Insights from NPS Inventory and Monitoring: Lessons and Emerging Opportunities

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NPS Office of Inventory, Monitoring, and Evaluation
Ft. Collins, Colorado
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USGS-FWS Forum on Ecoregional Monitoring
Anchorage, AK

What I want to share with your

- Overview of I&M program
- *Key elements* of NPS I&M
- Lessons from 32 replicates
- Emphasis on opportunities to use I&M investments

National Park Service
Natural Resource Challenge (FY2000)

Revitalize and expand the natural resource program within the park service and improve park management through greater reliance on scientific knowledge

NPS Natural Resource Challenge

- Learn what is in parks (inventories), and monitor the vital signs of natural systems
- Engage the scientific community and the public, and facilitate their inquiries
- Share the information widely

NPS Natural Resources Inventories

- Geologic Resources
- Soil Resources
- Air Quality
- Vegetation Mapping
- Weather and Climate
- Water Quality
- Base Cartography (mapping)
- Natural Resource Bibliography
- Biological Inventories: (Species Lists, Abundance and Distribution) – vertebrates and vascular plants

Plan A: Develop a consistent, “interchangable” set of indicators and protocols that all parks use so that we can “roll-up” the data

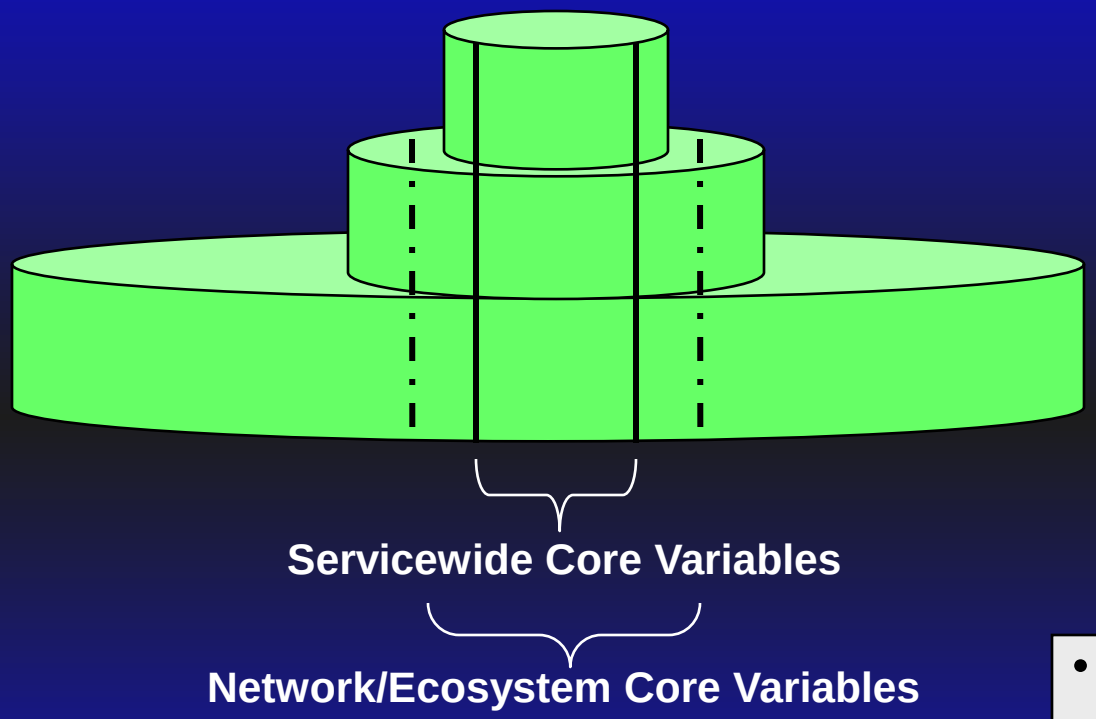
- Standardization is a “sign of maturity” in the information age
- Allows sharing and comparing of data; putting your data into context; better interpretation of results
- Efficient & coordinated development of methods, databases, analyses, & reports
- Consistent data for reports to Congress and public

Plan A: D e" set of indicator that we can "roll-

- Standar rmation age
- Allows sh r data into context;
- Efficient databases, analyses,
- Consiste c

The Wedding Cake

An alternative to “One Size Fits All”



National

Network/Ecosystem

Park

- **Primary use of data is at the local level**
- **Park buy-in, local partnerships very important**
- **Most relevant indicators and protocols differ between systems**

Monitoring Strategy is based on Funding

Funding (~ $100,000 per park) will add one professional position plus about $30-40 K operating

- Without integration and cost-sharing, parks could only monitor a few things; too few to assess a park's resources;
- Some parks already monitoring priority resources.
- Park buy-in and cost-leveraging through partnerships critical; must be relevant to park managers and flexible to allow integration and partnerships;
- Strategy: Create "monitoring networks" that share funding and staff among parks and leverage $$ w/ others to improve efficiency, consistency, and quality.

The 32 park networks are an administrative tool for sharing staff & funding.

I&M services > 270 park units.

The Burning Question

Who will use the monitoring results and what will they do with them?

Who are intended audiences and what is the most effective way to get the information to them?

Issues and Tasks involved in Managing the Natural Resources of a Park

- Inventory, Monitoring, Research studies
- Invasive species management
- Threatened & endangered species
- Restoration

Information is the common currency among all of these park stewardship activities

- Acquire funding for projects
- Address politics & people dynamics
- Management: how to allocate people, dollars

> 30% of resources dedicated to data management, analysis, reporting

- View monitoring as an information system
- ral mation k
- ion more useful and available at local level
- Make data available for research, education; modeling, more sophistical analyses

(Adapted from National Water Quality Monitoring Council)

Overall Purpose of Vital Signs Monitoring:

Determine status and trends in the condition of selected park resources

NPS I&M Program Monitoring Goals

Common to all 32 I&M Networks

- Determine status and trends in selected indicators of the condition of park ecosystems to … inform decisions, work effectively with other agencies …
- Provide early warning of abnormal conditions of selected resources …
- Provide data to better understand the … park ecosystems and to provide reference points for comparisons with other, altered environments.
- Provide data to meet certain legal and Congressional mandates …
- Provide a means of measuring progress towards performance goals. (Need monitoring for performance management)

Outline for Vital Signs Monitoring Plans

Executive Summary

1. Introduction and Background
2. Conceptual Models
3. Vital Signs
4. Sampling Design
5. Sampling Protocols
6. Data Management
7. Data Analysis and Reporting
8. Administration/Implementation of the Monitoring Program
9. Schedule
10. Budget
11. Literature Cited

