

Center for State of the Parks®

Natural Resources Assessment and Ratings Methodology

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INTRODUCTION

More than a century ago, Congress established Yellowstone as the world's first national park. That single act was the beginning of a remarkable and ongoing effort to protect this nation's natural, historical, and cultural heritage.

Today, Americans are learning that national park designation alone cannot provide full resource protection. Many parks are compromised by development of adjacent lands, air and water pollution, habitat fragmentation and insufficient funding. Park officials often lack adequate information on the status of and trends in conditions of critical resources.

The goal of the National Parks Conservation Association's Center for State of the Parks® (NPCA-CSOTP) is to provide accurate and timely information on natural and cultural resource conditions, as well as stewardship capacity, in our national parks. This information will help to sustain and/or improve conditions in the parks and ensure a lasting legacy for future generations. Center for State of the Parks®, through resource evaluations and the subsequent publication of park-unit and special reports intends to foster awareness of park resource conditions among our membership, the general public, the National Park Service (NPS), park advocacy groups, and policy-makers.

In support of our goal, we have developed a natural resource assessment methodology that integrates a broad range of information about the ecological and anthropogenic conditions affecting natural resources in national parks. This document describes our methodology and its elements, and the process we use to examine and rate natural resource conditions within national parks.

Our principal task is to evaluate the integrity of natural systems within the parks with special emphasis on biological integrity. To date, no rapid, affordable, comprehensive and authoritative protocol for evaluating and rating natural resource conditions and/or ecosystem health is in widespread, generally accepted use. However, *The State of the Nations Ecosystems* (The Heinz Center 2002) has enjoyed some success as the first holistic attempt to solidify our understanding (and the lack thereof) of the health of America's ecosystems. Many of the conceptual features applied in the Heinz Center's assessment have been adopted and utilized in our methodology. Further, a number of resource examination protocols, more focused on conservation planning and management effectiveness than on resource condition assessment, are existent (Hockings et al. 2000, The Nature Conservancy, 2000, Dinerstein et al. 2000). These works have been reviewed and have also been variously utilized in the development of our assessment methodology. Since our methodology was established, NPS has conducted a number of Coastal Watershed Assessments, which evaluate aquatic resources at parks on the nation's coasts and in the Great Lakes region. Currently, NPS is piloting the Watershed Condition Assessment Program, which incorporates both aquatic and terrestrial components of a park into the assessment and focuses on Vital Signs and other features identified by NPS Inventory and Monitoring Networks. No single assessment process has yet been settled on for this program.

Although the conservation-oriented management of natural resources toward long-term biological integrity is often beyond immediate human control, the NPS has nonetheless been charged with the mission to provide the American people with "the opportunity to enjoy and benefit from natural environments evolving through natural processes minimally influenced by human actions." (National Park Service 1988). The real challenge this mission represents for the NPS is to sustain the integrity of park

ecosystems while providing access and services to the public. Meeting this challenge necessitates NPS engagement in natural resources management that accommodates the human element to the extent that principal ecosystem attributes (structure, composition and function) are not compromised. Effective natural resource or ecosystem management is information-based and the informed development and implementation of underlying management plans pre-supposes an understanding of ecosystem attributes and their condition. To address natural resource information needs and guide management, the NPS has developed Natural Resource Management Policies (National Park Service 2001) which dictate the collection and analysis of data in the areas of inventory and monitoring, threat mitigation, and research. Our assessments rely heavily on the resultant data.

The development of our assessment and ratings methodology has entailed determining what specific types of resource information are generally available and most critical to understanding resource condition (assessment criteria) and then organizing the information into a suite of discrete and ratable supporting elements. The assessment criteria, their organization in our assessment scheme and their utilization in the evaluation of natural resource conditions in our national parks, are described herein.

THE PARK ASSESSMENT CHALLENGE

The NPCA-SOTP assessment methodology is based on an understanding of the working mission of the National Park Service as regards natural resources protection. The NPS is engaged in conservation-oriented ecosystem management that accommodates the visitor experience while preserving the ecological integrity of the parks. Recognizing the arguable disparity in application of the term “ecological integrity” (Wicklum and Davies 1995), we maintain that when properly defined it has solid conceptual merit. Grumbine (1994) identified from his review of ecosystem management literature, five requirements or goals for sustained ecological integrity. These are:

- Maintain viable populations of all native species in situ.
- Represent, within protected areas, all native ecosystem types across their natural range of variation.
- Maintain evolutionary and ecological processes (i.e. disturbance regimes, hydrological processes, nutrient cycles etc.).
- Manage over periods of time long enough to maintain the evolutionary potential of species and ecosystems.
- Accommodate human use and occupancy within these constraints.

The principal challenge to development of our park assessment methodology was to create an inclusive set of ratable criteria that were responsive to these fundamental goals and for which data are generally available. This challenge is far from trivial because the performance of a fully integrated ecological assessment that is wholly inclusive of these goals implies, for our purposes and resources, a prohibitively comprehensive suite of informational needs. The data requirements necessary to fully address the underlying questions of ecological integrity as directly measured by (and influenced by) a park ecosystem’s full compliment of attributes (populations, patterns,

processes, interactions, diversity, structure and function) as well as by climatic, environmental and anthropogenic factors are formidable, especially where both temporal and spatial data are needed. Not only is the collection of all such relevant data and its subsequent analysis and interpretation daunting, for even a single park ecosystem, but it also pre-supposes that the dynamics of ecosystems, their hierarchical structure, and scale dependencies are all well understood. What is understood about ecosystems and what further modifies our interpretation of ecological integrity and assessment information needs has been synthesized (Jensen et al. 2001) from Haynes et al. (1996) as the following four principles:

- Ecosystems are dynamic, evolutionary, and resilient.
- Ecosystems can be viewed spatially and temporally within organization levels.
- Ecosystems have biophysical, economic and social limits.
- Ecosystem patterns and processes are not completely predictable.

Our NPCA-CSOTP assessments are intended to be sensitive to the principles noted above (Grumbine 1994) but are restricted by time, economics and technology to currently available data. Further, our interpretation of ecological integrity from available assessment information cannot over-step the bounds of our understanding as regards the nature and properties of ecosystems. Current scientific understanding is greatest at lower levels of biological complexity (Silsbee and Peterson 1991), which also reflects the source-levels of the bulk of ecological data available for our assessments. In largest part, the data available for our assessments were also not collected in the context of a pre-organized, holistic ecological assessment plan but rather are associated with NPS inventory and monitoring programs, applied mitigation studies and hosted research that may or may not have useful application to our assessment work.

