APPENDIX N: NETN Vital Signs Selection Workshop Summary

Introduction

The Northeast Temperate Network (NETN) of the National Park Service Inventory and Monitoring Program hosted a 2 day workshop (19-20 May 2004) where subject matter experts convened to identify "high" priority Vital Signs for the NETN. Prior to the meeting, the core planning team developed workshop materials in order to set the stage for identifying and prioritizing NETN Vital Signs. In addition, the core planning team established four workgroups representing the dominant ecological communities within network parks:

- Aquatic resources (lakes, ponds, rivers, streams)
- Freshwater wetlands (Forested wetlands, open/shrub wetlands, peatlands, vernal pools)
- Intertidal (cobble beaches, rocky intertidal, soft-sediments)
- Terrestrial (forests, open uplands, plantations, old-fields)

Each workgroup was asked to review a pre-ranked list of Vital Signs to first determine if the list was complete. Next, each workgroup was asked to review the Vital Sign list and assign "high," "medium," or "low" levels of priority when the vital sign was considered with a regional or network level perspective, and to briefly justify why the network should consider the Vital Sign in the early stages of program development. High priority Vital Signs were defined by the Technical Steering Committee as those the NETN should consider as a starting point for implementation. Medium and low ranked Vital Signs, though excluded from the initial list of vital signs, will not be discarded from the list of potential Vital Signs because they could be added over time as the program matures, new concerns warrant a reevaluation of a vital sign's priority designation, and/or the network develops working partnerships with other agencies and ongoing monitoring programs. During this step in the process, workgroup members could also rename Vital Signs and/or change the category. After identifying the high priority vital signs, we asked the workgroups to identify mandatory and optional measures for each high priority Vital Sign. Finally, the workgroups re-convened for a brief overview of the high priority Vital Signs to identify commonalities among workgroups and workgroup specific Vital Signs.

The following content summarizes the results of each workgroup's efforts to identify a prioritized vital sign list and list of potential measures. The workgroup facilitators captured the basic discussion information using a database at the workshop and summarized these discussions in the text provided below. Each workgroup has a discrete section that presents any changes made to the initial list of Vital Signs, identifies the high priority Vital Signs, and defines the mandatory and optional measures for each high priority Vital Sign. The final section of this document presents all the high priority Vital Signs independent of workgroup and summarizes the results of the workshop and any outstanding issues.

Aquatic Breakout Session

Overview of Vital Signs

The objective of the aquatic workgroup was to review and rank the preliminary list of vital signs. In the initial review, workgroup participants could add, remove, rename or regroup vital signs. The second part of the review process was to rank the new list. The types of changes fell into four categories: renaming, lumping, splitting, and deleting (Table 1).

The vital sign "Core water chemistry" was changed to "Water chemistry" and now includes total dissolved ions, and total organic carbon as mandatory measures in addition to the previous mandatory measures of pH, temperature, dissolved oxygen, and specific conductance. The high priority remained. The vital sign "Water quality-lake trophic status" was changed to the more general "Water quality-trophic status" in order to include streams. The water quality vital signs of "algal biomass," "water clarity," and "nutrient loading" or "nutrients" were incorporated into trophic status. Although lake trophic status was originally ranked as medium, the addition of the other components to this new vital sign caused the workgroup to upgrade the rank to high.

One of the more significant changes the workgroup made was a splitting of "species composition-flora" and "species composition-fauna" into the more specific taxonomic groups: community compositions of fish, macroinvertebrates, and zooplankton for fauna; and phytoplankton, periphyton, and macrophytes for flora. Each community composition vital sign was ranked individually for lakes versus streams, and the highest ranking for each vital sign was chosen for the appropriate target resource. The workgroup ranked fish and macroinvertebrates in streams and zooplankton in lakes as high, while phytoplankton and macrophytes in lakes and periphyton in streams were ranked medium.

"Focal taxa fish," "species of concern," and "mandated species" all remained low priorities. Although the importance of these potential vital signs was recognized, the group felt that by definition, they would not be good indicators of ecological integrity and would perhaps more appropriately be monitored by park specific programs. "Water quality-microorganisms", was recognized as important for human health, but was a low priority in terms of its usefulness in assessing ecological integrity.

The vital signs "basic climate" and "acidic deposition and stress" were renamed "climate" and "atmospheric deposition," respectively. The importance of these vital signs was not questioned, but the ability of this program to improve greatly on the information that is already being collected by other networks was questioned. They remained high priority vital signs with the recognition that the inventory and monitoring program may not be collecting data, but rather compiling this information from other sources.

"Natural disturbance regime," "trophic dynamics," "phenology," and "nutrient cycling" were all considered beyond the scope of the inventory and monitoring program, although some of the measures and components of "trophic dynamics" and "nutrient cycling" were incorporated into "trophic status." There was a recognition that these vital signs may be important for understanding and interpreting data in the future, but for the present would be ranked as low priority for assessment.

The group felt strongly that a distinction should be made between inventory vital signs and monitoring vital signs. Inventory vital sign information would be collected or compiled at the start of the monitoring program, could potentially guide the design of the monitoring program, and would be critical for interpreting monitoring data by providing context. Inventory vital signs included "lake morphometry," "channel morphology," "spring/seep distribution," "landcover/landuse" and "contamination."

"Landcover/landuse" included the original vital signs of "landcover," "landuse," "landscape buffer" and "park boundary," while "contamination" included "heavy metal contamination." The frequency of collection/compilation of these inventory variables could range from biannually to once every decade, and would be guided by changes in the watershed including operational changes at a park.

"Water quantity" remained a high priority. The workgroup recognized that lake levels would perhaps be easy and relatively inexpensive, while continuous stream gauging might be prohibitively expensive.

The group did not reach consensus regarding "substrate composition." Some workgroup members felt it would be more appropriately named "benthic habitat." This received a rank of medium recognizing that in some parks it may be possible and (or) critical while in other parks it may be not as important and difficult to characterize across the entire park.

The vital sign called "park management" includes "land management," "park infrastructure," and "trail network." This vital sign was ranked low because workgroup participants felt that these features were probably already well monitored by the parks and (or) documented information that was available or could be accessed as necessary. "Visitor use" remained its own vital sign, ranked medium, with the primary concern relating to fish stocking/harvesting. This has a big impact at some parks such as Acadia, and is not currently being monitored. At other parks it is not a significant issue.

There was a fair amount of discussion regarding the category of stressors and how they should fit into a monitoring program of ecological integrity. The conclusions of the workgroup were that "invasive exotic species" and "septic/waste water discharge" were ranked high, "roads" was ranked medium, and the rest were ranked low. The group felt that "fertilizer use" and "herbicide/pesticide" use would be captured in "landcover/landuse"; "soil erosion" was not a serious network wide issue, but could become important on a case by case basis; "hydrologic alterations" (now including "beaver engineering") would be captured by "water quantity"; "UVB" was beyond the scope of this program; and "shoreline erosion/sea level rise" was more of an intertidal issue than one of freshwater aquatics.

High priority vital signs

The vital signs presented below are all high priority vital signs as assessed by the aquatic workgroup. These vital signs address the ecological integrity of the parks and were selected to address the physical, chemical, and biological aspects of the ecosystem. In most cases the workgroup recommended at least one mandatory measure, and in several cases they recommended multiple mandatory measures and additional optional measures. The workgroup also discussed and concluded that vital signs may be high priority for specific targets (lakes, streams, or springs/seeps) or may be high priority for all targets. Groundwater is only considered as a target where specifically addressed.

1. Climate

Climate data provide background explanation for changes or variation in other vital signs. Measures of climate such as precipitation and temperature are critical to understanding the ecological condition of aquatic resources and biota (Hynes, 1975; Poff, 1997).

Climate data are available so the parks probably will not have to collect them, but rather compile these data from other sources such as the National Oceanic and Atmospheric Administration (monthly reports) or the National Climatic Data Center (Sorenson and others, 1997). The short term response variability for climate is clear; however the response variability of changing climate over long time scales is still under investigation.

Mandatory measures include air temperature and precipitation. Optional measures to compile include windspeed and direction, precipitation by type, snow depth, snow water equivalent, relevant humidity, and solar radiation. Project managers would need to account for spatial variability to extrapolate regional information to parks.

2. Inventory - Stream Geomorphology

Baseline stream geomorphology will be important to collect and (or) compile from other sources because it is a major physical component of lotic ecosystems. This information falls into the category of inventory because it will involve infrequent/periodic measurements rather than annual sampling. Channel geomorphologic units change due to both natural and anthropogenic factors (Leopold, 1994). Bankfull discharge, which has a recurrence interval from between a year and a half to two years, has also been called the "channel forming discharge" and/or effective flow (Andrews, 1980; Leopold, 1994). Over-bank flow, or floods, occur at less frequent intervals and can affect riparian zones and land use as well as have significant effects on erosion, bed load transport, sediment accretion and deposition in the channel, and modification of geomorphic structure of the channel (Leopold and others, 1964; Hill and others, 1991). Anthropogenic developments in the basin can alter the recharge and runoff to the stream and affect runoff by increasing the amount of peak runoff and reducing the duration of runoff.

Mandatory measures include stream order, drainage area and gradient. In most cases, this will involve compiling available variables in a database. Optional measures could include run/riffle/pool geometry, bank full cross sectional geometry, stream sinuosity from aerial photos or topographic maps, and a substrate map of the stream bottom (areal extent of gravel, sand, silt, boulders, rubble/coble). Channel geomorphologic unit delineation and measurement can be accomplished with existing protocols from the USGS National Water Quality Assessment program or EPA's Environmental Monitoring and Assessment Program (Fitzpatrick and others, 1998; Lozorchak and others, 1998). Representative reaches (20 times the mean channel width from NAWQA or 40 times the mean channel width from EMAP) can be assessed by two people in two to three hours.

Optional more frequent measurements would include surveys of channel geomorphologic units to quantify habitat types for aquatic biota. Each geomorphologic channel unit provides unique combinations of depth, velocity, and substrate composition. Substrate composition was its own vital sign and is discussed below.

3. Inventory - Lake Morphometry

Morphometric mapping of lakes provides baseline data for future reference, and may be available from existing sources. Mapping which includes substrate types and extent of macrophyte growth could be used to interpret macrophyte growth patterns which respond to changes in light penetration, substrates, nutrients, and water depth (Goldstein, 2000).

Mandatory measures include surface area, maximum and mean depth, drainage area, lake type and origin, bathemetry and elevation. An optional measure would be flushing rate. Lake morphometry can be easily mapped with depth finders (fish finders) and GPS. This baseline information will be compiled initially, and could guide monitoring site selection.

4. Water Quantity

Information about water quantity is necessary for the interpretation of other vital signs such as eutrophication, sediment processes, or contaminants because stream discharge is used in calculating annual loads and annual watershed yields. Furthermore, water quantity determines the physical extent and volume of aquatic habitat at the parks. Numerous factors affect water quantity including, precipitation, evapo-transpiration, water withdrawals, and ground water recharge.

All measures are optional including streamflow, lake water levels, ground water levels, spring seep volume, and groundwater inputs, but measures such as lake water levels are considerably more easily obtained than streamflow, and thus are highly recommended. Existing stream gages with long historical records may be used to extend and interpret incidental measurements and (or) stage gages within parks if a relationship between the two sites is established. Although only two NETN parks have streamflow gages within or adjacent to park boundaries, the closest long-term streamflow gages have been identified in all cases.

5. Inventory - Springs and Seeps Distribution

Springs and seeps create unique aquatic resources. They are an integral component of groundwater fed streams and can be critical for understanding the thermal regime and biodiversity of aquatic habitats because they indicate the quantity and quality of water in surficial aquifers as well as the interaction of surface and ground water. Furthermore, they are a good indicator of ecological integrity because they can indicate which contaminants that have been applied in the watershed are reaching surficial groundwater and subsequently other aquatic resources (e.g., Cowdery, 1997).

Baseline inventory data should include the location and possibly the seasonality of springs and seeps in the park. Frequent monitoring water quality and quantity of springs and seeps may be beyond the scope of this program, but springs and seeps should be considered as a target for water quantity and water quality on a site specific basis. The relative importance of this information will depend on the size of the park/drainage basin. At smaller parks, the locations may be known; at the larger parks, aerial photography with thermal mapping can be used to locate springs and seeps after/during snowmelt. The size of the springs and seeps will change with climatic conditions and groundwater withdrawals. Water quality will depend on surrounding geology and land use in the watershed.