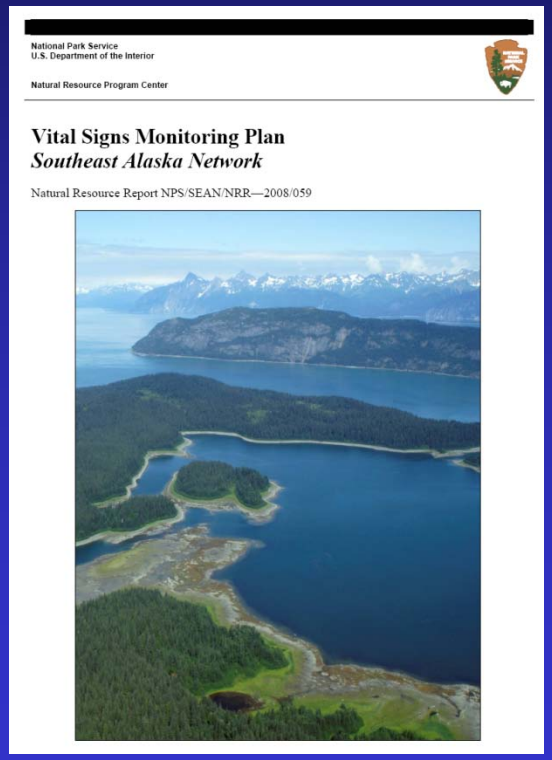
Appendices and supporting documents

Phase 1 Plan

Phase 2 Plan

Phase 1: Background work prior to selecting vital signs (2 yrs)

- Articulate goals and objectives for monitoring
- Summarize park context, resources and issues
- Synthesize existing data and understanding
- Draft conceptual models
- ID past and current monitoring
- List potential indicators


National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Vital Signs Monitoring Plan
Southeast Alaska Network

Natural Resource Report NPS/SEAN/NRR—2008/059

Good Conceptual models will :

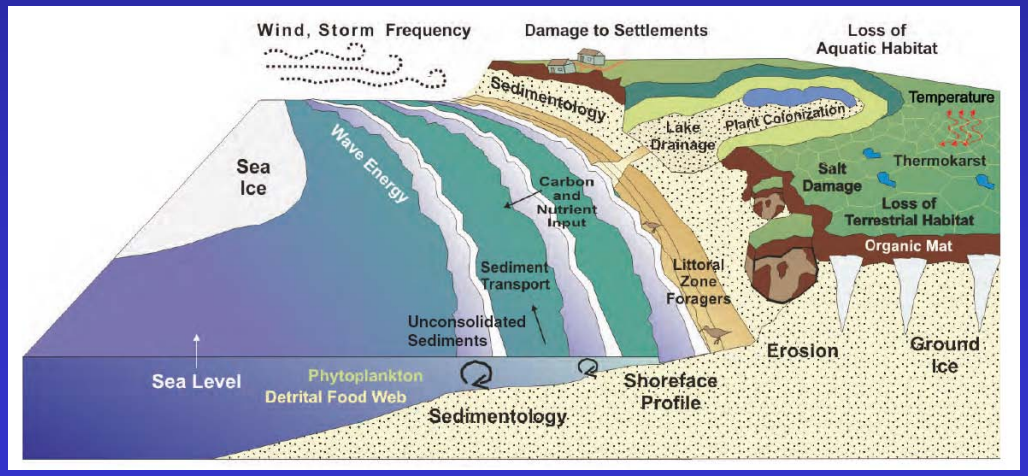
- Express understanding of system processes and dynamics
- Identify linkages across disciplinary boundaries
- Identify the bounds and scope of the system of interest
- Articulate what we know, and *don't know*

And foster communication

- Among scientists and program staff
- Between scientists and managers
- With the general public

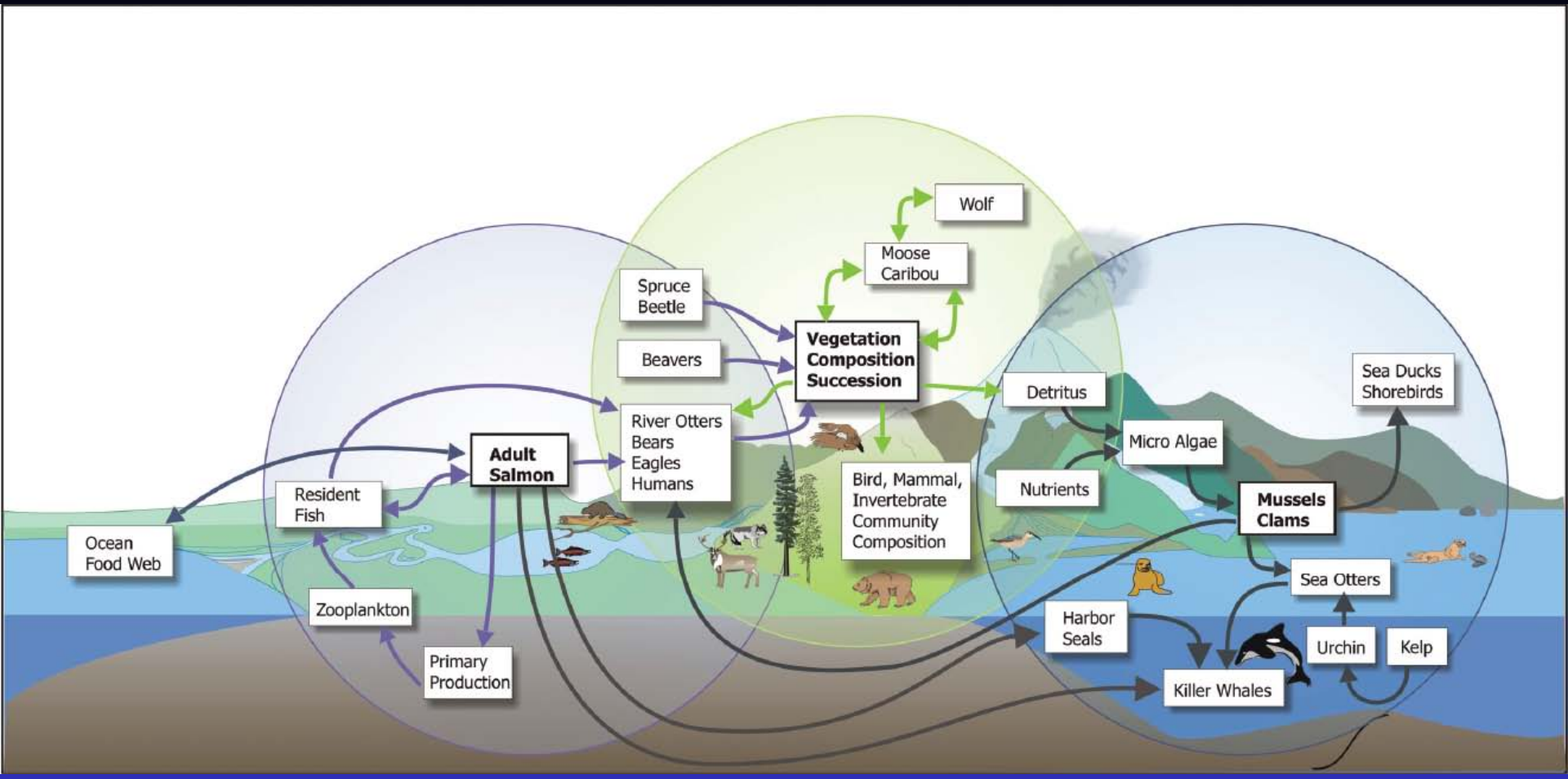
Conceptual models used by I&M

- Figure / diagram & legend
- Structural model (e.g., simulation flow chart)
- Text
- Tables
- Pictures
- References