Our approach then, was to establish a methodological framework that addresses and interprets ecosystem integrity more indirectly via the analysis of impacts, stressors and mitigation efforts on defined ecosystem attributes. This approach is in contrast to a planned attempt to directly measure and interpret changes in higher-order ecosystem attributes themselves. Our underlying assumption and justification for this approach is that aside from catastrophic events, the impacts and stressors that influence or diminish ecological integrity are primarily human in origin and that independent of human influence ecosystems will self-regulate, evolve and change, ultimately maintaining ecological integrity as a consequence of their nature.

Natural resource assessment is an inherently difficult task because natural systems feature organisms (most often complex assemblages of organisms) interacting with each other and with their environment via dynamic processes that vary over time. These are often affected by a myriad of human activities operating both within and outside park boundaries.

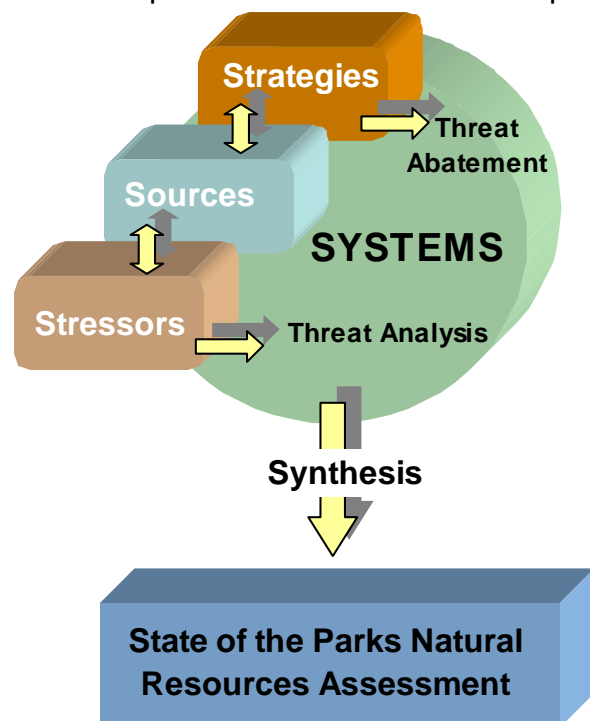
The NPCA-CSOTP natural resource assessment methodology seeks to document and evaluate the actual ecological, biological, chemical, and physical conditions of park natural resources. Our approach is to the extent possible and practicable, assemble and examine current scientific information on principal **ecosystem attributes**, **environmental conditions** and **biotic health measures** and use this information to provide a research documented overview of park natural resource conditions. Unfortunately, limitations in the availability or adequacy of data for these purposes exist and will often restrict our scientific understanding. The information

deficit generally stems from the expense associated with site-specific, long-term measurement of ecosystem attributes (most particularly processes) and/or the lack of technology or difficulty in determining a practical, affordable or direct approach for measurement. Further, the scientific community’s understanding of the nature of ecosystem organization and especially ecosystem change is itself changing and not complete. We must therefore ensure that our assessment results reflect both the limits of our information base and the limits of our ability to interpret change appropriately.

CONCEPTUAL MODEL

As a model for our approach we have adopted and modified The Nature Conservancy’s (TNC) “Five S’s” planning approach originally developed for their “bioreserve” initiative, and later adapted for their site conservation planning program (The Nature Conservancy 2000). This model has been successfully tested and refined through application by TNC on actual landscape-scale projects and is particularly attractive to us because it integrates understanding of both the natural environment and the human context that affects the targeted system (in our case, national parks). Another appealing aspect of the modified TNC framework is that the overall assessment relies in part on indirect measures of ecosystem integrity as based on observations of ecological stressors and mitigating strategies. This adds a valuable dimension to our assessments because we cannot always directly measure or even know how to directly measure and interpret, ecological stress or change, especially where its influences are subtle in a temporal sense. We have adapted the overall “Five S’s” conceptual model, modified some of the definitions, and have developed a different method for implementation. The relationship of the five S’s to one another and toward the production of the State of the Parks assessment is idealized below as Figure 1. The five S’s as defined here are:

- **Systems:** Specifically, ecosystem(s) comprised of the biological components (e.g., communities, species, organisms) that reflect the biodiversity at the park and their relationships to each other and their physical environment (air, waters, soils, climate). This is intended to be a description and definition of the park natural resources at the landscape and watershed level.
- **Stressors:** The types, magnitude and durations of degradation and impairment affecting the biological components at the park. These are measured as direct effects (e.g., chemical, biological, physical or behavioral) on the biological components where such data are available or inferred from the scientific literature where persuasive



and defensible supporting evidence exists.

- **Sources:** The agents generating the stresses. These are usually human activities (e.g., recreation, poaching, construction) or the more indirect result of human activities (e.g., air pollution, climate change) but may also be the result of natural disturbance regimes (fires, flood, drought etc.). However, unlike anthropogenic-related stresses, those arising from natural disturbance regimes are considered here to support an ecological process important to the regulation and succession dynamics of ecosystems.
- **Strategies:** Management plans and the types of actions used to abate sources of stress (threat abatement or mitigation) and persistent stresses (reclamation or restoration). Such actions may themselves represent stresses (e.g., control of exotic or aggressive species via use of xenobiotic substances).
- **Synthesis:** The process by which the influences of stressors, sources and strategies on the defined and characterized system are assessed. This process is driven by evaluation of the assessment criteria and is the basis for the ratings and the foundation for recommendations development.

FIGURE 1:
NPCA-CSOTP ASSESSMENT MODEL
As adapted from TNC “Five S’s”
Conceptual Model

Key to employing this model is the definition of the systems, stressors and strategies that will be evaluated. Because each park is unique these definitions must be framed within the context of the park-specific physical setting and its origins and current adjacent land uses as well as with an understanding of individual park resources and land-use history. Our first task then is to provide a contextual overview of the park, which describes the geologic, topographic, phyto-edaphic, climatic, hydrologic and historical setting.

The contextual overview provides the foundation for our **systems** definition. In our case, the systems are ecosystems and we begin by organizing the park ecosystem(s) into the broad terrestrial, freshwater, and marine communities that may exist. We define each of these communities by eco-region and major habitat type because the principle types of ecological communities reflect the habitat necessary to support native biodiversity (Ricketts et al. 1999, Abell et al. 2000). These major habitat type(s) within a park will often represent a range of spatial scales (Ricketts et al. 1999, Abell et al. 2000).

A species inventory is another important component of our ecosystem characterization. It is instrumental in helping to assess total and native biodiversity as well as identify, where relevant, keystone or particularly important representative or indicator species. The species inventory also includes categories of rare, threatened and endangered species, and also non-native, exotic and/or aggressive species. Certified NPSpecies lists compiled by NPS Inventory and Monitoring Networks are accessed when possible. Otherwise, lists compiled by park staff or their affiliates are collected. Unfortunately, park species lists and inventories are often incomplete as regards invertebrates, non-vascular plants and micro-biota. They also often do not

report data beyond presence/absence; species of management concern may be an exception to this.

