NatureServe Report · November 2008

Ecological Performance Standards for Wetland Mitigation

An Approach Based on Ecological Integrity Assessments

A Report to the Environmental Protection Agency

NatureServe

A Network Connecting Science With Conservation

NatureServe is a non-profit organization dedicated to providing the scientific basis for effective conservation.

Citation: Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, J. Christy. 2008. *Ecological Performance Standards for Wetland Mitigation: An Approach Based on Ecological Integrity Assessments*. NatureServe, Arlington, VA. + Appendices.

Funding for this report was provided by a grant from the Environmental Protection Agency (www.epa.gov) through Assistance Agreement #WD-83328301-01.

NatureServe
1101 Wilson Boulevard, 15th Floor
Arlington, Virginia 22209
703-908-1800
www.natureserve.org

Ecological Performance Standards for Wetland Mitigation

An Approach Based on Ecological Integrity Assessments

Don Faber-Langendoen, Greg Kudray, Carl Nordman, Lesley Sneddon, Linda Vance, Elizabeth Byers, Joe Rocchio, Sue Gawler, Gwen Kittel, Shannon Menard, Pat Comer, Esteban Muldavin, Mike Schafale, Tom Foti, Carmen Josse, John Christy

NatureServe

November 2008

Acknowledgments

Developing ecological performance standards for mitigation requires a variety of tools and expertise. The team of ecologists that helped developed this assessment were part of NatureServe's Ecological Integrity Assessment Working Group. Members consisted of NatureServe and Network member program staff, including Don Faber-Langendoen and Pat Comer (co-chairs), and Elizabeth Byers, John Christy, Greg Kudray, Gwen Kittel, Shannon Menard, Esteban Muldavin, Milo Pyne, Carl Nordman Joe Rocchio, Mike Schafale, Lesley Sneddon, and Linda Vance. We thank Andy Cutko, Tom Foti, Stephanie Neid, and Steve Rust, and David Braun and Dan Salzer of The Nature Conservancy for their input and participation in earlier meetings of the working group during 2004-2006, and Rob Riordan and Marta VanderStarre for their efforts and creative talent in the editing, design and production of this publication. We thank Jennifer Nichols for her assistance with the conceptual model figure.

Members are located in various programs around the country, including state Natural Heritage Programs found in Arkansas, Colorado, Maine, Montana, New Mexico, North Carolina, Oregon and West Virginia. Our various locations allowed us to draw on the expertise of our own and others' experiences in local or state assessment projects, as well as build on the collective history of our standard Heritage methodology for assessing ecological integrity.

As is evident from the results in this report, we have greatly benefited from the Rapid Assessment Methods (RAM) developed by the Ohio EPA, led by John Mack (ORAM), and the California Rapid Assessment Method (CRAM), led by Josh Collins, Marta Sutula and others. Although we differ in various ways from those methods in how we approach the primary goal of RAMs — we separate out ecological integrity or condition from ecological services or functions — we nonetheless have benefited greatly from their publications, phone conversations and workshop discussions.

We are grateful for financial assistance from the Environmental Protection Agency. We especially thank Rich Sumner and Palmer Hough for their encouragement of this follow-up project, which builds on an earlier set of Ecological Integrity Assessment protocols developed by NatureServe for EPA mitigation work (Faber-Langendoen et al. 2006).

The analysis and conclusions documented in this publication are those of NatureServe and may not necessarily reflect the views of the Environmental Protection Agency.

Contents

Appendices are provided in a separate document.

Executive Summary

Wetland mitigation and restoration practitioners, as well as scientists and policy makers, have been calling for stronger ecological performance standards to guide the wetland mitigation process. Here we present two methods for setting those standards: a) a watershed approach and b) ecological performance standards based on ecological integrity assessment methods.

A watershed approach can assist the process of wetland mitigation. The following criteria can be used to create an informal watershed approach.

1. Landscape integrity index – integrate cumulative impacts of past development activities, focusing on ecosystems.
2. Fish faunal intactness index – address cumulative impacts of past development on aquatic species.
3. Locations of critically imperiled (G1) and imperiled (G2) species and rare or high-quality ecosystem types – address presence and need of sensitive species and rare wetland types.
4. Ecosystem maps of the watershed. These are similar to wetland profiles, but integrate both biotic and abiotic aspects of wetlands. These maps will also help identify wetland types throughout the watershed, in order to avoid, where possible, permitting impacts to wetlands that are difficult or impossible to restore, such as fens or bogs, or may have a long time to recovery, such as forested wetlands. We recommend using the U.S. National Vegetation Classification (NVC) formation and NatureServe Ecological Systems levels for mapping, combined with maps of Hydrogeomorphic (HGM) classes.
5. Information on high priority conservation sites identified by a variety of conservation and wildlife agencies, and state and federal agencies.

Our ecological integrity assessment method for establishing performance standards for mitigation builds on the variety of existing wetland rapid assessment methods. It emphasizes metrics that are condition-based, separate from those that are stressor-based. The assessment uses the following steps.

1. Develop a conceptual model with key ecological attributes and identify indicators for wetland types, at multiple classification scales (NVC formation, NatureServe ecological system, coupled with HGM and Cowardin classifications).
2. Use a three-level approach to identify a suite of metrics, including Level 1 (remote sensing), Level 2 (rapid field-based), and Level 3 (intensive field-based) metrics.
3. Identify ratings and thresholds for each metric based on "normal' or "natural range of variation" benchmarks for each formation.
4. Provide a scorecard matrix by which the metrics are rated and integrated into an overall assessment of the ecological integrity of the ecosystem.
5. Provide tools for adapting the metrics over time as new information and methods are developed.

We provide an overview of the metrics and their ratings for the various assessment levels, as well as detailed protocols and scorecards for metrics at Level 1 and Level 2. Level 3 metrics are incomplete at this time, but we provide several examples.

The objective in setting performance standards and in conducting subsequent monitoring is to collect sufficient data to answer the hypothesis: has the mitigation wetland met the performance goal within the monitoring period? The performance standards developed above include a broad range of structural and functional measures, including hydrology, vegetation and soils, and rely on reference wetlands as a model for the dynamics of created or restored sites. We use several examples to show how ecological integrity assessments can be used to set ecological performance standards for mitigated sites, so that a more definitive answer can be given regarding the ecological success of mitigation efforts.

Our methods point towards the kinds of ecological applications that are needed for mitigation. Future studies are needed to advance these methods and test them on a variety of wetland mitigation sites.

Setting Ecological Performance Standards for Wetland Mitigation

Wetlands are a diverse set of ecological communities that occur at the transition between terrestrial and aquatic systems. They are a key habitat for many species that depend on their ecological structure, composition and function. They provide ecosystems services, such as flood control and improvement or maintenance of water quality. Their values to humans are both monetary (tourism opportunities) and non-monetary (recreational enjoyment, biodiversity appreciation).

Yet, globally, freshwater species and habitats are among the most threatened in the world (Saunders et al. 2002). Freshwater withdrawals have doubled since 1960 and more than half of all freshwater runoff is used by humans (Saunders et al. 2002). In the United States, wetland loss has been substantial over the past 200 years, though rates of loss continue to decline in the last few decades and may even have been reversed, based on the latest 1998-2004 survey (Dahl 2006). Prior to European colonization, wetlands comprised approximately 9% of the continental United States (Dahl 1990), but presently nearly 50% of the wetland area has been converted (NRC 1995). There are an estimated 107.7 million acres (43.6 million ha) of wetlands in the conterminous U.S. in 2004 or about 5.5% of the surface area of the conterminous U.S. (Dahl 2006).

Concern about the loss of wetlands in the United States has led to federal policies and regulations that protect wetlands on both public and private land. A primary vehicle for wetland protection and regulation is the Clean Water Act (Section 404). A principle objective of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency define the "waters of the United States" to include many wetlands because of their role in maintaining the water quality of those waters (NRC 2001).[1] Section 404 of the Clean Water Act requires that anyone dredging or filling in "waters of the United States" must request a permit from the U.S. Army Corps of Engineers.

In screening any project to determine the terms for a permit, three approaches are evaluated in sequence: 1) avoidance (avoid impacts to wetlands where practical), 2) minimization (minimize potential impacts to wetlands), and 3) mitigation (provide compensation for any remaining, unavoidable impacts through the restoration or creation of wetlands (Mitsch and Gosselink 2007). Compensatory mitigation, then, refers to the "restoration, creation, enhancement, and in exception cases, preservation of other wetlands, as compensation for impacts to natural wetlands" (NRC 2001). Thus, compensatory mitigation involves a process in which the ecological integrity, function, and/or services created/restored/enhanced from a mitigation wetlands is compared to the ecological integrity, function and/or services lost from an impacted wetland.

There is considerable controversy on the relative success of wetland mitigation (NRC 2001, Mitsch and Gosselink 2007). A key concern is that mitigation guidelines have not adequately addressed both "legal success" – that some type of wetland function and area has been replaced, and "ecological success" – that wetland of the same type occurs in the same setting or contains an acceptable level of function compared to wetlands in the region, often referred to as "reference wetlands" (Mitsch and Gosselink 2007) (see also "Reference Condition" on page 23). A study by the National Research Council (NRC) was asked to evaluate how well and under what conditions compensatory mitigation required under Section 404 is contributing toward satisfying the overall objective of restoring and maintaining the quality of the nation's waters. That report (NRC 2001) produced several key findings:

[1] With recent Court ruling, many isolated wetlands are no longer expected to be regulated under the Clean Water Act and many drier riparian wetlands (especially in the West) do not meet Section 404 definition of "waters of the U.S."

1. The goal of no net loss of wetlands is not being met for wetland functions by the mitigation program, despite progress in the last 20 years.
2. A watershed approach would improve permit decision making.
3. Performance expectations in Section 404 permits have often been unclear, and compliance has often neither been assured nor attained.
4. Support for regulatory decision making is inadequate.
5. Third-party compensation approaches (mitigation banks, in-lieu fee programs) offer some advantages over permittee-responsible mitigation.

In response to these and other 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 the Corps of Engineers began working with partner agencies and organizations to identify ways to improve wetland mitigation. A variety of projects and legislative revisions are now underway to improve the performance standards for mitigation. Here we focus on two key aspects of those revisions, relating to #2 (a watershed approach) and #3 (setting performance expectations).

Watershed Approach

Wetland condition or integrity (composition, structure and function) depends on the landscape and watershed within which they are found. There is an increasing desire to include landscape setting and context when planning mitigation projects, in order to improve success in mitigating for both hydrologic functions and wildlife needs that depend on connectivity to adjacent habitats. In addition, mitigation wetlands are more likely to achieve a comparable form and similar function to the original wetlands if they are restored within the same watershed. At the same time, the watershed approach can assist in determining whether an on-site mitigation project is more likely to succeed than an off-site project that is still within the same watershed.

There is also concern that some wetland types, such as bogs and fens, are difficult to restore, and others, such as forested wetlands, may require a long period of evaluation before it is possible to determine mitigation success (NRC 2001). Where possible, these types should be identified within the watershed and impacts should be avoided. A watershed assessment can highlight those wetlands that are more problematic for mitigation success. These and other aspects of a watershed approach need to be developed, including a wetland profile of watersheds based on (1) extent/distribution of HGM types, (2) landscape integrity, and (3) extent, distribution and condition of wetland types (Bedford 1996, Johnson 2005).

Ecological Performance Standards

There has been a strong interest in developing performance expectations for mitigation using an ecological indicator-based approach, coupled with guidance on site design and other mitigation tools. 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 (Harwell et al. 1999, Young and Sanzone 2002, U.S. EPA 2002, Parrish et al. 2003, Faber-Langendoen et al. 2006).

Assessing the current "ecological 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). The pre- and post-ecological condition of impacted sites can then be compared to these reference sites to determine net loss of ecological integrity. Mitigated sites can then be compared to these reference sites to assess their "success" in replacing the loss of ecological integrity from the impacted sites. However, selection and development

The NatureServe Network

NatureServe is a non-profit conservation organization whose mission is to provide the scientific basis for effective conservation action. NatureServe represents an international network of biological inventories—known as natural heritage programs or conservation data centers—operating in all 50 U.S. states, Canada, Latin America and the Caribbean. The NatureServe network is the leading source for information about rare and endangered species and threatened ecosystems. Together with these network member programs, we not only collect and manage detailed local information on plants, animals, and ecosystems, but also develop information products, data management tools, and conservation services to help meet local, national and global conservation needs.

of indicators to measure ecological integrity 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.

Purpose of this Report

The overall purpose of this report is to develop two key methods needed for wetland mitigation: a) a watershed approach and b) ecological performance standards based on ecological integrity assessment methods.

