species richness is a measure of biodiversity, a characteristic that makes this Network important. Since invertebrates are at the bottom of the food chain, they were considered particularly important indicators for long-term monitoring. Trophic level interactions and microclimate changes were also discussed as being important. Animal community composition contains attributes such as diversity and dominants. Other factors were similar to those discussed in vegetation.

c) Monitor and evaluate change in animal population distribution or relative abundance

Three specific animal groups were discussed:

1) keystone animals (spotted owls)
2) non-native animals (cats, axis and fallow deer, argentine ants, red fox, pigs, rats, dogs, turkeys), and
3) threatened and endangered animals and their habitat (tule elk, spotted owls, snowy plover, mission blue butterflies, bank swallows, San Francisco garter snake, bats, and red legged frogs).

The group thought that it was important to monitor specific taxa at the population level, but to consider affects to the ecosystem on the community scale.

d) Detect and assess the spread of disease

Several diseases have the potential to spread and become problematic. These include Johne's, West Nile virus, chronic wasting disease, Hanta virus, and Lymes disease. Several of these have the potential to affect human health.

AQUATICS GROUP (Lorraine Parsons, Brannon Ketcham, Leslie Allen, Marie Fontaine, Tom Gardali, Daphne Hatch, Steve Schwarsback, Terri Thomas, Kristen Ward)
Since this eco-type was dependent on water, the group divided their resources into two primary groups, surface water and groundwater. Surface water was either flowing or non-flowing. As the complex inter-relatedness of abiotic and biotic components was discussed, there was a regrouping into biotic and abiotic resources.

1. Abiotic resources
   a) Assess the effect of atmospheric deposition
      Since the Terrestrial group was developing potential indicators for air quality, the aquatics group only dealt with effects of contaminants and acid deposition. Monitoring of particulates, nitrogen deposition and acidification were thought to be the most important for understanding impacts to wetland systems.

   b) Monitor and evaluate changes in groundwater
      In order to monitor condition of groundwater, several measurements were considered of primary importance:
      - Contaminants or pollutants
      - Nitrate, an indicator of leaching
      - Quantity of water
      - Salinity, an indicator of saltwater intrusion

      Water quantity was considered to be complex. It was realized that it had to be tied to withdrawals and connectivity to surface water. Contaminant monitoring may be taken care of through the EPA's HAZMAT or Superfund programs.

   c) Monitor and evaluate the condition of surface water
      Surface water was separated into flowing water and non-flowing water. Most of the metrics discussed for long-term monitoring of condition were the same for both and included pH (acidity), pollutants, salinity/conductivity, nutrients (ammonia, nitrite, phosphorus), dissolved oxygen, and sediment load.

      For flowing waters, the measurement of flow needed to be understood and characterized. Continuous measurements were needed using stream gauges, tide gauges, and precipitation measurements. For both surface water and groundwater, measurements of water use, a stressor, were needed. Three user groups had to be monitored in order to get measures of total water use: NPS water use, illegal unpermitted withdrawals, and legal permitted withdrawals.

   d) Measure and assess changes in sediment load
      Sediment load in flowing water affects water quality and biota. It was also considered to be a complicated issue. In order to describe the current baseline sediment load condition, research was needed to document sediment load at erosion sources, stream bank erosion rates at selected locations, and sediment fate/transport through the system. Sedimentation studies would need to use sedimentation tables, topographic surveys, and Feldspar markers. Cross-section mapping of selected channel locations was also considered to be necessary.

2. Biotic resources
   Understanding of aquatic habitat and community change was based on scale, the same as the terrestrial resource grouping.

   a) Monitor and evaluate change in community at the landscape scale
      Aerial photography was the best tool for monitoring the wetland/riparian ecosystems at the landscape level. It was thought that aerial photography as a coarse level assessment tool could be improved upon through the addition of stream habitat assessment.

   b) Monitor and evaluate change in habitats and communities
      Habitat quality descriptions have many factors and metrics to consider. These include structure of the community, native/non-native species composition, biodiversity measurement, connectivity/fragmentation, and edge effect. Selection of specific taxa such as salmonids or benthic macroinvertebrates could be used as an indication of stress or pristine state. The biotic component of habitat quality was based on geology; therefore, abiotic monitoring must be included as a component. The abiotic component of habitat monitoring includes geomorphic function, structure and complexity, substrate description, hydrology and hydroperiod and topography.

   c) Monitor and evaluate change in populations
      Particular metrics at the population scale include species composition, presence/absence, relative abundance, diversity, distribution, and density. Demography of the population has additional metrics including survival, sex ratios, reproductive success and recruitment. Grouping and understanding special taxa, i.e. native/non-native and seasonal, was thought to be important.
      Several factors were thought to affect species composition and condition. It was thought that these needed to be understood and, perhaps, monitored also. These include edge affects, predator/prey densities, disease/pathogens (especially for amphibians and fish), and water nutrient levels.