6. Water Chemistry

Water chemistry directly addresses one of the inventory and monitoring objectives: to detect change in the status of physical, chemical, or biological attributes or vital signs of the ecosystem. It is an essential indicator to any long-term aquatic monitoring program (Gilliom and others, 1995). It is widely applicable, and critical for interpreting the biotic condition, and ecological processes of a resource. Water chemistry affects the bioavailability of contaminants, and the metabolism of aquatic species. For example ionic conditions affect osmo-regulation (Hoar and Randall 1969) and contaminant uptake (Sinley and others, 1974; Luoma 1989; Spry and Weiner 1991), dissolved oxygen and temperature affect metabolic rate (Hoar and Randall 1969). Successful reproduction requires the appropriate chemical conditions for fertilization and development of eggs and larvae (Holtze and Hutchinson 1989).

Water quality parameters are sufficiently well known that abnormal conditions and trends can be recognized or determined statistically. Mandatory measures include water temperature, specific conductance, pH, dissolved oxygen, % dissolved oxygen saturation, color and turbidity. Targets include lakes, streams, springs & seeps unless specified. Groundwater chemistry could be considered where monitoring wells are in place.

Optional measures include anions, cations, alkalinity/ANC, aluminum, iron, and dissolved organic carbon. Protocols for collection of water samples and standard methods of chemical analysis are widely available (e.g., Shelton 1994). Most of the mandatory water chemistry measures can be obtained in the field or with relatively inexpensive laboratory analyses. Optional measures will vary depending on the needs of individual parks.

7. Fish Community Composition - Streams

Fish species richness and composition is a highly relevant and applicable vital sign because fish communities integrate their physical, chemical, and biological environment through time (Tonn and others, 1983; Gurtz, 1993). The integration is manifest in the species richness and composition. Species richness and composition in small streams can be obtained easily with the proper equipment (electro-fishing or small seine) (Meador and others, 1993; Moulton and others, 2002). An alternative, non-evasive method is direct observation and counts by divers with mask and snorkel (Goldstein, 1978). On average, a site can be sampled in about two hours. The size of the stream dictates the number of individuals needed, which will range from two to five (Moulton and others, 2002). Although a representative sample of a fish community can be obtained from small to moderate sized streams, such a sample is not readily obtainable from larger rivers (Moulton and others 2002). Fish species composition can be evaluated with multimetric indices of biological integrity such as an IBI or by examination of species traits (Karr and others, 1986) (Goldstein and Meador 2004). These indices evaluate the quality of the resource by rating the ecological structure and functional composition of the community. While normally a reference site is used for comparison, for the monitoring program, the initial sample will constitute the baseline condition for comparison. Certain metrics can be diagnostic of specific environmental changes (Karr and others, 1986).

Mandatory measures include relative abundance and species richness in a representative sample, i.e., the numbers and identity of all species collected. Fish community composition in streams was ranked as high priority while fish community composition in lakes was medium priority.

8. Zooplankton Community Composition - Lakes

Zooplankton community composition and abundance is indicative of the trophic status of the lakes, reflects primary and secondary production (Porter, 1977), and also implies year class strength of most lotic fish species because early life history stages feed primarily on zooplankton. Therefore, community composition and abundance of the zooplankton not only reflect the abundance and composition of the phytoplankton, but also provides a basis for predicting certain aspects of the fish community and fishery. If the timing of zooplankton blooms of the larger sized taxa is concurrent with the hatching of salmonid and centrarchid eggs, then zooplankton provide an abundant food source for these early fish life history stages (Goldstein and Simon, 1998) which implies greater survival, year class strength, and recruitment to the fishery. Like other biotic communities, zooplankton respond to changes in water chemistry, nutrients, and predation by fish and other invertebrates. Changes in zooplankton taxa composition and abundance in lakes has not been applied as an environmental indicator to the same degree as fish or invertebrates in streams.

The mandatory measures of zooplankton species richness and abundance are collected by either horizontal or vertical tows with a plankton net. Abundance (density) is based on the volume of water filtered. Identification and subsampling require special training. Zooplankton collection in lakes was a high priority while zooplankton collection in streams was a low priority.

9. Trophic Status

Eutrophication causes degradation of park aquatic resources. Nutrient inputs cause nuisance algal blooms, unwanted macrophyte growth, odors, and even fish kills (Clady, 1977; Porcella, 1978; Porter and others, 1993). As land use changes from forest to agriculture or urban, the potential sources of nutrients increase. Trophic status is indicative of nutrient stress (Wetzel 1983). It is widely understood by resource managers that when status levels change management actions such as application of best management practices (BMPs) may be necessary to reduce inputs. Sufficient information exists in the literature to quantify the trophic status of park lakes based on the measures listed below (Carlson, 1977).

Mandatory measures include algal biomass, measures of water clarity such as secchi disk, and total and dissolved phosphorus. Optional measures include macrophyte distribution, diel oxygen curves, periphyton abundance, and dissolved oxygen profiles. Many of these measures are seasonal. Standard protocols (e.g., Sorenson and others, 1999) can be rapid, cost effective and easily tracked over time. Secchi disc readings, plankton tows for algal biomass (density) or chlorophyll a, and water samples for nitrogen and phosphorus can all be accomplished in a short period of time.

10. Macroinvertebrate Community Composition - Streams

Invertebrate community taxa richness and composition is a highly relevant vital sign in streams because macroinvertebrates integrate their physical, chemical, and biological environment like fish, however, they do so in a shorter temporal period than fish (most invertebrate life cycles are accomplished in a single year vs. multiple years for fish). Therefore invertebrates may provide a "first response" vital sign. The integration is manifest in the taxa richness and composition. Macroinvertebrate community composition has been used to evaluate water quality and aquatic resources (Hilsenhof, 1987; Lenat, 1993). Collection of invertebrate samples is relatively easy. Numerous protocols exist (Lazorchak and others, 1998; Moulton and others, 2002). For direct collections from natural stream substrates, two people can collect a sample in about an hour using standard equipment, nets with a 595/600 micron mesh (EPA uses this mesh size for the Environmental Monitoring and Assessment Program (Lazorchak and others, 1998). For indirect collections of artificial substrates or natural substrates placed in the stream for colonization, the collection time is less, but an initial site visit is necessary to insert the sampler. The analysis, counting and identification, is not a trivial matter and can take up to a day per sample. The identification of invertebrate taxa requires specialized training or a specialty laboratory (Moulton and others, 2000). Several invertebrate multimetric environmental indices are available for invertebrate data. The USGS has an Invertebrate Data Analysis System which calculates over 130 metrics available for use (Cuffney, 2003).

Mandatory measures include invertebrate taxa richness (measured to the lowest practicable taxa) and taxa abundance from a randomly selected subsample of 100 or 300 individuals from direct collections, but fewer individuals from indirect collections. Taxa abundance is the proportion of each taxa in the subsample. Macroinvertebrate collection in streams was a high priority while macroinvertebrate collection in lakes was a low priority.

11. Inventory Land Use/Land Cover

This vital sign includes "landcover," "landscape buffer," "landuse," and "park boundary." At a watershed level, land use and land cover affect the quality of aquatic environments (Stauffer and others, 2000; Meador and Goldstein, 2003). An initial inventory of land use and land cover will provide context for the observed ecological conditions. If changes occur in this condition, they can be interpreted in the context of land use or land cover at the watershed scale. Aquatic ecosystems respond to changes in landuse and this response is has been documented in urban, agricultural, and forested environmental settings (Meador and Goldstein, 2003).

This is a high priority vital sign, but the measures can be collected or compiled as part of an initial inventory and updated only as changes in the watershed become apparent. Most measures are optional depending on the park and need to reflect the varying scales and specific requirements of the parks. The only mandatory measure is a landcover/ecological system map. For most parks, these data already exist, are straight forward to interpret, and will help in site selection/prioritization.

Optional measures include a patch size distribution, patch connectivity and fragmentation, percent impervious surface in buffer or watershed, percent canopy shading for streams, buffer vegetation and buffer width. The park boundary already exists for all parks, and can be updated as necessary.

12. Atmospheric Deposition

"Atmospheric deposition" includes acid rain, inorganic toxics, mercury, etc. This vital sign was modified to include all atmospheric deposition (as opposed to just acidic deposition), and now includes only the deposition, rather than the response/stress to the aquatic resource. Estimates of atmospheric deposition are critical for understanding water chemistry and stress (Likens and Bormann, 1974). Swain and others (1992) estimated that 90% of the mercury entering remote lakes in Voyageurs National Park

(Minnesota) was derived from atmospheric deposition. However, these measures are expensive and may be covered sufficiently by other programs. Deposition at coarse resolutions is already measured as part of NADP and CASTNET networks. Information about deposition should drive site selection for measurements of water chemistry.

Optional measures include wet deposition, dry deposition, inorganic toxics and mercury. While mercury deposition is an issue throughout the Northeast, other types of atmospheric deposition may be mostly an issue in Acadia and the Appalachian Trail.

13. Inventory – Contamination

All members of the workgroup agreed that contamination (including heavy metal contamination) is ecologically relevant. The accumulation of trace elements and organic compounds in aquatic organisms can cause physiological problems and even death of aquatic organisms. Accumulated contaminants move upward through the food chain.

Initially there is a need for a better assessment of existing data to determine the sources and pathways of contamination. This vital sign may need to be added as a continuous monitoring variable at some parks after the initial inventory and assessment is complete. Some contaminants such as metals may be occurring at high levels "naturally." Responses may be difficult to interpret without long term data.

All measures are optional and site specific, and include measures of air toxic concentrations, MTBE/chloroforms/trichloroethylene in water, contaminant spills, toxic boat paint, use and concentrations in water, and bioaccumulation in indicator species. Initially it is recommended that an inventory of contaminant sources and historical sites of contamination be compiled in a database if this is not already done. This vital sign would, however, require very expensive laboratory analyses, and may be beyond the scope of this program financially. Composite sampling may help to keep costs down (Correll 2001).

14. Invasive Exotic Species

The presence and extent of invasive exotic species is a critical management concern at all parks in the network. Parks would benefit from quick identification and removal of new invasive species, and monitoring and removal of already established invasive exotic species. Catastrophic consequences to native species can result if this vital sign is not addressed with loss of biodiversity and replacement of native flora and fauna.

Routine surveys for the presence/absence of particular invasive species are mandatory at all parks. Lists of non-native species with the potential to invade individual parks already exist in most states**.** These lists will identify the types of habitats to examine for invasion. The relative abundance of established invasive species is optional.

15. Septic Systems/Wastewater Discharge

The workgroup felt it was important to collect the number of septic systems/wastewater discharges explicitly in order to understand trends in water quality and related measures of trophic status. Parks may not be able to affect change in nutrient inputs from wastewater sourcesoutside the park, but this information still helps to interpret trends in water quality.

Tracking the number of septic systems in the park is mandatory and is information that is most likely readily available. Tracking nearby septic permits and the location, quantity and quality of wastewater discharges are optional measures.

Other potential Vital Signs or issues

Although the workgroup is not recommending the following vital signs for immediate inclusion in a monitoring program, information regarding the vital signs is included below because either a minority of workgroup members felt that they should be high priority vital signs, or there was a general consensus that these medium vital signs should have their priority reassessed as potential vital signs further into the program as additional funding and (or) partnering with other agencies becomes available. Potential measures are included in some cases.

Phytoplankton Community Composition

Species richness and species abundance are optional measures. This vital sign was a medium priority for lakes and a low priority for streams. Phytoplankton respond to the physical and chemical conditions present at the time of collection; they reflect the water quality of the water mass they occupy (Clesceri and others, 1989; Porter and others, 1993).

Periphyton Community Composition

Species richness and species abundance are optional measures. Periphyton abundance (either cell volume or ash free dry mass) and chlorophyll a in streams can be a useful vital sign for nutrient enrichment, while species composition and abundance can be used in an Index of Biotic Integrity (Hill and others, 2000). This vital sign was a medium priority for streams and a low priority for lakes.

Macrophyte Community Composition

Species richness and species abundance are optional measures. Inherent in this vital sign are invasive aquatic plant species and a measure of lake eutrophication. Therefore, this sign was considered redundant. This vital sign was a medium priority for lakes and a low priority for streams.

Substrate Composition

This vital sign is an important indicator of aquatic habitat (Stauffer and Goldstein, 1997; Goldstein and others 2002), but may be reflected in invertebrate taxa composition and abundance. Sedimentation can be a major issue, so a rapid measure of embeddedness could be used. Questions remain as to the frequency of monitoring because changes in substrate composition are related to the frequency of high flow events (Andrews, 1980; Leopold, 1994). Detailed particle size analysis is expensive, but visual evaluation techniques and indices could be applied.