Ecosystem Drivers	Ecosystem Stressors (Agents of Change)	General Ecological Effects (Response, Things Affected)
Parent Materials (Geology)		
• Geology • Soils • Topography • Geological Change • Hydrology	♦ Erosion ♦ Land Form Changes ♦ Urban Development ♦ Seismic Events ♦ Extreme Storms (Precipitation)	• Sediment & Nutrient Transport • Toxic Materials Transport & Accumulation • Water Budget • Water Quality • Mass Wasting • Geologic Stability • Altered Soils Structure • Vegetation Community
Climate (Weather)		
• Precipitation • El Niño • Climate Change (Temperature) • Fog • Ocean Currents	♦ Flood ♦ Drought ♦ Winds ♦ Solar Radiation ♦ Erosion ♦ Temperature Change ♦ Global Climate Change	• Mass Wasting • Altered Soils Structure • Vegetation Habitat Type • Non-native invasive Propagule Transport • Fire Susceptibility
Fire		
• Fire Return Interval • Fire Seasonality • Fire Intensity	♦ Decreased Intensity* ♦ Increased Intensity* ♦ Altered Fire Return Interval ♦ Altered Timing of Fire Starts ♦ Fire Suppression ♦ Prescribed Burning	• Community Structure • Colonization & Dispersal of Non-native invasives • Native Community or Population Genetics • Water Budget • Water Quality • Seed Bank Structure • Vegetation Community Type

ARCN coastal shoreline



Southwest Alaska Network Biotic interactions model. Illustrates nutrient fluxes, trophic interactions, ecosystem engineers, and agents of disturbance.

Use of conceptual models varies with program maturity

Conceptual design of monitoring programs

Communicate understanding about ecosystem:

What are the major ecosystems? What do we know about them? What are key drivers and interactions?

Selecting indicators

Ensure selected indicators are integrative, comprehensive

Communicate why / how indicators are informative and important

Sample design and indicator integration

Inform sampling design; identify connections between indicators

Evaluation and operation

Basis of statistical models; facilitate integration & synthesis of data; communicate context and importance of results

A few key lessons:

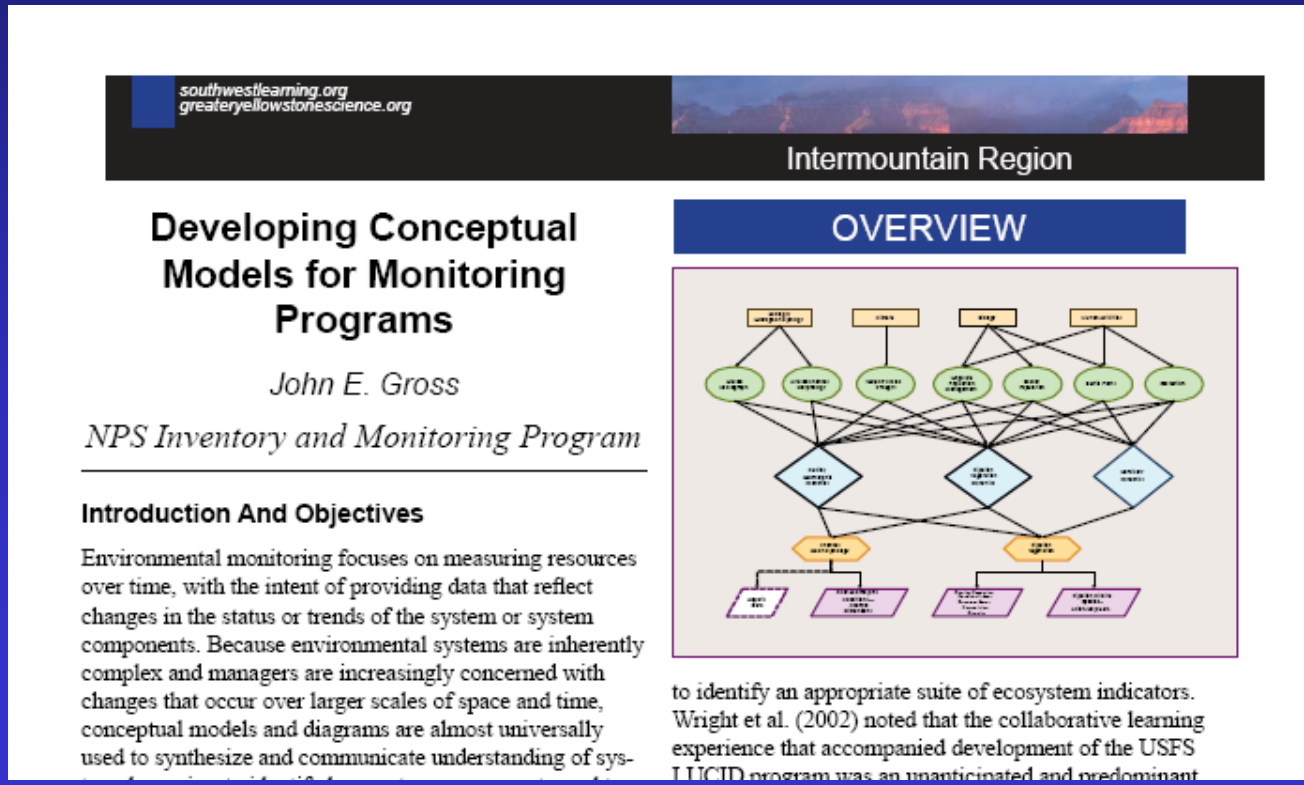
- Construct models for specific purposes
  - No 'one size fits all' solution
- Hierarchical models work well
- Up-front investments pays off
- Many of the insights accrue during model construction
- Models are statements of *hypotheses.* Revise as appropriate.

