Ecological Integrity Assessment and Performance Measures for Wetland Mitigation

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Photograph on the front cover:
Chicago Bog, New York; Laurentian-Acadian Acidic Basin Fen.
Photo by Don Faber-Langendoen, NatureServe

Funding for this report was provided by a grant from the U.S. Environmental Protection Agency Office of Wetlands, Oceans and Watershed – Wetlands Division

Suggestion Citation: Faber-Langendoen, D., J. Rocchio, M. Schafale, C. Nordman, M. Pyne, J. Teague, T. Foti, and P. Comer. 2006. Ecological Integrity Assessment and Performance Measures for Wetland Mitigation. Final Report, March 15, 2006. NatureServe, Arlington, VA.

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Table of Contents

List of Tables

List of Figures

ACKNOWLEDGEMENTS

We are grateful for financial assistance from the U.S. Environmental Protection Agency (EPA) Office of Wetlands, Oceans and Watershed – Wetlands Division through a Wetlands Program Development Grant. In particular Palmer Hough provided valuable coordination and advice throughout the project, including coordinating a national advisory group that gave input throughout this project. We also appreciate the input from the advisory group including William Ainslie, Aaron Allen, Steve Eggers, Sue Elston, Ruth Ladd, Bob Lord, John Mack, Steven Martin, Paul Minkin, Morgan Robertson, and Richard Sumner. The analysis and conclusions documented in this publication are those of NatureServe and may not necessarily reflect the views of EPA.

EXECUTIVE SUMMARY

The Environmental Protection Agency and other agencies have developed a National Wetlands Mitigation Plan that includes the need for assessing the effectiveness of biological and functional indicators that will help establish performance standards for wetland mitigation. We outline our approach for establish performance standards for wetlands mitigation using an adapted version of NatureServe's methodology for conducting ecological integrity assessments. We chose 18 wetland Ecological Systems (from fens to swamps, playas, flatwoods, and marshes) and, relying primarily on literature sources and field wetland manuals, identified indicators and metrics for assessing ecological integrity by 1) using a standardized classification of wetland types, including diagnostic characteristics, 2) identifying key ecological attributes and indicators of each system, with protocols for measuring those indicators to ensure consistent field measurements and documentation, 3) identifying practical metrics with ratings and thresholds based on "normal' or "natural" benchmarks, and 4) providing a scorecard matrix by which the indicators/metrics are rated and integrated into an overall assessment of the ecological integrity of the wetland. We identified over 50 metrics across the 18 systems, with metrics per system ranging from 13 (10 core, 3 supplementary) to 25 (12 core, 13 supplementary). Thirteen of the 15 metrics were widely shared among the systems, suggesting that a generic list of metrics could be developed, at least among broadly similar systems. A document is available for each system describing the rationale for selection and rating of each metric, the scorecard approach, and the protocols for collecting each metric. Our multimetric approach is somewhat similar to the IBI approach for aquatic systems, in that we use metrics to document degradation along a continuum from reference to degraded, but here we bring together biotic metrics with abiotic metrics as part of an overall assessment of ecological integrity. We discuss how our approach can assist the wetland mitigation process. We compare our approach to other functional assessments used in mitigation, such as the hydrogeomorphic (HGM) approach. Our methods still require field testing that is conducted using sampling procedures and design with quality assurance controls before being ready for inclusion in the mitigation process. Next steps include the need for field testing of metrics and evaluation of the ability to generalize these results across broad categories of wetlands.

INTRODUCTION

In response to independent critiques of the effectiveness of wetlands compensatory mitigation for authorized losses of wetlands under Section 404 of the Clean Water Act, the Environmental Protection Agency and other agencies have developed a National Wetlands Mitigation Plan. The Plan includes 17 tasks that are to be completed by 2005, including 2 tasks within the "Clarifying Performance Standards" section that deal with the need for assessing the effectiveness of biological and functional indicators. These performance standards are also part of a multi-agency compensatory mitigation plan checklist. EPA has developed an indicators-based (ecological endpoints) approach to assessing and reporting on ecological condition (Harwell et al. 1999, Young and Sanzone 2002, U.S. EPA 2002a), which can be used to assist with setting performance standards for mitigation. Such an approach is being widely promoted among a number of agencies, conservation organizations, and research scientists who focus on the critical role of indicators for assessing ecological integrity of communities and ecosystems, within the context of a thoughtful mitigation or monitoring program (Table 1).

Table 1. Comparison of terminology among various agencies and organizations for ecological integrity / condition assessments. Overarching goals and objectives are defined variously by each group. TNC = The Nature Conservancy, EPA = Environmental Protection Agency, NPS = National Park Service.

NatureServe	**TNC**	**EPA**	**NPS Vital Signs**
Comer et al. 2003	Parrish et al. 2003	Harwell et al 1999, Young and Sanzone 2002	Fancy 2005 (unpublished)
		Goal	
		Objective	
Category	Key Ecological Attribute Category	Essential Ecological Attribute (EEA)	Level 1 Category
		EEA subcategory	Level 2 Category
Key Ecological Attribute	Key Ecological Attribute	Ecological Endpoint	Vital Sign (Level 3)
Indicator/Metric	Indicator	Measure	Measure / Metric

Assessing the current ecological condition or integrity of an ecosystem requires developing measures of the structure, composition, and function of an ecosystem as compared to reference or benchmark ecosystems operating within the bounds of natural or historic disturbance regimes (Lindenmayer and Franklin 2002, Young and Sanzone 2002). Mitigated sites can be compared against these benchmark sites based on the values of specified indicators. However, selection and development of indicators can be challenging, given the diversity of organisms and systems, the large number of ecological attributes that could be measured, and concerns over cost-effectiveness and statistical rigor. It is equally challenging to develop indices that can summarize the state of ecosystems and help guide mitigation success or failure. This challenge is part of a larger need to develop meaningful indices of terrestrial and wetland ecological integrity (Andreasen et al. 2001), akin to Karr's Index of Biotic Integrity (IBI) for aquatic systems (Karr and Chu 1999). Properly constructed, such indices can be useful as an early warning system for ecological degradation, for priority setting among degraded systems, for protection of those in more pristine condition, or for judging the success of restoration or mitigation, the focus of this paper. These indices need to work both for assessments, where a snapshot of the current condition is taken, and for monitoring, where changes in condition are tracked over time (Andreasen et al. 2001).

Here, we outline our approach to helping establish performance standards for wetlands mitigation by presenting an adapted version of NatureServe's methodology for conducting ecological integrity assessments (Brown et al. 2004). We identify indicators and metrics for assessing ecological integrity by 1) using a standardized classification of wetland types, including descriptions of diagnostic or distinguishing characteristics, 2) identifying key ecological attributes and indicators of each of these groups that reflect composition , structure and function (pattern and process), with protocols for measuring those indicators to ensure consistent field measurements and documentation, 3) identifying practical metrics with ratings and thresholds based on "normal' or "natural" benchmarks, and 4) providing a scorecard matrix by which the indicators/metrics are rated and integrated into an overall assessment of the ecological integrity of the wetland. Our multimetric approach is somewhat similar to the IBI approach for aquatic systems, in that we use metrics to document degradation along a continuum from reference to degraded (Karr and Wu 1999), but here we bring together biotic metrics with abiotic metrics as part of an overall assessment of ecological integrity. We discuss how our approach can assist the wetland mitigation process. We compare our approach to functional assessments, such as the hydrogeomorphic (HGM) approach, which are also used to inform mitigation projects.

METHODS

WETLAND TYPES

The success of developing indicators of wetland ecological integrity depends on an understanding of the structure, composition, and processes that govern the wide variety of wetland systems. Ecological classifications can be helpful tools in categorizing this variety. These classifications help wetland managers to better cope with natural variability within and among types, so that differences between occurrences with good integrity and poor integrity can be more clearly recognized. For over fifteen years, NatureServe has provided international leadership in standardized ecological classifications. NatureServe and its science partners classify communities and ecosystems throughout the U.S. (FGDC 1997, Grossman et al. 1998, Comer et al. 2003, NatureServe 2005). NatureServe manages data on over 5,000 provisional plant associations in the U.S. National Vegetation Classification (USNVC) and about 600 ecological systems. While the NVC provides a conceptual/taxonomic hierarchy to organize alliance and associations, ecological systems provide a spatial-ecologic perspective on the relation of associations and alliances found in the NVC, much as soil associations help portray the spatial-ecologic relations among soil series in a soil taxonomic hierarchy. Systems can be described in term of their component vegetation types. For example, within a basin fen system, distinct associations reflect the zones from shrub/graminoid shore fen to acid conifer-hardwood swamp (Figure 1). Systems share with the HGM approach the use of hydrogeomorphic criteria, but also use biotic characteristics.