Visitor Use

Stocking/Fishing issues are significant management issues in some parks, but not in others. The workgroup recommended that this be a park specific vital sign to be monitored as needed. Parks generally do not know amounts of fish being harvested and (or) stocked where these activities are occurring.

Optional measures that the workgroup identified as higher priority include the number of fishing/shellfishing permits, and information regarding stocking (species stocked and location). Lower priority measures include the number of visitors by location and activity and the number of boats.

Roads

Roads were identified as a top management concern in most NETN parks. This vital sign was downgraded to medium because the aquatic workgroup felt that information surrounding roads as stressors could be picked up by other vital signs such as water chemistry, landcover/landuse and contamination. Site selection/sampling design should in some cases be driven by road locations. Specific road runoff studies are complex/expensive and may be beyond the scope of this monitoring program.

Optional measures include road network information, types of roads, measurements of quantity and quality of road runoff, amounts and types of de-icing chemicals applied, and the presence/quality of non-point source pollution control measures in place.

Conclusions

The workgroup was successful at meeting the objectives of reviewing and ranking the list of potential vital signs and providing initial justifications and measures for all of the vital signs ranked high and for most of the vital signs ranked medium. The goal of including vital signs for each of the three major components of ecosystems (physical, chemical, and biological) was accomplished and the list of high priority vital signs is well balanced among the three components. Many potential vital signs were consolidated into other vital signs during the process, but in retrospect it was useful to have all of these potential vital signs considered independently. The workgroup found it easier to consider individual vital signs and then group them rather than to separate vital signs with multiple components.

Table 1. Summary of Aquatic Workgroup vital signs, rankings, and workgroup justification

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
Climate	Basic climate	Climate	Measures such as temperature & precipitation critical to understanding ecological condition of aquatic resources. Provides background explanation for changes or variations in other vital signs. Available from other agencies- we can compile & regionalize.	M	H
Disturbance	Natural disturbance regime	Natural disturbance regime	High ecological relevance. Low management relevance.	L	L

Category	*Original Vital Sign*	*Workgroup Vital Sign*	*Justification*	*Initial Rank*	*Workgroup Rank*
Hydrology/ Geomorphology	Morphology - channel	Inventory- Stream morphology	Necessary to compile/collect this information in order to better design monitoring program. Could be monitored on a periodic/infrequent basis.	M	H
	Morphometry - lake	Inventory-Lake morpho-metry	Necessary to compile/collect this information in order to better design monitoring program.	M	H
	Spring/seep	Inventory- Spring/seep	Important to map distribution as inventory item. Include as target in other vital signs such as water quantity & quality	L	H
	Substrate composition	Substrate composition	Used on an optional/site specific basis at some parks. Too difficult to apply park-wide at all parks. May be reasonable at smaller parks.	M	M
	Water quantity	Water quantity	Important information, but optional because of cost/feasibility. Lake levels may be feasible, while streamflow could be prohibitively expensive.	H	H
Abiotic condition	Core water chemistry, Water quality - total dissolved ions, Water quality - total organic carbon	Water chemistry	Essential indicator for any long-term aquatic monitoring program. Critical for interpreting biotic condition & ecological processes. Easily collected-readily available protocols	M	H
	Focal taxa - Fish	Focal taxa-fish	By definition, not an indicator of ecological condition. May be more appropriately covered by other programs.	L	L
	Species composition - fauna	Fish community composition	Fish integrate physical, chemical & biological environment over long term-esp. in streams	H	H

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
	Species composition - fauna	Zooplankton community	Indicative of trophic status of lakes- respond to changes in water chemistry, nutrients, and predation by fish and other invertebrates. Hasn't been applied as widely as fish or macroinverts in streams.		H
	Species composition - flora	Phyto-plankton community	Medium priority in lakes, but not as important as other indicators		M
	Species composition - flora	Macrophyte community	Medium priority in lakes, but not as important as other indicators		M
	Species composition - flora	Periphyton community	Medium priority in streams, but not as important as other indicators		M
	Species of concern	Species of concern	Not necessarily a good indicator of ecological condition.	L	L
	Water quality - algal biomass, Water quality – clarity, Water quality - Lake trophic status, Water quality - nutrient loading	Water quality - trophic status	Indicative of stress- widely understood by land managers and often linked to management actions. Standard protocols can be rapid, cost effective & easily tracked.	H	H
	Water quality- macro-invertebrates	Macro-invertebrate community comp.	Macroinverts integrate physical, chemical & biological environment over short term- esp. in streams. Numerous protocols available.	M	H
	Water quality- micro-organisms	Water quality – micro-organisms	More a public health concern than indicator of ecological condition.	H	L
Ecological process	Nutrient cycling	Nutrient cycling	Low management relevance inititally. Could be useful to interpret other monitoring variables later in program	M	L

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
	Phenology	Phenology	Low management relevance inititally. Could be useful to interpret other monitoring variables later in program	M	L
	Trophic dynamics	Trophic dynamics	Low management relevance inititally. Could be useful to interpret other monitoring variables later in program	M	L
Focal park resource	Mandated Species	Mandated Species	By definition, not an indicator of ecological condition. May be more appropriately covered by other programs.	M	L
Landscape context	Landcover, Landscape buffer, Landuse, Park boundary	Inventory- Landcover/ Landuse	Important as an inventory variable- may need to update on a periodic basis as needed.	H	H
Management	Land management, Park infrastructure, Trail network	Park management	Minimal ecological relevance if already being tracked/evaluated by park staff.	M	L
	Visitor use	Visitor use	Fish stocking/fish harvesting the primary concern- only at some parks.	M	M
Stressor	Acidic deposition & stress	Atmospheric deposition	High ecological relevance. Best strategy may be to collect this information from other sources because of high cost/complexity	H	H
	Beaver engineering	Hydrologic alteration	Will be tracked with water quantity.	H	L
	Contamin-ation, Heavy metal contamination	Inventory- Contamin-ation	Important to map sources of contamination and compile this info in a database before the feasibility/necessity of a monitoring program can be assessed. Important at some parks, but expensive.	M	H
	Fertilizer use	Fertilizer use	Will be covered by landcover/landuse	M	L
	Herbicide/pesticide use	Herbicide/pesticide use	Will be covered by landcover/landuse	M	L

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
	Invasive exotic species	Invasive exotic species	Important management concern at all parks. Presence/absence surveys & early intervention critical for health/viability of native species.	H	H
	Roads	Roads	Top management concern, but could be picked up by other vital signs such as landuse & water chemistry. May guide site selection.	H	M
	Septic systems/Wastewater Discharge	Septic systems/ Wastewater Discharge	Important for understanding trends in water quality. Trophic status may give an indication of the extent of this problem, but worth collecting number of septic systems/discharges explicitly.	M	H
	Shoreline erosion/sea level rise	Shoreline erosion/sea level rise	Not a big concern for freshwater aquatics	H	L
	Soil erosion	Soil erosion	Site specific issue- not a widespread concern at most parks	H	L
	UVB	UVB	Low management relevance.	M	L

Table 2. Mandatory and optional measures for high priority Vital Signs recommended by the aquatic workgroup

Category	***Workgroup Vital Sign***	***Mandatory Measures***	***Optional Measures***
Climate	Climate	Air Temperature, Precipitation by type,	Relative humidity, Total solar radiation, Wind speed, Wind direction, Snow water equivalent, snow depth
Hydrology/ Geomorphology	Water Quantity		groundwater inputs, groundwater levels, lake water levels, sping/seep volume, stream flow
Abiotic condition	Inventory- Stream morphology	gradient, drainage area, stream order	run/riffle/pool survey, stream sinuousity, bankful cross sectional geometry

Category	***Workgroup Vital Sign***	***Mandatory Measures***	***Optional Measures***
	Inventory-Lake morphometry	surface area, drainage area, elevation, lake type/origin, maximum and mean depth, bathemetry	flushing rate
	Inventory-Spring/seep	distribution	seasonality
	Water chemistry	Specific conductance, % DO saturation, Temperature, Ph, color, turbidity	iron, cations, anions, alkalinity/ANC, aluminum, Dissolved organic carbon
Biotic condition	Fish community composition	Species abundance, Species Richness	
	Zooplankton community	Species abundance, Species Richness	
	Water quality - trophic status	algal biomass, measures of water clarity such as secchi disk, and total and dissolved phosphorus	macrophyte distribution, diel oxygen curves, periphyton abundance, and dissolved oxygen profiles
	Macroinvertebrate community comp.	Species abundance, Species Richness	
Landscape context	Inventory-Landcover/ Landuse	Landcover/ecological system map	buffer width, buffer vegetation, % impervious surface in buffer watershed, % canopy shading for streams, patch connectivity, patch fragmentation, patch size distribution
	Atmospheric deposition		Inorganic Toxics, dry deposition, mercury, wet deposition
Stressor	Inventory-Contamination		toxic boat paint use & concentrations in water, sediment contamination, MTBE/chloroforms/ trichloroethylene in water, contaminant spills, Air toxic concentrations, bioaccumulation in indicator species
	Invasive exotic species	presence/absence	abundance
	Septic systems/ Wastewater Discharge	Track number of septic systems in the park	Track nearby septic permits and the location, quantity and quality of wastewater discharges

Terrestrial Breakout Session

The terrestrial workgroup began with a short orientation to NETN parks and issues. The group then delved into the task at hand and 1) reviewed the list of 52 proposed terrestrial Vital Signs (Table 3) for comprehensiveness, 2) assigned each proposed Vital Sign a priority rank in accordance with the NETN rating criteria, and 3) discussed measures associated with the high priority Vital Signs, as well as some medium priority Vital Signs that could easily be bundled together for sampling with the high priority Vital Signs.

Overview of Vital Signs

During the initial review, the group suggested changing the name or category of several Vital Signs, and also suggested lumping several into broader Vital Signs. These changes are itemized in Table 3, and the most significant changes are briefly summarized here. The group suggested eliminating the category of management drivers ("Management") and wished instead to consider those Vital Signs within the Stressor category. The group recommended that several Vital Signs assessing the biotic condition of vegetation be combined into a more comprehensive vegetation inventory now called "Vegetation community structure and demography." The group suggested lumping all four proposed Vital Signs within the Landscape context category into a single comprehensive Vital Sign, now called "Landcover/landuse." The proposed Trail network Vital Sign was incorporated into the Visitor impacts (formerly called "Visitor use"). These changes reduced the number of proposed Vital Signs for the terrestrial workgroup from the original 52 to just 45.

The group was asked to consider whether the proposed list was sufficiently comprehensive, and if not, to suggest additional useful Vital Signs, particularly additional focal taxa. In response, the group suggested three additional potential focal taxa for terrestrial systems – 1) lichens, as indicators of air pollution and of old growth conditions;[1] 2) pollinator groups, due to their functional significance; and 3) arctic/alpine plants, due to the particular challenge posed to this group by climate change. However, the group did not rate these potential Vital Signs, nor discuss them in depth.

Ranking the Proposed Vital Signs

The group discussed each proposed Vital Sign and assigned each a priority rank in accordance with the NETN rating criteria. Of the 45 revised proposed Vital Signs considered by the terrestrial workgroup, the group ranked 11 "high" priority, 16 "medium" priority and 18 "low" priority. The rankings, justifications for these rankings, and key issues raised during discussion, are summarized in Table 3.

The 11 high priority Vital Signs included a key system driver (Climate), seven stressors (Atmospheric deposition & stress, Heavy metal contamination, Invasive exotic species, Ozone, Roads, Visitor impacts, White-tailed deer herbivory), and measures of both landscape context (Landcover/landuse) and biotic condition (Focal taxa – forest breeding birds, Vegetation community structure and demography). In general, these high priority Vital Signs all were deemed to have considerable ecological relevance and some management significance. Standard methods are available to measure most of these Vital Signs, and background datasets are available for some. For the most part, the medium priority Vital Signs also had ecological relevance and management significance, but were deemed less critical than the high priority Vital Signs. Most of the low priority Vital

[1] See Steve Selva's work on *Lobaria pulmonaria* and *Usnea* lichens.

Signs were considered not useful, either because of low ecological relevance to terrestrial systems, or because they yield information that is too variable or difficult to interpret.