Resources for developing conceptual models:

http://science.nature.nps.gov/im/monitor/ConceptualModels.cfm

Monitoring plans (see detailed appendices)

Integration and Application Network (IAN – Bill Dennison)



southwestlearning.org
greateryellowstonescience.org

Intermountain Region

Developing Conceptual Models for Monitoring Programs

John E. Gross

NPS Inventory and Monitoring Program

Introduction And Objectives

Environmental monitoring focuses on measuring resources over time, with the intent of providing data that reflect changes in the status or trends of the system or system components. Because environmental systems are inherently complex and managers are increasingly concerned with changes that occur over larger scales of space and time, conceptual models and diagrams are almost universally used to synthesize and communicate understanding of sys-

OVERVIEW

to identify an appropriate suite of ecosystem indicators. Wright et al. (2002) noted that the collaborative learning experience that accompanied development of the USFS LUCID program was an unanticipated and predominant

Identifying, ranking, and selecting Vital Signs

Vital Signs Monitoring Framework

Ecological Monitoring Framework (Abbreviated)	
Level 1 Category	**Level 2 Category**
Air and Climate	Air Quality; Weather and Climate
Geology and Soils	Geomorphology
	Subsurface Geologic Processes
	Soil Quality
Water	Hydrology ; Water Quality
Biological Integrity	Invasive Species
	Infestations and Disease
	Focal Species or Communities
	At-risk Biota
Human use	Point-Source Human Effects
	Non-point Source Human Effects
	Visitor and Recreation Use
Landscapes (Ecosystem Pattern and Processes)	Fire and fuel dynamics
	Landscape Dynamics
	Nutrient Dynamics
	Productivity

Vital Signs Monitoring Framework

Level 1 Category	Level 2 Category	Level 3 Category
Air and Climate	Air Quality	Ozone
		Wet and dry deposition
		Visibility and particulate matter
		Air contaminants
	Weather and Climate	Weather and Climate
Geology and Soils	Geomorphology	Glacial features and processes
		Coastal features and processes
		Stream / river channel characteristics
	Subsurface Geologic Processes	Geothermal features and processes
		Caves / karst features and processes
	Soil Quality	Soil function and dynamics
Water	Hydrology	Groundwater dynamics
		Surface water dynamics
		Marine hydrology
	Water Quality	Water chemistry
		Nutrient dynamics
		Toxics
		Microorganisms
		Aquatic macroinvertebrates and algae

Microsoft Access - [Vital Signs Monitoring Database - Switchboard]

File Edit View Insert Format Records Tools Window Help

Mojave Desert Network
Review and Initial Prioritization of Vital Signs

Session 1 - Step 1
Review/Feedback on Threats

View Prioritized List

Change Criteria Weights

Streamline and structure ranking process

- Presentation and capture of information and commments.
- Accommodates groups working at different pace.
- Immediate feedback.

Form View

NUM

Vital signs workshops – Use a database!!

Microsoft Access - [Review / Feedback on Level 2 Threats and Management Concerns]

File Edit View Insert Format Records Tools Window Help

Type a question for help

Tahoma 9

ID Code: 0101

Level 1: Air and Climate

Level 2: Air Quality

Threats: Declining air quality in network parks is primarily a result of urbanization adjacent to park units. Threats include both point and non-point sources of pollution. Specific causes of air quality degradation in and around parks include congenerational power plants, smog/ particulates/pollutants from Las Veg emmiss threats

Your Comments on Threats: Nitroge Dr. Edi monito monito limited

Management Concerns: Manage CO2, nu abiotic r invasive Great B

Your Comments on Management Concerns: Area of impacts of air quality on caves is poorly understood and needs research. May have different impacts based on karst vs lava tubes - changes in air quality also impact soils/hydro/etc. and ultimately cave

Distinguish between parks as a source of emmissions vs parks as a recipient - primarily related to particulates; seasonal variation in point source pollution

Go To Previous Record | Go To Next Record | Return to SwitchBoard

Record: 1 of 20

Additional comments about Threats to resources for this Level 2 category

NUM

start | Workshop_Approach... | Rev4_vital_signs_ma... | Vital Signs Monitoring ... | Review / Feedback o... | 10:30 AM

Populate database before ranking workshop

- Results from scoping workshops
- Literature
- Local knowledge
- Include managers

Microsoft Access - [Review and Initial Prioritization of Potential Vital Signs]

File Edit View Insert Format Records Tools Window

MS Sans Serif 10

ID Code: 04010102

Potential Vital Sign: Occurrence of invasive plants

Biologic

Parks: DEVA ☑ GRBA ☑ JOTR ☑ LAM

Examples of Measures: Total number of invasive plants, early warning

Justification: Executive Order 13112, February 3, 1999, obl species. The Government Performance and R on 6.3% of targeted acres of parkland (167,5 at an unprecedented rate due to increases in consequences on ecosystems worldwide and i damage from exotic invasive species involves ir concerns for threatened and endangered spec

Park	Management Significance VH	H	M	L	VL	N	null	Ecological Significance VH	H	M	L	VL	N	nul
DEVA	●	○	○	○	○	○	☐	●	○	○	○	○	○	☐
GRBA	○	●	○	○	○	○	☐	●	○	○	○	○	○	☐
JOTR	●	○	○	○	○	○	☐	●	○	○	○	○	○	☐
LAME	●	○	○	○	○	○	☐	●	○	○	○	○	○	☐
MANZ	○	●	○	○	○	○	☐	●	○	○	○	○	○	☐
MOJA	○	●	○	○	○	○	☐	●	○	○	○	○	○	☐

Go To Previous VS

Go To Next VS

Record: 8 of 70

Form View

ECOLOGICAL SIGNIFICANCE

Close Form

Ecological Significance

How many of these statements do you STRONGLY AGREE with?

o There is a strong, defensible linkage between the vital sign and the ecological function or critical resource it is intended to represent.

o The resource being represented by the vital sign has high ecological importance based on a conceptual model of the system or is well-supported by the ecological literature.

o The vital sign characterizes the state of unmeasured structural and compositional resources and system processes.

o The vital sign provides early warning of undesirable changes to important resources. It can signify an impending change in the ecological system.

o The vital sign reflects the functional status of one or more key ecosystem processes or the status of ecosystem properties that are clearly related to these ecosystem processes. [Note: replace the term ecosystem with landscape or population, as appropriate.]

o The vital sign reflects the capacity of key ecosystem processes to resist or recover from change induced by exposure to natural disturbances and/or anthropogenic stressors. [Note: replace the term ecosystem with landscape or population, as appropriate.]