Selection of potential vital signs monitoring indicators

The following list contains suggested candidates for vital signs long-term ecological monitoring developed by each group. Those in bold were thought by each group to be the most important. Workshop participants did not have time to use a multi-disciplinary discussion of all potential indicators and do a 1st-pass numeric ranking. Therefore, the indicators are presented in no particular order. Listed attributes were thought to be important, but not all attributes have to be measured for each indicator.

MARINE INDICATOR	ATTRIBUTE
1. **Rocky intertidal community**	percent cover, species composition, dominance
❑ Algal assemblages	
❑ **Starfish** (*Pisaster*)	keystone species
❑ Barnacle assemblages	
2. Sandy intertidal community	percent cover, species composition, dominance
❑ **Dune vegetation**	
❑ **Snowy Plover**	
❑ *Ammophila*	
❑ Sand Crabs *(Emerita)*	
3. **Shoreline habitat**	distribution by substrate type, habitat, size, location
❑ Seal haulouts	T&E species
❑ **Sea level height**	
4. Physical oceanography	water temperature, current patterns, upwelling intensity
❑ El Nino events	
5. Ocean community	presence/absence, distribution, relative abundance
❑ **Seabirds**.	
❑ **Marine mammals**	harbor seals and elephant seals at haul outs (reproductive success)
❑ **Rockfish**	particularly *Sebastes paucispinis, S. auriculatus*, and all species of juveniles as a measure of recruitment success
❑ Krill	primarily *Euphausia superba* and *E. pacifica*
6. Bay/Estuary community	presence/absence, distribution, relative abundance
❑ Submerged aquatic vegetation (e.g. eelgrass).	
❑ **Herring** distribution, abundance, fecundity (San Francisco Bay, Tomales Bay).	
❑ Shellfish.	
❑ **Shore birds**.	
❑ Aquatic birds.	
7. Marine invasive species	presence/absence, percent cover, relative abundance, distribution
❑ Green Crabs	
❑ **Smooth Cord Grass**	
❑ *Spartina*	
❑ *Ammophila*	
❑ Ice Plant	
❑ Zebra Mussels	
❑ Asian Clam	

TERRESTRIAL INDICATOR	ATTRIBUTE
1. **Air quality**	acid deposition, carbon dioxide, contaminants, ozone, sulfur dioxide, nitrates, particulates, visibility
2. **Soil**	nutrients, texture, chemical composition, moisture, temperature, depth of top soil, compaction
❑ Map	
❑ Macro & micro-biota	
3. **Weather**	temperature, rainfall, relative humidity
❑ Micro-climates	
4. Natural disturbance	event documentation (date, location, acreage, intensity…) resiliency of vegetative recovery (monitor as in #6)
❑ **Fire**	
❑ Flood	
❑ Mass wasting, landslides	
❑ **Earthquakes, earth movement** (USGS monitors)	
5. Social/anthropogenic stress	
❑ Dark night sky	location and intensity of light pollution
❑ Viewshed	photo-points
❑ Wilderness values	soundscape, visitor use
6. Terrestrial vegetation	
❑ **Habitat distribution**	aerial photography, richness, diversity, dominance
❑ Bishop pine	
❑ Lichens	air pollution
❑ Serpentine communities	
❑ Oaks	
❑ Disease	sudden oak death
❑ Chaparral	
7. Terrestrial wildlife	
❑ **Connectivity corridors**	
❑ Animal communities	species richness
Invertebrates	
❑ Trophic level interactions	
❑ Predator/prey relations	
❑ **Songbird guild**	
❑ Disease	West Nile virus, chronic wasting disease, Hanta virus, Lymes disease, Johne's