The maintenance of biological integrity within our national parks is contingent upon preserving essential ecosystem attributes and ensuring low exposure to ecological **stressors** (Suter 1993, Gerritsen et al. 1998, The Nature Conservancy 2000). We will attempt to compile and evaluate all available and relevant data on ecosystem attributes and environmental quality in order to analyze (both directly and indirectly) the effects of ecological stressors, which are chemical, physical, or biological in nature, upon natural resource condition and most specifically on biological integrity in the parks. In general, information exists on types of agents or **sources** of ecosystem(s) stresses (e.g., power plants, wastewater treatment plants, fire regime, climate). Data on source outputs (e.g. volume of pesticides used on adjacent lands, constituents in wastewater treatment plant spills) or on changes in agents of stress (# of fires/year historically vs. presently, water diversions with development) as well as on the actual measured condition of ecosystem components or processes are often less readily available. When acute or chronic ecological stress occurs, we may be able to directly assess its impact on an ecosystem (e.g., habitat destruction, species loss). In other cases, we may need to infer potential effects based upon similar occurrences documented elsewhere (e.g., effects of toxins in surface water samples on biological systems). Examining the extent, severity, frequency, and irreversibility of damage that a given stress may have on ecosystem attributes provides a more indirect way to assess resource condition and is featured in our methodology. In some cases, we may be able to link the ecological stressors to their sources. In this event, relevant information will also be reported and may be used to develop specific recommendations to guide the formulation of management **strategies** for natural resource protection.

Although the intent of the Center for State of the Parks assessments are to evaluate natural resource condition and not NPS management performance, resource management often has a direct bearing on resource condition and must be included in a comprehensive analysis. Further, providing findings to inform effective management of park natural resources presupposes an understanding of features, which govern management. Our assessment will also summarize management plans as regards natural resource condition, stress abatement, control or mitigation. It is recognized however, that many ecological stressors and their sources originate and are resident outside park boundaries (e.g., power plant emissions) and are not under the control of the NPS and/or not addressed by park management. In addition, historical land uses prior to park establishment may have impacted and may even continue to impact natural resource conditions but are not attributable to park management.

The integration of park ecosystem definitions/descriptions with an understanding of the nature, extent, severity and longevity of ecosystem stressors as well as mitigation strategies and actions constitutes the **synthesis** aspect of our assessment. This synthesis, in practice, involves the independent and collective consideration of the descriptive features and assessment criteria (i.e., information requirements, presented below) and features a subjective (ratings) component.

INFORMATION REQUIREMENTS

Our assessments rely on two fundamental categories of information. One is intended to provide park background descriptions and establish the context for

evaluation (**Park and Resources Context**). The other (**Assessment Criteria**) is intended to provide data relevant to evaluating discrete ecological, environmental and biotic ratings elements. The information categories for the State of the Parks natural resource assessment are organized as Table 1 and provide not only the context and structural rationale for our evaluations, but also constitute the report outline for our technical natural resources assessment document.

Park and Resources Context

This non-rated informational category provides background and context for subsequent application of the assessment criteria upon which the resource condition ratings are based. It contains descriptors that help place a park into a broader physical, geographic and biological context in order to interpret and better evaluate the resident ecosystem(s). It is also intended to provide an understanding of bordering land-use practices as well as park-specific uses in effect prior to the establishment of a park, especially as regards their influences on present natural

TABLE 1.

INFORMATIONAL CATEGORIES AND REPORT OUTLINE FOR THE *State of the Parks- Natural Resource Assessments*

I. Park and Resources Context

- A. Bio-geographic and Physical Setting
 - i. Park Location, Size/Area
 - ii. Climatic Regime
 - iii. Geology and Land Forms
 - iv. Hydrologic Overview
 - v. Ecological and Habitat Classifications
- B. Regional and Historical Context
 - i. Land Use History
 - ii. Adjacent Land Use
- C. Unique Park Resources and Designations
 - i. Aesthetic Resources
 - ii. Unique Features
 - iii. Special Designations
- D. Park Science and Resource Management
 - i. Management Plans
 - ii. Research and Monitoring
 - iii. Education and Outreach

II. Assessment Criteria

- A. Ecosystem Measures

- i. Ecosystem Extent and Function
 - ii. Species Composition and Condition
- B. Environmental Quality and Biotic Health
 - i. Water Resources
 - ii. Air Quality
 - iii. Soils and Sediments
 - iv. Biotic Health

resource conditions. The description of aesthetic resources and unique land forms which are important and specific to the park and the visitor experience are also included in this informational category as are any special global or national status designations associated with the park by virtue of habitat importance, biodiversity or protected species. Finally under this category, the current status of Natural Resources management in the park, including a review of management documents is evaluated along with responsive programming in research and monitoring as well as education.

Bio-Geographic and Physical Setting

These descriptive elements (descriptors) give the park's purpose and position the park within the regional landscape, describe park size and dimensions, and convey the organization of current natural systems across the park. The first descriptor (**Park Location, Size/Area**) is used in part, to help ensure that the parks are evaluated at the appropriate ecological scales and provides information on activities on adjacent lands (i.e. urban areas, agriculture).

The **Geologic, Hydrologic** and **Climatic** features of the park are intended to give a general overview of the topography and underlying geology as well as the air shed and watershed patterns that may affect the park, and are included because soil types or flow patterns for example, affect pollutant transport, deposition, and residency in the park, impacting wildlife or vegetation.

Under the **Ecological and Habitat Classifications** descriptor, the park will be classified and described by ecoregion (Abell et al. 2000, Ricketts et al. 1999) This descriptor will also delineate appropriate communities [Terrestrial (using vegetation community associations, when available), Aquatic – Freshwater, Marine), cover types and/or major habitat types as relevant to the park assessment.