VERY HIGH: Strongly agree with all 6 of the statements above.
HIGH:
MODERATE: Strongly agree with at least 4 of the statements above.
LOW:
VERY LOW: Strongly agree with at least 1 of the statements above.
NONE: This is an important attribute to monitor, but I do not strongly agree with any of the statements above.
NULL: No opinion, or did not score this attribute

start | Workshop_Approach... | Rev4_vital_signs_ma... | Vital Signs Monitoring ... | Review and Initial Pri... | 10:44 AM

<u>After</u> ranking vital signs, *select* VS for funding

Final selection based on:

- Cost vs information
- Historical data
- Partnerships
- Logistics
- Negotiations

ARCN Vital Signs (abbreviated)

Level 1 Category	Level 2 Category	Level 3 Category	ARCN Vital Sign	Measures	BELA	CAKR
Air and Climate	Air Quality	Wet and Dry Deposition	Wet and Dry Deposition	• Concentrations of airborne Pb, Zn, Cd, Cu, Cr, Hg, Al, B, Fe, Ti, Total S, Total N, NO_3^- using the moss *Hylocomium splendens* as a passive sampler • Hg levels in lake trout and sheefish	•	•
		Air Contaminants	Air Contaminants	• Levels of pH, SO_4^{2-}, NO_3^-, NH_4^+, Cl^-, Ca^{2+}, Mg^{2+}, K^+, and Na^+ (NADP*) • Hg • IMPROVE* monitoring network for visibility and fine particles		
	Weather and Climate	Weather and Climate	Climate	• Temperature, precipitation, relative humidity, wind speed and direction	•	•
			Snowpack	• Annual deposition	•	•
Geology and Soils	Geo-morphology	Coastal/ Oceanographic Features and Processes	Coastal Erosion	• Accretion, erosion, and bluff retreat of coastline	•	•
			Sea Ice	• Extent • Presence/Absence	Δ	Δ
	Soil Quality	Soil Function and Dynamics	Permafrost	• Depth of active layer • Presence/absence and geographical extent of permafrost-related features	•	•
Water	Hydrology	Surface Water Dynamics	Surface Water Dynamics and Distribution	• Surface area and number of lakes • Node frequency, sinuosity, distance between nodes, network patterns, bifurcation rates of streams	†	†

- ● I&M Network funds monitoring
- ▲ Other program monitors
- † High priority; monitor if funding available

Lessons:

- Select an indicator framework – early.
  - Really helps collaboration and communication.
- Use database in workshops to describe, evaluate, and rank indicators. Revise in workshop.
- Separate indicator ID, ranking, and selection

"Phase 3" Activities:

- Protocol development summaries
- Design overall sampling approach
- Schedule protocol development
- Finish data management plan
- Analysis and reporting plan
- Staffing and budget

Monitoring Objectives

Objectives should be realistic, specific, and measurable; they should be monitoring objectives, not management objectives or sampling objectives.

What exactly will the protocol do?

Monitoring Objectives

Are each of the objectives measureable, and is the set of objectives achievable?

Does the set of objectives give the reader a good sense of what the resulting data set will include?

When the data collected by the protocol are analyzed after several years, will the data set be able to deliver on what is "promised" by the monitoring objectives?

Do any of the objectives state that the protocol will demonstrate a cause-effect type relationship?

- Most cause-effect objectives require a more expensive research design.

Vital Sign or Protocol	Measurable Objectives
Terrestrial plant species and communities	Determine long-term trends in species composition and community structure (e.g., cover, density by height class of woody species) of selected focal plant communities. Determine annual variation in recruitment and mortality for selected populations of long-lived perennial plant species of special management interest.

Not …

Vital Sign or Protocol	Measurable Objectives
Terrestrial plant species and communities	Evaluate nutrient-caused changes in aquatic plant communities and effects on fish species. Collect data on vegetation communities and changes over time. Determine cause of annual variation in grass cover.

It's difficult to articulate clear, concise, and focused monitoring objectives.

Good objectives:

- Communicate goals to collaborators / contractors
- Effectively guide protocol development
- Save time and money developing protocol

I&M guidance for monitoring objectives:

http://science.nature.nps.gov/im/monitor

Guidelines for long-term monitoring protocols

Karen L. Oakley, Lisa P. Thomas, and Steven G. Fancy

Abstract Monitoring protocols are detailed study plans that explain how data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs. Protocols are necessary to ensure that changes detected by monitoring actually are occurring in nature and not simply a result of measurements taken by different people or in slightly different ways. We developed and present here guidelines for the recommended content and format of monitoring protocols. The National Park Service and United States Geological Survey have adopted these guidelines to assist scientists developing protocols for more than 270 national park units.

Key words format, guidelines, monitoring, national park, natural resources, policy, protocol, sampling

Wildlife Society Bulletin 2003, 31: 1000-1003

Recommended Protocol Format

- Protocol Narrative
- Series of Standard Operating Procedures (SOPs)
- Supplementary Materials

Example SOPs from bird monitoring protocol

SOP 1: Before the Field Season
SOP 2: Field Season Schedule

SOP 3: Training Observers
SOP 4: Establishing and Marking Sampling Plots
SOP 5: Conducting the Variable Circular Plot Count

SOP 6: Documenting Habitat Variables
SOP 7: Data Management
SOP 8: Data Analysis

SOP 9: Reporting
SOP 10: After the Field Season
SOP 11: Procedures for Changing the Procedures

Protocol development takes a long time, involves a lot of work, and can be very expensive.

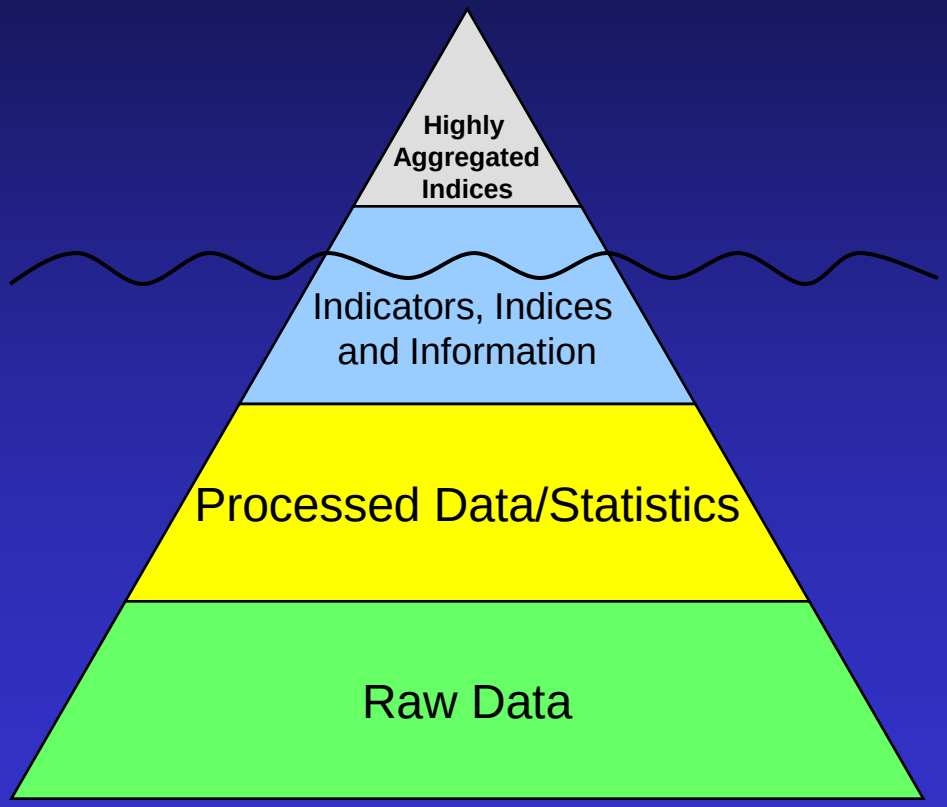
Lesson: Use or modify existing protocols when possible.