With respect to a watershed approach, NatureServe has worked closely with federal and state partners to classify and map large portions of the U.S. landscape, using Ecological Systems and the revised upper levels of the U.S. National Vegetation Classification (NVC; Comer et al 2003, Comer and Schulz 2007, FGDC 2008, Faber-Langendoen et al. 2008). These classifications and maps can work in concert with existing methodology on at-risk (rare and endangered) species and ecosystems, as well as exemplary occurrences of all ecosystems, to help characterize wetlands. We use these and other landscape characterization methods to develop an informal approach to assessing watersheds to assist with mitigation planning.

With respect to ecological performance standards, NatureServe has been developing a standardized method for evaluating on-site condition of wetlands in the United States using criteria and indicators for ecological integrity (Faber-Langendoen et al. 2006, 2008). Indicators are rated based on "natural" reference benchmark standards, allowing users to determine current wetland status and performance standards to maintain or improve the quality of the wetland. In a previous EPA-funded pilot, we developed criteria, indicators and specific metrics for 18 wetland Ecological System types (Comer et al. 2003) in different regions of the U.S. (Faber-Langendoen et al. 2006). However, our report identified several new directions. First, we found that metrics were similar among related wetland types (fens, marshes, swamps), suggesting that we should consider a more general framework before focusing on specific wetland types. Second, working at the level of detailed wetland types (there are over 200 wetland Ecological System types), while appropriate for some applications, is not always needed for other applications. Third, metrics chosen for the pilots varied from remote sensing based to intensive plot-based within the same assessment, making implementation and interpretation more difficult.

Here, we outline a variety of new methods to structure our selection of indicators for all U.S. wetland systems, including a) use of an improved hierarchical framework for wetland classification, b) a three-level approach to the development of metrics (remote, rapid, intensive), c) ecologically comprehensive rapid (level 2), field-based metrics and ratings for all broad, wetland types, with suggested metrics for level 1 and level 3 and d) a report card structure for aggregating metrics by major ecological attributes (landscape context, size, vegetation, hydrology and soils). We build on the variety of existing rapid wetland assessment and monitoring materials, particularly those in the California Rapid Assessment Manual (CRAM, Collins et al. 2006, 2007), the Ohio Rapid Assessment Manual (Mack 2001), and prior work by NatureServe (Faber-Langendoen et al. 2006). We demonstrate how these methods can be used to help set ecological performance standards for wetland mitigation.

Methods for a Watershed Approach

A watershed approach that can assist the process of wetland mitigation should include the following considerations (adapted from NRC 2001).

1. Consider the hydrogeomorphic and ecological landscape and climate.
2. Identify wetland types throughout the watershed, in order to avoid, where possible, permitting impacts to wetlands that are difficult or impossible to restore, such as fens or bogs, or may have a long time to recovery, such as forested wetlands.
3. Restore or develop natural variability in hydrologic, biologic, and to soil and other physicochemical conditions.
4. Whenever possible, choose wetland restoration over creation.
5. Carefully consider site placement in the context of landscape setting, to ensure that impacts from the surrounding landscape will not compromise the success of the mitigated wetland.
6. Conduct early monitoring for both the site and its landscape setting.

Although an ideal watershed approach would be based on a formal watershed plan, developed by Federal, state, and/or local environmental managers in consultation with affected stakeholders, such plans often do not exist.[2] However, an informal approach may suffice if it is based on "a structured consideration of watershed needs and how wetland types in specific locations can fulfill those needs." Such information could include current trends in habitat loss or conversion, cumulative impacts of past development activities, current development trends, presence and needs of sensitive species or rare wetland types, site conditions that favor or hinder the success of mitigation projects, such as chronic environmental problems from flooding or poor water quality, local watershed goals and priorities.

We suggest the following methods can be used to create an informal watershed approach.

1. Landscape integrity index – integrate cumulative impacts of past development activities, focusing on ecosystems.
2. Fish faunal intactness index – address cumulative impacts of past development on aquatic species.
3. Locations of critically imperiled (G1) and imperiled (G2) species and rare or high-quality ecosystem types – address presence and need of sensitive species and rare wetland types.
4. Ecosystem maps of the watershed at the NVC formation and NatureServe Ecological Systems levels, combined with maps of Hydrogeomorphic classes of the watershed (akin to wetland profiles, but integrating both biotic and abiotic aspects of wetlands) that:
   - address site placement in the context of landscape setting;
   - address hydrologic functions;
   - identify wetlands that are difficult to restore or have a long time to recovery, and
   - identify exemplary occurrences of all ecosystem types.
5. Information on high-priority conservation sites identified by a variety of partners.

Additional methods could be developed to address trends in habitat loss, conversion and development. Each of these methods is briefly described in the following paragraphs.

[2] *Compensatory Mitigation for Losses of Aquatic Resources, Proposed Rule*. Federal Register, Vol. 71, No. 59. 15520-15556, Tuesday, March 28, 2006.

Landscape Integrity of the Watershed

NatureServe has developed a prototype Landscape Integrity Model (LIM) (Tuffly and Comer 2005, Rocchio 2007), which is a regional Geographic Information System (GIS) model of landscape condition, originally established as a 30m grid of unique values, then segmented into four classes from "highly degraded" to "minimally degraded" (Figure 1). The prototype model is similar to the Landscape Development Index used by Mack (2006) and Tiner (2004), but relies on the use of existing geographical datasets of stressors, such as roads and land use, to characterize the landscape. The index is described in more detail in the "Landscape Integrity Model" section that follows (page 35). It provides a means of characterizing the range of variation in the ecological integrity across a watershed.

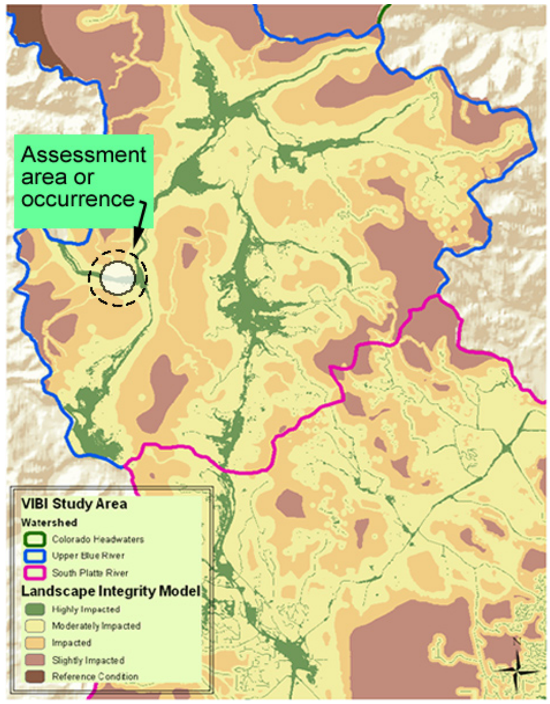


FIGURE 1
Watershed Evaluation Based on a Landscape Integrity Model.
Values for landscape context metrics and condition metrics for a wetland area at a site can be derived from the model (adapted from Rocchio 2007).

To use the landscape integrity model as part of wetland mitigation projects, sites or assessment areas chosen within the watershed or landscape can be overlaid on the model and evaluated with respect to landscape integrity. First the wetland occurrence or polygon is defined and its size measured (Fig. 1). A landscape context area can then be defined around the occurrence. The landscape integrity model provides the data for the "landscape integrity index" metric, based on the average score of the pixels within the landscape context (see "Landscape Integrity Model" on page 35). The same model can be used to assess the condition within the occurrence, particularly if the wetland is large (Fig. 1). Together, these metrics provide a simple means of characterizing the integrity of the occurrence and its setting.

Fish Faunal Intactness

Watershed intactness is a critical aspect of the biological balance of the nation's ecological systems (NRC 2001). It is of particular importance in freshwater systems that are impacted by pollution, habitat alteration, fisheries management and invasive species. One approach to measuring watershed intactness is to focus on a few key indicators. Fish Faunal Intactness is one such approach that can describe the current biotic condition of the watershed (EPA Report on the Environment 2008, Chapter 6). This indicator tracks the intactness of the native freshwater fish fauna in each of the nation's major watersheds by comparing the current faunal composition of those watersheds with their historical composition. In this case, historical data are based on surveys conducted prior to 1970. The indicator specifically measures the reduction in native species diversity in each 6-digit USGS hydrologic cataloging unit (HUC) in the 48 contiguous states. Intactness is expressed as a percent based on the formula:

reduction in diversity = 1 – (# of current native species / # of historic native species).

This indicator makes use of empirical, rather than modeled, data sets and focuses on a well-known group of organisms with a fairly strong historical record. The fish distributional data underlying this indicator have been gathered by NatureServe, and are derived from a number of sources, including species occurrence data from state natural heritage programs, a broad array of relevant scientific literature (e.g., fish faunas), and expert review in nearly every state. Data were assembled during the period 1997-2003. Maps of HUCs (which are not necessarily directly equivalent to watersheds) showing fish fauna intactness are available across the lower 48 states (the underlying data were recorded across small 8-digit HUCs, but data were pooled and reported by larger 6-digit HUCs to reduce potential errors of omission in the smaller "watersheds").

Information from this indicator provides an important summary of the cumulative impacts that have occurred in a HUC or watershed. For those HUCs or watersheds where the indicator points to a unit or watershed in good condition, impacts to wetlands should be avoided. For HUCs or watersheds in poor condition, efforts to restore wetlands through mitigation could be encouraged.

Locations of At-risk Species and Ecosystems

Several layers of information could be developed to identify the locations of rare and endangered species and community types:

- Data on the locations of populations of species or locations of rare community types that are imperiled throughout their range (at risk of extinction). Examples of such data include NatureServe's list of species or communities ranked globally critically imperiled (G1) and imperiled (G2) or species with status under the U.S. Endangered Species Act.
- Data on the locations of species populations or communities that are imperiled within the state (at risk of extirpation from that state). Examples of such data include NatureServe's list of species or communities that are ranked state critically imperiled (S1) or imperiled (S2) or with any legal protected status within the state.

This information can be used to prioritize potential mitigation sites based on the locations of wetlands in need of restoration and that support rare species (thus restoration presumably benefits these species). In addition, this same information may help in the permitting process by giving wetlands that support rare elements a higher level of scrutiny prior to any permit being released.

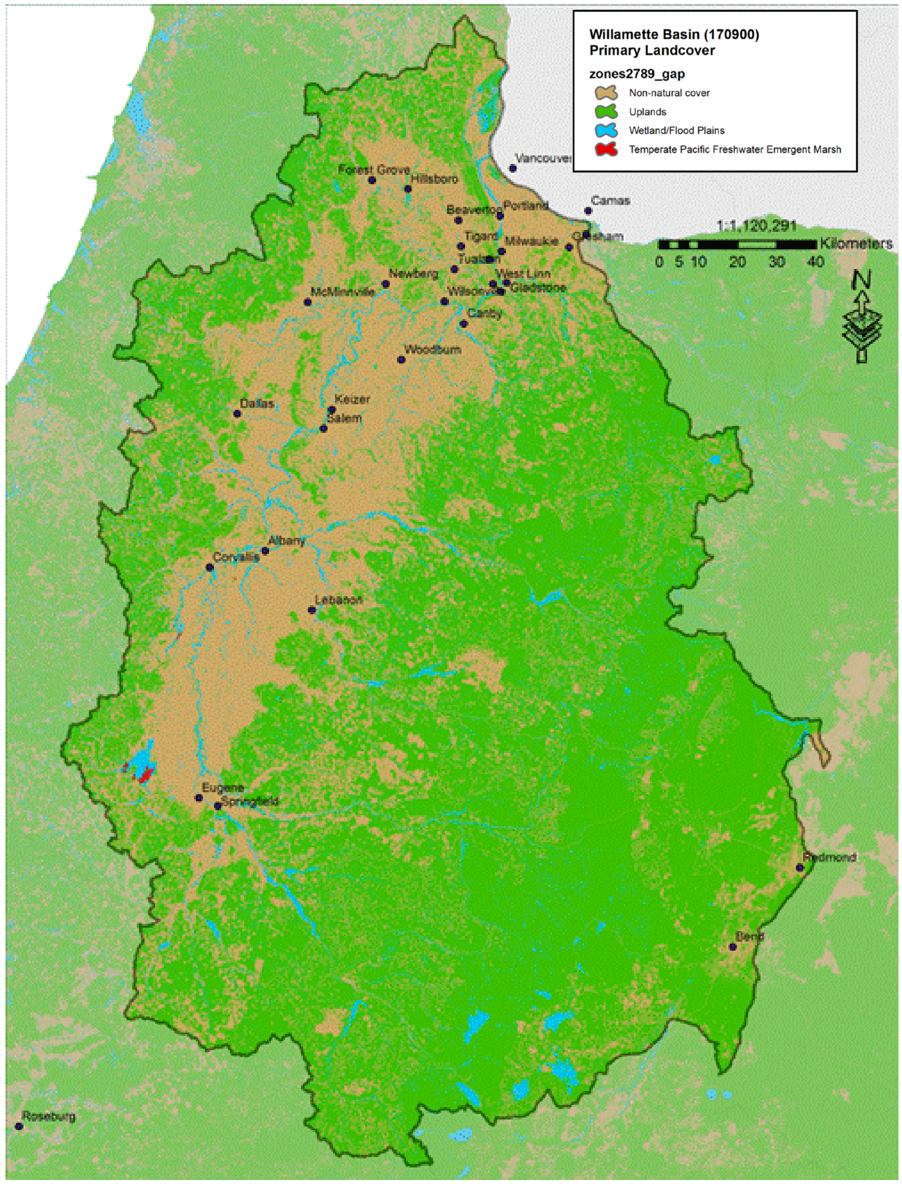
Ecosystem Maps and Exemplary Sites

Maps of wetland types at the NVC formation and NatureServe Ecological Systems levels, combined with Hydrogeomorphic wetland class maps of the watershed provide a ready tool for addressing watershed approaches (Figure 2, following page). These maps will allow mitigation planners to address site placement in the context of landscape setting of mitigated and reference wetlands, to assess their hydrologic functions, and to identify wetlands that differ in how they should be handled in the process of mitigation review. For example, impacts to wetlands that are difficult to restore, such as bogs and fens, should be avoided. Wetlands with a long recovery or restoration period, such as many forested wetlands, should require a longer monitoring period.