Regional and Historical Context

This section is broken down into two principal descriptors that convey general information about the park. **Land Use History**, will document important historical practices and events regarding prior land use within the park and how it may have altered previous or current resource conditions. Specifically, human activity prior to park protection may have significantly altered current habitat quality, so its lasting impact must be considered when evaluating current habitat condition (Van Driesche and Van Driesche, 2000, Redford and Richter 1999, Saunders et al. 1991). Any reduction in the spatial extent of the habitat, increased fragmentation, or reduced structural complexity may indicate ecosystem stress and contribute to loss of biodiversity in the park. In most

cases, this information will concentrate on the last 150-300 years (depending on park location) of European settlement. Information previous to European settlement is often sparse

Since park boundaries rarely follow ecosystem boundaries, ecosystem integrity and large-scale processes such as wildlife home range and migration often need to be maintained at a much larger scale than simply within the confines of park boundaries. Increased urbanization, land development and accompanying road construction isolate the park from other natural areas (e.g., National Forests) by disrupting the connectivity between these areas, and consequently interfering with the natural movement patterns of certain wildlife species. Because much of what occurs outside park boundaries can influence biological systems within park boundaries, the **Adjacent Land Use** descriptor characterizes the external natural setting, extent and types of adjacent and regional development and potential vectors for the transmission to the park of natural, invasive or anthropogenic agents and events. For example, adjacent agricultural activities may be the source of pesticides and fertilizers, or result in livestock grazing within park boundaries. Also, watershed features outside the park can impact park resources once affected water crosses park boundaries. Logging activities may cause erosion and thus lead to increased downstream sedimentation. Construction or land disturbance may provide opportunities for non-native or invasive species to establish with subsequent movement into a park. The **Adjacent Land Use** descriptor then, characterizes the type of existing or potential effects of various external land use practices on natural resources within the park and also describes the surrounding landscape setting of the park in terms of the degree and trends of urbanization or isolation from human development.

Unique Park Resources and Designations

This information grouping addresses park resources that are integral to the National Park Service's natural resource management goals of preserving "...topographic features, geologic features, paleontologic resources, and aesthetic values, such as scenic vistas, sound, and clear night skies." (National Park Service 1991). The first descriptor set (**Aesthetic Resources**) indicates the extent to which **Scenic Vistas, Sound, and Dark Night Skies** are expressed in the park and aims to capture any changes that may occur over time. The visitor experience can be diminished by reduced or impaired visibility from the presence of atmospheric particulates that scatter light or because of adjacent development. It can also be affected by the presence of industrial noise (e.g., traffic or airplane over-flights) or bright surrounding night-lights. The **Unique Features** descriptor set is more specific and only relevant for some parks, depending on the presence of features such as unique **Topographic, Geologic and/or Paleontologic Features** (e.g., canyons arches, hot springs, fossil beds), which continue to be shaped and altered by on-going natural processes (e.g., weathering), but also by human-induced changes (e.g., acid rain or poaching). The **Special Designations** descriptor relates the status or designation of the park in a broader context as ecologically or globally important (World Heritage Site, International Biosphere Reserve etc.) and also identifies the rare, threatened or endangered (RTE) status of park species and/or critical habitats.

Park Science and Resource Management

The **Management Plans** descriptor will convey relevant information about how park natural resources are currently managed by discussing sections in existent management plans that focus on natural resources planning, management, and directives. Park sponsored, hosted, or cooperative research programs and plans will be described along with monitoring activities (e.g., IMPROVE, Vital Signs, I&M participation) in the **Research and Monitoring** descriptor. Science interpretive programs, educational activities and outreach will be described in the **Education and Outreach** descriptor.

Assessment Criteria

The constraints of time, personnel, and money associated with our assessments, precludes our ability to collect new data or sponsor research. Our task then is to identify those ecosystem attributes, environmental features, and biotic stressors for which data are generally available and that give us the best indication of overall ecosystem functioning and biotic integrity (Suter 1990, Landres 1992, National Park Service 1992, Angermeier and Karr 1994, Gibson et al. 2000, National Research Council 2000, The Nature Conservancy 2000, National Park Service 2001). Realizing that at higher levels of ecological organization, system complexity increases and available data often decrease, our ability to assess all desired ecosystem attributes will be limited. Collectively, the ecosystem, environmental, and biotic measures (assessment criteria) chosen should be applied to the park's full array of communities and species, as well as capture expressions of essential ecological processes and species interactions that are necessary to sustain biological integrity (Suter 1990, Jameson et al. 1998, National Research Council 2000, The Nature Conservancy 2000, National Park Service 2001, Maryland Department of the Environment 2002). Our challenge is to select a limited but inclusive number of ratable criteria that provide a representation of overall ecosystem(s) condition.

Our selection process for the assessment criteria was guided by the views of some of the leading experts in ecosystem assessments regarding which ecosystem components and processes are most critical for long-term ecosystem sustainability (Odum 1985, Suter 1990, Silsbee and Peterson 1991, Landres 1992, Suter 1993, Angermeier and Karr 1994, Christensen et al. 1996, Vora 1997, Peterson et al. 1998, Rapport and Whitford 1999, National Research Council 2000). We also based our criteria on a review of other ecosystem assessment efforts (Parks Canada 1998, The Heinz Center 2002, The Nature Conservancy 2000) as well as the monitoring and evaluation work undertaken by the National Park Service (National Park Service 1992, Peterson et al. 1995, National Park Service 2001) and relevant government agencies (Karr et al. 1986, Hunsaker and Carpenter 1990, Gerritsen et al. 1998, Jameson et al. 1998, U.S. Environmental Protection Agency 1998, Gibson et al. 2000, Maryland Department of Natural Resource 2001, Maryland Department of the Environment 2002).

Our assessment criteria are organized into two broad categories called **Ecosystem Measures**, and **Environmental and Biotic Measures**. The Ecosystem Measures category is further organized into the sub-categories of **Ecosystem Extent and Function** and **Species Composition and Condition**. Environmental and Biotic Measures include the sub-categories of **Air Quality, Water Resources, Soil and**

Sediments, and **Biotic Health**. These categories and their contributions to our ecological understanding of park natural resource conditions are presented and defined below.

Ecosystem Measures

Ecosystem Extent and Function

This assessment grouping includes **Cover and Habitat**, **Fragmentation**, and **Community (Vertical) Structure**. We selected **Cover and Habitat**, the size and principal cover types of the ecosystem(s) or communities within the park, in order to address expansion or loss of habitat types (Andren 1994, Tilman et al. 1994, Wilcox and Murphy 1985). **Fragmentation** is included to address spatial continuity or intactness of a particular habitat type (Van Driesche and Van Driesche 2000; Bender 1998, Andren 1994, Dunn et al. 1993, Wilson 1992, Noss 1990, Wilcox and Murphy 1985, Fahrig and Merriam 1985, Diamond 1975), and **Community (Vertical) Structure** to examine potential changes in a habitat(s) structural complexity (Pacific Northwest Research Station 2002, Naeem et al. 1994, Noss 1990, Diamond 1975). Fragmentation and structure are important determinants of a habitat's overall ability to sustain long-term biodiversity (Perry and Amaranthus 1997). The patch size, shape, and distribution of habitat across the landscape influences population sizes and dispersal patterns and can determine whether the habitat will provide long-term support to a particular species.