These classifications primarily focus on natural systems. Less information is available on semi-natural systems, such as systems that have become degraded to the point of changing to an alternate state (e.g., Melaleuca forests on sites once dominated by graminoid marshes), or arise after abandonment of cultural sites (e.g., old-fields on abandoned farmland that was once forest). Semi-natural systems can also include some mitigated sites where the early stages of mitigation may produce a weedy wetland with little floristic or biotic resemblance to any known natural system. Simply re-establishing the abiotic characteristics (the biophysical template) is not sufficient to establish presence of a system. NatureServe is working to describe some general types of semi-natural systems to assist field applications of the classification in these circumstances.

For the purposes of this project, we selected 18 wetland systems found in three regions of the United States; the northeast (7 systems), the southeast (4 systems), and the Rocky Mountains (7 systems) (Table 2). We organize them by trends in hydroperiod regimes, as reflected in commonly used terms for wetlands, such as those of Mitsch and Gosselink (2000). Elsewhere, we provide a demonstration field key for the 18 systems; however, considering the wide geographic distribution of the 18 types, the key is somewhat artificial.

Given the wide use of hydrogeomorphic (HGM) classifications for wetland assessment, we also note the HGM type(s) that a System belongs to (Table 2). In many cases, systems contain greater specificity of regional vegetation and ecological criteria within an HGM class. For example, the HGM “Depression” class contains both alkaline and acidic

a. b. c.

Figure 1. Illustration of turnover in plant communities within an ecological system (Laurentian-Acadian Acidic Basin Fen). a. = medium shore fen in distance, b = dwarf-shrub/herb acid fen, c = transition to conifer-hardwood acidic swamp.

Table 2. List of System types assessed in this report. Types are compared to “wetland type” (corresponding to commonly used terms for wetlands, such as those of Mitsch and Gosselink 2000) and to hydrogeomorphic (HGM) classes (Brinson 1993). The Code and Name fields are from NatureServe (2005). System types are ordered roughly by hydroperiod regimes, from relatively stable water tables, with little surface water to more widely fluctuating water tables and more frequent surface water.

CODE	ABBR.	REG-ION	WETLAND TYPE	HGM	NAME
CES201.583	LA AC FEN	NE	Fen	Depressional	Boreal-Laurentian-Acadian Acidic Basin Fen
CES201.585	LA AL FEN	NE	Fen	Depressional	Laurentian-Acadian Alkaline Fen
CES306.831	RM SM FEN	W	Fen	Slope	Rocky Mountain Subalpine-Montane Fen
CES203.265	AC LP SF	SE	Flatwoods	Depressional	Atlantic Coastal Plain Northern Wet Longleaf Pine Savanna & Flatwoods
CES203.191	WG FL PO	SE	Flatwoods	Depressional	West Gulf Coastal Plain Flatwoods Pond
CES304.786	IM BA PL	W	Playa	Depressional	Inter-Mountain Basins Playa
CES201.575	LA AL SW	NE	Swamp	Depressional	Laurentian-Acadian Alkaline Conifer-Hardwood Swamp
CES201.574	LA AC SW	NE	Swamp	Depressional	Laurentian-Acadian Conifer-Hardwood Acid Swamp
CES203.505	SC SE SB	SE	Swamp	Slope	Southern Coastal Plain Seepage Swamp and Baygall
CES203.372	WG SE SB	SE	Swamp	Slope	West Gulf Coastal Plain Seepage Swamp and Baygall
CES201.582	LA WM SS	NE	Wet Meadow	Depressional; Slope; Riverine	Laurentian-Acadian Wet Meadow-Shrub Swamp
CES306.812	RM AM WM	W	Wet Meadow	Depressional; Slope; Riverine	Rocky Mountain Alpine-Montane Wet Meadow
CES201.594	LA FR MA	NE	Freshwater Marsh	Depressional; Riverine	Laurentian-Acadian Freshwater Marsh
CES300.729	NA EM MA	W	Freshwater Marsh	Depressional; Riverine	North American Arid West Emergent Marsh
CES201.587	LA FL FO	NE	Riparian	Riverine	Laurentian-Acadian Floodplain Forest
CES306.821	RM LM RWS	W	Riparian	Riverine	Rocky Mountain Lower Montane Riparian Woodland and Shrubland
CES306.832	RM SM RS	W	Riparian	Riverine	Rocky Mountain Subalpine-Montane Riparian Shrubland
CES306.833	RM SM RW	W	Riparian	Riverine	Rocky Mountain Sublapine-Montane Riparian Woodland

fens in the Laurentian-Acadian region. In some cases, similar systems may be in different HGM classes, e.g., the Rocky Mountain SubAlpine-Montane Fen is in the Slope class, whereas the Laurentian-Acadian fens are in the Depressional class. The Systems types allow for greater specificity in developing conceptual models of the natural variability and stressors of the system and the thresholds that relate to impacts of stressors. Still, in many cases the kinds of metrics that are used to assess structural and functional differences among HGM classes may be shared among the various systems, even if the details differ.

SELECTING METRICS FOR THE INDEX

Before discussing our selection of metrics, we note some issues in terminology. For clarity, we distinguish "measures" from "metrics." Measures are those values that are collected directly in the field (e.g., diameter of tree at breast height, species percent cover) and metrics are values derived from specific measures (e.g., basal area, stand structural class, species diversity). We also separate "indicators" from "metrics," indicators being a broader term for a closely related set of metrics. For example, coarse woody debris is an indicator, whereas volume of coarse woody debris and biomass of coarse woody debris are two closely related metrics for that indicator. For a given system, a single metric is typically used for an indicator, but when comparing across systems, we may have different metrics for the same indicator. We have yet to determine whether it is possible to agree on a single metric for an indicator, but we expect that some metrics are more appropriate in some systems than others.

Characteristics of a Good Suite of Metrics

Andreasen et al. (2001) outline six characteristics that a practical index of ecological integrity should have:

- Multi-scaled
- Grounded in natural history
- Relevant and helpful (to the public and decision-makers, not just scientists)
- Flexible
- Measurable
- Comprehensive (for composition, structure and function).

We outline how we address each of these characteristics as part of our methodology for developing indices of ecological integrity based on a suite of metrics.

<u>Multi-scaled</u>

We address multi-scale issues by including both stand-level and landscape-level metrics. We use a "Landscape Context" category that addresses fragmentation, buffer, and land-use issues around a given wetland. Stand-scale issues are addressed by other categories. Although this is a simplified version of scales, it is an effective approach that meets management and mitigation needs (see also Noon 2002, Lindenmayer and Franklin 2002). Still, the fundamental application of the index we develop is at the stand level. A separate set of metrics and indices are needed if the index of ecological integrity is intended to address the landscape itself, e.g., a watershed or ecoregion (Tiner 2004).

Grounded in Natural History

Expert judgments about the choice of metrics that inform an index must be grounded in a thorough knowledge of the assemblages of organisms and ecological factors that they depend on, including interactions with other organisms, site factors, and natural disturbances. Equally important is the knowledge of how particular threats may affect these organisms. For this reason, we developed a concise ecological description of each system, in the form of a narrative, and summarize known stressors or threats to the system. We worked as a team, each member having expertise in one or more of the various systems, whether northeast, southeast, or western U.S. After describing the natural history of a system and the list of stressors or threats to that system, team members highlighted the ecological attributes that were most helpful in describing changes in ecological integrity.

Relevant and helpful

To ensure that our selection of metrics and indices were useful to decision-makers and scientists in the mitigation process, we worked with an EPA advisory group, comprised of EPA and Corp of Engineer staff (see Appendix 1). Their review was essential to both the general process of developing a good set of indices and to their role in helping set standards for mitigation. It is important to stress that these metrics and indices will not address all aspects of mitigation evaluations. For example, evaluations of a mitigation project may require criteria for what constitutes a good site design.