These maps can be integrated with known community and ecosystem occurrences from Natural Heritage databases that document the exemplary locations of important ecosystems in the watershed. For over twenty-five years, NatureServe and the Natural Heritage Network have been documenting the viability and integrity of individual occurrences of ecosystems[3] (Stein et al. 2000, NatureServe 2002, Brown et al. 2004). Working from the concept of ecological integrity, NatureServe assigns levels of integrity and conservation value using a report-card style approach (Harwell et

[3] The Natural Heritage methodology was originally developed by The Nature Conservancy (TNC), but Heritage methods staff transferred to NatureServe when it was formed in 2000. Since then, NatureServe has worked with the Network of Natural Heritage Programs to maintain and improve the methodology, while continuing to collaborate with TNC.

FIGURE 2A
Ecosystem Characterization of the Willamette Basin Watershed (6 digit HUC). The source for this portion is National GAP Program data using ETM (3-season multi-temporal) imagery with the classification based on using a mix of CART (non-forest) and GNN (forest) (J. Kagan pers. com. 2008).



al. 1999). Occurrences with higher levels of integrity and conservation value would generally be ranked A, B, or C (from "excellent" to at least "fair"), and those with significant degradation would be ranked D ("poor"). The "grades" are referred to in NatureServe databases as an "Element Occurrence Rank" (EO Rank), which is akin to an "Ecological Integrity Rank." This rank is defined as "a succinct assessment of the degree to which, under current conditions, an occurrence of an ecosystem matches reference conditions for structure, composition, and function, operating within the bounds of natural or historic disturbance regimes, and is of exemplary size" (Faber-Langendoen et al. 2008). This definition contains the core concept of ecological integrity but includes reference to size, given its importance in assessing conservation value.

The overall rank is assigned by first rolling up the major attributes of vegetation, hydrology and soils into a Condition rank, then combining Condition, Size and Landscape Context into an overall rank. Element occurrences and their ranks are assigned by Natural Heritage Programs throughout the country, and are a good source for identification of exemplary wetland occurrences within watersheds (Brown et al. 2004). When combined with ecosystem maps, these ranked occurrences can provide a comprehensive spatial view of the overall condition of ecosystems across the watershed (Fig. 2).

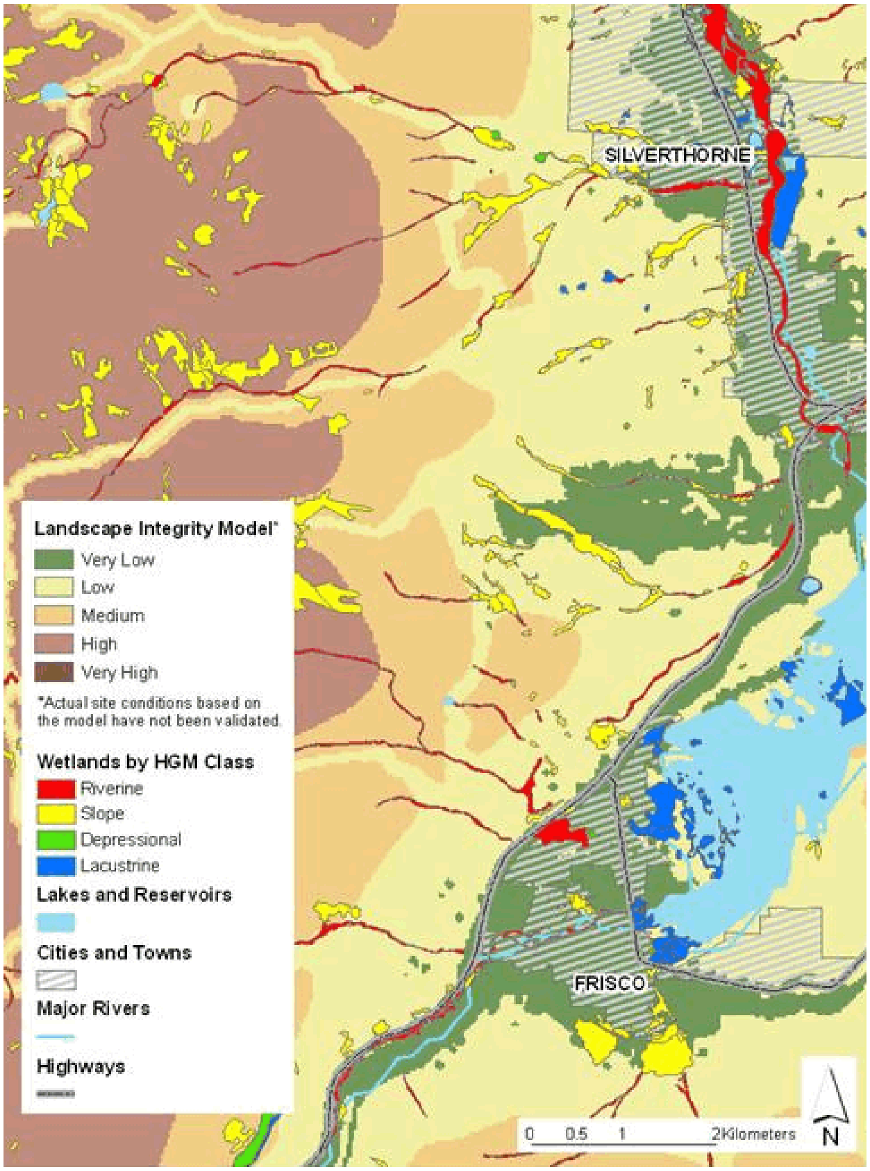


FIGURE 2B

A map of Summit County showing wetland polygons labeled by hydrogeomorphic wetland class superimposed on a map of landscape integrity. The landscape integrity values are based on the Landscape Integrity Model from Rocchio (2007). Data sources for HGM layer include Johnson (2005), based on work by SAIC (2000). Map created by Joanna Lemly, Colorado Natural Heritage Program.

High-Priority Conservation Sites and Focal Areas

There are a variety of agencies and organizations that identify sites of high conservation value or have high priority for wildlife, birds and other organisms. Among these are The Nature Conservancy's (TNC's) portfolio of conservation sites, and State Wildlife Action Plans that list high-priority focal areas. But it has been difficult to access this information.

LandScope America (www.landscope.org), NatureServe's joint website with the National Geographic Society, will publish a full, aggregated set of conservation sites across the U.S. for the first time later this year. The conservation priorities theme of LandScope America will include maps and data on local, state and national conservation priorities (such as public agency plans, TNC ecoregional plans, State Wildlife Action Plans, regional greenprints, and so on). By displaying multiple sets of priorities in a single view, LandScope will show how these various approaches relate to each other and where they overlap. The information can be used to characterize high-priority sites across a watershed.

Information on high-priority conservation sites and focal areas will help mitigation projects avoid impacting existing wetland within these areas, as well as encourage restoration efforts in sites proximal to these areas. Partners can be identified that may be interested in working with the mitigation process because of the opportunity to increase wetland values.

Summarizing the Watershed Approach for Mitigation

The five components of our suggested watershed approach — landscape integrity index, fish faunal intactness index, locations of at-risk species and ecosystem types, ecosystem maps of the watershed, and information on high priority conservation sites — address many of the key needs of a watershed approach for mitigation (NRC 2001). The watershed approach considers the hydrogeomorphic and ecological landscape of the sites. It identifies wetland types throughout the watershed in order to avoid, where possible, permitting impacts to wetlands that are difficult or impossible to restore, such as fens or bogs, or may have a long time to recovery, such as forested wetlands. It identifies watersheds where restoration may be a priority, and where optimal areas of wetlands may be for restoration. It provides guidance on site placement in the context of landscape setting, including where those settings are seriously degraded or disturbed. Finally, it provides some simple landscape-based tools for monitoring the site and the landscape setting (Figures 1 and 2).

There is growing interest in using a watershed approach to guide wetland mitigation and restoration. For example, the Colorado Wetlands Program is a voluntary, incentive-based program to protect wetlands and wetland-dependent wildlife on public and private land. Statewide strategies are being considered to better guide and coordinate these efforts. A Rio Grande project within the state proposes a scientific foundation upon which statewide strategic goals can be built and set priorities to more effectively protect, sustain or restore the ecological health of Colorado's wetland ecosystems by creating a wetland profile that describes the types, abundance and ecological condition of wetlands in Colorado (Rocchio pers. comm. 2008). This profile will then be used to formulate statewide strategies for setting wetland protection, mitigation and restoration priorities (see also Johnson 2005). These watershed datasets can also be used to model the suitability of potential watershed sites for mitigation purposes (Van Lonkhuyzen et al. 2004).

Ecological Performance Standards and Ecological Integrity

There is a growing consensus on the performance requirements needed for mitigated wetlands (NRC 2001, ELI 2004). Our suggested performance standards build on the following recommendations (adapted from NRC 2001):

1. Mitigation goals are set in the context of a watershed approach.
2. Impacted sites are evaluated using the same ecological and functional assessment tools as used at the mitigated site (i.e., it should be possible to determine how similar the mitigated site is to the impacted site). This requires identification of the wetland type and its hydrogeomorphic position at both sites.
3. Mitigation projects evaluate the full range of ecological integrity and natural functions.
4. Mitigation goals are clearly stated so that the desired range of ecological integrity and function are specified. Structure, composition and function are all relevant to the goals.
5. Assessing wetland ecological integrity and function requires a science-based, rapid assessment procedure.

We rely on three major tools to address these recommendations. First, the overall watershed approach noted in #1 above has been addressed earlier (see "Methods for a Watershed Approach" above). Second, we use standardized classifications of ecosystem types, including descriptions of diagnostic or distinguishing characteristics. These classifications provide important guidance on recommendations #2–#4 above by ensuring that mitigated sites are as equivalent to impacted sites both in terms of the type of wetland being mitigated and its condition. We emphasize the formation and formation subclass levels of the NVC, the Ecological Systems of NatureServe and the HGM classes (Brinson 1993, Smith et al. 1995). Classifications also provide a ready means of understanding what the expected range of integrity and functions might be. For example, when a site has been identified as having a bald cypress-tupelo forest type within a riverine context, it provides important guidance on what the range of integrity and functional values are, and what the desired range might be for mitigation.

Third, we assess wetland composition, structure and function using an ecological integrity assessment approach based on reference conditions and natural and historic ranges of variation. Measures of ecological integrity provide the needed tools to address wetland functions identified in #5 above, coupled with recommendations #2–#4. Identifying criteria (metrics) that describe the major ecological attributes will ensure that the basic components of wetland pattern and process are covered (Figure 3).

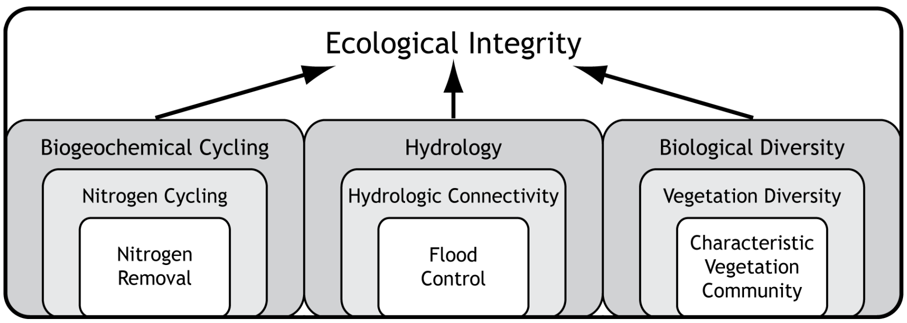


FIGURE 3
A schematic illustration of ecological integrity as the integrating function of wetlands, encompassing both ecosystem structure and processes. Integrity includes processes such as hydrology and hydrologic connectivity that address functions such as flood control (from Fennessey et al. 2007; based on Smith et al. 1995).