Lesson: A standard indicator framework and database facilitates collaborative development, or discovery and reuse of protocols.

Interagency database: http://nrmp.nbii.gov/portal/server.pt

NPS I&M Protocol Database
http://science.nature.nps.gov/im/monitor/protocoldb.cfm

Once you're collecting data, how do you ensure it's useful?



Scientific Information Needs and Expectations of I&M Networks

Question: What kinds of information would you like to get from your Inventory and Monitoring Network?

- Executive summaries
- Verbal presentations/ briefings
- Annual status reports
- Technical reports
- Scientific journal publications
- Synthesis reports
- Management recommendations
- Resource education (interpretive)
- Raw data

Search

Search A to Z

Select Brief:

Air & Climate
Climate
Geology & Soils
Geothermal
Yellowstone Volcano
Biological Integrity
Amphibians
Bison
Elk
Grizzly Bears
Invasive Plants
Lake Trout
Land Birds
Trumpeter Swans
Whitebark Pine
Wolves
Yellowstone Cutthroat
Human Use
Land Use
Landscapes
Fire

GRYN Executive Briefs

GRYN Home

Greater Yellowstone Network

Executive Briefs

As part of the National Park Service's effort to "improve park management through greater reliance on scientific knowledge," a primary role of the Inventory and Monitoring (I&M) Program is to collect, organize, and make available natural resource data and to contribute to the Service's institutional knowledge by facilitating the transformation of data into information through analysis, synthesis, and modeling.

The parks of the Greater Yellowstone Network include:

- Yellowstone National Park,
- Grand Teton National Park,
- Bighorn Canyon National Recreation Area.

The Greater Yellowstone Network has been acquiring and synthesizing the topics listed in the table of contents to the left as part of their monitoring program. Click on any link to get a more detailed executive brief for each topic.

Pages are organized in an interactive manner, additional information can be obtained within each page by clicking on the different symbols noted below:

Potential concern for that topic
D Additional details
G Graphic.

Search

Search A to Z

Select Brief:

Air & Climate
Climate
Geology & Soils
Geothermal
Yellowstone Volcano
Biological Integrity
Amphibians
Bison
Elk
Grizzly Bears
Invasive Plants
Lake Trout
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Whitebark Pine
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Yellowstone Cutthroat
Human Use
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Landscapes
Fire

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GRYN Home

Greater Yellowstone Network

Whitebark Pine

*PDF Version

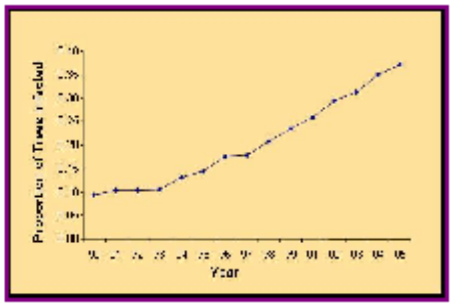
Click D for more detail or G for graphic.

Importance

Whitebark pine is considered a "keystone" species in the subalpine ecosystem D. It's best known role in these ecosystems is as a high-energy food source for a variety of wildlife species, including grizzly bears. Dramatic declines of whitebark have been reported throughout its range G due to two major factors: 1) an introduced fungus, white pine blister rust, and 2) heavy mortality from the endemic mountain pine beetle.

Status

- Thirty-six of the 51 (71%) transects had some indication of blister rust G.
- Although blister rust was widespread, the infection severity was relatively low.
- The estimate proportion of trees infected with blister rust within the GYE to be 0.189 ± 0.05 SE, and most infected trees had ⩽ 2 cankers D G.



Discussion

Our preliminary results indicate that the occurrence of white pine blister rust is widespread throughout GYE, although in most cases, severity is at relatively low levels.

Additional Resources

- Contacts

Search

Search A to Z

Select Brief:
- Air & Climate
- Climate
- Geology & Soils
- Geothermal
- Yellowstone Volcano
- Biological Integrity
- Amphibians
- Bison
- Elk
- Grizzly Bears
- Invasive Plants
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GRYN Executive Briefs

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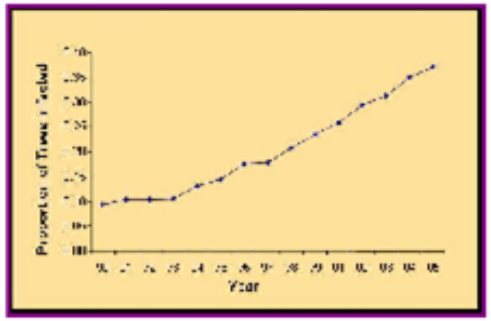


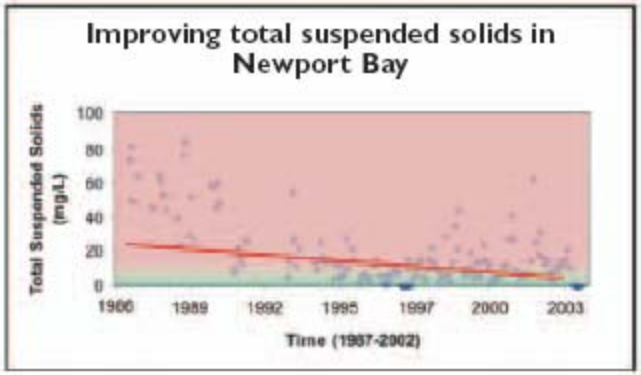
Discussion

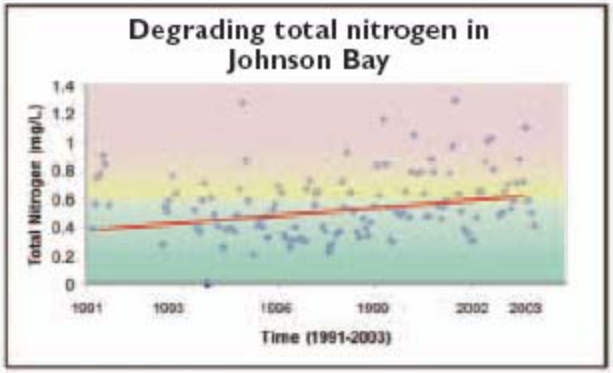
Our preliminary results indicate that the occurrence of white pine blister rust is widespread throughout GYE, although in most cases, severity is at relatively low levels.