Field applications and other testing will be essential to improve the relevance of the metrics and approach developed here.

Flexible

Mitigation projects, like many assessment and monitoring projects, will vary as to how much effort can be invested in evaluating acceptable performance. For this reason, our methods included two procedures that add flexibility. First, we divided the metrics into "core" versus "supplementary" metrics (see Table 3). *Core metrics* represent the minimal metrics that should be applied to assess ecological integrity. *Supplementary metrics* are those which should be applied if available resources allow a more in depth assessment or if these metrics add desired information to the assessment. We recognize that what is core may vary depending on the particular application or questions, so our categories should be seen as a recommendation, not a fixed list.

Second, we divide the metrics that comprise the index into three tiers based on the level of intensity of sampling required to document a metric (Table 3). Tier 1 metrics can be

Table 3. Example of the structure of an ecological integrity tables, showing overall set of metrics for the Laurentian-Acadian Conifer-Hardwood Alkaline Swamp (HGM Depressional Class). Tier: 1 = Remote Sensing, 2 = Rapid or Extensive, 3 =Intensive. Shaded metrics are core metrics. Unshaded metrics are supplementary metrics.

Category	Essential Ecological Attribute	Indicator & Metric	Tier
LANDSCAPE CONTEXT	Landscape Composition	Adjacent Land Use	1
		Buffer Width	1
	Landscape Pattern	Percentage of unfragmented landscape within 1 km.	1
		Distance to nearest road	1
BIOTIC CONDITION	Community Structure	Stand Live Basal Area	2
		Coarse Woody Debris (volume)	3
	Community Composition	Saplings / Seedlings of Native Woody Species	2
		Percent of Cover of Native Plant Species	2
		Floristic Quality Assessment (Mean C) [where available]	3
ABIOTIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland	2
		Sediment Loading Index	1
	Hydrology	Water Table Depth (Tier 2)	2
		Water Table Depth (Tier 3)	3
		Hydrological Alterations	2
		Surface Water Runoff Index	1
	Chemical / Physical Processes	Soil Organic Carbon	3
		Soil Bulk Density	3
		Nutrient/ Pollutant Loading Index	1
SIZE	Absolute Size	Absolute Size	1,2
	Relative Size	Relative Size	1,2

assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 metrics typically require some kind of ground sampling, but may use qualitative or semi-quantitative data. Tier 3 metrics typically require a more intensive plot-based or other intensive sampling approach. A given metric could be assessed at multiple tiers, though some metrics cannot be done at Tier 1 (i.e., they require a ground visit). Dividing the metrics into tiers helps scientists and managers choose a set of metrics that are cost-effective. For example, estimates of live tree basal area can be done rapidly by swinging a prism from a fixed plot in a forest or it can be done more intensively by measuring each stem in a fixed area plot.

By including flexibility in the choice of metrics, we also require an additional flexibility in the calculation of an overall ecological integrity index based on the metrics. If not all sites have the same set of metrics being collected, then the calculation of the index must allow for varying levels of metric information to contribute to its value.

Measurable

Many factors feed into what makes for a workable, measurable metric, including management significance & utility, ecological relevance, feasibility of implementation, and response variability (Table 4, see also Shriver et al. 2004). These criteria can be hard to quantify directly, but served as a heuristic tool to guide our selection. Our description of each system led us to focus on a number of possible metrics that could describe changes in ecological integrity. We compiled information on those metrics, working with the best available literature information and consulting with knowledgeable practitioners. We then solicited peer review from within our team and an EPA advisory group to address issues of measurability. We either screened out metrics that did not meet these criteria, or moved them to a supplementary category.

We develop documentation for each metric that specifies how it should be measured, the basis for choosing the metric, including the rationale for how it should be scaled. The process of documenting the metric in this way ensures that anyone can review these metrics and determine just how well they meet the criteria for "measurability." Still, further testing is warranted to ensure that criteria for measurability are properly assessed. Our documentation of the metrics is similar to that of some HGM assessments (e.g., Hall et al. 2003) and to the Standard Operating Procedures of the NPS Vital Signs Program (Oakley et al. 2003).

Comprehensiveness

To ensure a minimal level of comprehensiveness, we structured our metrics under four main categories: 1) Landscape Context, 2) Biotic Condition, 3) Abiotic Condition, and 4) Size. We expect that at least one metric should be available for each of the four categories (Table 3). Previous versions of our methodology combined Biotic and Abiotic Condition together, (NatureServe 2002, Brown et al. 2004), but from an interpretive point-of-view, it is valuable to look at biotic and abiotic metrics separately. There has

Table 4. Rating criteria used to evaluate metrics (from Shriver et al. 2004).

Rating Category	Rating Criteria
Management Significance & Utility	-relevant to assessment questions and/or determining thresholds -sensitive to and/or indicative of stress -not redundant unless improves performance -relative to determining quantitative thresholds -linked to management actions -widely applicable (e.g., useful for multiple purposes)
Ecological Relevance	-clear linkage to ecological function or integrity or specific resource -anticipatory -indicative of status of other resources
Feasibility of Implementation	-availability of standard, well-documented methods -lack of sampling impacts on indicator -rapid, cost-efficient and/or can be bundled with other indicators for measurement -easily measured with little equipment or specialized knowledge, and large sampling window -baseline data available -long-term data management feasibility
Response Variability	-low or controllable measurement error, high repeatability of measurement -temporal variability predictable and/or described -spatial variability understood or controllable -sufficient discriminatory ability

also been much effort put into developing biotic indices of integrity for wetland systems (such as the Vegetation Index of Biotic Integrity by DeKeyser et al. 2003, Mack 2004, Jones 2005), and the use of these indices within our framework is more clearly understood by having a separate Biotic Condition category.

Our categories include both pattern and process attributes. Thus our categories are similar to the categories of the EPA framework of attributes (Table 5), with EPA providing categories for attributes of both pattern and the process. That is Landscape Context, Biotic Condition and Abiotic Condition (Chemical & Physical Characteristics emphasizes patterns whereas Natural Disturbance Regime, Ecological Processes, and Hydrology & Geomorphology emphasize processes. We recognize "size" as a separate category because of its distinctive role in affecting many processes in a system.

In addition to these four main categories, we use a subcategory level that we call "key ecological attributes" This level is similar to the subcategory level of the EPA framework of attributes, which helps provide a comprehensive view of relevant attributes of an ecological system (Table 5). For example, the "Community Composition" attribute focuses on the species composition of the wetland. Other attributes address abiotic characteristics or stressors of the wetland system (e.g., energy / material flow, pattern of groundwater flows, nutrient enrichment, and landscape pattern). Referring to this framework helps maintain a comprehensive view of metrics that can contribute to the index.

REFERENCE SITES, THRESHOLDS AND RANGES OF NATURAL VARIABILITY

Reference sites

In choosing the metrics, it is important to assess the behavior of the metric over a range of conditions, using reference sites or literature to determine the optimal values of the metric. The reference condition is at one end of a continuum from a "natural" or "unimpacted" state to a totally degraded state (perhaps leading to an alternative semi-natural state). The natural reference sites may represent the state of the ecosystem prior to European settlement or be considered the best condition that can be obtained. As Andreasen et al. (2001) put it, "The assumption of 'naturalness' for a reference condition is never unassailable." They and others note that terms such as "normal," "acceptable," or "sustainable" attempt to address this issue by focusing more on the current state of affairs with respect to structure, composition, and processes, and the range of ecological factors and natural disturbances that they depend on. Reference conditions that attempt to define a natural ecological system are often derived from either the conditions that existed prior to anthropogenic disturbance or to conditions in a relatively undisturbed but comparable system in the ecoregion. Alternatively, reference conditions can be inferred from a combination of historical data, a composite of best remaining regional conditions, and professional judgment (Young and Sanzone 2002).

Table 5. Summary of major categories and subcategories of ecological indicators developed by EPA (from Young and Sanzone 2002). Ecological indicators (also called ecological endpoints by EPA) are measurable characteristics related to the structure, composition, or functioning of ecological systems. Multiple indicators may be associated with each category or subcategory. Subdivisions within the Chemical and Physical Characteristics category are based on review of other reporting formats.