Wetland Classification and Performance Standards

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. Classifications are also important in establishing "ecological equivalency;" for example, an impacted salt marsh should be replaced with a mitigated salt marsh with equivalent or better integrity.

There are a variety of classifications for structuring ecological integrity assessments and for establishing ecological equivalency. The HGM classification developed by Brinson (1993) was developed in order to assist the Corps of Engineers with the evaluation of wetland impacts. HGM identifies groups of wetlands that function similarly, based on three fundamental factors that influence how wetlands function, including geomorphic setting, water source and hydrodynamics (Smith et al. 1995). Typically, function is assessed through compositional and structural surrogates. Nationally, there are seven broad wetland classes, with regional variants. No detailed set of wetland types are nationally available. The HGM classification meets several important needs for mitigation:

- It specifically addresses wetland function, using a surrogate approach based on structure and composition.
- Manuals for its application are available across many regions of the country.

The wetland classification system of Cowardin et al. (1979) forms the basis for the National Wetlands Inventory (NWI) Classification and Mapping Program across the United States. This classification was designed to be used as an inventory tool for wetlands and deepwater habitats. The NWI system has been widely used for reporting on the status and trends of wetland acres across the U.S. (e.g. Dahl 2006). Table 2 (page 17) and Appendix IV show how the NWI classification can be structured to link to the U.S. National Vegetation Classification.

A third major classification is that of the U.S. National Vegetation Classification (FGDC 1997, 2008, Grossman et al. 1998, Jennings et al. 2008). It was developed to classify both wetlands and uplands, and identifies types based on vegetation composition and structure and associated ecological factors. Nationally, there are eight very broad classes, but seven other nested hierarchical levels permit resolution of types from broad-scale formations to fine-scale associations. At the formation level, there are thirteen wetland types, and at the association scale there are two-thousand wetland types recognized across the U.S. Each of the associations has been assessed for conservation status, so their relative rarity on the landscape is also known. Thus the NVC meets several important needs for mitigation:

- It can be used to characterize the entire watershed, both upland and wetland
- It uses broad categories that are helpful in assessing the relative difficulty of mitigating certain kinds of wetlands (e.g., floodplain and swamp forest, bog & fen, etc.).
- It provides information on the relative rarity of wetland types.
- It is very compatible with Cowardin classification, allowing for reporting of status and trends assessments for both wetland area and wetland integrity.
- It is a federal standard for all agencies, facilitating sharing of information on wetland types in other contexts (FGDC 19997, 2008).

An additional classification approach, the Ecological Systems classification (Comer et al. 2003), can be used in conjunction with the NVC. Ecological Systems provide a spatial-ecologic perspective on the relation of associations and alliances (fine-scale plant community types), integrating vegetation with natural dynamics, soils, hydrology, landscape setting and other ecological processes. They can also provide a mapping application of the NVC, much as soil associations help portray the spatial-ecologic relations among soil series in a soil taxonomic hierarchy. Systems types facilitate mapping at meso-scales (1:24,000–1:100,000). Increasingly, comprehensive systems maps are becoming available across the country. Currently there are about 600 ecological systems, of which about 250 are wetlands. Ecological Systems are somewhat comparable to the group level of the revised NVC hierarchy, and can be linked to higher levels of the NVC hierarchy, including formations. Thus Ecological Systems meet several important needs for mitigation:

- Ecological Systems integrate biotic and abiotic variables that take advantage of the hydrologic perspective of HGM and the vegetation emphasis of the NVC. They can be more effective at constraining both biotic and abiotic variability within one classification unit than either NVC or HGM, which should facilitate development of ecological indicators.
- Mid-scale valuable for mitigation equivalency.
- Comprehensive maps of all major wetland types, suitable for characterizing watersheds.
- Explicitly linked to the NVC.

Although use of a single classification would be desirable, each of the above classifications addresses important needs. The NWI (Cowardin) classification is the mapping standard for wetlands across the U.S. and is the source of information on trends in wetland acreages (Dahl 2006). The NVC formation types correspond to the Cowardin types that are commonly used to report wetland acreages, and provide a link to the federal NVC classification standard. The NVC and Ecological Systems provide a multi-scale set of wetland types, allowing users to systematically refine the classification scale, including to a level of association types, which are commonly used by state Natural Heritage programs to track wetland diversity and by NatureServe and state programs to assess wetlands conservation status. HGM provides an important means of addressing a critical aspect of wetland function, namely hydrology and landscape setting. Many wetland assessment tools have been developed around HGM classifications, and where individual sites are classified using other classifications, they should also be assigned to the HGM class, to determine how this might factor into assessments of its ecological performance. We provide guidance on the integration of these various classifications (see "Wetland Classification and Performance Standards" above).

Ecological Integrity Assessments

Our approach to establishing performance standards for mitigation builds on the NatureServe methodology for conducting ecological integrity assessments (Brown et al. 2004, Faber-Langendoen et al. 2008). We develop the assessments using the following steps.

1. Develop a conceptual model with key ecological attributes and identify indicators for wetland types, at multiple classification scales (NVC formation, NatureServe ecological system, coupled with HGM and Cowardin classifications).
2. Use a three-level approach to identify a suite of metrics, including remote sensing, rapid ground-based, and intensive ground-based metrics.
3. Identify ratings and thresholds for each metric based on "normal" or "natural range of variation" benchmarks for each formation.
4. Provide a scorecard matrix by which the metrics are rated and integrated into an overall assessment of the ecological integrity of the ecosystem.
5. Provide tools for adapting the metrics over time as new information and methods are developed.

Ecological Integrity Model and Identification of Metrics

Definition of Ecological Integrity

Building on the related concepts of biological integrity and ecological health, ecological integrity is a broad and useful endpoint for ecological assessment and reporting (Harwell et al. 1999). "Integrity" is the quality of being unimpaired, sound or complete. To have integrity, an ecosystem should be relatively unimpaired across a range of characteristics and spatial and temporal scales (De Leo and Levin 1997). Ecological integrity can be defined as "an assessment of the structure, composition, and function of an ecosystem as compared to reference ecosystems operating within the bounds of natural or historic disturbance regimes" (adapted from Lindenmayer and Franklin 2002, Young and Sanzone 2002, Parrish et al. 2003).

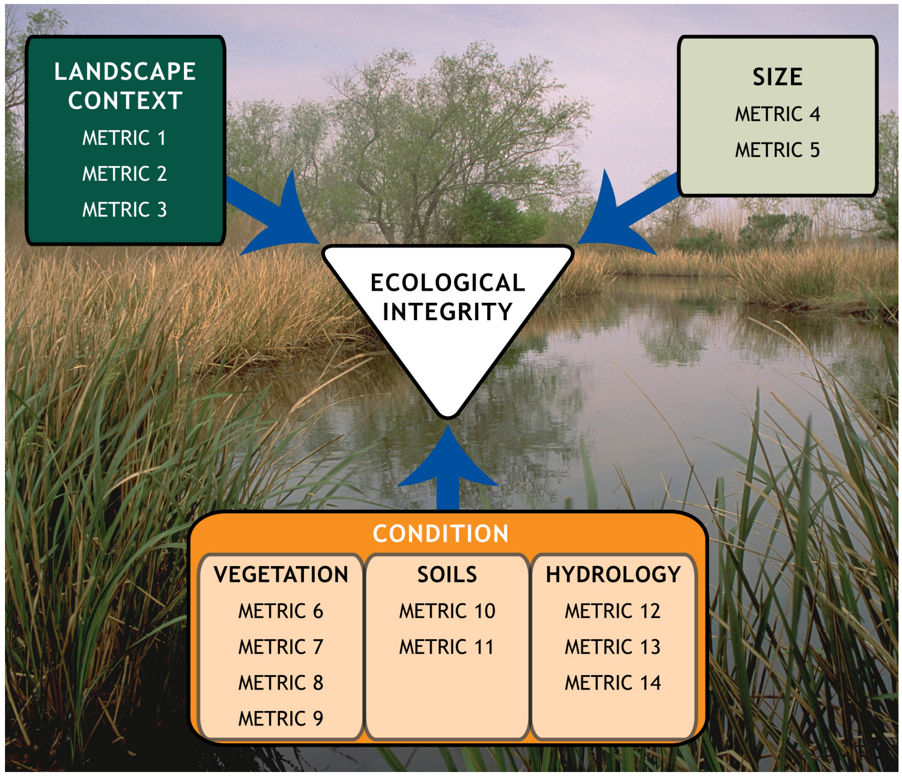
Our approach to assessing ecological integrity is similar to the Index of Biotic Integrity (IBI) approach for aquatic systems. The original IBI interpreted stream integrity from twelve metrics reflecting the health, reproduction, composition and abundance of fish species (Karr and Chu 1999). Each metric was rated by comparing measured values with values expected under relatively unimpaired (reference standard) conditions, and the ratings were aggregated into a total score. Building upon this foundation, others suggested interpreting the integrity of ecosystems by developing suites of indicators or metrics comprising key biological, physical and functional attributes of those ecosystems (Harwell et al. 1999, Andreasen et al. 2001, Parrish et al. 2003). Our index of ecological integrity brings together metrics of biotic and abiotic condition, size, and landscape context.

Conceptual Model

A conceptual ecological model delineating linkages between key ecosystem attributes and known stressors or agents of change is a useful tool for identifying and interpreting metrics with high ecological and management relevance (Noon 2003). We developed a simple conceptual model identifying a) major attributes of wetland ecosystems, such as vegetation, hydrology, and soils, landscape context, and size that help characterize overall structure, composition and process, as well as various aspects of wetland function, and b) important drivers and stressors acting upon wetland systems (Figure 4).

FIGURE 4

Conceptual Model for Wetland Ecosystems. The major attributes of ecosystem integrity are shown in the model. Ecosystem drivers, such as climate, geomorphology and natural disturbances maintain the overall integrity of the system, whereas stressors act to degrade it.



Using the model as a guide, we identify a core set of metrics that best distinguish a highly impacted, degraded or depauperate state from a relatively unimpaired, complete and functioning state. Metrics may be properties that typify a particular ecosystem or attributes that change predictably in response to anthropogenic stress. The suite of metrics selected should be comprehensive enough to incorporate composition, structure and function of an ecosystem across a range of spatial scales. Ideally, indicators of the magnitude of key stressors acting upon the system will be included to increase understanding of relationships between stressors and effects (Tierney et al. 2008).

In the last ten years, there has been a great deal of research to identify practical suites of metrics that address the different aspects of ecosystem structure, composition and function. To select our level 2 (rapid field) metrics, we build on a variety of existing remote and rapid assessments manuals, particularly that of the California Rapid Assessment Manual (CRAM, Collins et al. 2006, 2007), the Ohio Rapid Assessment Manual (Mack 2001), and NatureServe (Faber-Langendoen et al. 2006). We engaged ecologists from across our own Network of Natural Heritage Programs and from other agencies and organizations to review and test the metrics. Our current list of 14 condition metrics is summarized in Table 1.

Rank Factor	Major Ecological Attribute	Indicator
Landscape Context	Landscape Structure	Landscape Connectivity
		Buffer Index
		Surrounding Land Use Index
	Landscape Stressors	Landscape Stressors Checklist
Size	Size	Patch Size Condition*
		Patch Size
Condition	Vegetation (Biota)	Vegetation Structure
		Organic Matter Accumulation
		Vegetation Composition
		Relative Total Cover of Native Plant Species
	Vegetation (Biota) Stressors	Vegetation (Biota) Stressors Checklist
	Hydrology	Water Source
		Hydroperiod
		Hydrologic Connectivity
	Hydrology Stressors	Hydrology Stressors Checklist
	Soils (Physicochemical)	Physical Patch Types
		Water Quality
		Soil Surface Condition
	Soils (Physicochemical) Stressors	Soils (Physicochemical) Stressors Checklist

** optional metric*

TABLE 1
Example of an ecological integrity table, showing the rank factors, major ecological attributes, and indicators for wetland ecosystems, showing only condition metrics. The checklists provide additional information on stressors to the wetland site or occurrence. See Table 10 (page 37) for a complete list of condition and stressor metrics.