Ecosystem function addresses those biological, chemical, and physical processes that regulate and produce natural change. They provide for the flow of energy and matter into and through ecosystems. Their unimpaired functioning is critical for long-term ecosystem sustainability (Odum 1985, Gibson et al. 2000) and therefore, successful park resource conservation. Included in the assessment are **Community Function** (including processes such as primary productivity and decomposition) and **Disturbance Regimes**. Primary productivity is perhaps the most essential ecosystem function because it transforms energy into a form usable for biological life (Landres 1992). It is the conversion by plants of inorganic atmospheric carbon (CO₂) via solar energy into energy-rich organic forms (biomass) that can be used by other organisms to meet their metabolic demands. Changes in the rates of or net amounts of the primary productivity of plants, provides an indication of the ecosystem's ability to support the numbers and diversity of species that depend on it. Decomposition is an important ecosystem function because it is the process by which dead organic material is broken down into its major chemical constituents, soil organic matter precursors formed and nutrients made available for plant uptake. Most nutrient requirements of plants are met through this biogeochemical process (Schlesinger 1991). Changes in decomposition can lead to shortages of plant-available nutrients that in turn can interfere with plant productivity. Fully functional ecosystems are inherently subjected to natural **Disturbance Regimes**, such as fires, floods, drought, herbivory, and windstorms that are essential for the maintenance of some ecological processes like succession. Indeed, disturbances such as fires or windstorms create canopy openings that favor regeneration and succession in plant communities. This results in landscape-scale spatial patterns of plant communities at various stages of succession and creates varied habitat types that support species diversity (Perry and Amaranthus 1997). Decades of effective fire suppression and flood control in many managed settings have interfered with this natural sequence of events, and consequently have greatly altered vegetation

patterns as well as species diversity across the landscape. An emerging threat to functional ecosystems that is included as well is climate change. Changes in climate can lead to shifts in vegetative communities with respect to elevation and geographic range, and facilitate the spread of invasive species. Changes in climate may also affect the frequency and magnitude of natural disturbances such as fires, insect outbreaks, droughts and floods.

Species Composition and Condition

Assessment of this ecological measures grouping includes three main descriptor sets; **Species Biodiversity (Total and Native)**, **Trophic Structure**, and the **Biotic Interactions** that occur between species and populations. Each species or functional group of species performs certain functions that help to sustain the dynamic balance and proper functioning of the entire system (Perry and Amaranthus 1997, Peterson et al. 1998). Therefore, the conservation of species biodiversity is essential to ensure long-term ecosystem integrity and resilience. Loss of species diversity can occur when habitat alterations create unfavorable conditions for certain species, especially habitat specialists with very specific habitat and resource requirements. Species can also be displaced or pushed to extinction by competitive pressures from other species, such as habitat generalists or invasive species with overlapping resource requirements. **Total Species Diversity** (Tilman 1996, Tilman and Downing 1994, Solbrig 1991, Naeem et al. 1991, Saunders et al. 1991, Diamond 1975, Paine 1966) provides important information about habitat quality and the effect of species interactions upon species composition. The difference between **Total Species Diversity** and **Native Species Diversity** indicates non-native species diversity. Non-native species (Noss and Harris 1986, Noss 1990, Vitousek 1990, Wilson, 1992, Suter 1993, Vitousek et al. 1996, Cox 1999) are often successfully invasive to a natural system because they tend to be habitat generalists, tolerate a wide range of environmental conditions, and often lack natural predators in the systems where they become successfully established. These invasive non-native species directly impact native species, especially vulnerable and threatened ones, through competition leading to their displacement and/or extinction, by rearranging trophic structure, and through hybridization. They may also indirectly alter broader ecological patterns, such as habitat structure, or processes, such as fire regimes, nutrient cycling, hydrology, and energy budgets.

Our aim is to characterize and assess the population attributes and processes (Busing 1998, Nunney and Elam 1994, Murphy et al. 1990, Ricklefs 1990, Taylor 1990, Pulliam 1988, Thorne and Williams 1988, Knight and Eberhardt 1985, Ellner and Hairston 1994, Wielgus et al. 1994, Templeton and Levin 1979, Bengtsson 1989, Wielgus and Bunnell 1993, Moyle and Williams, 1990) that influence the long-term survival of native species. Large populations with stable population cycles (i.e., equal birth and death rates) and even population structures (e.g., sex and age-class distributions) are more likely to survive and be resilient to disturbances and stresses. For such populations, a decrease in population size, higher death rates, or reduced birth rates might indicate environmental stresses such as limited habitat resources to support high population numbers. A species' habitat and resource requirements as well as the geographic extent of suitable and available habitat within and beyond park boundaries are important to understand where environmental stress is of concern. A species' ability to disperse and colonize larger areas ensures that larger populations can persist, thus increasing the species' resilience to perturbations. This depends on the availability of

habitat with a minimum suitable area and the spatial arrangement between parcels of habitat. Any stress that impacts a species' required habitat or resource could undermine that species' long-term viability, and consequently be a threat to the park's biodiversity. Altered biotic interactions, such as increased predation or increased competition for scarce resources, can further jeopardize the fate of a declining population. Finally, spatially fragmented populations can make a species more resilient to perturbations (e.g., disease) if population groups are sufficiently large in numbers and habitat characteristics do not interfere with migrations and source-sink dynamics.

The general condition of native species populations reflects habitat quality. Evidence of species' extirpations provides an indication of degraded habitat quality, while successful species' reintroductions suggests improved resource conditions and habitat quality. Vulnerable or endangered species often provide the early warning of resource degradation because they tend to be most sensitive to habitat quality due to specific resource requirements. The presence of threatened or endangered species in a park may alternatively indicate higher habitat quality and suggest the park serves as a refuge.

The **Trophic Structure** (Van Driesche and Van Driesche 2000, Folke et al. 1996, Paine 1996, Wilson 1992, Pimm et al. 1991) of a system reflects the availability of resources within the habitat and is influenced by the biotic interactions among species, such as predation, competition, and herbivory. Trophic relationships organize organisms into functional groups that emphasize their similarities and differentiate community structure. By examining the biotic interactions within a community we can determine how resources are partitioned between coexisting species. For example, increased food web complexity often leads to increased community stability because there are more routes for energy transfer through the ecosystem (Christensen et al. 1996, Perry and Amaranthus 1997). The presence of top predators in a community plays a significant role in the trophic dynamics of an ecosystem because they regulate the population size of their prey and tend to have large habitat area requirements. The presence of numerous habitat specialists, those with specific resource requirements, may also provide an indication of ecosystem integrity by reflecting the availability of a full array of biological, chemical, and physical resources.