AQUATIC INDICATOR	ATTRIBUTE
1. **Water quality**/ quantity	pH, dissolved oxygen, salinity, conductivity, nutrients, contaminants (mercury), sediment, flow by depth to surface
2. Sediment quality/ topography	texture, pH, moisture, salinity, nutrients, contaminants, surface elevation, compaction
3. Aquatic invertebrates	general species composition, presence/absence, general abundance/density, species diversity, non-native species, keystone species, special status species, bioaccumulation
❑ **Benthic macroinvertebrates**	
4. Fish	same as aquatic #3
❑ **Salmonids**	keystone species
❑ Tidewater goby	T&E
❑ Syncharis pacifica	
5. Mammals	same as aquatic #3
❑ **Amphibians**/reptiles	
❑ **Riparian songbirds**	foraging guilds, riparian songbird nesting success
❑ Neotropical migrants	
6. Aquatic & riparian vegetation	species composition, percent cover, structure/canopy complexity, keystone species, special status species, presence/absence, non-native species, species diversity
❑ Phytoplankton	
❑ Macroalgae	
❑ **Vascular riparian plants**	include shading
❑ Cape ivy	invasive plant
❑ Spartina	invasive plant
❑ **Eel grass**	
7. Aquatic habitats	landscape level using aerial photography, gap analysis,
❑ Habitat fragmentation	pool/riffle ratio
❑ Stream habitat surveys	
❑ **Riparian corridor connectivity**	
❑ Wetland distribution	
8. **Geomorphic form**	bank/stream erosion rates, channel cross-section, progradation, gravel beds

The exercise to identify potential vital signs indicators ended the workshop. The next step was to identify criteria to rank the indicators and go through a quantitative exercise to actually rank them.

Through emails immediately following the workshop, the participants identified and ranked the criteria for use in selecting and ranking the indicators. Using comments from the participants, the long list of criteria was sub-divided by function. One grouping of criteria will be used as a means of ranking the level of threat to the significant resource for vital signs monitoring purposes:

Severity of threat	3 (most important)
Significance of resource	2
Health and safety	1

The list was also useful for identifying and ranking several characteristics of a good monitoring protocol:

Repeatable over time	4	
Quality assurance	3	exists and is accepted.
Natural variability understood	2	
Knowledge about indicator known	1	general biology, function, niche…

The criteria that the participants developed for ranking the vital sign indicators follows in Table 3. The last step the parks need to take is to rank the indicators.

TABLE 3. Ranking criteria for vital signs indicators.

CRITERIA	WEIGHTING FACTOR	EXPLANATION
Relevance to the resource at risk	5.0	Does the indicator represent the resource?
Accuracy for measuring the attribute	4.5	Can the indicator be measured accurately ?
Sampling simplicity	4.0	Is the protocol simple for sustainability?
Sample size	3.5	Is the sample size small yet robust?
Umbrella species	3.0	Is this a guild with species in different niches?
Feasibility to implement	2.5	Are logistics, equipment, and protocols easy?
Sensitivity to detect change	2.0	How long will it take? What level of change?
Cost effectiveness	1.5	Is the cost low enough to sustain?
Comparison to other areas	1.0	Can the data be rolled-up to a larger context?

References include:

- NPS 75
- Draft GOGA/PORE I&M Plan (1996)
- Enabling legislation references from each park

Participant List

Science and the Ecological Model

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APPENDIX A: I&M Program Baseline Inventories

The natural resource baseline inventories (NPS-75) allow parks to account for natural resources and represent "core" sets of information to park managers needing to effectively protect park resources. Inventories are conducted in accordance with clearly defined protocols and quality-assurance standards. The Service-wide core inventories include:

a) automated bibliography (NRBIB)
b) base cartography
c) species occurrence of vertebrates and vascular plants currently known to occur in parks (species list in NPSpecies)
d) species distribution for species of concern (T&E, exotics)
e) vegetation maps based on recent aerial photography following a standard classification
f) soils maps through a partnership with the Natural Resource Conservation Service
g) geologic maps through a partnership with the US Geological Service and State geological agencies
h) water resources inventory with locations documented digitally
i) water chemistry for all "key" water bodies
j) air quality data summarized into an air quality atlas to assess air quality conditions in parks developed by the NPS Air Resources Division
k) air quality related values (visibility and identification of other resources that may be affected)
l) meteorological data through collection of basic parameters including precipitation and temperature