Vital Sign Measures

In the next phase of the breakout session, the group discussed specific measures for quantifying the high priority Vital Signs, as well as measures for medium priority Vital Signs which might be easily bundled together with the high priority group; these medium-priority Vital Signs included Natural disturbance regime, Nutrient cycling, Productivity, Park infrastructure, Species composition – flora, Vegetation/canopy condition, and several focal taxa. Key measures for these Vital Signs are discussed below, and summarized in Table 4.

High priority Vital Signs

1. Climate

Climate is a key driver of natural systems affecting system structure, composition, and function. Monitoring this basic variable will also provide a long-term record of the stress associated with climate change. While management applications related to climate are limited, climate data is useful for ruling out other causes for system responses. Some climate data is already collected in or near the NETN parks and can be compiled easily; collection of other data may be warranted in some cases. Continuous daily temperature and precipitation are mandatory climate measures; additional useful measures include snow depth on site, relative humidity, wind speed and direction, and solar radiation. It would be useful to co-locate other atmospheric measurements such as acid deposition and heavy metal inputs and atmospheric ozone concentrations with these climate measurements.

2. Vegetation Community Structure and Demography

The group rolled three original proposed Vital Signs into this more comprehensive vegetation inventory, to create a fundamental and anticipatory indicator of future cover, function, habitat quality and stress response. Standard methods are readily available, and the response variability associated with many of these measures is well understood. The group suggested reviewing the State of Maine's subset of the USFS FIA measures, used to monitor state ecological reserves, as a starting point for this Vital Sign. They recommended stratification to select sampling locations, and resampling of permanent plots, perhaps on a 5-year return interval. The group noted that many additional Vital Signs might be monitored in conjunction with these surveys, such as composition, canopy condition, white-tailed deer herbivory, additional focal taxa such as forest breeding birds or lichens, and invasive exotic species, particularly forest insect pests and earthworms. The group pointed out that legacy features might be useful to monitor even within parks that are not subject logging or forest management, because legacy features could potentially be artificially created within younger forests that lack such features.

3. Focal Taxa – Forest Breeding Birds

This was the only focal taxa designated high priority by the terrestrial workgroup. This taxa provides a useful biotic indicator of the effects of habitat fragmentation, and is a highly visible and charismatic taxa much loved by the public. The NPS has some management control over fragmentation within the park, though fragmentation outside the park boundary is a critical stressor for many of the smaller parks. This Vital Sign provides an opportunity for NPS to coordinate with other organizations monitoring bird populations, and to incorporate volunteers into the I&M program. Many reference datasets and standard methods are available, and the response variability is fairly well understood. However, some members expressed concern that it can be hard to attribute variation in bird populations to a specific cause. The group indicated we should employ some measures of composition/relative abundance/species richness and distribution using point counts and/or distance sampling, and that we consult protocols compiled by the NPS and those developed by the Patuxent Center. We should carefully assess the power of our sampling design, and consider sampling more points less frequently (perhaps twice as many every other year) to increase statistical power.

4. Landcover/Landuse

Landcover data provides key information on the status and extent of ecological systems; landuse data for the larger park region provides important information on habitat alteration and a wide variety of stressors associated with landuse change. This Vital Sign includes measures of "buffers" to natural systems and to the parks in general, which are useful indicators of the degree of anthropogenic influence. This Vital Sign has some management significance, as parks have control over both landuse change within the park, and the size and composition of landscape buffers. Landcover/landuse data is readily available from remote sensing. Periodically updated landcover/landuse maps are essential components of this Vital Sign; these might be updated on a 10-25 year return interval. Additional mandatory measures are cover type patch size distribution, some measure of connectivity and fragmentation, and land ownership within park buffers. The amount of impervious surface within park watersheds would also be a useful measure. It should be possible to monitor aspects of many additional Vital Signs using remotely-sensed data; these include large disturbances, road networks, productivity, vegetation stress, rare plant communities and perhaps trail networks and focal species habitat. One member recommended we investigate new methods employed by Steve Sader at the University of Maine, perhaps using IKONOS imagery; these may allow remote sensing of regeneration. Data on park infrastructure development could be compiled into this spatial database.

5. Visitor Impacts

Visitor impacts ranked high priority despite localized ecological impacts due to the clear management implications of this fundamental park issue. Many of the NETN parks are heavily visited, and thus allow substantial opportunity for adaptive management of visitor impacts. Impacts related to trail use were considered of particular importance to the Appalachian Trail, and the group noted that poor trail maintenance could substantially impact resources along the trail. The group debated the utility of monitoring visitor activities, density and location versus visitor impacts – there are advantages to both approaches. The former can be monitored via motion detectors placed at key locations; the latter can be monitored along trails, and in back-country areas together with vegetation inventory surveys. It was noted that both snowmobiles and ATVs are currently in use within Acadia NP.

6. Atmospheric Deposition & Stress

Atmospheric deposition is a stressor of high ecological relevance to both terrestrial and aquatic systems throughout the NETN. Acidic deposition stresses terrestrial vegetation and alters system functioning and biogeochemical cycles. This issue has management significance at higher level than NPS, in the form of legislation controlling emissions. Standard methods available for monitoring both inputs and associated stress. The ecological response to this stress varies across the landscape in complex ways, only some of which are understood. Patterns of wet deposition data are currently monitored through the NADP network and are well understood; relevant data for NETN parks should be acquired from this network. Patterns of dry deposition are less well understood, but some dry deposition data could be acquired from the CASTNET network. Patterns of occult deposition, from clouds and fog, are less well understood, and could be important sources of acidity within coastal NETN parks such as Acadia. The group was undecided as to whether occult deposition should be monitored at Acadia; this is an issue for further consideration. The group recognized that acid stress response should be monitored in addition to inputs, and advocated sampling of streamwater ANC, but was less sure whether soil chemistry and nutrient cycling should also be monitored. The former would also provide a useful measure of terrestrial system nitrogen saturation as well as water quality. Heavy metal deposition is also monitored by the NADP and CASTNET networks, that data should also be acquired and compiled by the I&M program.

7. Heavy Metal Contamination

The group considered heavy metal contamination to be a significant emerging ecological problem with both research value and management significance. Heavy metals such as mercury, zinc, lead and cadmium are toxic and can accumulate in biota. Thresholds of toxicity are not yet well established, though they are perhaps better established in aquatic than terrestrial systems. The group recommended acquiring data on atmospheric inputs from existing sources (the NADP and CASTNET networks, discussed above) but did not have time to fully consider whether measures of biotic accumulation and response were mandatory or optional.

8. Invasive Exotic Species

Invasive exotic species are a significant and growing stressor with clear ecological relevance to terrestrial systems within NETN. This Vital Sign has relatively strong management implications via exotic species control programs. Numerous groups of invasive exotic species are of concern, including terrestrial plants, insect pests and pathogens, and earthworms; it might be wise to develop separate Vital Signs focusing on these groups. The group questioned whether feral animals would/should be included within invasive exotic species monitoring and management programs. Appropriate monitoring strategies will depend upon the group of organisms in question and might include surveillance, perhaps in conjunction with the field vegetation surveys, followed by monitoring after initial detection. The literature and support information available on invasive exotic species is extensive.

9. Ozone

Atmospheric ozone pollution is an important stressor of terrestrial vegetation with clear ecological relevance. This Vital Sign has management significance at higher level than NPS via air quality legislation. Standard methods for monitoring are available. Bob Kohut recommends that both atmospheric ozone concentrations and ozone stress on indicator species be monitored as mandatory indicators. Ozone concentration data is available from CASTNET network and other sources, and need only be acquired by NETN. Ozone stress on specific indicator species should be monitored within NETN parks.

10. Roads

The Roads Vital Sign originally contained three components: the road network, road chemical use, and roadkill. The terrestrial workgroup considered only the first to have strong ecological relevance in terrestrial systems, as an important source of landscape fragmentation and an entry point for invasive species. The group thought perhaps the aquatic and wetland workgroups were better suited to considering the impacts of road chemical use and roadkill. This Vital Sign has some management significance in terms of changes to the road network within parks. The group wondered if the road network could best be monitored via remote sensing together with Landcover/landuse.

11. White-tailed Deer Herbivory

This was a controversial Vital Sign for the terrestrial workgroup. While some in the group felt deer herbivory has high ecological relevance for regeneration and substantial management significance, others considered it inappropriate for NPS to consider a native species to be a "Stressor." This also stimulated discussion of how the historic and/or natural range of variability of a particular measure might contribute to evaluating ecological integrity. Some questioned whether this Vital Sign should include additional herbivores. Most of the group advocated monitoring browse impacts rather than herbivore populations.

Other Potential Vital Signs or Issues

Several important issues relating to medium- and low-priority Vital Signs were raised during discussion within the terrestrial workgroup.

During discussion of **Natural disturbance regime**, the group recognized that large/infrequent disturbances might best be monitored from remote sensing together with Landcover/landuse, while small/frequent disturbances might best be monitored from field surveys together with Vegetation community structure & demography.

The group considered **Productivity** to be a useful indicator of the state of terrestrial systems, but ranked it medium priority rather than high because they questioned whether it was useful for identifying specific problems.

The group was unsure if and how **Feral animals/pets** should be monitored. Some felt feral animals should be considered part of the Invasive exotic species Vital Sign. The group was unsure of the ecological impact of pets within NETN parks, and wondered whether this problem was already sufficiently managed by park personnel.

In discussion of **Herbicide/pesticide use**, the group questioned whether it was useful to quantify amounts used within and surrounding the parks, or whether it was better to measure specific impacts within NETN parks.

Though it ranked low priority, the group spent considerable time discussing **Land management**. The land management activities that occur in all the NETN national historical parks and historic sites have considerable ecological relevance, but are tied to the parks' cultural mandate. For this reason, the group questioned the utility of monitoring those activities within the I&M program. However, some in the group thought fire management activities should be monitored.

One member of the group noted that it might be more useful to monitor ant-dispersed herbaceous species than spring ephemerals as a **Focal taxa** for terrestrial systems, because they persist longer and may be more useful as an indicator of ecological condition. Spring ephemerals can be hard to define as a guild.

Finally, the discussion of **Vegetation/canopy condition** noted that this Vital Sign might be hard to quantify. Two possibilities for doing so would be to monitor canopy crown condition using field surveys, or to assess vegetation stress from remote sensing.

Several important general issues were raised during discussion in the terrestrial workgroup. First, the group discussed whether some potential Vital Signs were more appropriate as issues for inventory, surveillance, research or management, than for monitoring. The distinction between inventory and monitoring is an important one that has been specifically addressed by the I&M program – the program recognizes that an initial inventory of park resources is essential to the development of an effective monitoring program. While potential Vital Signs such as landcover/landuse are already being assessed in NETN parks in an initial inventory, landcover/landuse change over time is an important element to monitor, though probably at longer return intervals than some other Vital Signs.

The distinction between monitoring and surveillance is less clear. The group discussed the need for surveillance to detect the presence of certain invasive exotic species – which might then be monitored or eradicated. More generally, one member advocated a policy of surveillance for several Vital Signs in order to determine whether certain thresholds of response had occurred, which might then trigger monitoring. This issue should be clarified during Phase 3 protocol development.

Likewise, the distinction between research and monitoring is important – scientific research is hypothesis-driven, while monitoring seeks to elucidate changes in resources over time, and/or to determine the effects of management action on resources. During discussions of deer herbivory, the group briefly debated whether the impacts of deer herbivory on terrestrial ecosystems were an issue for research or monitoring. Most, though not all, felt that deer impacts were important stressors on terrestrial regeneration that should be monitored over time.

The group debated whether some potential Vital Signs, such as some invasive exotic species and feral animals/pets, were management issues that would be addressed and assessed by NPS programs other than the I&M program. While it is clear that monitoring is an important component of adaptive management which allows assessment and finetuning of management strategies, it is an NPS administrative decision whether to monitor known management issues as part of the I&M program, or separately within management programs.

Second, the group debated whether some proposed Vital Signs were appropriate issues for NPS to monitor from an ideological standpoint. Specifically, one group member questioned whether it was appropriate for NPS to consider the concept of "health," "condition" or "integrity" of natural vegetation and systems, or to assess the impacts of current, historically-high populations of native herbivores on vegetation. The underlying philosophy seemed to be that native systems and species should be free to exist without human intervention and/or management. Most of the group disagreed with this philosophy because anthropogenic change so pervasively affects these native systems and species. Indeed, it is a stated goal of the I&M Program to identify vital signs that "represent the overall health or condition" of park resources.