Metrics can be thought of as the measurable expressions of an indicator (Table 1). For example, "Relative Total Cover of Native Plant Species" is an indicator of "community composition," a key ecological attribute, but a specific metric is needed to quantify this indicator (e.g., total cover of exotic species subtracted from total cover of all vegetation and divided by 100). Another example is "organic matter accumulation," which is an indicator of a key ecological attribute of "community structure." A specific metric used to quantify this indicator for forested wetlands may be "coarse woody debris: volume per hectare of fallen stems over 10 cm diameter."

The primary emphasis of the metrics is on measuring a relevant aspect of the ecosystem itself that responds to stressors. We refer to these as "condition metrics." We can also measure the stressors themselves, but information from these metrics provides only an indirect measure of the status of the system – we will need to infer that changes in the stressor correspond to changes in the condition of the system. We refer to these as "stressor metrics." We prefer to use condition metrics, but occasionally a stressor metric is measured when measuring condition may be challenging or not cost-effective (e.g., Surrounding Land Use Index indicator within Landscape Context).

Regardless of whether stressors are used as metrics, it is helpful to catalogue known stressors at a site to guide interpretation and possible correlations between ecological integrity and stressors. Table 1 refers to checklists of stressors for all major attributes to help interpret the integrity of the major attributes of an ecosystem occurrence. Checklists of stressors are included in the "Stressor Checklists" section (page 50).

The metrics are placed within an interpretive framework, based on our conceptual model, organizing the metric by major ecological attributes — broad attributes that have an important (driving) function in the viability or integrity of the element — and by rank factors (Table 1). The conceptual model is fairly general, but helps guide the selection of metrics, organized across a standard set of ecological attributes and factors (e.g., Harwell et al. 1999, Young and Sanzone 2002, Parrish et al. 2003).

Metrics and 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 set realistic performance standards for wetland mitigation by allowing assessments 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, and realistic expectations can be set for whether and how bogs, fens, swamp forests and other types can be successfully mitigated.

The HGM classification developed by Brinson (1993) was developed in order to assist the Corps of Engineers with the evaluation of wetland impacts (see "Wetland Classification and Performance Standards" above). HGM identifies groups of wetlands that function similarly, based on three fundamental factors that influence how wetlands function, including geomorphic setting, water source and hydrodynamics (Smith et al. 1995). Typically, function is assessed through compositional and structural surrogates. There are limitations in using structural surrogates to address function (Hruby 2001), and the wetland classes identified through HGM do not always address the uniqueness of certain wetland types (e.g., bogs and fens, or swamp forests). Conversely, other important classifications of wetlands, such as the NVC and the NWI (Cowardin) classifications (see "Wetland Classification and Performance Standards" above) do not always distinguish between various hydrogeomorphic classes, at least not at higher levels. We recommend that the HGM and NVC classifications supplement each other when addressing wetland mitigation (Table 2).

TABLE 2

Formation types of the U.S. National Vegetation Classification guide the specificity of metrics, including their relation to HGM class (Brinson 1993). The NWI types can be readily crosswalked to the NVC formation level.

	NVC Type	HGM Class						
Wetland Category	Formation	Riverine	Depressional	Slope	Flats – Minearl	Flats – Organic	Estuarine Fringe	Lacustrine Fringe
Swamp	Mangrove	X	X				X	
	Tropical Flooded & Swamp Forest	X	X			(X)		X
	Temperate Flooded & Swamp Forest	X	X	(X)	(X)			X
	Boreal Flooded & Swamp Forest	X	X					X
Bog & Fen	Tropical Bog & Fen		X	X		X		
	Temperate & Boreal Bog & Fen	(X)	X	X		X		
Marsh	Salt Marsh		X				X	
	Tropical Freshwater Marsh	X	X	(X)	X			X
	Temperate & Boreal Freshwater Marsh	X	X	X	X			X
	Tundra Wet Meadow	X	X	(X)	X			X
Aquatic	Marine and Estuarine Aquatic Vegetation						X	
	Freshwater Aquatic Vegetation	X	X		X	(X)		X

Thus for the purposes of developing an ecological integrity assessment, we start our organization of metric by using the broadest levels of the NVC, the formation level. We then step down, as needed, to finer scales, based on HGM and Ecological System level differences that are important to setting performance standards (Table 2). For example, a metric developed for the hydrology of Temperate Flooded & Swamp Forest may have variants for riverine, depressional and other HGM classes, as needed. A complete set of NVC wetland types, from Formation to Macrogroup, with links to Ecological Systems, is provided in Appendix VII.

A more detailed comparison of wetland classifications is provided in Appendix IV.

A 3-Level Approach to Selection of Metrics

The selection of metrics to assess ecological integrity can be executed at three levels of intensity depending on the design of the data collection effort (Brooks et al. 2004, Tiner 2004, US EPA 2006). This "3-level approach" to assessments, summarized in Table 3 (following page), allows the flexibility to develop data for many sites that cannot readily be visited or intensively studied, permits more widespread assessment, while still allowing for detailed monitoring data at selected sites. In the context of mitigation projects, the three levels allow for comparison of impacted sites against mitigated sites in a cost-effective manner.

Level 1 Remote Assessments rely almost entirely on GIS and remote sensing data to obtain information about landscape integrity and the distribution and abundance of ecological types in the landscape or watershed (Mack 2006, US EPA 2006). Limited ground-truthing may be a component of some sites.

Level 2 Rapid Assessments use relatively rapid field-based metrics that are a combination of qualitative and narrative-based metrics with quantitative or semi-quantitative metrics. Field observations are required for many metrics, and observations will typically require professional expertise and judgment (Fennessey et al. 2007).

Level 3 Intensive Assessments require more rigorous, intensive field-based methods and metrics that provide higher-resolution information on the integrity of occurrences within a site. They often use quantitative, plot-based assessment procedures coupled with a sampling design to provide data for detailed metrics (Barbour et al. 1996, Blocksom et al. 2002). Calculations of indices for assessing Biotic Condition are often used, e.g., Floristic Quality Index, or Vegetation Index of Biotic Integrity ("VIBI") (DeKeyser et al. 2003, Mack 2004, Miller and Wardrop 2006, Miller et al. 2006). The focus of the general Level 3 assessment for biota is on the vegetation, since this is readily observable and measurable, and has been found to be a good indicator of overall condition, but Level 3 assessments typically can include metrics for soils, hydrology, water chemistry, and the surrounding landscape.

Ideally, information at the three levels of assessment provides relatively consistent information about ecological integrity, with improved interpretations as the level of intensity goes up. To achieve this, the various levels need to be calibrated against each other. For example, a rapid metric for assessing vegetation composition may use either an expert evaluation of a "Vegetation Composition" narrative metric, or perhaps a rapid version of a Floristic Quality Assessment Index based on walking through an occurrence and compiling a plant species list. The corresponding intensive metric may require a detailed listing of the plant species and their abundance based on plots and transects. Data gathered using both methods can be calibrated against each other (Mack 2004). Similarly an overall Level 3 index of vegetation or ecological integrity can be used to calibrate the Level 1 remote-sensing-based index of integrity (Mack 2006, Mita et al. 2007).

Although vegetation is the main biotic attribute measured for Level 3 assessments, other components of biodiversity can also be measured for specialized studies. The most common ones are birds, amphibians, insects and other macroinvertebrates. They are typically more time-consuming and costly to measure, but their response may differ enough from that of the vegetation that they provide additional valuable information on ecological integrity.

To ensure that the 3-level approach is consistent in how ecological integrity is assessed among levels, a standard framework or conceptual model for choosing metrics is used (as shown in Figure 1). Using this model, a similar set of metrics are chosen across the three levels, organized by the standard set of ecological attributes and factors: landscape context, size, condition (vegetation, hydrology, soils).

TABLE 3

Summary of 3-level approach to conducting ecological integrity assessments (adapted from Brooks et al. 2004, USEPA 2006).

	Level 1 – Remote Assessment	Level 2 – Rapid Assessment	Level 3 – Intensive Assessment
General description	Remote assessment	Rapid field-based assessment	Detailed field-based assessment
Evaluates condition of individual assessment areas/sites using:	• Metrics within the site that are visible with remote sensing data • Landscape/watershed condition metrics around the site • Limited ground truthing	• Relatively qualitative or narrative field metrics within the site • Remote sensing metrics for landscape context, with limited to expanded ground truthing	• Relatively detailed quantitative field metrics • Remote sensing and/or field metrics for landscape context, expanded ground truthing/resolution
Based on:	• GIS and remote sensing data • Layers typically include: –Land cover –Land use –Other ecological maps • Stressor metrics (e.g., land use, roads)	• Condition metrics (e.g., hydrologic regime, species composition) • Stressor metrics (e.g., ditching, road crossings, pollutant inputs) • Calibration based on reference sites	• Condition metrics that have been calibrated to measure responses of the ecological system to disturbances (e.g., indices of biotic or ecological integrity) • Validation of metrics based on reference sites
Potential mitigation uses	• Identifies priority sites • Identifies status and trends of acreages across the landscape • Identifies integrity of ecological types across the landscape • Informs targeted restoration and monitoring	• Identifies/confirms priority sites • Informs monitoring of many attributes • Provides baseline data for implementation of restoration or mitigation projects • Supports landscape/ watershed planning • Supports rapid assessment of mitigation based on reference sites	• Informs monitoring of a select set of attributes • Identifies status and trends of specific occurrences or indicators • Supports monitoring for restoration, mitigation and management projects
Example metrics	• Landscape Development Index (integrated a series of land use categories) • Land Use Map • Road Density • Impervious Surface	• Landscape Connectivity • Vegetation Structure • Invasive Exotic Plant Species • Forest Floor Condition	• Landscape Connectivity • Structural Stage Index • Invasive Exotic Plant Species • Floristic Quality Index (mean C) • Vegetation Index of Biotic Integrity • Soil Calcium:Aluminum Ratio

Development of Metric Ratings

Metrics are chosen because they are considered informative about the overall integrity or sustainability of the site; that is, they show a "stressor-dose response" to changes in stressor levels. The response of the metrics can be summarized either as a continuous function or through a series of categorical ratings. For rapid metrics, it is more common to use the categorical ratings. At the level of individual metrics, ratings may range from simple pass/fail to A – F. The more ratings a metric has the more sensitive it is judged to be in indicating degradation or restoration. For example, the relative total cover of exotics may be essentially zero in highly intact examples of ecosystems. Even small percentage changes of 1-2% are considered significant indicators of decline in condition. Thus the metric is divided into five ratings, when applied as a Level 2, field-based metric (see Table 4).

TABLE 4

This metric can be used for Level 2 rapid field-based assessments, where estimates of cover would be made rapidly over the site. It could also be refined to be a Level 3 metric, if vegetation plots were laid to carefully estimate cover. Rarely, it could be used as a Level 1 metric, where invasive exotics are visible from imagery, but the rating scheme could be simplified, combining A–C, then D, then E.

RANK FACTOR – Major Attribute	CONDITION – Vegetation
Metric:	Relative Total Cover of Native Plant Species
Definition:	Percent cover of the plant species that are native, relative to total cover (sum by species)
Metric Ratings	**Metric Criteria**
A = Excellent	>99% cover of native plant species
B = Good	97-99% cover of native plant species
C = Fair	90-96% cover of native plant species
D = Poor	50-89% cover of native plant species
E = Very Poor	<50% cover of native plant species

Level 1 metrics and rating

A comprehensive set of Level 1 metrics are developed for all wetlands beginning on page 33. Rating for the metrics are still under development. Protocols for evaluating metrics from remote sensing imagery are still under development. These protocols will provide details on how to measure, score and weight each metric, and include justification for how the metric rating criteria were developed.

Level 2 metrics and ratings

A comprehensive set of metrics and ratings are developed for all Level 2 metrics beginning on page 36. Protocols for evaluating Level 2 metrics in the field are provided in Appendix II. These protocols ensure that metrics are consistently measured, evaluated and scored. They also include justification for how the metric rating criteria were developed.

These metrics and their variants are intended to be comprehensive across the nation, based on a number of broad wetland classes. The metrics have not yet been widely calibrated, but various tests are underway. Further testing is also needed to determine if greater specificity is needed in the wetland classes (i.e. moving from NVC Formation to Ecological Systems) in order to be able to consistently rate the metrics. For example, if the variation in the amount of coarse and fine woody debris consistently differs between Pacific salt marshes and Atlantic salt marshes, then it would be difficult to apply the current version of that metric to both kinds of saltmarshes, or the variation would have to be explicitly stated in the narrative of that metric.

Level 3 metrics and ratings

Level 3 assessments are an active area of research. A number of field studies have been conducted in which a Vegetation Index of Biotic Integrity (VIBI) was developed (e.g., DeKeyser et al. 2003, Mack 2004, Miller et al. 2006, Rocchio 2007). A VIBI can be developed that either serves as an indicator of all ecological attributes, or, if other metrics are developed for hydrology and soils, it serves as an indicator of the biotic attribute of the wetland. In addition, other biotic components, such as amphibians or macroinvertebrates, could be measured separately.