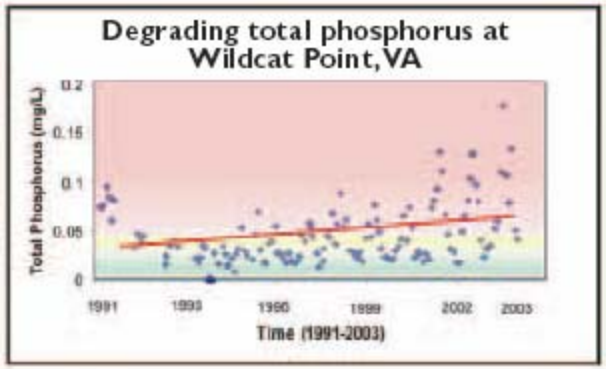
Additional Resources

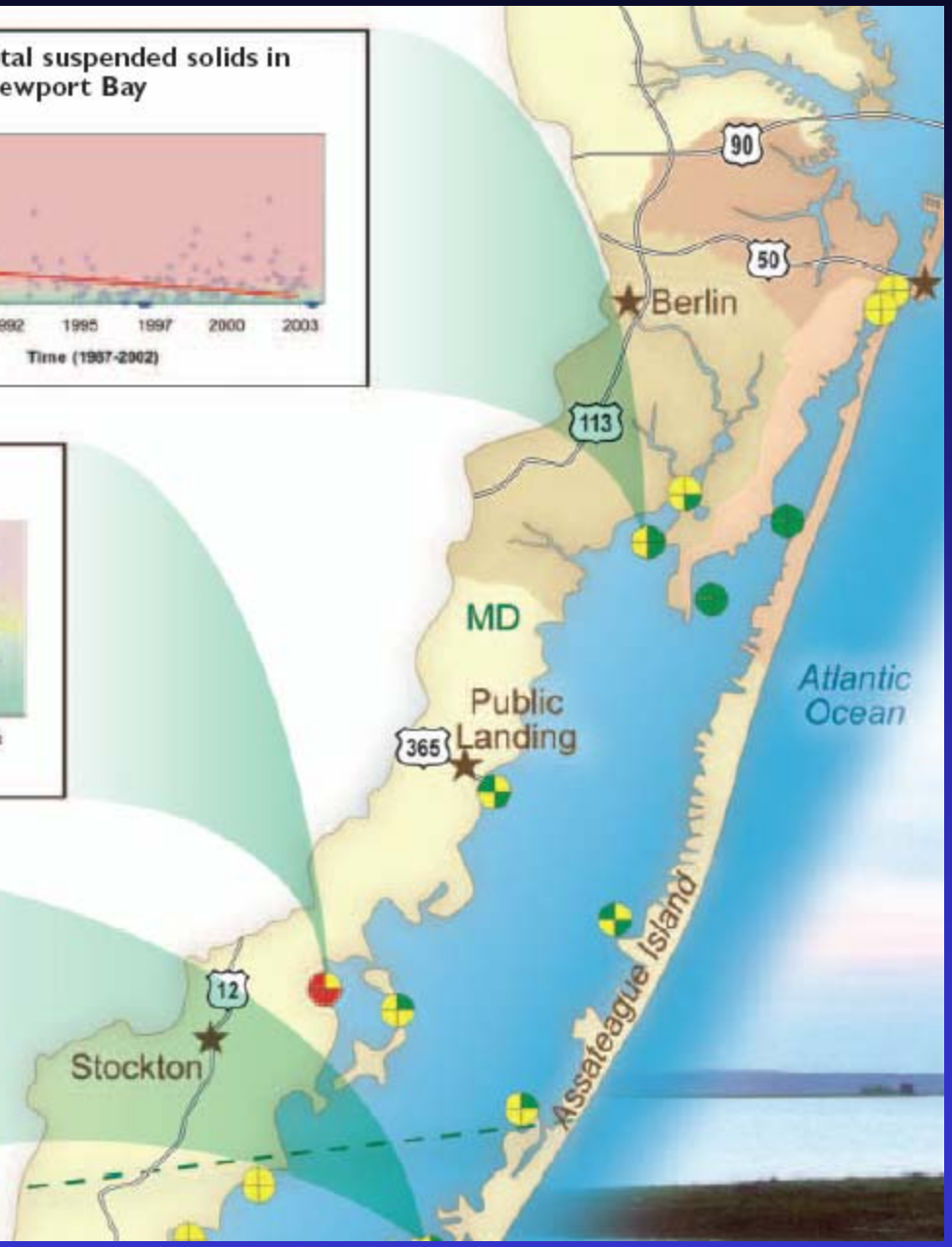
- Contacts
- Reports
- Learning Center
- Links

indicators that warrant further scrutiny. Continued monitoring of the additional water quality stations added in 2001 will allow us to evaluate trends throughout the bays in coming years. The following three graphs are examples of significant trends.









Reporting Park condition

Herbert Hoover NHS – Resource Stewardship Strategy (simplified table)

Important Resources and Values	Indicators	Current Condition	Target Condition
Prairie Community	Shannon Diversity – Native Plants	1.51	>2.63
	Invasive Plant Relative Cover	11%	<8%
	# of Grassland Bird Species	5	5
Stream Community	State Water Quality Standards	Not Met	Met
	Proper Functioning Condition	Nonfunctional	Functioning

Example: John Day Fossil Bed NM

UCBN Vital Sign	Measure	Current Condition	Data Sources
Stream/river channel characteristic	Pool depth (mean/reach)		8
	Width-depth ratio (mean/reach)		8
Surface water dynamics	Mean daily base flow (Sept)	6.4 cfs (2006)	1
	Mean daily peak flow (April)	47 cfs (2007)	1
Water Chemistry	Temperature (7-day mean min)	24° (2006-2007)	1, 4
	Dissolved oxygen (7-day mean min)		4