Third, a related and important issue discussed in this workgroup was how to apply the concept of resource "condition" or ecological integrity to highly modified systems. These concepts are more easily applied to natural systems, but substantial land within the national historic parks and sites is maintained as open fields for cultural reasons. The group struggled with the concept of choosing Vital Signs that represent the health or condition of these modified semi-natural or cultural systems. This is an issue that will require further consideration.

Fourth, the group debated the utility and cost-effectiveness of biogeochemical approaches to monitoring. In general, this group considered biogeochemical approaches to be prohibitively expensive and of lower priority, though there was some discussion of perhaps perpetuating ongoing watershed analyses within Acadia in conjunction with the I&M program. The assembled group did not include specific expertise within the field of biogeochemistry. For this reason, it might be useful to seek additional review and input from a small group of scientists with expertise in biogeochemistry – a discipline developed in part to provide indicators of ecosystem status and functioning. This additional review might also provide needed input on the related issue of the best measures for monitoring acidic stress on terrestrial systems, and the question of monitoring occult deposition inputs at Acadia.

Fifth, the group discussed the existence of adequate baseline data. Good baseline data exists for some proposed Vital Signs but not all. The group noted that a long-term monitoring dataset can detect trends despite the lack of baseline data for comparison.

Sixth, one group member strongly advocated a GIS approach to data management for monitoring in general. He felt that data collected for many of the high priority Vital Signs should be maintained in a spatial database to allow spatial analysis.

Finally, the group recognized that climate change was a key stressor for terrestrial systems over the long-term, but struggled to identify useful Vital Signs associated with this stressor. The group discussed two relevant Vital Signs, Phenology and Species migration – climate change, in some depth, but ranked both only medium priority. In part, this was because NPS has less ability to manage this stressor than some of the others. The medium priority rating for phenology was also partly due to the inherent variability of this response. However, the group recommended further consideration of how species migration in response to climate change could be monitored along the altitudinal and latitudinal gradients of the Appalachian Trail.

Table 3. Summary of Terrestrial Workgroup vital signs, rankings, and workgroup justification

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
Climate	Basic climate	Climate	Widely applicable. Few specific management applications, but useful to rule out other causes. Already measured, data widely available.	M	H
Disturbance	Natural disturbance regime, Beaver engineering	Natural disturbance regime	Important background information. Limited management significance. Currently not measured. High response variability.	L	M
Biotic condition	Species of concern	At-risk biota	Not a useful indicator, rare plants have specific requirements.	L	L
	Bats	Bats	Low ecological relevance and management significance.	L	L
	Demography - dominant vegetation, Stand structure retention - legacy features, Stand structure	Vegetation community structure and demography	Anticipatory measure of future cover, function, habitat quality & stressors. Indicator of disturbance. Could be bundled with multiple VS. Standard methods available. Variability understood. Legacy features can be created in young stands	M	H
	Focal taxa - additional	Focal taxa - additional	Relevance depends upon taxa considered. Consider lichens, pollinator groups, arctic/alpine plants.	M	M
	Focal taxa - Forest interior breeding birds	Focal taxa - Forest interior breeding birds	Biotic indicator of fragmentation effects. Can coordinate with other organizations, use volunteers. Many reference datasets and standard methods available. Response variability understood.	M	H

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
	Focal taxa - Obligate lepidopterans/odonates	Focal taxa - Lepidopterans/odonates	Narrow ecological significance. Low management significance. Applicable to additional wetland, upland habitat than specified.	L	L
	Focal taxa - Red backed salamander	Focal taxa - Red backed salamander	Indicator of acid deposition, microclimate. Can use volunteers. Response perhaps not well known.	M	M
	Focal taxa - Soil biota	Focal taxa - Soil biota	Group considers our understanding of soil biota insufficient to use herein.	L	L
	Focal taxa - spring ephemerals	Focal taxa - spring ephemerals	Linked to earthworm populations, herbivory. Some management significance. Consider changing to ant-dispersed herbaceous species.	M	M
	Focal taxa -Grassland birds	Focal taxa -Grassland birds	Does not clearly relate to ecological integrity, but does have clear land management implications. How to consider ecological integrity of highly modified systems?	M	L
	Rare plant community	Rare plant community	Might provide a coarse filter for rare species, but irrelevant to "health." Species will respond individually to climate change. Perhaps harder to monitor than individual rare species. Consider as focal park resource.	M	M
	Species composition - fauna	Species composition – fauna	Difficult to consider in general - perhaps consider large predators specifically.	H	L
	Species composition - flora	Species composition - flora	Broader than dominant vegetation. Non-clonal herbs may provide early warning. Some	H	M

Category	Original Vital Sign	Workgroup Vital Sign	Justification	Initial Rank	Workgroup Rank
			management implications. Can bundle with other vegetation inventory.		
	Species migration - climate change	Species migration - climate change	Good long-term dataset to document clear response to critical stressor. Could bundle with vegetation inventory. Consider transects upslope on AT. Consider latitudinal change also.	L	M
	Vegetation condition	Vegetation/ canopy condition	Can provide important early warning. May be difficult to quantify. Bundle with vegetation inventory. Consider defining as canopy condition, and/or remotely sensed stress	H	M
Ecological process	Nutrient cycling	Nutrient cycling	High ecological relevance, some management significance. Group considers this expensive, but perhaps warranted in specific cases such as Ca depletion, N saturation. Perhaps consider with atmospheric deposition	M	M
	Phenology	Phenology	High ecological relevance, indicator of climate change. Other groups are measuring this - should NPS too? Some phenology easily measured using volunteers. Response variability may be high.	M	M
	Productivity	Productivity	Indicator of system state. Can be monitored using remote sensing using standard protocol. Has NPP been useful in identifying specific problems?	M	M

Category	Original Vital Sign	Workgroup Vital Sign	Justification	Initial Rank	Workgroup Rank
	Soil respiration	Soil respiration	Ecological relevance and management significance are vague.	L	L
	Trophic dynamics	Trophic dynamics	Feasibility is low. Perhaps consider monitoring coyotes.	M	L
Focal park resource	Amphibians	Amphibians	Wetlands workgroup should consider this in more detail.	M	M
	Breeding birds	Breeding birds	Duplicative. See comments under Biotic Condition.	M	M
	Mandated Species	At-risk biota	Duplicative. See comments under Biotic condition.	M	L
	Viewshed	Viewshed	Very limited ecological relevance.	L	L
Landscape context	Landcover. Landscape buffer, Landuse, Park boundary	Landcover/ landuse	High ecological relevance and management significance. Easily monitored using remote sensing.	H	H
Manage-ment	Land management	Land management	A controversial VS. Some felt activities necessary for park's cultural mandate should not be monitored. Group thought fire management might require monitoring.	H	L
	Park infrastructure	Park infrastructure	Localized ecological impacts, clear management significance. NPS maintenance produces this information. Consider lumping with landcover/landuse.	M	M
	Visitor use	Visitor impacts	Localized ecological impacts. Clear and useful management significance. Trail impacts particularly important to AT. Monitor visitor impacts such as trampling.	M	H
Stressor	Acidic deposition &	Atmospheric	High ecological	H	H

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
	stress	deposition & stress	relevance. High management significance at higher level than NPS. Standard methods available, wet deposition data available. Response varies across landscape, some aspects of variation are understood. Consider occult deposition at Acadia? Best measure of response?		
	Contamination	Contamination	Low ecological relevance for terrestrial systems.	M	L
	Dark night sky	Dark night sky	Some limited ecological relevance, but less than other VS herein. High management significance. Could be monitored by volunteers.	L	L
	Feral animals/free-ranging pets	Feral animals/free-ranging pets	Group suggests feral animals should be considered exotic species. Group questions if pets should be monitored or just managed. Monitoring or management issue?	M	L
	Heavy metal contamination	Heavy metal contamination	Significant emerging ecological problem with research value and management significance. Thresholds of toxicity not well established, perhaps better established in aquatic systems. Bundle inputs with atmospheric deposition.	H	H
	Herbicide/ pesticide use	Herbicide/ pesticide use	Perhaps better considered by aquatic workgroup. Measured via impacts within park or easier to measure	M	M

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
			amounts used?		
	Hunting	Hunting	Measured by state, NPS has little influence.	M	L
	Invasive exotic species	Invasive exotic species	Clear ecological relevance. High management significance. Consider invasive plants, herbivores (insect pests), earthworms, pathogens, etc. Group suggests surveillance is needed. Clarify distinction between monitoring, management, surveillance. Split VS? Feral animals included?	H	H
	Noise	Noise	Relatively low ecological relevance. Should know background levels, perhaps measured by others.	L	L
	Ozone	Ozone	Clear ecological relevance. Clear management significance at higher level than NPS. Standard methods available and atmospheric concentrations are available.	M	H
	Roads	Roads	Group considered road network important ecologically and to management within terrestrial systems, but not road chemical use. Roadkill considered an amphibian/wetland issue. Consider within landcover/landuse?	H	H
	Soil erosion	Soil erosion	Localized ecological impacts. Erosion on AT is important with management	H	L

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
			implications.		
	UVB	UVB	Ecologically relevant most strongly to amphibians - thus more relevant to wetland group. Is funding ending for current Acadia monitoring?	M	L
	White tailed deer herbivory	White tailed deer herbivory	A controversial VS. Some felt this has high ecological and management significance, others found it is inappropriate to consider a native species a "stressor." Group wants to monitor impacts, not deer population. Should NPS consider "overpopulation" of native species? Are additional herbivore species of interest?	H	H

Table 4. Mandatory and optional measures for high priority Vital Signs recommended by the terrestrial workgroup.

Category	***Workgroup Vital Sign***	***Mandatory Measures***	***Optional Measures***
Climate	Climate	precipitation by type, temperature	snow water equivalent, relative humidity, snow depth, wind speed and direction, solar radiation
Biotic condition	Vegetation community structure and demography	mortality, regeneration, stand structural stage, basal area by species, composition, canopy condition, snags, coarse woody debris,	earthworm presence
	Focal taxa - Forest breeding birds	Species richness, population trend	
Landscape context	Landcover/landuse	landcover/ecological system map, ecological system change, road network	patch fragmentation, patch connectivity, patch size distribution, disturbance extent, regeneration, proximity indices, , , type of

			road & road network change, % impervious surface in watershed, nearby human population density, land ownership in park boundary
Management	Visitor impacts	Number of visitors by location and activity, trampling disturbance, soil erosion	wildlife disturbance,number snowmobiles, social trail development, trail network change
Stressor	Atmospheric deposition & stress	Wet & dry deposition from NADP and CASTNET, stream alkalinity/ANC, streamwater nitrate	soil base saturation, occult acidic deposition, soil Ca:Al ratio
	Heavy metal contamination	Atmospheric deposition	bioaccumulation in indicator species, metal contaminants in water
	Invasive exotic species	surveillance	extent, abundance
	Ozone	foliar injury to indicator species, atmospheric ozone concentration	
	White tailed deer herbivory	vegetation browse intensity, regeneration impacts	Deer population size

Wetland Breakout Session

Overview of Vital Signs

The workgroup began by reviewing the categories of Vital Signs and deciding that the group would transcend discussions about Vital Sign categories and focus on the tasks of determining if the proposed list was complete and the ranking the list and identifying measures. The group decided to change the "septic/wastewater discharge" and "fertilizer use" Vital Signs to "Nutrient Enrichment" (Table 5). The group added the "Heavy Metal Contamination" to the "Contaminants" Vital Sign to create more general and comprehensive Vital Sign. The group also added a new Vital Sign "Emerging Wildlife Diseases" and then ranked it as a low priority due to the difficulty in tracking these over time.

High priority Vital Signs

1. Climate

The workgroup thought that acquiring basic climate data was important for any long-term monitoring program because these variables provide background explanation that is important in the interpretation of changes to wetland condition. All the parks in the network identified global climate change as a pervasive stressor to all park resources, not just wetlands. Therefore, monitoring basic climate data is a necessary component of a Vital Signs program.

The workgroup recommended that it was more efficient to access existing weather and climate resource systems and make that information available to park managers than to install new park based weather stations. This provision was qualified with the understanding that if an existing climate data source is not available within an acceptable distance, or necessary data is not collected by existing sources, then the network should consider installation and maintenance of an appropriate weather station.

The workgroup also recommended that network parks should cooperate with existing snow cover monitoring programs to obtain annual snow cover trends. These measures should minimally include snow depth and snow cover duration. The workgroup recommended these measures because of the relationship between winter precipitation and seasonal wetland hydrology.