Landscape Condition
- Extent of Ecological System/Habitat Types
- Landscape Composition
- Landscape Pattern and Structure

Biotic Condition
- Ecosystems and Communities
  - Community Extent
  - Community Composition
  - Trophic Structure
  - Community Dynamics
  - Physical Structure
- Species and Populations
  - Population Size
  - Genetic Diversity
  - Population Structure
  - Population Dynamics
  - Habitat Suitability
- Organism Condition
  - Physiological Status
  - Symptoms of Disease or Trauma
  - Signs of disease

Chemical and Physical Characteristics
- ❖ **Air Quality and Climate**
- ❖ **Soil Quality**
- ❖ **Water Quality**
- Nutrient Concentrations
  - Nitrogen
  - Phosphorus
  - Other Nutrients
- Trace Inorganic and Organic Chemicals
  - Metals
  - Other Trace Elements
  - Organic Compounds
- Other Chemical Parameters
  - pH
  - Dissolved Oxygen
  - Salinity
  - Organic Matter
  - Other
- Physical Parameters

Ecological Processes
- Energy Flow
  - Primary Production
  - Net Ecosystem Production
  - Growth Efficiency
- Material Flow
  - Organic Carbon Cycling
  - Nitrogen and Phosphorus Cycling
  - Other Nutrient Cycling

Hydrology and Geomorphology
- Surface and Groundwater flows
  - Pattern of Surface Flows
  - Hydrodynamics
  - Pattern of Groundwater Flows
  - Salinity Patterns
  - Water Storage
- Dynamic Structural Characteristics
  - Channel/Shoreline Morphology, Complexity
  - Extent/Distribution of Connected Floodplain
  - Aquatic Physical Habitat Complexity
- Sediment and Material Transport
  - Sediment Supply / Movement
  - Particle Size Distribution Patterns
  - Other Material Flux

Natural Disturbance Regimes
- Frequency
- Intensity
- Extent
- Duration

An additional consideration in choosing reference sites is to consider the degree of variability across the range of a system, both within and between different ecological regions. A balance may need to be struck between a general set of reference conditions, and the particularities of individual site variation. If warranted, important ecoregional variation should be recorded.

In order to fully test a metric, additional sites are needed that span the gradient of stressor or threat levels. An increasing number of studies are testing wetland metrics in this way (DeKeyser et al. 2003, Mack 2004, Jones 2005). The intent is to show that the metric is responsive to increasing impacts of stressors, or conversely, that it may show a response to mitigation efforts that seek to restore a site (Fig. 2).

Thresholds

Many metrics show a graded response to various stressors or threats; that is, there is no abrupt change in a system attribute as a particular stressor continues to impact a site (Fig. 2). With sufficient information, it is possible to construct a continuous rating for the metric; more often, given the variability in response of metric, or incomplete knowledge about the variability of the metric, a series of categorical thresholds are chosen that represent different "states." Even where a continuous relationship is statistically defensible, the interpretation can be enhanced by specifying thresholds along the continuum that are labeled as A, B, C, or D (Fig. 2; see also Harwell et al.1999). The labels reflect the assumption that the metric is being chosen because of its ability to detect positive or negative changes in ecological integrity.

We develop ratings for four states – Excellent (A), Good (B), Fair (C), and Poor (D) (Table 6). Our approach for this project was not to engage in a primary, field-based testing approach; rather, we develop our metrics by compiling the best available information, thereby providing a point-of-departure by which to understand the wetland systems. This approach is exemplified by Keddy and Drummond's (1996) survey of the literature on temperate deciduous forests of eastern North America in order to develop thresholds and ratings for a series of forest metrics. First, the typical range in natural variability can be obtained from the wetland system description and narrative (see "Wetland Types" above), and any additional literature on specific metrics. Second, we develop thresholds, from acceptable ranges of variation (A or B ranks) to cautionary or fair ranges of variation (C rank) to failing or poor (D ranked). In some cases, there is insufficient documentation or range of variation in a metric, and we use only a three-point scale.

Documentation of Metrics

After all the available information on a metric has been selected and thresholds have been developed to rate the field measures, documentation is provided for each metric (including methods for sampling, ratings, rationale, references). This section explains

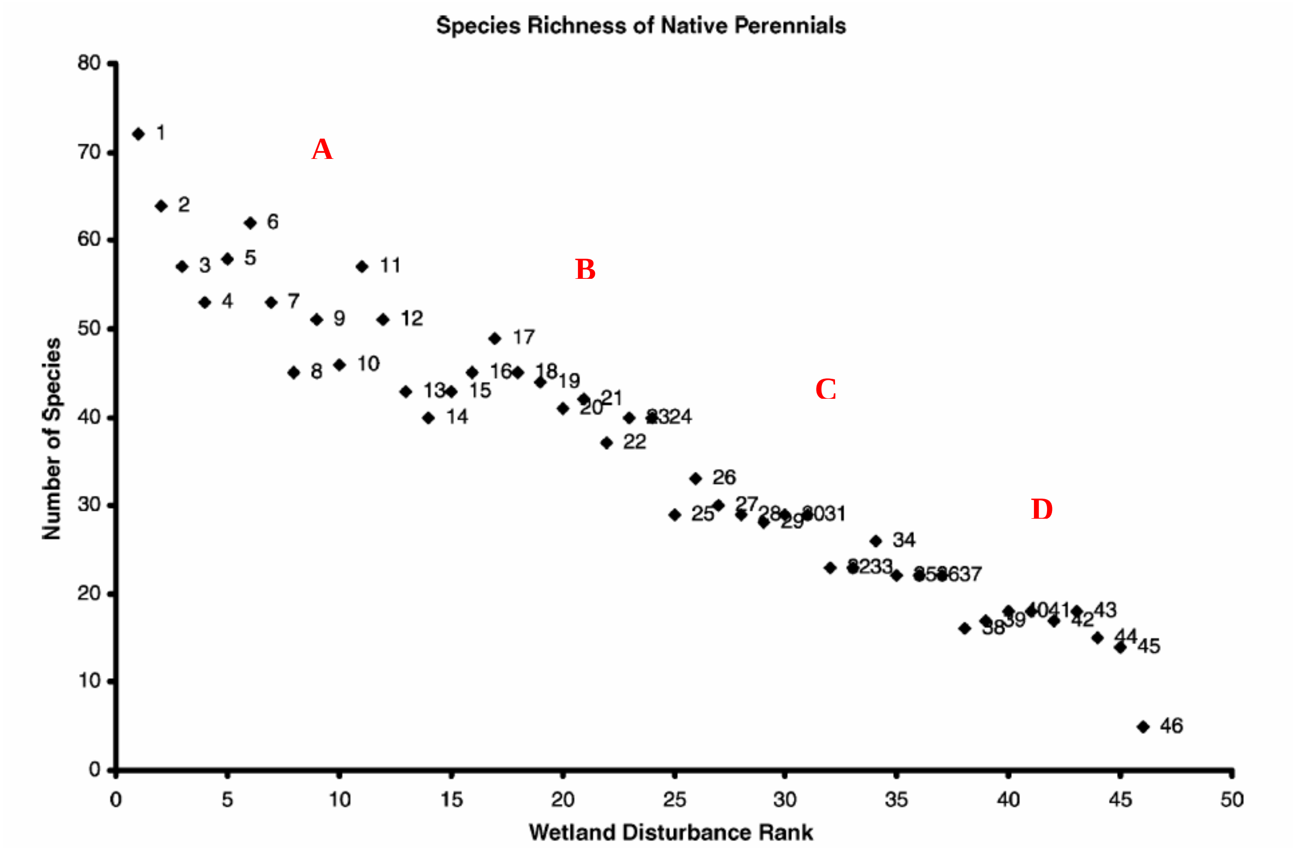

Figure 2. Example of the change in a metric over a disturbance gradient, showing how it declines more-or-less continuously to increasingly levels of disturbance. *Adapted from E.S. DeKeyser et al. Ecological Indicators 3 (2003) 119–133.*

Table 6. Selected set of metrics for the Laurentian-Acadian Conifer-Hardwood Alkaline Swamp System (HGM Depressional Class), showing how each metric is rated based on specified thresholds. Definitions are provided for each metric. Tier: 1 = Remote Sensing, 2 = Rapid or Extensive, 3 =Intensive.