Current Strategy

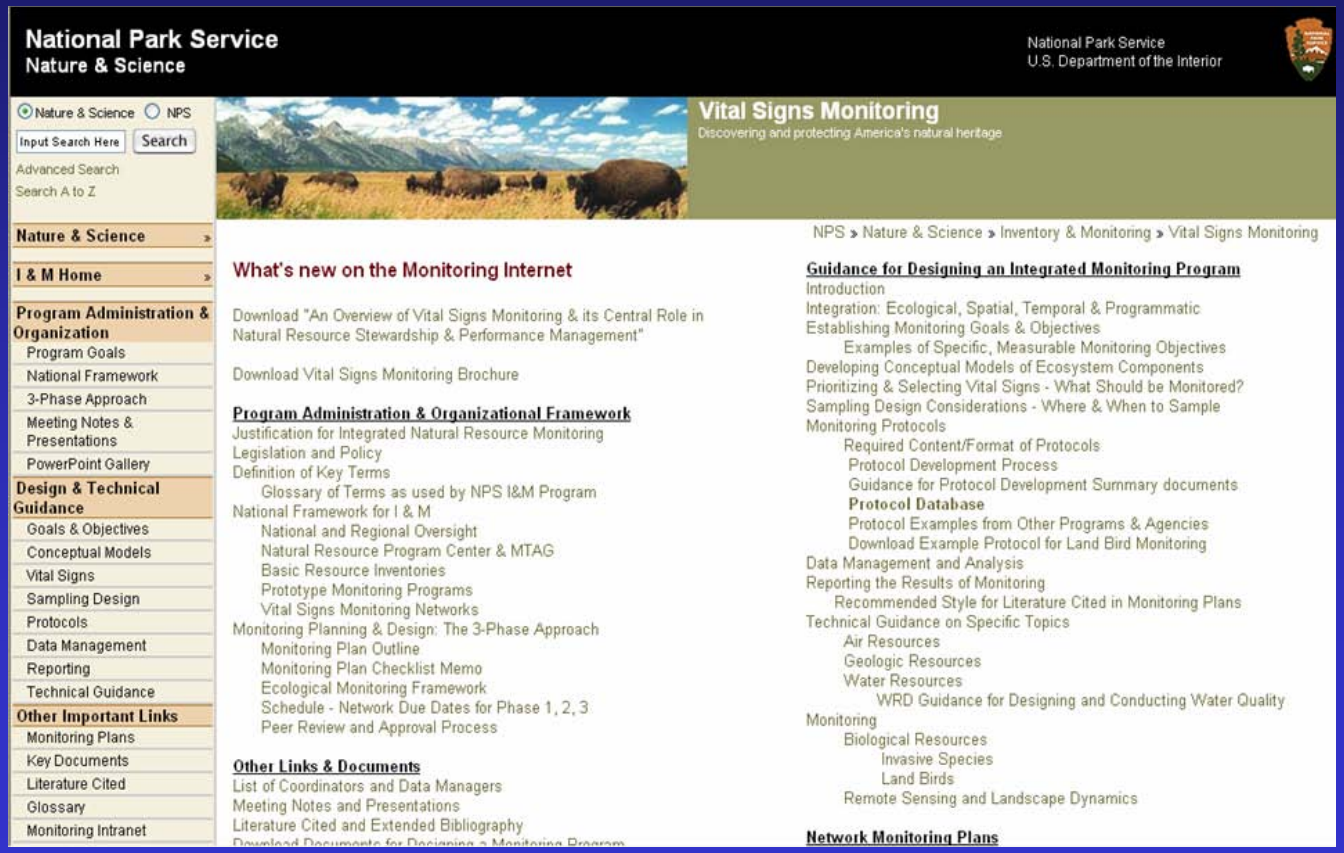
Example of a Vital Signs Summary Table - John Day Fossil Beds NM (JODA) - Painted Hills Unit

UCBN Vital Sign	Measure	Current Condition	Data Sources
Stream/river channel characteristic	Pool depth (mean/sample reach)		8
	Width-depth ratio (mean/sample reach)		8
Surface water dynamics	Mean daily base flow (September) discharge	6.4 cfs (2006)	1
	Mean daily peak flow (April) discharge	47 cfs (2007)	1
Water chemistry	Temperature (7-day mean daily max)	24° C (2006-2007)	1,4
	Dissolved oxygen (7-day mean daily min)		4
Aquatic macroinvertebrates	Species richness		4,5
	% dominant family		4,5
Invasive/exotic plants	Incipient invasions (# new species)	2	2,3,5,8
	Canarygrass (*P. arundinaceae*) gross area	0.5 acres (2007)	3
	Medusahead (*T. asperum*) gross area	170 acres (2007)	3
	Cheatgrass (*B. tectorum*) frequency (0.1 m^2 plot)		2
Riparian vegetation	Coyote willow (*S. exigua*) density (stems/m^2)		8
	Black cottonwood (P. *trichocarpa*) density		8
	Tree canopy cover (%)		8
	Exotic species (% of total cover)		8
	Native species richness		8
Sagebrush-steppe vegetation	Bare ground cover (%)		2,5
	Big sagebrush (*A. tridentata*) cover (%)		2
	Juniper (*J. occidentalis*) density (stems/m^2)		2
	Native forb richness		2
Bats	Bat species richness	14	6
	Riparian bat activity ([mean calls/night]/100)	120 (2007)	7
Land cover and use	Proportion annual grasslands (%)		9
	Mean shrub patch size (ha.)		9

1 USGS National Water Information System (http://waterdata.usgs.gov/nwis/uv?14046778)
2 UCBN Sagebrush Steppe Monitoring Annual Report (Rodhouse et al. 2008, http://www.nature.nps.gov/publications/nrpm/nrtr.cfm)
3 Oregon Natural Heritage Information Center final report (Beuchling 2008, http://science.nature.nps.gov/im/units/ucbn/reports/index.cfm)
4 UCBN Water Quality Monitoring Annual Report (Starkey et al. 2008, http://science.nature.nps.gov/im/units/ucbn/reports/index.cfm)
5 UCBN Natural Resource Condition Assessment (Bell et al. 2009, http://science.nature.nps.gov/im/units/ucbn/reports/index.cfm)
6 JODA Vertebrate Inventory Report (Rodhouse et al. 2003, http://science.nature.nps.gov/im/units/ucbn/reports/index.cfm)
7 UCBN bat protocol development database (available from the UCBN upon request, Lisa_Garrett@nps.gov)
8 UCBN Integrated Riparian Monitoring Annual Report (Rodhouse et al. 2009, http://www.nature.nps.gov/publications/nrpm/nrtr.cfm)
9 UCBN Land Cover and Use Monitoring Annual Report (Dicus et al. 2010, http://www.nature.nps.gov/publications/nrpm/nrtr.cfm)

Summary of key factors for NPS I&M

- Design and implementation multi-year process.
- Early focus on engagement and relevance.
- Strong objectives are critical
- Data management is *central*; 30% of I&M budget
- Success is more strongly related to staff than to any other factor.

http://science.nature.nps.gov/im/monitor/index.cfm

Fancy et al. 2009. Monitoring the condition of natural resources in US national parks. Environmental Monitoring and Assessment 151: 161-174.