2. Hydrology

Hydrologic conditions are extremely important for wetland structure and function. Hydrology affects most abiotic factors, which in turn affect the biotic condition of the wetland. Without basic hydrologic information, it is not possible to interpret the condition of any wetland resources and this is therefore, a high priority for any wetland monitoring.

The workgroup recommended that surface and sub-surface water level, and water level duration form the primary measures for monitoring wetland hydrology. Establishing sources and quantity of inflow and outflows was not considered to be a primary measure due to cost and site selection difficulties.

3. Water Chemistry

The workgroup considered this to be the only high priority abiotic condition vital sign. Information from basic water chemistry measures can be directly related to the condition of a wetland and may be correlated with other wetland vital signs. In order for causal relationships between physical and biological processes to be fully understood, the workgroup thought it was necessary to obtain basic water chemistry measures in wetlands.

The workgroup recommended three mandatory measures: temperature, pH, and conductivity. These were selected because their response variability is understood, they are cost effective, provide meaningful management directed information, and are good indicators of wetland condition. This vital sign generated a discussion that centered on the effectiveness of a measure to produce meaningful information. Data from some traditional water quality measures are difficult, if not impossible to interpret in a monitoring setting when the measures are taken on regular, but infrequent intervals. For example, Dissolved Oxygen (DO) was suggested as a potential measure because it is easy to accomplish and commonly obtained. The work group decided against DO because it is too easily affected by other factors that occur on a daily or seasonal basis which would make comparison of data obtained from different sampling cycles difficult or impossible to compare.

4. Species Composition – Fauna

This was one of two biotic condition vital signs identified by the wetland workgroup as high priority. The workgroup thought that faunal composition was highly relevant and applicable to wetland condition. Monitoring specific measures of indicator groups was considered to be high priority vital sign because it integrates stressor, condition, and response vital signs.

The workgroup discussed the difficulty of identifying indicator faunal groups for specific wetland types and parks. For example, a different faunal community would be expected in a vernal pool than would be found in an emergent marsh. Similarly, the faunal community in an Acadia National park vernal pool may be different that the community found in a Saratoga National Historic Park vernal pool.

The workgroup recommended that wetland indicator fauna be specified for each wetland type and each park and should be a primary component of protocol development. The principal metric for this vital sign is abundance by indicator species.

5. Species Composition – Flora

This was one of two biotic condition vital signs identified by the wetland workgroup as high priority. The workgroup thought that floral composition was highly relevant and applicable to wetland condition. Knowing the relative abundance and species composition of the floral community provides basic biological information that can be related to stressor and abiotic vital signs. Monitoring the vegetation community is also a good early detection strategy for management of invasive species.

Wetland vegetation monitoring provides a good indicator of wetland condition because plant species vary in their response to stress. Monitoring wetland flora is relatively low cost, sampling is efficient, and changes in plant species composition and abundance can be accurately measured.

The principal metric for this vital sign is abundance by species.

6. Landuse/Landcover

Landcover is an important vital sign because it integrates across multiple spatial scales; from the buffer around an individual wetland, to the wetland complex within a park's boundary, to the distribution of wetlands within the region. Landcover change was identified as a high priority issue for all network parks due to concerns arising from the negative effects of habitat conversion adjacent to park boundaries. By implementing a basic landcover change monitoring program inferences can be drawn between measurable changes in park wetland integrity and anticipated negative effects. For example, increased development around parks increases the likelihood of invasive species introduction, feral animals, and water quality changes resulting from increased impervious surfaces.

Landcover change detection has been identified by most other networks within the Inventory and Monitoring Program, especially those in the eastern United States where human populations have increase dramatically during the last century.

The recommended measures proposed by the workgroup exist in two different spatial scales. Broad scale measures would be used to provide basic landcover change within and around parks. Finer scale measures (wetland level) included the abundance of plant species within 100-meters and 500- meters from the wetland edge. The workgroup recommended that for vernal pools and some forested wetlands, canopy cover should be included as a measure.

7. Atmospheric Deposition

The workgroup thought that compiling acidic deposition data was important for any long-term monitoring program because this stressor has demonstrated negative affects on water chemistry and can alter wetland function and biogeochemical processes. All the parks in the network identified acid deposition as a pervasive stressor to all park resources, not just wetlands. Therefore, acquiring and synthesizing data from existing sources, including the National Atmospheric Deposition Program (NADP), is a necessary component of a vital signs program.

The workgroup recommended that it was more efficient and cost effective to acquire existing acid deposition information and make that information available to park managers than to install new park based monitoring stations.

8. Contamination

The workgroup recognized that monitoring contaminant concentrations in the wetland environment and biota is a high priority. However, the workgroup recommended that contaminant experts be solicited for recommendations for specific compounds and biota to monitor. The workgroup also recommended that potential sources of contamination be identified (i.e., gas stations, landfills, industrial sites, shipping channels, power plants, etc.).

9. Nutrient Enrichment

The negative effect of nutrient enrichment in wetlands, and other waters, is well documented. Habitat quality can be adversely impacted from increased nutrient inputs, anoxic conditions can arise, and changes to the biotic community can occur.

The workgroup decided that randomly monitoring nutrient concentrations in wetlands is not an effective design. Sampling is costly, nutrient concentrations are variable, dependent upon vegetation uptake, and may not provide a direct measure of nutrient loading. However, because nutrient enrichment is considered a high priority for wetland systems, inventorying existing potential sources of nutrient enrichment as well as proposed additional sources (i.e., building permits, road development, etc.) is considered necessary.

Potential measures for this vital sign include fertilizer use within parks and residential density within buffer adjacent to park.

10. Invasive Exotic Species

The negative effects of invasive species are second to direct habitat loss in the reduction of biodiversity. The national I&M program and all the parks in the Northeast Temperate Network have identified invasive species as a high priority vital sign and management issue. The workgroup emphasized the importance of developing a monitoring program that a) will identify potential wetland invasive species before they become established in a park; and, b) is sensitive enough to detect any new invasions at a point when management can be most effective.

The workgroup recommended that the role of the vital signs program is early detection of invasive wetland species, not monitoring the effectiveness of invasive wetland species control programs.

Potential measures for this vital sign include presence/absence of any invasive wetland species.

Table 5. Summary of Wetland Workgroup vital signs, rankings, and workgroup justification

Category	Original Vital Sign	Workgroup Vital Sign	Justification	Initial Rank	Workgroup Rank
Climate	Basic climate	Basic climate	Management Significance - good baseline information that integrates across multiple systems including wetlands, easy to obtain and may help explain observed patterns in wetland condition over time; Feasibility - Look for adjacent meteorological stations in immediate vicinity of each NETN park. Initial costs may be high if stations need to be established within parks	M	H
Disturbance	Natural disturbance regime	Natural disturbance regime	Ecological Relevance - Weather related disturbance events are priorities for ACAD, other may be for other NETN parks; Insect outbreaks may be a component of a remotely sensed landcover change monitoring program or could be integrated from other ongoing programs.	L	L
Hydrology/ Geomorpholo gy	Hydrology	Hydrology	Management Significance - Driving parameter in wetland ecology; Feasibility - Some easy measures that can explain much of the variation in wetland condition; Ecological Relevance - driving parameter in wetlands, can not explain much without knowing the basic hydrology of each wetland	M	H
Abiotic condition	Core water chemistry	Water Chemistry	Response Variability – variability is measure specific; Management Significance - Provides useful management directed information; Feasibility - Easy, relatively cheap; Ecological Relevance – provides the necessary physical parameters to assess basic wetland condition.	H	H
	Sediment characteristics	Sediment characteristics	Response Variability - highly variable; Management Significance - hard to interpret, no clear linkage to management; Feasibility - Highly variable; Ecological Relevance – Confusing to interpret	L	L

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
Biotic condition	Focal taxa - Amphibians	Focal taxa - Amphibians	Response Variability – Amphibians are taxa sensitive to wetland condition (both physical and biological parameters); Management Significance – can be a component of Phenology monitoring; Feasibility – park monitoring can integrate with other existing programs; Ecological Relevance – some taxa are good indicators of wetland condition. This Vital Sign will likely be a component of the "Species Composition – fauna" Vital Sign.	H	M
	Rare plant community	Rare plant community	Management Significance – Distribution can be incorporated as a landscape measure;	M	L
	Species composition - fauna	Species composition - fauna	Ecological Relevance – high, knowing the status of wetland obligate fauna important to tracking wetland condition over time. Must identify indicator taxa for wetland types and NETN regions.	H	H
	Species composition - flora	Species composition - flora	May be good indicator of stress; Different vegetation respond to stress at different rates that can be easily observed and quantified; relatively low cost and provides information that can be used in management.	H	H
	Species of concern	Species of concern	Management Significance - Park focused study; Feasibility - Not an I&M level concern;	L	L
		Emerging Diseases	Response Variability - Uncertain; Feasibility - May be hard to develop a means to study; Ecological Relevance - Very interesting question, not easy to implement.		L
	Vegetation condition	Vegetation condition	This will be integrated into Species Composition – Flora metrics	H	L
	Water quality - algal biomass	Water quality - algal biomass	Response Variability - sensitive; Management Significance - Gives potentially good feedback for wetlands that have open water; Feasibility – Chlorophyll-a feasible for suspended phytoplankton, periphyton measures may not be	H	M

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
			readily available; Ecological Relevance - Look into available science -- does it support monitoring objectives? May be a Vital Sign that is implemented later in program development.		
	Water quality – macro-invertebrates	Water quality – macro-invertebrates	Feasibility - requires technological expertise; Ecological Relevance - Science may not support predicted patterns; Could be integrated into program over time and within specific parks but may not be the highest priority for initial program development.	M	M
	Water quality - nutrient loading	Water quality - nutrient loading	Response Variability – Measuring nutrient concentrations produces highly variable results; Management Significance - Not sensitive to management concerns -- may be caused by natural as well as anthropogenic sources; Feasibility - Too costly; Ecological Relevance - Not sensitive to management concerns -- may be caused by natural as well as anthropogenic sources;	H	L
Ecological process	Nutrient cycling	Nutrient cycling	Response Variability - hard to interpret; Management Significance - may not give useful answers to management questions; Feasibility - too costly; Ecological Relevance - important, would be useful bit does not outweigh the variability and indirect relationship to management decision making.	M	L
	Phenology	Phenology	Feasibility - Link into other programs and utilize relatively simple measures; Ecological Relevance – good indicator of the biological response to climate change	M	M
	Productivity	Productivity	Feasibility - too much financial investment, too complicated	M	L
	Trophic dynamics	Trophic dynamics	Feasibility - Huge investment more research than monitoring;	M	L
Focal park resource	Amphibians	Amphibians	Management Significance – Important park resources;	M	M

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
			Ecological Significance – may be appropriate indicator taxa; Feasibility – can integrate with regional and national protocols		
	Breeding birds	Breeding birds	Response Variability - variable; Management Significance - difficult to interpret because trends may not be due to changes in park resources; Ecological Relevance - cause and effect difficult to interpret; Feasibility – easy to implement and integrate with ongoing programs, strong public interest.	M	M
	Mandated Species	Mandated Species	Management Significance - Important, but not emphasis of I&M program. Should be responsibility of individual parks	M	L
	Viewshed	Viewshed	Management Significance - Park issue. Deals with aesthetics, Adjacent land use; Feasibility – may be incorporated into landcover change detection monitoring.	L	L
Landscape context	Landcover, Landscape buffer, Landuse, Park boundary	Landuse/ Landcover	Response Variability - Good indicator of changing conditions for all park resources, integrates across multiple spatial scales; Management Significance - Measures that are Park focused, Acquire many remotely sensed measures simultaneously that can be applied to multiple systems and park stressors. Important measure for wetland management includes buffer quality around each wetland. Roads metrics should be included in this Vital Sign.	H	H
Management	Land management	Land management	Management Significance - Irrelevant to wetlands in NETN parks except restoration work at SAIR.	H	L
	Park infrastructure	Park infrastructure	Management Significance - Park driven management, not a monitoring issue;	M	L
	Trail network	Trail network	Management Significance - Not a monitoring issues;	M	L