Category	**Key Ecological Attribute**	**Indicator & Metric**	**Tier**	**Definition**	*Metric Rating Criteria*			
					Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
LANDSCAPE CONTEXT	Landscape Composition	Adjacent Land Use	1	Addresses the intensity of human dominated land uses within 100 m of the wetland.	Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
		Buffer Width	1	Wetland buffers are vegetated, natural areas that surround a wetland.	Wide > 100 m	Medium. 50 m to <100 m	Narrow. 25 m to 50 m	Very Narrow. < 25 m
		Etc.						
BIOTIC CONDITION	Community Composition	Stand Live Basal Area	3	Assesses stand structure using basal area of live trees.	>20	>20	10-20	<10
		Percent Cover of Native Plant Species	2	Percent cover of the plant species that are native, relative to total cover	100% cover of native plant species	85-< 100% cover of native plant species	50-85% cover of native plant species	<50% cover of native plant species
		Etc.						
ABIOTIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland	2	Addresses the intensity of human dominated land uses within the wetland.	Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
	Hydrology	Water Table Depth (Tier 3)	3	Determines average water table depth based on measurements from shallow groundwater wells.	Water table depth in June-early July is < 40 cm	Water table depth in June-early July is 40-60 cm	Water table depth in June-early July is < 60 cm OR water table is above soil surface through July and August	Water table depth in June-early July is < 60 cm OR water table is above soil surface through July and
		Etc.						
SIZE	Absolute Size	Absolute Size	1,2	The current size of the wetland	> 10 acres	5 to 10 acres	1 to 5 acres	< 1 acre
		Etc.						

how to collect the information (measures) needed for the metric and how to calculate the metric from these field data (see example in Appendix 2).

ECOLOGICAL INTEGRITY SCORECARD

Scorecard

The role of the scorecard is to help translate the information gathered at the level of key ecological attributes and metrics so that it can be understood in light of the goals and objectives. Ultimately, a metric is useful only if it provides information which guides management decisions or quantifies the success of past decisions. Ecological integrity must be assessed from field data and presented in a format that can be clearly understood by managers, scientists, policy makers, and the public. Strong communication tools will be needed to accomplish this goal, and we use a scorecard as one primary communication tool.

A key requirement for scorecard is that it warns the user when stressors are leading to changes in ecological integrity that require a management response. That is, the scorecard provides the analytical tool for moving from an agreed-upon set of metrics to assessing progress towards agreed-upon goals for mitigation, restoration, or monitoring. In a typical scorecard, "performance criteria," or rating scales, have been established for each metric. The scorecard approach brings together the relation among metrics and their ratings. For example, metrics of species diversity, composition, and vegetation structure can be individually rated, and then the scorecard combines them in a way that informs the users as to the index of biotic condition at the site. Its index can in turn be combined with other categories to provide an overall ecological integrity index or score. The metrics should contribute to a better understanding of overall ecological integrity and the stressors acting on that integrity.

A scorecard takes the individual metrics and produces an overall score or index based on 1) expert scientific judgment (e.g., as recommended historically by NatureServe 2002, or by Parrish et al. 2003), or 2) a formal index that integrates these measures based on a specified algorithm, e.g., a point-based approach that generates a Vegetation Index of Biotic Integrity (see Mack et al. 2004?). We develop the latter methodology here because it is more repeatable, objective, and transparent, all good qualities of an index. We use two approaches. Our primary approach is to use a point-based system, where we rate the individual metrics from Excellent (A) to Poor (D), assign points for each rating (5, 4, 3, 1) and aggregate them into four categories – landscape context, biotic condition, abiotic condition, and size (Table 7). The weights are derived from the basic weighting scheme used in Karr's IBI approach, where 5 (good), 3 (fair) and 1 (poor) points were used. Distinctions between Excellent (A) and Very Good (B) can be subtle, so only a single point separates them, whereas distinctions between fair (C) and Poor (D) should be strong; hence a low value of 1 is assigned to D.

Table 7. Example of how individual metrics are aggregated into an overall category rating for the Biotic Condition category. In the Rating columns, there was insufficient information for the first three metrics to distinguish A from B thresholds, so they are combined. The Weight column shows the weight given to each metric, based on its importance to the overall score. The Floristic Quality Assessment (FQA) index is weighted heavily when available, because it integrates much information on disturbances to the stand. The remaining metrics are weighted equally, the weights depending on whether or not an FQA metric is available. Scores are summed and the overall sum is scored.

Indicator/Metric	**Tier**	**Rating**				**Weight***	**Score**
		A	**B**	**C**	**D**		
Stand Live Basal Area	2	5		3	1	0.15 (0.25)	
Coarse Woody Debris (volume)	3	5		3	1	0.15 (0.25)	
Saplings / Seedlings of Native Woody Species	3	5		3	1	0.15 (0.25)	
Percent of Cover of Native Plant Species	2	5	4	3	1	0.15 (0.25)	
Floristic Quality Assessment (Mean C) [where available]	3	5	4	3	1	0.40(N/A)	
Biotic Condition Rating A=4.5 - 5.0 B=3.5 - 4.4 C=2.5 - 3.4 D=1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when metric for FQA is not available.

A secondary approach is to replace the point-based approach with a combination table approach, whereby the combination of ratings for a set of metrics is explicitly defined (similar to Boolean logic). This approach is particularly useful where metric ratings may interact (e.g., a C-rating in one metric is only achievable if another metric is at least B).

The challenge with a scorecard approach that relies on both individual metrics and indexes to derive an overall ecological integrity rank is not to obscure the knowledge gained from individual metrics or indices. At the same time, the challenge is to focus on a subset of metrics that are of most value to interpreting ecological integrity, and letting other metrics be used as needed for specific objectives. Thus scorecards could benefit from reporting both the ratings of the indices as well as ratings for individual metrics that the indices are based on (Table 7).

SAMPLING DESIGN

For any given ecological integrity assessment at a site or across a region, consideration will need to be given to how best to sample the wetlands to obtain a reliable estimate for the various metrics. Development of this aspect of the assessment is beyond the scope of this project. We do give consideration to what is known about the statistical and ecological properties of the metrics, but ultimately the choice of any given set of metrics may depend on how costly they are to sample, the particular objectives and the needed precisions for the project. When choosing metrics, consideration should be given to other assessment, monitoring, and mitigation projects in a region, and the metrics being used by them, in order to allow data to be compiled for combined analyses that might strengthen the assessment at any given site.

FIELD METHODS

Many field sampling protocols have been developed for wetlands, and the metrics we choose for ecological integrity assessment typically have well-described field protocols. We reference and briefly summarize those protocols throughout our documents, but at this time do not develop independent field manuals to accompany these metrics. We will assess the feasibility of doing so as more systems are completed.

RESULTS

SYSTEM SUMMARY

We developed ecological integrity assessments for each of 18 wetland systems (Table 1). Seven are found in the Rocky Mountains region, seven from the Northeastern U.S., and four from the Southeastern U.S. Each system is described and the metrics compiled using the standard template (Table 8). The individual reports for each system are available on request.

SELECTED METRICS

A summary of the indicators and metrics chosen for all systems is provided in Table 9, which shows the metrics used for each system, organized by HGM class. We created separate columns for indicators versus metrics when summarizing the metrics across all systems. We retained all metrics as defined by each team member, but group them by indicator to show the degree of close relationship among the metrics. As noted in the methods discussion, it is helpful to separate "indicators" from "metrics" because the "indicator" term serves as a broader term for closely related sets of metrics (e.g., a coarse woody debris indicator can have separate metrics based on either volume or biomass).