Environmental and Biotic Measures

The physical, chemical and biological condition of the environment has pronounced effects on the health and integrity of organisms and in-turn ecosystems. These effects are not always immediately apparent (e.g., land clearing or even the phosphate pollution-driven eutrophication of lakes) but are often subtle, indirect and not readily visible (e.g., DDT effects on shell thickness of birds of prey or long-term acid deposition effects on soil chemistry and microbial processes). Environmental stressors (usually anthropogenic in origin) can variously impact discrete organisms or entire populations, alter biogeochemical processes, promote disease or non-native invasion, fragment habitat or alter habitat quality and structure. Our assessment methodology includes this grouping to specifically address the influences of environmental stressors on **Biota** but also on the quality of the supporting abiotic framework for life, specifically; **Water Resources, Air Quality, , and Soils and Sediments.**

Biota

The condition of the park biota is a direct reflection of habitat quality, especially in terms of exposure to environmental stressors. Environmental stressors can result in population changes, genetic isolation, toxicity and disease, nutrient or food-supply limitations and even extirpation. This descriptor is intended to help evaluate whether environmental quality factors (discussed hereafter) or other anthropogenic agents and factors (e.g., land use history, visitor impacts, acoustics, exotics competition, poaching etc.) are exerting deleterious influences on the park biota. Climate change is a factor of increasing concern in terms of both plant and animal communities.

Water Resources

Changes in water quality and quantity may affect terrestrial organisms that have direct contact with or ingest water and aquatic organisms that use water bodies as their primary habitat. Water quality can be degraded when groundwater is contaminated by the effects of land-use practices, such as fertilization, pesticide application, waste and water treatment systems, or acid mine drainage. Both natural and anthropogenic activities can also affect the quality of water received from surface runoff, storm-water runoff, and precipitation. High concentrations of pathogens, metals, or pesticides may be detrimental to the health of an organism that ingests surface water. Aquatic communities may also be affected by chemical changes in their aquatic habitat, such as elevated concentrations of nitrogen and phosphorus that lead to eutrophication or increased amounts of oxygen-depleting substances such as organic wastes that can lead to anoxic conditions (Novotny and Olem 1994). Accelerated soil erosion and/or irrigation return flow can result in increased salinity and high concentrations of pesticides, while atmospheric deposition can introduce persistent organic pollutants and toxic pollutants into water bodies (Novotny and Olem 1994). Heavy metals, such as lead, mercury, copper, nickel, zinc, and chromium, tend to bind to organic matter and soil particles (Bohn et al. 1985) and may collect in bottom sediments where they can harm or kill bottom-dwelling organisms. Eventually, toxic pollutants accumulate in fish and shellfish and tend to bioaccumulate with each step up the food chain. Water diversions and dams that change some of the physical characteristics of the aquatic habitat (e.g., flow regimes, water temperature, and increased sedimentation due to erosion) also influence species viability. These changes can disrupt fish migrations and alter the structure of riparian and aquatic vegetation thus degrading essential habitat for wildlife species that depend on it for breeding, cover and as a food source (Maryland Department of the Environment 2002).

Air Quality

Air quality affects vegetation at the level of cellular processes (e.g., photosynthesis, respiration, and photorespiration) that are essential for sustaining plant life and converting solar energy into forms that are used by other organisms in complex food webs. We have selected air quality metrics that have been shown to have an effect on flora or fauna in natural systems. In particular, atmospheric deposition of excess amounts of SO₂ and NO_x can lead to acidic soil conditions that can cause root damage, stunted growth, and sometimes death to sensitive plants. Other documented plant effects include foliar injury, reduced leaf area, interference with photosynthesis and reproduction, and lowered pest and disease resistance (Schlesinger 1991). High concentrations of gaseous fluoride can cause leaf injury and premature fruit fall to sensitive plants (Alabama Cooperative Extension 2002). Two of the most plant-toxic

atmospheric oxidants are tropospheric ozone and peroxyacetyl nitrate (PAN). Vegetation effects include chlorosis, necrosis, depressed flowering and bud formation, and decreased disease resistance (Alabama Cooperative Extension 2002). Effects on wildlife include irritations of eyes and bronchial passages by disrupting cell membrane function. The atmosphere also ties land to sea on a global scale by circulating its chemical constituents in a well-mixed form. Many stressors that degrade air quality are anthropogenic in origin, and sources include urbanization, agriculture, industry, and transportation.

Soils

The ability of the soil to support native vegetation is based on physical, chemical and biological properties. Soil texture, water-holding capacity, organic matter content, and the chemical form and concentration of available nutrients in concert with critical soil biological activities collectively establish a range of suitable conditions for plant growth. Because of the extremely long time frames associated with soil development, it is considered a nonrenewable resource and losses of soil via erosion or its degradation via chemical or physical means are of large concern. In addition to soil losses via erosion, physical degradation of soils can occur through compaction or extensive waterlogging while salinization, acidification, or the accumulation of xenobiotic agents (industrial pesticides, herbicides and fungicides) represent types of chemical degradation of soils.

SYNTHESIS, RATINGS and RECOMMENDATIONS

Each of the assessment criteria described in the preceding section are delineated as discrete elements that constitute ratable indicators, at various levels, of ecological, biological and environmental condition, from species to ecosystem function. The supporting ratings elements are organized as the worksheets of Appendix A. Including multiple ratings elements for each assessment criteria in this process lowers the variability and uncertainty associated with an individual assessment criterion (Gerritsen et al. 1998) but assumes the ratings elements are ecologically relevant or are sensitive to stressors so that any significant deviation in response can be discriminated from natural variability (National Research Council 1990, Gerritsen et al. 1998, Gibson et al. 2000, National Park Service 2001). Ratings from the worksheets can be rolled up into an overall natural resources rating for the park (Appendix A). The natural resources rating reflects assessment of more than 120 discrete ratings elements associated with environmental quality, biotic health, and ecosystem integrity. Environmental and Biotic Measures (EBM) address air, water, soils, and climatic change conditions, as well as their influences and human-related influences on plants and animals. Ecosystem Measures (ESM) address the extent, species composition, and interrelationships of organisms with each other and the physical environment for terrestrial and freshwater communities.

Scoring

Each of the ratings elements is assigned a score of 0-3 based on the interpretation of extent, severity, and duration of influences. If sufficient information is

not available to make a scoring determination, an IND label (Inadequate or no data) is assigned to the element. In the event the ratings element is not applicable to the assessment of a given park unit, a NA (not applicable) label is assigned and the associated element is not included in the roll-up scoring calculations.

Limiting the scoring possibilities to values of 0, 1, 2 or 3 reduces much of the uncertainty (and subjectivity) associated with finer scales. Our ratings sophistication suggests that we can generally discriminate between a problem and not a problem (e.g., a 3 or not a 3) as regards a ratings element. If a problem is indicated we can generally discriminate between whether the problem is catastrophic (complete and irreparable loss rates a 0), acute and/or widespread (rating = 1) or more contained and benign (rating = 2). There is much less comfort and we submit, much more subjectivity in trying to discriminate between a 5 and a 6 or a 3 and a 4, for example on a 1 to 10 based scale. Once each ratings element (for which adequate data exists) is scored, the total additive element scores, for each category, are divided by the total score possible, and the percentage calculated becomes the rating. Element category scores are then rolled-up to produce the EBM, ESM, and Overall scores.