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
	Visitor use	Visitor use	Management Significance - Major park concern, but on a park-by-park basis. May not be a reasonable VS to measure on a network basis; Feasibility - Can be done.;	M	M
	Wetland restoration	Wetland restoration	Management Significance - Aside from SAGA, few wetland restoration activities occur. Necessary measures will be captured under VS's.;	M	L
Stressor	Acidic deposition & stress	Acidic deposition & stress	Feasibility - Utilize existing data and make it available to parks.;	H	
	Beaver engineering	Beaver engineering	Assess extent of beaver activity with remote sensing Management Significance - Question whether beaver activity is true stress, or just inconsistent with ongoing park management; Beaver activity should be a measure included in landscape monitoring.	H	L
	Contamination, Heavy metal contamination, Herbicide/ pesticide use	Contamination	Management Significance - Lot's of potential measures. Network must work with experts to identify priority contaminants and biologic responses that should be monitored. Feasibility - This Vital Sign comes with a range of measures and a range of costs and could quickly become too expensive.	M	H
	Dark night sky	Dark night sky	Management Significance - Park centered issue	L	L
	Feral animals/free-ranging pets	Feral animals/free-ranging pets	Feasibility - May be serious logistical problem; Ecological Relevance - Significant question that may be best administered on a park level.	M	L
	Fertilizer use, Septic systems/Wastewater Discharge	Nutrient Enrichment	Measuring nutrient concentrations in wetlands is too variable, may not be directly related to sources, and is expensive. However, because nutrient enrichment is a major stressor to park wetlands the network should monitor changes in the potential sources of inputs (i.e.	M	H

Category	Original Vital Sign	Workgroup Vital Sign	Justification	Initial Rank	Workgroup Rank
			septic systems, fertilizer use, residential density in park buffer)		
	Hunting	Hunting	Ecological Relevance - Few if any game fish. Hunting is not permitted in parks, not relevant to wetland systems.	M	L
	Hydrologic alteration	Hydrologic alteration	Ecological Relevance - captured by other Vital Signs elements	M	L
	Invasive exotic species	Invasive exotic species	Management Significance - Serious management, and ecological concern, high priority for all network parks; Network should focus on early detection of new invasives in wetlands.	H	H
	Noise	Noise	Management Significance - Not an I&M monitoring issue, though a potentially significant ecological issue because high noise levels can disrupt wildlife communication systems; may be appropriate to consider establishing baseline sound levels in wetlands.	L	L
	Ozone	Ozone	defer to experts in terrestrial and aquatic workgroups for guidance on future monitoring	M	M
	Roads	Roads	Captured in landuse/landcover Vital Sign measures. Does not need to be its own Vital Sign.	H	L
	UVB	UVB	Management Significance and Ecological Relevance- Some uncertainty and lack of understanding specific to wetland impacts. Also being measured regionally	M	M
	White tailed deer herbivory	White tailed deer herbivory	Not a major stressor specific to wetland condition.	H	L

Table 6. Mandatory and optional measures for high priority Vital Signs recommended by the wetland workgroup

Category	***Workgroup Vital Sign***	***Mandatory Measures***	***Optional Measures***
Climate	Basic climate	relative humidity, precipitation by type, snow water equivalent, snow depth, temperature, wind speed and direction, solar radiation	
Hydrology/ Geomorphology	Hydrology	Water duration, water depth	
Abiotic condition	Water Chemistry	conductivity, pH, Temperature	
Biotic condition	Species composition - fauna	abundance by indicator species	
	Species composition - flora	Presence/absence, Percent cover by species, Stem Density	
Landscape context	Landuse/ Landcover	basic change detection metrics, wetland buffer condition (100 and 500 m), canopy cover for vernal pools, local permitting, road network changes, beaver activity	
Stressor	Acidic deposition & stress	Obtain and synthesize NADP data from existing ongoing monitoring programs	
	Contamination	concentration of relevant compounds in the environment and appropriate indicator taxa. Network must work with contaminants experts to determine what compounds and what taxa to monitor.	
	Nutrient Enrichment	Residential Density within buffer, nearby septic permits, amount fertilizer used within and nearby park	
	Invasive exotic species	conduct walk-through inspections for early detection, monitor regional invasive species network	

Intertidal Breakout Session

Overview of Vital Signs

High priority Vital Signs

1. Climate

The workgroup thought that acquiring basic climate data was important for any long-term monitoring program because these data provide are critical to understanding and interpreting intertidal zone species changes. Typical climate measures, such as air temperature, wind speed and direction, and precipitation (measured for rain and snow) are important. Snow/ice depth within the intertidal zone would be a particularly valuable measure as there is evidence that this may have a significant effect of controlling the species composition and abundance in the intertidal zone.

The workgroup noted that many well-documented data sources exist and that it would be desirable to make that information available to park managers, though these data may not directly drive management actions.

2. Natural Disturbance Regime

Storms and important natural events that shape the intertidal zone through physical movement/transport of intertidal substrate and associated biota. Measures of the frequency and duration of storm events is required. These data are readily available from the above-mentioned climate measures. Wave energy or wave climate is directly coupled to storms and is a good natural disturbance regime measure for the intertidal zone. The location of offshore wave gages (usually deployed by NOAA) in relation to ACAD and BOHA should be investigated.

Measuring the duration of ice cover within the intertidal zone, as well as depth of ice cover, represent important signs of natural disturbance. See above comments on climate.

3. Substrate Composition

This vital sign is an important indicator of biotic change. Bedrock substrates and very large boulder substrates are not likely to change significantly over-time, but cobble, gravel, sand and mud substrates of the intertidal zone are subject to change seasonally, especially in response to storm events. Substrate composition may shift gradually over time, or episodically from one composition to another. Removal of smooth rocks from cobble beaches by visitors is a frequent occurrence, but the impact on substrate composition is unkown.

4. Water Chemistry

Information from basic water chemistry measures can be directly related to changes in distribution of flora and fauna, and may be correlated with other intertidal vital signs. Having basic water quality information helps to establish relationships between physical and biological processes, and gives support to management actions. For these reasons, the workgroup thought it was necessary to obtain basic water chemistry measures in the intertidal zone and nearshore subtidal zone, including water temperature, conductivity/salinity, water clarity. Water clarity can be simply measured by the secchi disk method or by using a submersible light meter. The workgroup indicated that water quality measures are well documented and useful for long-term measurements.

5. Community Type

Having a well-documented map of intertidal substrate types and biotic assemblages is critical to understanding current conditions, monitoring long-term changes, and may be an important resource for the formulation of an intertidal zone quantitative (e.g., quadrat or transect) monitoring program. Recent substrate and biotic assemblage maps are available for 21 of the 34 BOHA islands.

6. Species Composition – Fauna

Knowledge of faunal species richness, species abundance, and distribution is critical to an intertidal monitoring program. Such assessements must be done for the diversity of intertidal habitats (e.g., rock substrate, cobble beaches, mudflats, others). The workgroup expressed concern about the high spatial and temporal variability associated with sampling intertidal fauna.   Some baseline data exists for Boston Harbor Islands which may help in assessing variability and in selecting indicator species, but little exists for Acadia National Park. The workgroup discussed the difficulty of identifying indicator faunal groups for specific intertidal types. There was disagreement over the most appropriate method, though no methods were considered "rapid." Despite these concerns, this is a high priority vital sign. The concept of seasonality may also be important to consider and incorporate into the monitoring design for intertidal fauna (e.g., time of larval set for blue mussel or barnacle). Monitoring of select faunal species may be particularly useful in documenting the impact of visitor trampling (e.g., stature of barnacles).

7. Species Composition – Flora

Knowledge of macro-algal species richness, abundance, and distribution is critical to an intertidal monitoring program. This may be an especially important indicator of trampling by park visitors. Determining and monitoring the algal species composition within the intertidal zone is not a simple task, but should prove easier than for intertidal fauna.

8. Harvesting

Resource harvesting is often focused on intertidal zone habitats. Shellfish and bait worms are harvested from soft-bottom mud and sand flats throughout the both ACAD and BOHA. Rockweed and knotted wrack (Fucus and Ascophyllum) are harvested primarily for lobster packing. Commercial harvest of sea cucumbers, lobsters, sea urchins, and others are harvested from subtidal zones, often immediately adjacent to the intertidal. As part of an intertidal monitoring program, ACAD and BOHA should access existing data from regulatory agencies (e.g., state agencies, town shellfish wardens, fishing permits issued, etc.) on harvesting activity and intensity.

9. Visitor Use

The intertidal zone, especially the rocky intertidal, is a frequently visited habitat and often the focus of park-led interpretive tours at both ACAD and BOHA. Trampling and removal of resources can be significant. In order to understand why the biotic components of the intertidal zone are changing, it is important to monitor visitor use, and more specifically, intensity of visitors, location of visitor use, and activities of visitors (e.g., walking, resource removal). Trampling and other visitor use impacts are likely localized to areas with available parking (e.g., at ACAD) or ferry access (at BOHA). In the soft-bottom intertidal habitats, recreational or non-commercial shellfishing occurs. The parks may have existing visitor monitoring data available.

10. Invasive Exotic Species

Non-native and invasive species have assumed dominant roles in defining the species composition and structure of intertidal habitats throughout New England. A recent inventory of the BOHA intertidal zone found that over 20% of the species (animals and plants) present are classified as non-native. Monitoring of faunal and floral species composition and abundance (see above) will serve to evaluate the status and change in the status of non-native species.

11. Shoreline Erosion / Sea Level Rise

Sea level is an important physical process that controls the distribution and spatial pattern of intertidal habitats. As sea level rises, the boundary of intertidal habitat types will shift. Sea level is presently rising at a rate of about 2-4 mm/yr along the New England coastline and is predicted to accelerate in response to global warming. Sea level is presently measured by NOAA tide gauges in Boston and Bar Harbor.

Shoreline erosion results in the movement of intertidal sediments and change in biotic communities. Storm wave energy is an important factor inducing shoreline erosion. Boat wakes can reportedly be a significant human-induced process that can increase shoreline erosion. A study to evaluate the impact of boat wakes on shoreline geomorphological processes at BOHA is presently underway.

Shoreline types should be monitored. This may be best accomplished by the substrate-type mapping identified in the "substrate type" high priority vital sign.

Table 7. Summary of Intertidal Workgroup vital signs, rankings, and workgroup justification

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
Climate	Basic climate	Climate	Response Variability - All criteria apply; Management Significance - These core parameters not directly linked to management actions; Feasibility - Many well-documented baseline data sources available; Ecological Relevance - Useful information to interpret species responses.	M	H

Category	*Original Vital Sign*	*Workgroup Vital Sign*	*Justification*	*Initial Rank*	*Workgroup Rank*
Disturbance	Natural disturbance regime	Natural disturbance regime	Response Variability - All criteria apply; Management Significance - No direct relationship to management; Feasibility - Documented in literature/by other VS monitoring. Analysis needed; Ecological Relevance - Useful information to interpret species responses.	L	H
Hydrology/ Geomorphology	Tidal Patterns	Tidal Patterns	Management Significance - Not directly related to management issues but important to understanding biotic changes; Feasibility - Data may be available from other sources;	M	M
	Substrate composition	Substrate composition	Management Significance - Not directly related to management issues but important to understanding biotic changes. Cobble beaches subject to change due to theft/storms; Ecological Relevance - Mud flats substrate can change seasonally and long-term.	M	H
Abiotic condition	Core water chemistry	Water chemistry	Response Variability - Well documented methods. Useful for long-term measurements; Management Significance - These core parameters not directly linked to management actions; Feasibility - Inexpensive, easy to implement. Low impact to resources; Ecological Relevance - Useful for understanding changes in distribution of flora & fauna.	M	H

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
Biotic condition	Focal Taxa - Additional		Response Variability - Temp & spatial variability less than multiple taxa studies; Management Significance - All criteria apply; Feasibility - Can decrease the variability in sampling design, less costly, easy to find specialists to conduct studies. May need to identify multiple focal taxa.; Ecological Relevance - All criteria apply.;	M	M
		Community Type	Ecological Relevance - Important for tracking long-term, large scale changes.;		H
	Species composition - fauna	Species composition - fauna	Response Variability - High spatial and temporal variability; Management Significance - All ranking criteria; Feasibility - Numerous well-documented methods and considerable disagreement! No methods considered "rapid". Good baseline data for BOHA, very little for ACAD; Ecological Relevance - All ranking criteria;	H	H
	Species composition - flora	Species composition - flora	Response Variability - High temporal & spatial variability; Management Significance - Same as "fauna". Also indicator of trampling; Feasibility - Easier to assess species composition of macroalgae & other higher plants since they are sessile; Ecological Relevance - Same as "fauna".	H	H