Fifty metrics were used among all 18 systems, with an average of about 15 metrics proposed per system (Table 9). All systems identified both core and supplementary metrics. The number of metrics ranged from 13 (10 core, 3 supplementary) to 25 (12 core, 13 supplementary. Many metrics are shared among the systems, partly because closely related systems were chosen within and among regions. Several metrics were widely shared among the systems, and they covered all four main categories (S = supplementary):

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- Landscape Context:
  - Adjacent Land Use
  - Buffer Width
  - Percentage of Unfragmented Landscape within One Kilometer
- Biotic Condition
  - Percent Cover of Native Plant Species
  - Floristic Quality Assessment
- Abiotic Condition
  - Land Use Within the Wetland
  - Hydrologic Alterations
  - Sediment Loading Index (S)
  - Nutrient Pollutant Loading Index (S)
  - Soil Organic Carbon (S)
  - Soil Bulk Density (S)
- Size
  - Absolute Size
  - Relative Size

In addition, metrics tend to be more commonly shared among systems of the same HGM class and of the same broad physiognomic/structural class. This makes sense because the hydrologic and other abiotic factors are comparable for systems within an HGM class, (e.g., flashiness index is applicable to riparian systems, whereas water table depth is more applicable to saturated peatland systems), and the biotic factors are more similar within vegetation categories (e.g., tree structural attributes are applicable to forested systems).

Table 8. Template for ecological integrity assessment report. Each of the 18 systems has a complete report that follows this template (available on request).

A. Introduction

A.1. Ecological System Description

- Classification Summary
- Environment
- Vegetation & Ecosystem
- Dynamics
- Landscape
- Size

A.2 Ecological Integrity

- Threats
- Justification of Metrics
  - Landscape Context
  - Biotic Condition
  - Abiotic Condition
  - Size
- Ecological Integrity Metrics

A.3 Scorecard Protocol

- Landscape Context
- Biotic Condition
- Abiotic Condition
- Size Rating
- Overall Ecological Integrity Rating Protocol

B. Documentation for Metrics

B.1 Landscape Context Metrics

Metric 1

- Definition:
- Background:
- Rationale for Selection of the Variable:
- Measurement Protocol:
- Metric Rating:
- Data:
- Scaling Rationale:
- Confidence that Reasonable Logic and/or Data Support the Index:

Metric 2

(Etc.)

B.2. Biotic Condition Metrics

B.3. Abiotic Condition Metrics

B.4. Size Metrics

C. References

Table 9. Master list of metrics across all eighteen wetland Systems (see Table 2 for full names of Systems, wetland types, and HGM classes).

				LA AC FEN	LA AL FEN	RM SM FEN	AC LP SF	WG FL PO	IIM BA PL	LA AL SW	LA AC SW	SC SE SB	WG SE SB	LA WM SS	RM AM WM	LA FR MA	NA EM MA	LA FL FO	RM LM RWS	RM SM RS	RM SM RW
CATEGORY		**WETLAND TYPE (HGM CLASS)**		F (D)	F (D)	F (S)	FL (D)	FL (D)	PL (D)	SW (D)	SW (D)	SW (S)	SW (S)	WM (D, S)	WM (D, S)	MA (D, R)	MA (D, R)	R (R)	R (R)	R (R)	R (R)
KEY ECOLOGICAL ATTRIBUTE	INDICATOR	METRIC	TIER																		
LANDSCAPE	**CONTEXT**																				
Landscape Composition	Adjacent Land Use	Adjacent Land Use	1	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X
	Buffer Width	Buffer Width	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Road Presence	Road Network extent / Distance to Nearest Road	1	X	X					X	X					X		X			
Landscape Pattern	Fragmentation	Percentage of unfragmented landscape within 1 km	1	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X
	Connectivity	Connectivity	1				X	X													
		Riparian Corridor Continuity	1																X	X	X
	Environmental / Disturbance Characteristics	Percent of Recharge Zone in Natural Condition	2										X								
		Area of Contiguous Fire Maintained Landscape	?					X													

BIOTIC	**CONDITION**																				
Community Composition - Tree	Tree Regeneration	Saplings/Seedlings of Native Woody Species	2, 3				S			X	X							X	X	X	
	Tree Richness and Composition	Abundance (Cover, Basal area) of Woody Native Plant Species	2, 3				X					X									
Community Structure - Tree	Tree Canopy Patch Structure	Canopy Patch Structure	2, 3				X						X								
	Tree Size/Age	Tree Size/Age	3				X						X								
	Tree Condition	Tree Condition	3																		
	Coarse Woody Debris	Coarse Woody Debris	2, 3							X	X										
	Tree Basal Area	Total Tree Live Basal Area	2, 3							X	X										
Community Composition - Groundlayer	Groundlayer Richness and Composition	Percentage of Specific Growth Forms (Native Graminoids, Perennial Herbs, Increasers)	2, 3	X	X	X	X							X							
		Species Richness/Cover of Native Plant Species (Understory, All)	3				X													X	X
		Percent Cover of Native Plant Species	2, 3	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
		Floristic Quality Assessment (Mean C or other)	3	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X
		Presence/Abundance of Indicator Plant Species	2, 3			S	X						X								
		Vegetation Index of Biotic Integrity*	3			X									X					X	
	Invasive Species	Invasive Species – Plants	2, 3					X	X			X				X	X				

		Invasive Species - Animals (Amphibians)	2, 3														S				
	Animal Indicators	Insect Indicators	3				S														
		Vertebrate Indicators	3				S														
Community Extent	Biotic Patch Richness	Biotic Patch Richness	2			S			S						S		S		S	S	S
	Interspersion of Biotic Patches	Interspersion of Biotic Patches	2			S			S						S		S		S	S	S
ABIOTIC	**CONDITION**																				
Energy/ Material Flow	Land Use Within the Wetland	Land Use Within the Wetland	2	X	X	X			X	X	X	X		X	X	X	X	X	X	X	X
	Sediment Loading Index	Sediment Loading Index	1	S	S	S			S	S	S			S	S	S	S		S	S	S
Hydrology	Upstream Surface Water Retention	Upstream Surface Water Retention	2									X							X	X	X
	Upstream/Onsite Water Diversions	Upstream/Onsite Water Diversions	2									X						X	X	X	X
	Flashiness Index	Flashiness Index	2,3													X	X				
	Floodplain Interaction	Floodplain Interaction	2, 3															X	X	X	X
	Water Table Depth	Water Table Depth	2, 3	X	X	X		X	X	X	X		X	X	X						
	Surface Water Runoff	Surface Water Runoff Index	1-3	S	S	S			S	S	S			S	S	S	S	S	S	S	S
	Hydrological Alterations*	Hydrological Alterations*	2,3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Bank Stability	Bank Stability	2, 3															X	X	X	X
	Beaver Activity	Beaver Activity	2, 3															S	S	S	

Nutrient Cycling	Litter Cover	Litter Cover	2			S						S			S		S		S	S	S
Nutrient Enrichment	Nutrient Enrichment	Nutrient/ Pollutant Loading Index	1-3	S	S	S	X		S	S	S		X	S	S	S	S		S	S	S
		Nitrogen Enrichment (C:N)	3			S		S	S			S			S		S		S	S	S
		Phosphorous Enrichment (C:P)	3			S		S	S			S			S		S		S	S	S
	pH of soil water	pH of soil water	3			S															
Soil Organic Content	Organic Soil Horizons	Organic Soil Horizons	2			S						S									
	Soil Organic Matter Decomposition	Soil Organic Matter Decomposition	2									S			S				S	S	S
	Soil Organic Carbon	Soil Organic Carbon	3	S	S	S		S	S	S	S	S		S	S	S	S	S	S	S	S
Soil Physical Properties	Soil Bulk Density	Soil Bulk Density	3	S	S	S		S	S	S	S			S	S	S	S	S	S	S	S
SIZE																					
Absolute Size	Absolute Size	Absolute Size	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		Absolute Size of Best Condition Area	2				X														
Relative Size	Relative Size	Relative Size	1,2	X	X	X			X	X	X		S	X	X	X	X	X	X	X	3X

* When available, this metric can replace several other metrics. See details in individual Systems.

** This metric can be developed as a quantitative "Index of Hydrologic Alterations," in which case it replaces several other metrics. See details in individual Systems.

DISCUSSION

ECOLOGICAL INTEGRITY ASSESSMENT BASED ON METRICS

The work involved in compiling these ecological integrity assessments is demanding, but essential, if we are to create a good index based on clearly defined metrics. Even so, these documents provide a general overview as to the current state of knowledge about the natural variability of these ecological systems, and the most likely candidates for metrics. We are confident that, as developed, these assessments could be successfully applied for mitigation, monitoring and assessment, recognizing that further field testing and verification are still needed.