Similar to other rating methodologies currently in use (Karr et al. 1986, Gerritsen et al. 1998, Ricketts et al. 1999, Abell et al. 2000, Gibson et al. 2000, The Nature Conservancy 2000), our approach results in a single multi-metric index score (percentage). In our case however, a score can also be tabulated for each of the assessment element groupings, the two assessment criteria categories, and the overall park natural resource condition.

Information Adequacy or Basis

In addition to producing a 0-100 scale score for each element category and roll-up categories of Environmental and Biotic Measures, Ecosystems Measures, and Overall, the assessment ratings also provide a basis for interpreting the adequacy or completeness of information upon which the element category or roll-up scores are based. This is accomplished by also tabulating the percentage of IND (insufficient or no data) ratings assigned to the elements relative to the total number of applicable elements for a given category. This information adequacy or basis is also reported on a 0 – 100% scale and reflects the extent to which data requirements for the assessment are met.

Interpretation

Our natural resource assessment summarizes the condition of natural systems in a park given current management practices and considering the impact of previous and presently existing stressors on natural resources. The ratings integrate information from various metrics into an aggregate score that may indicate a need for action or intervention to protect a resource (Gerritsen et al. 1998, Gibson et al. 2000, National Research Council 2000, Maryland Department of the Environment 2002). The ratings are also extremely useful for comparative and communication purposes. In these regards, a general interpretive tool is provided (Table 2) to assist in evaluating what the rating scores indicate about the status of resource conditions.

TABLE 2. INTERPRETIVE GUIDE TO RATINGS SCORES

Ratings Range	Interpretation
91-100	EXCELLENT – excellent estimated viability of the ecosystem(s) and secure
81-90	GOOD – good estimated viability of the ecosystem(s) and apparently secure
61-80	FAIR – fair estimated viability of the ecosystem(s) but vulnerable
36-60	POOR - poor estimated viability of the ecosystem(s) and imperiled
0-35	CRITICAL – ecosystem(s) estimated as unviable and/or irreparably lost

Based on our assessment and the corresponding ratings, we will relay key findings on resource conditions in the park. These findings may identify threat abatement strategies, restoration efforts, or increased park stewardship capacities that would target the stresses and sources of stresses that impact park natural systems. Our methodology, where based on field-collected metrics that measure the impact of stress to the system, allows us to infer and identify the sources of stress to these systems. If a direct causal relationship between the ratings element, stress, and source of stress can be established, we can communicate these findings to appropriate legislative or regulatory authorities for threat abatement.

We fully expect that the rating system and indeed our methodology as a whole will evolve over time as more evaluations are conducted and more solid reference conditions are established. Assessments will also require updating as new scientific information becomes available. We will maintain a database of this information as our research progresses that will be used to make more refined comparisons as our knowledge base increases.

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Appendix A. Ratings Worksheets

Generic National Park- GENR

Category I. Ecosystem Extent and Function			
Park Unit and Ecoregion Characterization:			
Community Descriptors:			
Indicator or Representative Species:			
Ratings Element	Specific Concerns/Events/Notes	Level	Reference
<i>IA. Cover and Habitat Characterization</i>			
IA1. Habitat loss or degradation			
IA2. Intra-patch integrity			
IA3. Cover loss or bare soil increase			
IA4. Cover density/homogeneity			
IA5. Canopy and understory architecture change			
IA6. Substrate quality/quantity			
IA7.			
<i>IB. Fragmentation</i>			
IB1. Patch connectivity			
IB2. Species Isolation			
IB3. Dispersal barriers			
IB4. Habitat loss			
IB5. Recolonization barriers			
IB6.			
<i>IC. Community Structure & Function</i>			
IC1. Complexity and niche diversity			
IC2. Degradation of structure			
IC3. Patch size/shape changes			
IC4. Intra-patch microclimate alteration			
IC5. Inter-patch isolation and edge microclimate			
IC6. Generalist species domination of patches			
IC7. Age class distribution			
IC8. Primary production			
IC9. Decomposition/Cycling			
IC10. Substrate/hydrologic change			
IC11.			
<i>ID. Disturbance Regimes</i>			
ID1. Natural disturbance recovery			
ID2. Perturbation resistance			
ID3. Adjacent lands development effects			
ID4. Fire			
ID5. Flood			
ID6. Drought			
ID7. Grazing/Browsing, Fencing			
ID8. Climate change			
ID9. Visitor impact			
1D10.			

Ratings Guideline: For a given ratings element, data indicate or observation(s) are made, or persuasive inferential evidence exists to the effect of:

- | Level | Benchmark |
|----------------|---|
| 3 ----- | No net loss, degradation, negative change or alteration |
| 2 ----- | Limited, isolated, contained or restored loss, degradation, negative change or alteration |
| 1 ----- | Pronounced, widespread, uncontained and/or key species/critical process degradation, negative change or alteration |
| 0 ----- | Complete and irreparable loss, absolute degradation, negative change or alteration |

In the event that insufficient information or no data or persuasive evidence exist to make a reasonable determination , the level should be marked: IND = Insufficient or No Data. In the event the ratings element is not a feature or is not relevant to the site assessment, the level should be marked: NA= Not Applicable

Generic National Park- GENS

Category II. Species Composition & Condition (SCC)			
Park Unit and Ecoregion Characterization:			
Community Descriptors:			
Indicator or Representative Species:			
Ratings Element	Specific Concerns/Events/Notes	Level	Reference
<i>IIA. Total Species</i>			
IIA1. Diversity (age, size class, distribution)			
IIA2. Exotic species			
IIA3. Invasive species			
IIA4. Genetic variability			
IIA5.			
<i>IIB. Native Species</i>			
IIB1. Composition change			
IIB2. Disease and parasites			
IIB3. Threatened and endangered species			
IIB4. Extirpation			
IIB5. Population change			
IIB6. Dominant species density-dependence			
IIB7. Reintroduction			
IIB8. Keystone species			
IIB9.			
<i>IIC. Trophic & Biotic Interactions</i>			
IIC1. Web dynamics -species loss			
IIC2. Predation rates			
IIC3. Grazer/Browser effects			
IIC4. Food chain length			
IIC5. Competitor change			
IIC6. Predator-prey disruption			
IIC7. Dominance alteration			
IIC8. Species hybridization			
IIC9. Allelopathy			
IIC10.			