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
	Species of concern	Species of concern	Response Variability - Same as Focal Taxa.; Management Significance - Some species (harlequin, black ducks, wading birds, purple sandpipers) of management concern; Feasibility - Same as Focal Taxa. No species of concerns obvious indicators in these areas; Ecological Relevance - Some species (harlequin, black ducks, wading birds, purple sandpipers) of ecological concern.	L	L
	Vegetation Condition	Vegetation Condition	Feasibility - Can be accomplished concurrently with other qualitative monitoring (redundant with species composition).	H	L
Ecological process	Nutrient cycling	Nutrient cycling	Response Variability - High spatial variability; Management Significance - Tightly coupled to the nutrient enrichment issue, esp.in mudflats. May increase in significance in future; Feasibility - Difficult to quantify in this environment. BOHA has extensive water quality data - other existing programs may supply additional info; Ecological Relevance - Not highly important in rocky intertidal, perhaps more in mudflat sediments. More applicable in basins with low flushing rates. Are better indicators.	M	M

Category	Original Vital Sign	Workgroup Vital Sign	Justification	Initial Rank	Workgroup Rank
	Phenology	Phenology	Response Variability - Medum variability. May not be able to predict "health of park; Management Significance - Very important with respect to climate change issues. Perhaps not valuable sign for NPS local management issues. May affect national policy; Ecological Relevance - Patterns do exist related to species life history as related seasonal changes.	M	M
	Productivity	Productivity	Response Variability - High spatial & temporability; Management Significance - Not redundant; Feasibility - Determining density of grazers could be accomplished by either focal taxa or species composition monitorng. Analysis if this information needed; Ecological Relevance - Larger issue than just "predator compostion". Grazers and predators such as sea stars have high impacts on intertidal species.	M	M
	Trophic dynamics	Trophic dynamics	Response Variability - High spatial & temporability; Management Significance - Not redundant; Feasibility - Determining density of grazers could be accomplished by either focal taxa or species composition monitorng. Analysis if this information needed.; Ecological Relevance - Larger issue than just "predator compostion". Grazers and predators such as sea stars have high impacts on intertidal species.;	M	M

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
Focal park resource	Breeding Birds	Breeding Birds	Feasibility - Information will hopefully be captured by other workgroup monitoring efforts; Ecological Relevance - Resting and feeding migratory birds more important than breeding birds as indicators.;	M	L
		Migratory Birds	Response Variability - High variability; Management Significance - Areas can be managed to reduce human disturbance. Strong constituency among park visitors.; Feasibility - All criteria apply; Ecological Relevance - All criteria apply;		M
	Harbor Seals	Harbor Seals	Management Significance - Could limit human impacts if visitor use increases in future; Ecological Relevance - Not that many, only around in winter.;	L	L
	Mandated Species	Mandated Species	Management Significance - Parks usually have management plan (including monitoring component) for mandated species; Ecological Relevance - No known mandated species exclusive to intertidal. Bald eagle utilize intertidal, Common tern at BOHA.;	M	L
	Viewshed	Viewshed	Management Significance - In ACAD enabling legislation;	L	L
Landscape context	Landcover	Landcover	Ecological Relevance - Movement between systems and recruitment patterns occur differently than in terrestrial systems.;	M	L
	Landscape buffer	Landscape buffer	Ecological Relevance - Landscape buffer issues related to human development are important t mudflats. Most not relevant to rocky shores,;	H	M
	Landuse	Landuse	Management Significance - Tightly coupled to nutrient enrichment issues, which are important to mudflats.;	H	M

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
	Park boundary	Park boundary		M	L
Management	Park infrastructure	Park infrastructure	Management Significance - Increasing visitor use and new/rebuilt facilities at BOHA. Charley says: this is stupid- this is not a Vital Sign.; Feasibility - Sin;	M	L
		Harvesting	Management Significance - Highly relevant due to commercial and recreational in both rocky intertidal & mudflats. Want to understand what harvest levels are; Feasibility - Data may be available from external sources; Ecological Relevance - Major disturbance issue relative to trophic dynamics.;		H
	Trail network	Trail network	Management Significance - This is related to visitor use.	M	M
	Visitor use	Visitor use	Management Significance - This is related to trampling, and resource taking/damage. Usually localized to designated visitor use areas and should be able to be controlled by education, etc.; Feasibility - Visitor use should be monitored in the intertidal zone. Fishing/shellfishing permits should be quantified. VS should analyze, not collect this information;	M	H
Stressor	Acidic deposition & stress	Atmospheric deposition	Ecological Relevance - N/A Seawater is well buffered!	H	L

Category	***Original Vital Sign***	***Workgroup Vital Sign***	***Justification***	***Initial Rank***	***Workgroup Rank***
	Contamination	Inventory-Contamination	Management Significance - Oil and contaminant spills are a major concern,; Feasibility - Other prescribed monitoring activities will provide baseline information in the event of resource damage. Should be high priority for INVENTORY; Ecological Relevance - Baseline inventory of sediment hydrocarbon levels useful for damage assessment.	M	L
	Dark Night Sky	Dark Night Sky	Management Significance - N/A for this system;	L	L
	Fertilizer use	Fertilizer use	Feasibility - Easy way of quantifying nutrient enrichment. More useful if linked to aquatic or other workgroups; Ecological Relevance - Amount of fertilizer use may be relevant for mudflats.	M	M
	Heavy metal contamination	Heavy metal contamination	Ecological Relevance - Same issues as CONTAMINATION	M	L
	Herbicide/pesticide use	Herbicide/pesticide use	Feasibility - May want to inventory in tidal mudflats; Ecological Relevance - Watershed issues that tie into mudflats. Dilution too great in intertidal.;	M	L
	Hydrologic alteration	Hydrologic alteration	Management Significance - Site specific management concern.	M	L
	Invasive exotic species	Invasive exotic species	Ecological Relevance - Large potential for alteration of species distribution and abundance.	H	H
	Noise	Noise		L	L
	Roads	Roads	Ecological Relevance - Low-priority research issue to investigate the effects of deicing material on intertidal.	H	L
	Septic systems/Waste water Discharge	Septic systems/ Wastewater Discharge	Management Significance - Should be aware of discharge issues; Feasibility - Most information obtained from associated monitoring efforts.	M	M

Category	Original Vital Sign	Workgroup Vital Sign	Justification	Initial Rank	Workgroup Rank
	Shoreline erosion/sea level rise	Shoreline erosion/sea level rise	Management Significance - High issue with boat wakes in BOHA.; Feasibility - Info on sea level rise available from other sources.; Ecological Relevance - More prevalent in BOHA due to softer sediments.	H	H
	UVB	UVB	Ecological Relevance - N/A to intertidal;	M	L

Table 8. Mandatory and optional measures for high priority Vital Signs recommended by the intertidal workgroup

Category	Workgroup Vital Sign	Mandatory Measures	Optional Measures
Climate	Climate	Temperature, precipitation by type, wind speed and direction	relative humidity, snow depth
Disturbance	Natural disturbance regime		
Hydrology/ Geomorphology	Substrate composition	Substrate composition	redox potential
Abiotic condition	Water chemistry	Temperature, conductivity, secchi disk	pH
Biotic condition	Community Type	Substrate and biotic assemblage mapping	
	Species composition - fauna	Species richness, species abundance, and species distribution	seasonality
	Species composition - flora	Species richness, species abundance, and species distribution	seasonality
Management	Harvesting	Analysis of other data sources	
	Visitor use	Number of visitors by location & activity, number fishing/shellfishing permits, trampling disturbance impacts	number boats, wildlife disturbance impacts??
Stressor	Invasive exotic species	Species richness, species abundance, and species distribution	
	Shoreline erosion/sea level rise	Relative surface elevation, shoreline change	

Overall Workshop Summary

Northeast Temperate Network High Priority Vital Signs

The core planning team identified and ranked seventy-six potential Vital Signs in 8 categories and 4 workgroups prior to the workshop. After the workshop participants reviewed and revised the proposed list of Vital Signs, twenty-seven (27) were identified by at least one (1) workgroup as high priority for NETN (Table 9). These Vital Signs represent an integrated list of ecological processes, biotic and abiotic conditions, and stressors to park ecosystems, and are directly relevant to the natural resource management issues of a majority of NETN parks (Table 9). Nineteen of the twenty-seven Vital Signs (70%) apply to nine (9) or more network parks, creating a framework to design a standardized, comprehensive monitoring program where protocols can be designed and implemented within the majority of network parks. The exceptions to a comprehensive, network-wide monitoring program occur with the intertidal and lake ecological systems where these resources add system specific Vital Signs that are not readily transferable to parks without lakes and intertidal communities (i.e. intertidal substrate composition, sea-level rise, lake morphometry, and zooplankton community).

All four workgroups identified climate, species composition flora/fauna, and invasive exotic species as high priority Vital Signs, but 59% (16/27) of high priority Vital Signs were identified by 1 workgroup (Table 9). Three workgroups identified water chemistry, landcover/landuse, atmospheric deposition, and contamination as high priority Vital Signs and two workgroups identified hydrology, visitor impacts, and nutrient enrichment.

Using the list of twenty-seven Vital Signs, NETN staff and the core planning team, will begin to build a comprehensive ecological monitoring plan intended to provide an integrated program that addresses significant issues to NETN park natural resources. The results of this workshop and recommendations solicited from biogeochemists and contaminants experts, will be presented to the NETN Board of Directors, park staff, and the Technical Steering Committee at a meeting this August. A draft of the NETN Phase 2 report, including a chapter describing the prioritization and justification of selected Vital Signs, will be submitted to the National I&M program and available for review 1 October 2004.

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The NETN core planning team warmly acknowledges all workshop participants for taking the time out of already over committed schedules to assist the National Park Service with this important effort. The results of this workshop provide the foundation, direction, and justification for the development and implementation of a long-term ecological monitoring program throughout NETN parks and will provide the necessary information to better manage park natural resources. We would also like to thank the Acadia NP and Schoodic Education Research Center staff for their participation, logistical support, and assistance with workshop preparation.

Table 9. High priority Vital Signs for Northeast Temperate Network Parks based on the prioritization by Vital Signs Selection Workshop, the number of workgroups (#WG's) that rated each Vital Sign as a high priority, and the parks where each Vital Sign applies to natural resource management decision making.

Category	High Priority Vital Signs	# WG's	ACAD	APPA	BOHA	MABI	MIMA	MORR	ROVA	SAGA	SAIR	SARA	WEFA
Climate	Climate	4	X	X	X	X	X	X	X	X	X	X	X
Disturbance	Natural Disturbance Regime	1	X	X	X	X	X	X	X	X	X	X	X
Hydrology/ Geomorphology	Hydrology	2	X	X	X	X	X	X	X	X	X	X	X
	Intertidal Substrate Composition	1	X		X								
Abiotic condition	Stream morphology	1	X	X		X	X	X	X	X	X	X	
	Lake morphometry	1	X			X							X
	Spring/seep distribution	1	X	X	X	X	X	X	X	X	X	X	X
	Water chemistry	3	X	X	X	X	X	X	X	X	X	X	
Biotic condition	Fish community composition	1	X	X		X	X	X	X	X	X	X	X
	Intertidal Community Type	1	X		X								
	Zooplankton community – Lakes	1	X			X							X
	Species Composition – fauna	4	X	X	X	X	X	X	X	X	X	X	X
	Species Composition – flora	4	X	X	X	X	X	X	X	X	X	X	X
	Water quality - trophic status	1	X			X							X
	Macroinvertebrate community comp.	1	X	X	X	X	X	X	X	X	X	X	X
	Vegetation Community Structure and demography	1	X	X	X	X	X	X	X	X	X	X	X
	Focal Taxa – Forest Breeding Birds	1	X	X		X	X	X	X	X		X	X
Landscape context	Landcover/ Landuse	3	X	X	X	X	X	X	X	X	X	X	X
Management	Visitor Impacts	2	X	X	X	X	X	X	X	X	X	X	X
	Harvesting	1	X		X	X							
Stressor	Atmospheric deposition	3	X	X	X	X	X	X	X	X	X	X	X
	Contamination	3	X	X	X	X	X	X	X	X	X	X	X
	Invasive exotic species	4	X	X	X	X	X	X	X	X	X	X	X
	Shoreline Erosion/sea level rise	1	X		X								
	Ozone	1	X	X	X	X	X	X	X	X	X	X	X
	White-tailed Deer Herbivory	1	X	X		X	X	X	X	X	X	X	X
	Nutrient Enrichment	2	X	X	X	X	X	X	X	X	X	X	X

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