These assessments are timely, given the needs of many organizations and agencies who need to know "how things are doing.' Conservation groups want to know "how their portfolio is doing" (Parrish et al. 2003). Agencies need to be able to know "how their resources are doing." Mitigation and restoration projects need to know "how well the system is being mitigated or restored." An ecological integrity assessment with a scorecard provides a strong tool for assessment and monitoring, provided that the underlying ecological description/model and threats analyses are well developed, metrics are carefully chosen, and data are well-collected.

These assessments can be helpful in encouraging collection of similar data, even when users may need to pick and choose among the metrics provided for each system. There are strong benefits to collecting information on individual metrics in a standardized fashion. For example, if water depth is measured in consistent fashion among different studies, this will greatly increase our knowledge of the natural variability of this metric and its response to degrading stressors. Different users may ultimately still choose to analyze and report their data in different ways based on their own needs. But underlying data sources can be shared.

CLASSIFICATION LEVEL

We use a combination of classification approaches, developed by NatureServe in conjunction with partners, focusing on the Ecological Systems types, with the option of going down to alliance and association level (Comer et al. 2003, NatureServe 2005). Our system types are more detailed than other wetland classifications (we have documented over 180 wetland types across the United States), but we feel this level of detail is needed for at least some of the metrics. We expect that we can aggregate the systems into broader classes in order to facilitate selection of the metrics, but we also expect that ratings for many metrics will need to be fine-tuned to account for system-specific variation, and perhaps even alliance or association-level variation.

Our approach is perhaps at odds with other rapid assessment techniques where no *a priori* classification is used; that is, a set of metrics are developed that apply to all wetlands, and only the rating per se is adjusted for individual wetland types. Fennessy et al. (2004) are concerned that too detailed a classification will hinder the ability to develop a comprehensive set of metrics for all wetland types, thereby preventing rapid-based assessments from being completed. We feel that an ecologically robust classification framework is important, to ensure that a sound ecological basis is developed for the metrics chosen, that threats to the system are as specific as possible, and ratings are appropriate for the ecological and biodiversity attributes to be measured. A comprehensive approach is achievable by working with a Network of Natural Heritage Programs in every state and academic and agency partners.

TIERED APPROACH

Given the cost of collecting metric information and the need to test these metrics over time, it is important that a rapid set of metrics be available that are easily collected and amenable to testing. Our tiered approach, in which remote sensing (Tier 1) and rapid ground survey (Tier 2) metrics are distinguished from intensive (Tier 3) metrics, provides the needed flexibility for a variety of purposes. Fennessy et al. (2004) provide additional guidance on rapid wetland assessment methods.

AGGREGATING METRICS INTO INDICES AS PART OF THE SCORECARD

We used two approaches to aggregate the metrics into indices – one a point-based approach, the other based on combination tables and boolean logic. We emphasize the former; applying it to 17 of the 18 systems (the Atlantic Coastal Plain Northern Wet Long Leaf Pine Savanna and Flatwoods used the combination table and Boolean logic approach). The point-based approach assumes that there are little to no interactions among metrics, or at least none that would affect the outcome of the rating, and it is more straightforward and simpler to display. It could also address interactions among key metrics by combining them into a joint metric. The combination table approach can address interaction affects more easily, but can become complicated to display. It is too early to say which approach has greater strength, or the degree to which they essentially produce the same answer. Further testing will be done using field data to assess the relative merits of each.

ECOLOGICAL INTEGRITY ASSESSMENT AND MITIGATION

EPA and others have identified the need for a good set of ecological endpoints (indicators) that would help address performance standards for wetland mitigation. The assessment developed here can provide many of those performance standards, with respect to measuring the ecological condition or integrity of a site. For each type of natural wetland, we can describe their patterns and processes, natural range of variability, and significant stressors, and develop a set of metrics and ratings that assess key attributes. This information can help set standards for what to measure and how to judge success in a mitigation project. It helps determine when actions are leading to improvements in ecological integrity as required by specific mitigation criteria. The scorecard can be used to set minimum performance standards or benchmarks which must be achieved in order to restore/mitigate a wetland. Of course, mitigation performance criteria may be determined on a case-by-case basis, depending on the condition of the wetland in the first place. The scorecards also provide a tool to monitor mitigation progress toward case-specific standards. That is, as the site changes over time, the change in ratings will indicate whether ecological integrity is improving or not.

Missing from these assessment tools are other aspects of mitigation, such as standards for good site preparation, or ways of estimating the trajectory that a wetland site may be on. Other researchers (e.g., Mack 2004) have given careful thought to how these can be used in conjunction with the approach developed here. In addition, some wetland mitigation projects may specify functions that are not easily captured here. If the wetland mitigation site requires habitat for black bear, including food sources, such as hard mast (oak, hickory, beech) and soft mast species (dogwood, sassafras, serviceberry, cherry), none of the measures directly addresses that metric (Stanturf et al. 1998). But, such information could be determined if species-specific tree regeneration or tree live basal area is collected as part of other metrics that assess overall ecological condition, particularly where the system being restored may be expected to have a mix of these species. The structure of the scorecard can be set up to accommodate function-based metrics, while still retaining a separate roll-up of “integrity” (Table 10). This allows a simultaneous assessment of integrity and functions using the same tool.

COMPARISON TO OTHER APPROACHES

There are many other efforts to develop ecological integrity assessments. The overall scorecard approach was earlier described by Harwell et al. (1999), though details were not provided. Parrish et al. (2003) outline in general form some of the methods used here. There are also many particular applications that have been developed in the last ten years, including those that include a three-tiered approach for conducting wetland assessments (Fennessy et al. 2004). Our documentation of the measures is similar to that of some HGM assessments (e.g., Hall et al. 2003) and to the Standard Operating Procedures by NPS Vital Signs Program (Oakely et al. 2003). Unlike many of these studies, our approach is intended to be synoptic and usable across the country. We build these assessment tools from existing information and expertise to ensure that the best available information is put to use to generate a first approximation of an ecological model and metrics. This approach provides a realistic first approximation of tools needed for ecological integrity assessments, and sets the stage for the most likely direction for further testing of metrics. In addition, we can specify the full range of natural wetland types; thereby ensuring that wetland mitigation projects can set realistic performance standards for the specific system being mitigated. We also allow individual metrics to be tailored to specific systems, while working with a broadly consistent framework that ensures some commonality as to how ecological integrity is being defined. More work is needed to compare across systems to see whether greater consistency can be achieved.

Table 10. Example of how a scorecard can incorporate some aspects of functional assessments. The top part of the table shows the roll up of metrics that contribute to ecological integrity evaluations. Additional metrics that relate to functional evaluations are rated separately.

Category	Baseline Rating	Current Rating	Desired Rating
Landscape Context	**C (2.5)**	**C (3.0)**	**B (3.5)**
Biotic Condition	**C (3.4)**	**B (4.2)**	**A (5.0)**
Species Richness of Native Plants	A (5.0)	A (5.0)	A (5.0)
Percent cover of Native Species	A (5.0)	A (5.0)	A (5.0)
Saplings of Native Woody Species	A (5.0)	A (5.0)	A (5.0)
Floristic Quality Assessment	C (1.0)	B (3.0)	A (5.0)
Abiotic Condition	**B (3.5)**	**B (4.0)**	**A (5.0)**
Size	**C (3.0)**	**C (3.0)**	**C (3.0)**
Overall Ecological Integrity	**C (3.15)**	**B (3.65)**	**B (3.98)**
Ecological Services			
Fish & Wildlife Habitat			
Nutrient Removal			
Flood Attenuation			

More broadly, ecological integrity is only one aspect of wetland systems that may be of interest when assessing wetlands. These include 1) Wetland conservation status / biodiversity value, which includes aspects of wetland irreplaceability, 2) Wetland ecological integrity, and 3) Wetland functional value (Fig. 3). (Hruby 2001, Fennessy et al. 2004). The first aspect, assessing the conservation status and irreplaceability value of wetland types and occurrences, can be part of a risk assessment process, where more irreplaceable wetland are preferentially targeted for threat abatement or subject to greater degree of protection, thereby avoiding wetland losses that lead to challenging mitigation or restoration efforts. This assessment can begin by assessing the relative conservation status (or risk of extirpation) of a given wetland type. For example, the Heinz Center (2002) uses the "At-risk wetland plant communities" (based on NatureServe's conservation status assessment approach), as an indicator of overall wetland or aquatic condition.