Ratings Guideline: For a given ratings element, data indicate or observation(s) are made, or persuasive inferential evidence exists to the effect of:

- | Level | Benchmark |
|----------------|--|
| 3 ----- | No net loss, degradation, negative change or alteration |
| 2 ----- | Limited, isolated, contained or restored loss, degradation, negative change or alteration |
| 1 ----- | <i>Pronounced, widespread, uncontained and/or key species/critical process degradation, negative change or alteration</i> |
| 0 ----- | Complete and irreparable loss, absolute degradation, negative change or alteration |

In the event that insufficient information or no data or persuasive evidence exist to make a reasonable determination , the level should be marked: IND = Insufficient or No Data. In the event the ratings element is not a feature or is not relevant to the site assessment, the level should be marked: NA= Not Applicable

Generic National Park- GENS

Category III. Biotic Impacts and Stressors (BIS)			
Park Unit and Ecoregion Characterization:			
Community Descriptors:			
Indicator or Representative Species:			
Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IIIA. Animals			
IIIA1. Acoustics			
IIIA2. Climate Change			
IIIA3. Disease			
IIIA4. Environmental Quality			
IIIA5. Exotics Competition			
IIIA6. Land Use History			
IIIA7. Management			
IIIA8. Natural Disaster			
IIIA9. Food Source			
IIIA10. Poaching			
IIIA11. Population Dynamics			
IIIA12. Isolation/Insulation			
IIIA13. Visitor Impact			
IIIA14.			
IIIB. Plants			
IIIB1. Climate Change			
IIIB2. Disease			
IIIB3. Environmental Quality			
IIIB4. Exotics Competition			
IIIB5. Land Use History			
IIIB6. Management			
IIIB7. Natural Disaster			
IIIB8. Nutrient Supply			
IIIB9. Poaching			
IIIB10. Population Dynamics			
IIIB11. Substrate Loss			
IIIB12. Isolation/Insulation			
IIIB13. Visitor Impact			
IIIB14.			

Ratings Guideline: For a given ratings element, data indicate or observation(s) are made, or persuasive inferential evidence exists to the effect of:

- | Level | Benchmark |
|----------------|---|
| 3 ----- | No net loss, degradation, negative change or alteration |
| 2 ----- | Limited, isolated, contained or restored loss, degradation, negative change or alteration |
| 1 ----- | Pronounced, widespread, uncontained and/or key species/critical process degradation, negative change or alteration |
| 0 ----- | Complete and irreparable loss, absolute degradation, negative change or alteration |

In the event that insufficient information or no data or persuasive evidence exist to make a reasonable determination, the level should be marked: IND = Insufficient or No Data. In the event the ratings element is not a feature or is not relevant to the site assessment, the level should be marked: NA= Not Applicable

Generic National Park- GENS

Ratings Category IV. Environmental Quality Factors (EQF)			
Park Unit and Ecoregion Characterization:			
Community Descriptors:			
Indicator or Representative Species:			
Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
<i>IVA. Air</i>			
IVA1. Acid Deposition (Acid Rain)			
IVA2. Cl-oxides, Cl-nitrate			
IVA3. HFC's, FHC's, HC's			
IVA4. Nitrogen Oxides			
IVA5. Sulfur Oxides			
IVA6. Particulates			
IVA7. Ozone			
IVA8. VOC's			
IVA9. Visibility			
IVA10. Hg			
IVA11.			
Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
<i>IVB. Water Resources</i>			
IVB1. Acid Deposition			
IVB2. Algae			
IVB3. Alkalinity			
IVB4. Benthic Index			
IVB5. Chlorophyll a			
IVB6. Diatoms			
IVB7. Discharge/Drainage			
IVB8. Dissolved Gasses			
IVB9. Diversion			
IVB10. Drawdown			
IVB11. Flow			
IVB12. Metals			
IVB13. Nutrients			
IVB14. Organic Matter			
IVB15. Organic Wastes			
IVB16. pH			
IVB17. Plankton			
IVB18. Recharge			
IVB19. Salinity			
IVB20. Sedimentation			
IVB21. Submerged Macrophytes			
IVB22. Temperature			
IVB23. Turbidity			
IVB24. Xenobiotics			
IVB25. Climate Change			
IVB26.			

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IVC. Soils			
IVC1. Acidity, Alkalinity, pH			
IVC2. Compaction			
IVC3. Erosion			
IVC4. Infiltration/Permeability			
IVC5. Metals			
IVC6. Nutrients			
IVC7. Organic Matter			
IVC8. Organic Wastes			
IVC9. Salinity & Sodicity			
IVC10. Soil Fauna & Flora (micro & macro)			
IVC11. Climate			
IVC12. Xenobiotics			
IVC13.			

Ratings Guideline: For a given ratings element, data indicate or observation(s) are made, or persuasive inferential evidence exists to the effect of:

- | Level | Benchmark |
|--------|---|
| 3----- | No net loss, degradation, negative change or alteration |
| 2----- | Limited, isolated, contained or restored loss, degradation, negative change or alteration |
| 1----- | Pronounced, widespread, uncontained and/or key species/critical process degradation, negative change or alteration |
| 0----- | Complete and irreparable loss, absolute degradation, negative change or alteration |

In the event that insufficient information or no data or persuasive evidence exist to make a reasonable determination, the level should be marked: IND = Insufficient or No Data. In the event the ratings element is not a feature or is not relevant to the site assessment, the level should be marked: NA= Not Applicable

Generic National Park - GNR

Ratings Category	Total Levels Values (TLV)	Total Levels Addressed (TLA)	Total Applicable Levels (TAL)	RATING 100 x (TLV/3TLA)	BASIS 100 x (TLA/TAL)
ECOSYSTEM MEASURES (ESM)					
I. Ecosystem Extent and Function (EEF)					
IA. Cover and Habitat Characterization					
IB. Fragmentation					
IC. Community Structure and Function					
ID. Disturbance Regimes					
II. Species Composition and Condition (SCC)					
IIA. Total Species					
IIB. Native Species					
IIC. Trophic and Biotic Interactions					
ENVIRONMENTAL & BIOTIC MEASURES (EBM)					
III. Biotic Impacts and Stressors (BIS)					
IIIA. Animals					
IIIB. Plants					
IV. Environmental Quality Factors (EQF)					
IVA. Air					
IVB. Waters					
IVC. Soils					
OVERALL					

Ratings Range

Interpretation

91-100	EXCELLENT – excellent estimated viability of the ecosystem(s) and secure
81-90	GOOD – good estimated viability of the ecosystem(s) and apparently secure
61-80	FAIR – fair estimated viability of the ecosystem(s) but vulnerable
36-60	POOR - poor estimated viability of the ecosystem(s) and imperiled
0-35	CRITICAL – ecosystem(s) estimated as unviable and/or irreparably lost