It may be harder to create a general set of Level 3 metrics across the nation. Level 3 metrics are often more sensitive to regional variation and differences caused by finer-scale differences among wetlands. A brief introduction to Level 3 metrics is provided beginning on page 57, but much more work is needed on how to conduct a Level 3 assessment. Protocols for evaluating metrics in the field are also under development. Some example protocols are provided in Appendix III.

Given the focus on a particular site for mitigation, and the need for quantifiable evaluations of mitigation success, it may often be desirable to use at least a few Level 3 metrics for setting performance standards. More work is needed on the concept of how Level 2 and Level 3 assessment information is combined to generate performance standards

Ecological Integrity Scorecard

The goal of our mitigation assessment is to both establish the level of integrity at a given site, and relate this to reference sites. Ratings for each metric provide us with a quantifiable level of detail. But, it will often be useful to provide an overall synopsis or to guide the managers about the overall status of a mitigated wetland. We develop a scorecard, whereby occurrences are ranked using “A” (excellent), “B” (good), “C” (fair), and “D” (poor) integrity.

A number of approaches for aggregating rapid field-based metrics are available, each with a variety of strengths and weaknesses (Faber-Langendoen et al. 2007). Here, for Level 1 and Level 2 assessments, we use a simple non-interaction point-based approach, where we treat each metric independently. We first structure the system so that each metric is assigned a weight, based on how important it is considered to be in evaluating ecological integrity and each rating for a metric is assigned a point value with A = 5 points, B = 4 points, etc. (see Table 5, following page). When a field value is assigned for a metric (e.g., the Buffer Index is given a B rating), it is first converted to a point rating (i.e. B = 4), then the points are multiplied by the weight (4 x 2 = 8). The weighted points for each metric in a major attribute (e.g., landscape context) are summed and divided by the sum of the weights to get a weighted average. Presuming each major attribute is weighted the same, the weighted average of each attribute can be summed and divided by the total number of attributes. A fully worked example is shown in Table 5. The point-based approach is consistent with that of many IBI scoring methods (e.g. Karr and Chu 1999) (for additional information on the scorecard approach see “Scorecard Protocols for Level 2 Assessments: Point-Based Approach” on page 53).

The scorecard provides a ready means of evaluating both impacted and wetland sites for Level 1 and 2 assessments. Level 3 assessments, based on VIBI and other metrics ,may require somewhat different approaches to aggregating metrics.

Many mitigation projects would benefit from a scorecard approach, where reference, impacted and mitigated sites are all scored using the same metrics. Then over time, as evaluations are completed using the metrics, their values, and that of the major attributes, can be compared (see “Adapting the Method Over Time” on page 23).

TABLE 5

Summary of scores and ranks for metrics, factors, and the overall ecological integrity for a Level 2 Rapid Field-based Assessment. Vegetation, Hydrology and Soils are major attributes within the Condition rank factor.

MAJOR ATTRIBUTES Metric	Assigned Metric Rating	Assigned Metric Points	Weight (W)	Metric Score (M)	Rank Factor Score (M/W)	Rank Factor Rank	Ecological Integrity Score	Ecological Integrity Rank (EO rank)
VEGETATION (BIOTA)					3.6	C		
Vegetation Structure	C	3	1	3				
Organic Matter Accumulation	C	3	0.5	1.5				
Vegetation Composition	B	4	1	4				
Relative Total Cover of Native Plant Species	B	4	1	4				
			∑=3.5	∑=12.5				
HYDROLOGY					4.0	B		
Water Source	C	3	1	3				
Hydroperiod	B	4	1	4				
Hydrologic Connectivity	A	5	1	5				
			∑=3	∑=12				
SOILS (PHYSICOCHEMISTRY)					4.0	B		
Physical Patch Types	B	4	0.5	2				
Water Quality	B	4	1	4				
Soil Surface Condition	B	4	1	4				
			∑=2.5	∑=10				
SIZE					4.3	B		
Relative Size	A	5	0.5	2.5				
Absolute Size	B	4	1	4				
			∑=1.5	∑=6.5				
LANDSCAPE CONTEXT					4.3	B		
Landscape Connectivity	A	5	1	5				
Buffer Index	B	4	1	4				
Surrounding Land Use	B	4	1	4				
			∑=3	∑=13				
					∑=20.5			
RATING: A = 4.5–5.0, B = 3.5–4.4, C = 2.5–3.4, D = 1.0–2.4							4.1	B

Adapting the Method over Time

It is important to remember that our efforts to assess ecological integrity are approximations of our current understanding of the system. In reality, ecosystems are far too complex to be fully represented by a suite of metrics and attributes. Moreover, our metrics, indices and scorecards must be flexible enough to allow change over time as our knowledge grows. What is important is that we present as clearly as we can how we are conducting our assessments, so that we foster communication and understanding among people with different backgrounds, goals and points of view.

NatureServe upgrades its databases to manage and store the ecological assessments, including the component metrics, and will accept improved versions of metrics as they are field-tested and validated. It is critical that such metrics become standardized across the range-wide distribution of wetland types, so that consistent and repeatable assessments of ecological integrity are available. Programs and partners are encouraged to test and refine these metrics, keeping in mind the overall definitions and purposes of ecological integrity assessments.

Reference Condition

In selecting and establishing metrics for assessing ecological integrity, an assumption is made that some type of reference condition can be defined; that is, it is possible to describe a series of states of wetland integrity, from minimally disturbed to degraded. Optimal conditions are typically defined with respect to an acceptable or natural range of variation (or historic range of variation). For many elements, what is natural or historical is difficult to define, given the vagaries of those concepts and the relative extent of human disturbance over time. For example, in an undocumented past, people may have used fire to clear patches of forest over several millennia, altering land/waterscapes and influencing species distributions. However, through careful scientific study, reflections on historical data, and comparisons with the best-preserved occurrences, we can often distinguish effects of intensive human uses and begin to describe a natural range of variation for ecological attributes that maintain the occurrence over the long term. It is this practical concept that we apply to evaluating wetland integrity.

Reference wetlands (or reference set) are the wetland sites selected to represent the range of variability that occurs in a wetland type as a result of natural processes and disturbances (e.g., succession, channel migration, fire, erosion and sedimentation), as well as anthropogenic alteration (e.g., grazing, timber harvest, and clearing) (Klimas et al. 2006). Reference wetlands serve several purposes. First, they establish a basis for defining what constitutes a characteristic and sustainable level of integrity across the suite of attributes selected for a type. Second, reference wetlands establish the range and variability of conditions exhibited by assessment variables and provide the data necessary for calibrating assessment variables and models. Finally, they provide a concrete physical representation of wetland ecosystems that can be observed and re-measured as needed (Smith et al. 1995, Klimas et al. 2006). Reference standard wetlands are the subset of reference wetlands that exhibit metric ratings for the type at a level that is characteristic of the least altered (or minimally disturbed) wetland sites in the least altered landscapes (Klimas et al. 2006, Stoddard et al. 2006). As defined below, these reference standards would typically have "A" (excellent) ratings for individual metrics and categories. To complete the full reference set, B-, C- and D-rated sites will be identified and rated as variously degraded versions of A-ranked reference standards.

In establishing reference standards, the geographic area from which reference wetlands are selected is sometimes referred to as the reference domain (Smith et al. 1995). The reference domain may include all (ideally), or part, of the geographic area in which a type occurs.

Ecological Integrity Assessment and Mitigation

As a tool in mitigation, Ecological Integrity Assessments address the recognized need for enhancing the ecological performance standards of wetlands. It does so by addressing the key requirements of such standards listed by the NRC (2001):

1. *Mitigation goals are set in the context of a watershed approach.* See "Methods for a Watershed Approach" on page 5, where this topic is addressed.

2. *Impacted sites and mitigated sites are evaluated using the same ecological assessment tools.* Ecological Integrity Assessment methods provide a general framework for addressing the range of conditions of ecosystems. The same metrics that are used to address condition for mitigation sites are part of general assessments of the condition of ecosystems elsewhere. For example, there are many rapid assessment methods that rely on the same kinds of metrics needed for mitigation (e.g., Mack et al. 2004, Sutula et al. 2006). NatureServe's methodology for evaluating wetlands of all types, as described in this report, is also based on similar metrics. Thus measures of ecological performance are becoming more widely available for a variety of ecological systems.

3. *Mitigation projects evaluate the full range of ecological integrity and ecological attributes relevant to functions.* Ecological integrity assessments (EIAs) address the major attributes relevant to assessing ecological functions of ecological systems, including vegetation, hydrology, soils (physicochemistry), landscape context and size (see Table 1). The EIA approach does not make explicit statements about "functions" that a wetland performs; however, it does implicitly assume that a wetland with high ecological integrity is performing all the expected functions for the HGM class in which it is found (see Figure 3).

4. *Mitigation goals are clearly stated so that the desired range of ecological integrity and function are specified.* Structure, composition and function are all relevant to the goals. Ecological integrity assessments are based on clearly stated metrics and ratings that assess the full range of ecological integrity and function. In so far as mitigation goals require clarity on these aspects of mitigation, they can be addressed by using EIAs.

5. *Assessing wetland function is based on a science-based, rapid assessment procedure that incorporates at least the following characteristics:*
    a. Effectively assess goals of wetland mitigation projects,
    b. Assess all recognized functions,
    c. Incorporate effects of the position in the landscape,
    d. Reliably indicate important wetland processes or scientifically established structural surrogates of these processes,
    e. Scale the assessment to results from reference sites,
    f. Sensitivity to changes in performance over a dynamic range (i.e., the metric is sensitive enough to show a range of responses to a stressor, not just a pass/fail),
    g. Integrate over space and time (i.e., the metric should be useful across the spatial range of a type and be useful for monitoring over time), and
    h. Generate parametric and dimensioned units, rather than non-parametric ranks, in order to allow for greater rigor in statistical testing.

    The EIA approach outlined here incorporates all of these characteristics. In particular, characteristic "a" is summarized in "Outline of the Mitigation Application" (page 27). Characteristic "e" is still under development, but reference sites are in the process of being compiled and tested for these metrics. Characteristics f, g, and h depend in part on the level of assessment (1, 2, or 3) chosen. Level 2 metrics do not perform as well for characteristic "h."

The ecological integrity assessment approach addresses the goals of mitigation, namely the "restoration, creation, enhancement, and in exceptional cases, preservation of other wetlands, as compensation for impacts to natural wetlands" (NRC 2001) because it provides standardized measures to assess wetland integrity and function at both the impacted and mitigated site. Our methods are developed in a general and comprehensive way. They point toward the kinds of applications that are needed for mitigation. Future studies are needed to advance these methods and test them on a variety of wetland mitigation sites.

Ecological Integrity and Wetland Function

Major recognized functions of wetlands are assessed in an EIA through major structural, composition and process attributes, such as vegetation, soils, hydrology and landscape context, which can be thought of as surrogates for function, but more importantly are direct measures of integrity. This approach to assessing function differs from previous methods such as HGM (Smith et al. 1995) in that these surrogates are not combined into additional algorithms whose endpoints are expected to measure or estimate a function. Rather, endpoints directly relate to the integrity or condition of the surrogate attributes. In other words, we assume that most natural, wetland functions are directly related to the integrity of the surrogate attributes (Fig. 3; Mack et al. 2004).

Much of the data collected by HGM methods emphasizes similar compositional, structural and abiotic features of wetlands to that of an EIA approach. It should be possible to collaborate on protocols so that similar data are collected by both approaches. In this way, even if an EIA approach does not compute the actual functional indices, it can make use of the data to assess ecological integrity, and provide that perspective alongside the functional assessment of the wetland. An extended comparison of the EIA metrics proposed here with those of an HGM functional assessment is provided in Table 6 (page 26), based on the work of Klimas et al. (2004).

TABLE 6

Comparison of Rapid Field-Based Metrics for Assessing Wetland Integrity with HGM Metrics for Assessing Wetland Function.

The table is provided courtesy of T. Foti. The HGM variables are taken from a study of the Mississippi River Alluvial Plain in Arkansas by Klimas et al. (2004). HGM metrics are subclass-specific and ecoregion-specific; they have been simplified for this table. See Klimas et al. (2006) for a similar study elsewhere in Arkansas. Details of each NatureServe metric are provided in Table 10 (page 37).