The third aspect, that of wetland functional value, has been widely developed as part of the functional assessments completed by the hydrogeomorphic (HGM) approach. Functional assessments categorize wetland types by creating seven very broad wetland classes (Appendix 3), then allowing regional applications to specify subclasses. We suggest that the ecological systems, despite sometimes crossing HGM classes, can be seen as furthering the specificity of HGM types by incorporating variation in biotic expression.

Similar to ecological integrity assessments, functional assessment may seek to estimate the status of ecological integrity (Table 11). However, these methods may differ from condition assessments in that they evaluate the level or capacity of wetland functions, whereas condition assessments evaluate the condition of key ecological factors or driving ecological processes to indicate ecological integrity. Other functional assessments simply are concerned with the level or capacity of each function regardless of how or whether it relates to ecological integrity. Condition assessments are more "holistic" in that they consider ecological integrity to be an "integrating super-function" (Fennessy et al. 2004). In other words, a wetland with excellent integrity will perform all of its functions at full levels expected for its wetland class or type. Functional assessments are compartmental and consider each function individually making it more difficult to assess overall integrity.

Because functional measures, in part, assess the overall composition and structure of a wetland system, many field measures may be shared between functional and ecological integrity assessments. But the chosen metrics may or may not be same. For example, metrics that assess flood / storm water control or wildlife habitat utilization may not have a direct correspondence to ecological integrity (Hruby 2001, Hruby 2004). Many HGM functional assessments collect very similar data to an ecological integrity assessment; what differs is that the functional assessments may take these data and develop logical operators to infer function. For example, in a functional assessment, a series of parameters (e.g., litter + O-horizon thickness + coarse woody debris + snags) are combined with flooding frequency to estimate the degree to which a wetland exports organic carbon, whereas in an ecological integrity assessment, these parameters would be

Table 11. Comparison of Condition and Functional Wetland Assessments. See Fennessy et al. (2004) for further comparisons between the two approaches.

	Condition Assessment	**Functional Assessment**
Purpose	Estimate current ecological integrity	-Estimate ecological integrity (HGM); -Societal Value of ecological functions (others)
"Currency"	Condition of Key Ecological Factors	Level of functions and ecological services
Approach	Holistic; ecological integrity = "integrating super function"	Compartmental; each function assessed individually.
Method	Combines indicators into conceptual model of key ecological factors	Combines indicators into conceptual model of ecological functions and values
Application	Mitigation, monitoring, state water quality standards, and Heritage Network.	Mitigation and monitoring.

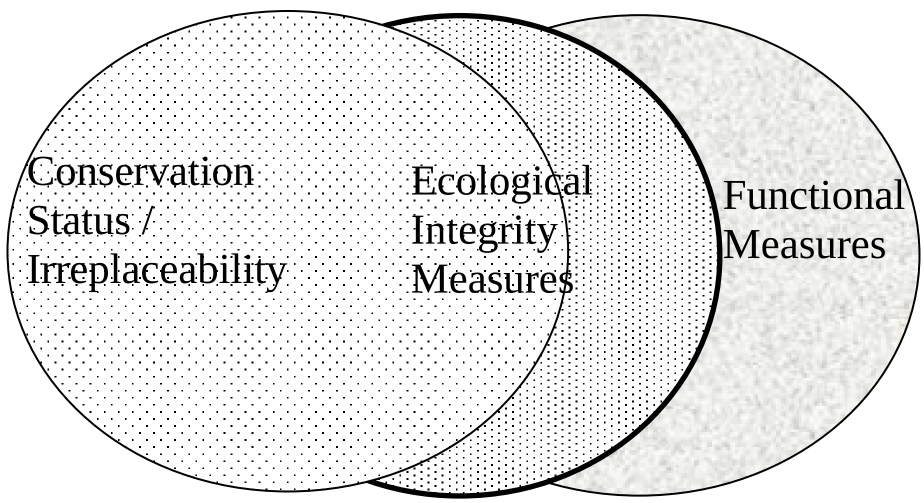

Figure 3. Ecological integrity is one aspect of wetland systems that may be of interest when assessing wetlands. Conservation status / irreplaceability and functional measures may also be of interest.

combined into abiotic and biotic metrics to develop integrity indices based on the acceptable range of variation for these measures in natural systems.

There is much to be gained by working together on these assessments, in order to encourage investigators and users to share data and interpret the data to meet their objectives. Thus we see much value in increased collaboration when developing wetland assessments, given the overlapping areas of interest.

Finally, our methods still require field testing using sampling procedures and design with quality assurance controls before being ready for inclusion in the mitigation process. Next steps include the need for field testing of metrics and evaluation of the ability to generalize these results across broad categories of wetlands.

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APPENDICES

APPENDIX 1. LIST OF NATIONAL ADVISORY GROUP MEMBERS

Palmer Hough, U.S. Environmental Protection Agency, Headquarters (Chair)

Steve Martin, U.S. Army Corps of Engineers, Norfolk District
Steve Eggers, U.S. Army Corps of Engineers, St. Paul District
Ruth Ladd, U.S. Army Corps of Engineers, New England District
Paul Minkin, U.S. Army Corps of Engineers, New England District
Aaron Allen, U.S. Army Corps of Engineers, Los Angeles District
Morgan Robertson, U.S. Environmental Protection Agency, Headquarters
Richard Sumner, U.S. Environmental Protection Agency, Office of Research and Development
Bob Lord, U.S. Environmental Protection Agency, Region 4
Sue Elston, U.S. Environmental Protection Agency, Region 5
William Ainslie, U.S. Environmental Protection Agency, Region 4
John Mack, Ohio Environmental Protection Agency

APPENDIX 2. EXAMPLE OF DOCUMENTATION FOR METRICS

Percentage of Native Perennial Herbs and Native Increasers

Definition: This metric estimates the relative abundance of native perennial graminoids and forbs as compared to all herbaceous species.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: Native graminoids, forbs, and shrubs dominate these fens. With increasing human disturbance, native perennial herbs (graminoid and forb) cover decreases relative to the total herbaceous cover, and the abundance of some native species increases (e.g., native increasers) (Galatowitsch et al. 2000). These changes are typically the result of a change in hydrology due to soil compaction, physical disturbance, or upstream alterations. Response of shrub cover to disturbances is more difficult to assess and is currently excluded. Thus shrub cover may vary widely.

Measurement Protocol: Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the wetland system and make a qualitative ocular estimate of the cover of each species growing in the wetland. The cover classes identified in Peet et al. (1998) are recommended (solitary/few, 0-1%, 1-2.5%, 2.5-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-90%, 90-95%, 95-99%) but any cover class system can be used as long as they same system remains consistent when comparing data with time or different site. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Mack 2004; Peet et al. 1998).

The metric is calculated by dividing total cover of native perennial graminoids and forbs by total cover of all herbaceous species and multiplying by 100. The same calculation is performed for native increasers.

Once qualitative or quantitative cover data are collected, these values are then used to determine the metric status in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Cover of native perennial graminoids and forbs 100%; shrub cover variable; Cover of native increasers is with natural range of variability (0-10%)	Cover of native perennial graminoids and forbs 85-100%; shrub cover variable Cover of native increasers is outside natural range of variability (10-20%)	Cover of native perennial graminoids and forbs < 60-85%; shrub cover variable Cover of native increasers is outside natural range of variability (20-50%)	Cover of native perennial graminoids and forbs < 60%; shrub cover variable Cover of native increasers is outside natural range of variability (> 50%)

Data: Native increasers include: cattail (*Typha angusitifolia*) and reed canary grass (*Phalaris arundicancea*). Others will be added as more information becomes available.

Scaling Rationale: The criteria are based on extrapolated thresholds from work done by Galatowitsch et al. (2000).

Confidence that reasonable logic and/or data support the index: Medium

APPENDIX 3. HYDROGEOMORPHIC (HGM) CLASSES

Brinson (1993) describes the following Classes:

Riverine
Depressional
Slope
Lacustrine Fringe
Tidal Fringe
Mineral Flats
Organic Flats