Major Attribute	NatureServe Metric (Level 2)	Klimas et al. 2004 Variables (Level 3 equivalent)
LANDSCAPE CONTEXT	Landscape Connectivity	Non-riverine or riverine: $V_{CONNECT}$ – Percentage of wetland tract perimeter within 0.5 km of suitable habitat
	Buffer Index	Non-riverine or riverine: V_{CORE} – Percentage of wetland tract perimeter with 300 ft (~100 m) buffer from surrounding land uses. No measure of condition of buffer.
SIZE	Patch Size Condition*	None
	Patch Size (ha)	V_{TRACT} – Size of the assessment area and all contiguous forested wetland areas
VEGETATION (BIOTA)	Vegetation Structure	V_{STRATA} – Number of strata present V_{TBA} – Tree basal area V_{TDEN} - Tree density V_{SSD} – Shrub/sapling density V_{GVC} – Ground vegetation cover
	Organic Matter Accumulation (coarse and fine debris)	V_{LITTER} – Litter cover V_{OHOR} – Thickness of O horiz. V_{AHOR} – Thickness of A horiz. V_{SNAG} – Snag density V_{WD} – Small and medium woody debris V_{LOG} – Large woody debris
	Vegetation Composition	V_{TCOMP}, V_{COMP} – Species dominance related to reference standard
	Relative Total Cover of Native Plant Species	Not recorded, but notes on invasives has been used is specific studies
HYDROLOGY	Water Source	In HGM, overall water source determines the classification
	Hydroperiod	V_{FREQ} – Flood frequency [rarely Flood Duration]
	Hydrologic Connectivity	This is either a "natural" aspect of HGM "water source" or could be treated as one of the "stressors"
		V_{POND} – Percentage of site capable of ponding water
SOILS (PHYSICO-CHEMISTRY)	Physical Patch Types	None
	Water Quality	None
	Soil Surface Condition	V_{SOIL} – V_{CEC} – Cation Exchange Capacity (estimated from texture) – for altered areas. Soil integrity.

** optional metric*

Outline of the Mitigation Application

The objective in setting performance standards and in conducting subsequent monitoring is "to collect sufficient data to answer the hypothesis: has the mitigation wetland met the performance goal within the monitoring period" (Mack et al. 2004). As outlined previously, the performance standards developed for mitigation include a broad range of structural and functional measures, including hydrology, vegetation and soils, and rely on reference wetlands as a model for the dynamics of created or restored sites. We introduce, by way of example, some ways in which ecological integrity assessments can be used to set ecological performance standards. Other aspects of performance standards, such as site preparation, are not addressed.

Table 7A (following page) summarizes a series of performance standards for wetland mitigation developed for Ohio (Mack et al. 2004). It also includes a list of Level 2 (rapid field-based) and Level 3 (intensive field-based) metrics from the EIA approach developed in this study that are relevant to measuring progress on those performance standards. Thus the metrics developed for this EIA methodology cover many of the performance standards needed for mitigation. It may not be necessary to measure all metrics, but metrics should be chosen that span the range of major ecological attributes.

Table 7B (page 29) illustrates how field values and thresholds for these EIA metrics can be used to track the progress of a mitigated site. The table is incomplete and provides a few examples only. There can be substantial challenges in achieving benchmarks for certain metrics in certain wetlands. Figure 5 (page 30) shows how mitigation of vegetation structure for swamp forests in Ohio may require a 10- to 100-year monitoring window (see Mack et al. 2004, Klimas et al. 2006). However, many forested (bottomland hardwood) wetlands in Arkansas and across the Lower Mississippi Valley may develop structural features more quickly than in Ohio. Thus, where studies from Ohio show that 15 cm (6") trees require 30 years to develop, 10" trees, 60 years, etc., such development may be twice as rapid in the Lower Mississippi Valley. Restoration of forested swamps in mitigation projects appears very practical there over short (decadal) time frames. Many hundreds of thousands of acres have been mitigated or restored, often with good success, and there is a broad understanding of the requirements for mitigation (T. Foti pers. comm. 2008). Thus performance standards will need to be adjusted to specific Ecological Systems.

TABLE 7A

Performance Standards for Wetland Mitigation (based primarily on standards developed for Ohio mitigation projects by Mack et al. (2004), and corresponding metrics that provide data to assess performance.

These examples provide a sense of direction for how EIAs can be applied to mitigation. Case studies are now needed to apply the method.

Performance Metrics (Mack et al. 2004)	Level 2 (NatureServe)	Level 3 (NatureServe)
A. Site		
Design		
Acreage	Patch Size	Patch Size
Basin morphometry	—	
Perimeter-area ratio	—	
Hydrology		
Hydrologic regime	• Hydroperiod • Water Source • Hydrologic Connectivity	TBD
Unvegetated Open Water	—	
Biota – Vegetation		
Perennial native hydrophytes	Vegetation Composition	
Invasive species	• Relative Cover of Native Plant Species • Invasive Exotic Plant Species	• Relative Cover of Native Plant Species • Invasive Exotic Plant Species
Vegetation-ecological standards	Vegetation Composition	Floristic Quality Assessment (Mean C) Vegetation Index of Biotic Integrity
Woody Species Establishment (Shrub Swamps, Swamp Forests)	Vegetation Structure	Vegetation Structure
Other Biota:		
Amphibians – Ecologic standards	—	
Other taxa groups – Ecologic standards (breeding birds, macro-invertebrates)	—	
Soil		
Biogeochemical standards	• Water Quality • Soil Disturbance	TBD
Other		
Ecological Services	Physical Patch Types	TBD
B. Landscape Context/Watershed		
—	Landscape Connectivity	Landscape Connectivity
—	Buffer Index	Buffer Index
—	Surrounding Land Use	Surrounding Land Use

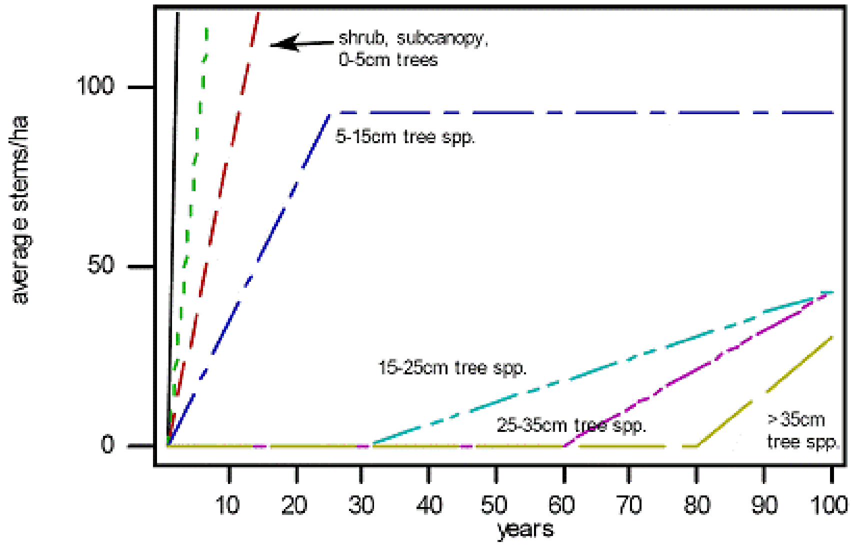
Performance Standards (Mack et al. 2004, NatureServe, this report)	Reference	Year				
	Impacted wetland/ Reference site (R)	1	2	3	4	5
A. Site						
Design						
Acreage	Size = X_R acres	Size = X_1 acres	Size = X_2 acres	Size = X_3 acres	Size = X_4 acres	Size = X_5 acres
Basin morphometry						
Perimeter-area ratio						
Hydrology	H Index = X_R	H Index = X_1	H Index = X_2	H Index = X_3	H Index = X_4	H Index = X_5
Hydrologic regime						
Unvegetated Open Water	—					—
Biota – Vegetation	V Index = X_R	V Index = X_1	V Index = X_2	V Index = X_3	V Index = X_4	V Index = X_5
Perennial native hydrophytes						
Invasive species	Invasives = $X_{R\%}$	Invasives = $X_{1\%}$	Invasives = $X_{2\%}$	Invasives = $X_{3\%}$	Invasives = $X_{4\%}$	Invasives = $X_{5\%}$
Vegetation-ecological standards						
Woody Species Establishment (Shrub Swamps, Swamp Forests)						
Other Biota:						
Amphibians – Ecologic standards	—					—
Other taxa groups – Ecologic standards (breeding birds, macro-invertebrates)	—					—
Soil	S Index = X_R	S Index = X_1	S Index = X_2	S Index = X_3	S Index = X_4	S Index = X_5
Biogeochemical standards						
Other						
Ecological Services						
B. Landscape Context/ Watershed	L Index = X_R	L Index = X_1	L Index = X_2	L Index = X_3	L Index = X_4	L Index = X_5
Landscape Connectivity						
Buffer Index						
Surrounding Land Use						

TABLE 7B

Conceptual schedule for required monitoring and reporting activities, with benchmark variables. X_R= the reference site or impacted site value that is chosen as the basis for assessing performance. X_1= the measure of a metric in Year 1, etc. At Year 5, the X value can be compared against the reference value and a decision made on the progress of the mitigation project. Examples of possible benchmark values are shown for various metrics and performance standards. Metrics in shaded rows were not chosen as part of the monitoring project.

FIGURE 5

Hypothetical performance curves for tree and shrub establishment. Graph shows expected performance at 10 and 100 years derived from reference wetland data for depressional wetland forests (from Mack et al. 2004, Figure 16).



Examples of Ecological Performance Standards for Wetland Mitigation

We conclude with a few case studies illustrating the use of ecological performance standards based on ecological integrity metrics for mitigation purposes. These examples highlight existing guidelines that are similar to and compatible with the proposed NatureServe approach. There are currently a variety of approaches to addressing compensatory mitigation, including mitigation banks, in-lieu-of-fee mitigation programs, and umbrella banking agreements (Wilkinson and Thompson 2005). Future studies are needed to test these performance standards on a variety of wetland mitigation sites.

U.S. Army Corps of Engineers, Chicago District

The Chicago District provides a technical guide for Clean Water Act Section 404 permit applicants preparing compensatory mitigation plans. The purpose of the document is:

> *"to identify the types and extent of information that agency personnel need to assess the likelihood of success of a mitigation proposal. Success is generally defined as: a healthy sustainable wetland/water that – to the extent practicable – compensates for the lost functions of the impacted water in an appropriate landscape/watershed position. This checklist provides a basic framework that will improve predictability and consistency in the development of mitigation plans for permit applicants."*

Details of the supplemental mitigation performance requirements in the Chicago District are presented in Attachment C to the technical guide (www.lrc.usace.army.mil/co-r/mitgr.htm). Table 8 provides an abbreviated set of specifications that are needed for documenting baseline information and for establishing the mitigation work plan.

TABLE 8

U.S. Army Corps of Engineers, Chicago District, Compensatory Mitigation Plan Checklist – Supplement (abbreviated text).

Mitigation Work Plan
a. Maps marking boundaries of proposed mitigation types
b. Timing of mitigation: before, concurrent or after authorized impacts
c. Grading plan (elevations, slopes, microtopography)
d. Description of construction methods
e. Description of soil erosion and sediment control measures
f. Construction schedule
g. Planned hydrology 1. Source of water 2. Connection(s) to existing waters 3. Hydroperiod, percent open water, water velocity 4. Potential interaction with groundwater 5. Existing monitoring data, if applicable; location of monitoring wells and stream gauges on site map 6. Stream or other open water geomorphic features (e.g., riffles, pools, bends, deflectors) 7. Structures requiring maintenance (show on map) 8. Representational cross sections
h. Planned vegetation 1. Native plant species composition (e.g., list of acceptable native hydrophytic vegetation) 2. Source of native plant species ... stock type (bare root, potted, seed) and plant age(s)/size(s) 3. Plant zonation/location map (refer to grading plan to ensure plants have acceptable hydrological environment) 4. Plant spatial structure – quantities/densities, % cover, community structure (e.g., canopy stratification) 5. Expected natural regeneration from existing seed bank, plantings, and natural recruitment
i. Planned soils 1. Soil profile 2. Source of soils … target soil characteristics … soil amendments (e.g., organic material or topsoil) 3. Soil compaction control measures
j. Planned habitat features (identify large woody debris, rock mounds, etc., on map)
k. Planned buffer (identify on map) 1. Evaluation of the buffer's expected contribution to aquatic resource functions 2. Physical characteristics (location, dimensions, native plant composition, spatial and vertical structure)
l. Other planned features, such as interpretive signs, trails, fence(s), etc.

Ohio Environmental Protection Agency

The Ohio EPA has developed a series of wetland assessment tools to assist in setting performance standards for wetlands (Mack et al. 2006). They developed a condition-based approach to assessing functional replacement for wetland mitigation using a reference wetland data set of natural wetlands. All major wetlands types were sampled, spanning a gradient of human disturbance. From this data set, wetland program tools were developed, including 1) multi-metric biological indices (IBIs) and hydrological and biogeochemical indicators; 2) a rapid (condition-based) wetland assessment tool (Ohio Rapid Assessment Method for Wetlands); and 3) a wetland classification scheme that accounts for variability in ecosystem processes (functions) and ecological services (values) of different types of natural wetlands. Ensuring functional replacement occurs in a several-step process. Mack et al. (2006) summarized the steps as follows:

> *"First, as part of permit application, the HGM class and dominant plant community of the impacted wetland(s) are determined. This determination accounts for the ecosystem processes (functions) and ecological services (values) of different wetland types without the necessity of developing a comprehensive list of those functions and values.*
>
> *Second, the condition of the impacted wetland is assessed with the rapid condition tool (ORAM v. 5.0) or a wetland IBI providing a measure of 'functional capacity.'*
>
> *Third, the size of the wetland to be impacted is determined and appropriate mitigation ratios are applied.*
>
> *Fourth, any residual moderate to high functions or values the impacted wetland(s) may still be providing, despite moderate to severe degradation, are evaluated using checklist with a narrative discussion.*
>
> *Fifth and finally, requirements for mitigation are specified in the permit. If there is 1) replacement by size of the impacted wetland, 2) replacement of the type of wetland impacted, and 3) replacement of the quality of the impacted wetland as measured by quantitative, condition-based ecological performance targets, then there is very strong assurance that functional replacement is occurring since there was 'no net loss' of wetland acreage, a mitigation wetland of same HGM class and dominant plant community was created with functions and ecological services equivalent to the impacted wetland, and a mitigation wetland was created of equivalent 'quality' as measured by biological (e.g. IBIs), hydrological, and biogeochemical indicators (and therefore of equivalent functional performance)."*

Performance standards, quantitative monitoring and data analysis techniques were developed for wetland size, basin morphometry, perimeter:area ratio, hydrologic regime, basic vegetation establishment, woody species establishment (successional trends), soil chemistry and wetland IBIs. The steps provide a clear, ecologically based set of performance standards. The standards are rigorous enough to allow for statistical testing of mitigation performance, based on monitoring data. A meaningful and adequate mitigation monitoring program is absolutely necessary to determine whether the mitigation wetland has "succeeded" or "failed."

Level 1 (Remote Sensing) Metrics for Wetlands

Level 1 Assessments are based primarily on metrics derived from remote sensing imagery. A variety of remote-sensing based methods have been proposed for assessing ecological integrity. The assessments are often used as a means of prioritizing sites for field visits, and the ecological integrity ranks that can be developed from remote sensing imagery may be somewhat coarse. Using Level 2 or Level 3 assessments methods will provide a more accurate assessment, and ranks based on those assessments would supersede these ranks. Level 1 ranks can also be tested as predictors of Level 2 or 3 ranks, to see how successful the Level 1 metrics are in predicting the level of integrity found at a site (Mita et al. 2007). Completing the iteration, the Level 2 and 3 ranks can also be used to re-calibrate the landscape metrics and ranks in subsequent applications.

Metrics for Level 1 Assessment

A synopsis of the ecological metrics and ratings for Level 1 assessments is presented in Table 9 (following page). Metrics may belong on one or more "tiers," referring to levels of intensity of sampling required to document a metric. Tier 1 metrics are able to be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 metrics typically require some kind of ground sampling, but may require only qualitative or semi-quantitative data. For Level 1 assessment, Tier 1 metrics are emphasized, but some Tier 2 metrics may also be used, where some limited ground-truthing is possible.

The assessment of integrity includes landscape context, size and condition of occurrences, as best as these can be assessed using remote sensing imagery. Together, metrics for these three rank factors are used to assign an ecological integrity index for an occurrence or site.

Metrics may be categorized as either condition or stressor metrics. Condition metrics are used to assess the ecological characteristics of the system (e.g., vegetation structure of a stand). Stressor metrics are used to measure activities or processes which are known or hypothesized to degrade the condition of the system, such as surrounding land use, air pollution or roads. Although condition metrics are the preferred tool for assessing ecological integrity, these can be hard to obtain for Level 1 assessments; stressor metrics are a rapid and cost-effective way of assessing the likelihood that a system is in good condition.

For each metric, a rating will be developed and scored, from excellent (A) to poor (D), usually in a 4-category scale, but sometimes 3 or 5. Currently these are only available for the Landscape Integrity Index. Protocols are still being developed for Level 1 metrics.

TABLE 9

Overview of remote sensing-based metrics for assessing wetland condition and stressors.

Rank Factor	Major Ecological Attribute	Metric Name	Tier	Metric Type	Metrics Definition
Landscape Context	Landscape Context	Landscape Integrity Index	1	S	A measure of the intensity of human-dominated land uses within 4000 ha (10,000 ac) landscape area from the center of the occurrence. Each land use type occurring in the landscape area is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the target system.
	Landscape Context Stressors	Landscape Stressors Checklist	1	S	A measure of the distance to nearest road, which addresses the potential impacts to the site of roads or major trails.
Size	Size	Patch Size	1	C	A measure of the current size (ha) of the occurrence or stand.
Condition	Biota	Vegetation Structure	1	C	An assessment of the overall structural complexity of the vegetation layers, including presence of multiple strata, age and structural complexity of canopy layer, and evidence of disease or mortality.
	Biota Stressors	Biotic Condition Stressors Checklist	1	S	A checklist of stressors that could affect biotic condition.
	Soils & Substrate	Land Use Within the Site	1	S	A measure of the intensity of human-dominated land uses within the site.
	Soils & Substrate Stressors	Physical Stressors Checklist	1	S	A checklist of stressors that could affect physicochemical condition.

Landscape Integrity Model

Table 9 includes a Landscape Integrity Index. Because this index plays a key role in Level 1 assessments, we summarize its use here. The index is derived from a Landscape Integrity Model developed by NatureServe (Tuffly and Comer 2005, Rocchio 2007). The model is similar in approach to the Landscape Development Index used by Mack (2006) and that of Tiner (2004). The algorithm integrates various land use GIS layers (roads, land cover, water diversions, groundwater wells, dams, mines, etc.) that are considered potential stressors to wetland integrity. These layers are the basis for developing a stressor-based set of metrics that are combined into an overall landscape integrity index. The metrics are weighted according to their perceived impact on ecological integrity, into a distance-based, decay function to determine what effect these stressors have on landscape integrity. The result is that each grid-cell (30 m) is assigned an integrity "score." The product is a landscape or watershed map depicting areas according to their potential "integrity." The index can be divided into four rank classes, from Excellent (slightly impacted), "A," to Poor (highly impacted), "D" (Figure 6).

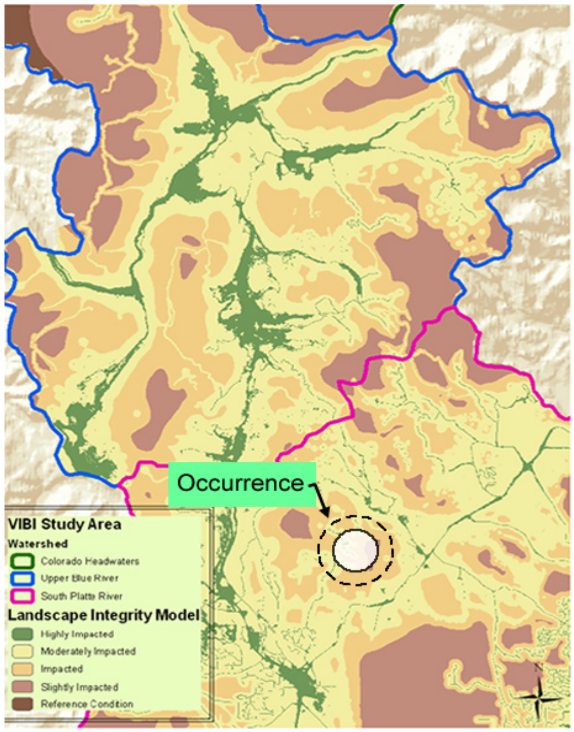


FIGURE 6

Demonstration of the Level 1 Assessment based on a Landscape Integrity Model. Values for landscape context metrics and condition metrics for an occurrence can be derived from the model (adapted from Rocchio 2007).

To use the landscape integrity model as part of a Level 1 assessment, locations are chosen within the watershed or landscape (see occurrence labeled in Fig. 6). These locations are any or all examples of an ecosystem type that is of interest, e.g., all or some forest stands, or wetlands, identified to level of ecosystem type. Points or polygons are established for each of these locations, and these are overlaid on the Landscape Integrity Model. A landscape context area is defined around the occurrence (Fig. 6). The landscape integrity model provides the data for the "landscape integrity index" metric, based on the average score of the pixels within the landscape context. The same model can be used to produce the data for the "land use within the site" metric. Finally, size of the occurrence can also be measured. Together these metrics provide a simple means of characterizing the integrity and EO rank of the occurrence.

Scorecard Protocols for Level 1

Scorecard protocols for Level 1 metrics are under development, but are expected to follow the protocols for Level 2 assessments (see "Ecological Integrity Scorecared" on page 21 and "Scorecard Protocols for Level 2 Assessments" on page 53).

Level 2 (Rapid Field-Based) Metrics for Wetlands

Based on the overall ecological integrity conceptual model (Fig. 1, Table 1), we compiled a list of indicators/metrics of integrity for each wetland type that covered the five major attributes: hydrology, soils, vegetation, size and landscape context. These metrics should reflect the composition, structure and function (pattern and process) of the type. We also reviewed a variety of existing rapid wetland assessment and monitoring materials to develop the general method, particularly that of the California Rapid Assessment Manual (CRAM, Sutula et al. 2006, Collins et al. 2006, 2007), the Ohio Rapid Assessment Manual (Mack 2001), and NatureServe (Faber-Langendoen et al. 2006).

Metrics for Level 2 Assessment

A synopsis of the ecological metrics and ratings is presented in Table 2. Metrics may belong on one of three possible "tiers," referring to levels of intensity of sampling required to document a metric. Tier 1 metrics are able to be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 typically require some kind of ground sampling, but may require only qualitative or semi-quantitative data. Tier 3 metrics typically require a more intensive plot sampling or other intensive sampling approach. A given metric could be assessed at multiple tiers, though some metrics cannot be used at Tier 1 (i.e., they require a ground visit). As part of a rapid assessment, we emphasize Tier 2 metrics for most attributes, but rely on Tier 1 metrics to assess the landscape context attribute.

Metrics may also be categorized as either condition or stressor metrics. Condition metrics are used to assess the ecological characteristics of the system (e.g., hydroperiod of a wetland). Stressor metrics are used to measure activities or structures which are known or hypothesized to degrade the integrity of the system (e.g., number of dams on a river or in a watershed surrounding a wetland). Condition metrics are the primary tool for generating an ecological integrity rank. Stressor metrics can, however, be a rapid and cost-effective way of assessing the likelihood that a system is in good condition, but they typically should be scored separately from condition metrics and used as supporting information. Separating the metrics into these two categories also allows the ecologist to assess the relative correlation of stressors to condition.

For each metric, a rating is developed and scored, from excellent (A) to poor (D), usually in a 4-category scale, but sometimes 3 or 5. Protocols for each metric (including definition, background, methods and scaling rationale) are provided under "Procedures for Conducting Ecological Integrity Assesessments" (page 59). Each metric is rated and then aggregated with other metrics by major ecological attribute: Landscape Context, Size, Vegetation, Hydrology and Soils.

The metrics vary in their level of quantification. Ratings for some of the metrics are based on quantifiable, measurable ratings; others are more narrative in context and may require expert judgment and experience. In some cases, such as vegetation structure and composition, it is possible to gather quantitative data (see Appendix VI for an example field form). But at the level of broad wetland formations, such as Temperate & Boreal Freshwater Marsh or Bog & Fen, it is very difficult to specify with reliability any quantitative metrics that are meaningful to ecological integrity. Nonetheless the data are a valuable record of the condition of the vegetation, and can provide documentation for later use, as we better understand how to apply these metrics. In addition, gathering at least some data will also improve the ability to calibrate this rapid assessment approach against more detailed surveys, and, perhaps more importantly, at a finer scale of classification, such as Macrogroup or Ecological System. Finally, many vegetation ecologists will find that they can easily add a Level 3 vegetation metric, such as the Floristic Quality Index (see Appendix III), as part of their Level 2 assessment, and thereby substitute that metric for the Vegetation Composition metric.

TABLE 10A

Overview of Rapid Field-Based (Level 2) Metrics for Assessing Wetland Integrity.

Tier: 1 = Remote sensing-based metric, 2 = Rapid field-based metric. Metric Type: C = condition metric, S = stressor metric or checklist (grey shaded cells). Shaded rows contain metrics that are not used directly to assess integrity, but are considered informative. Ratings for each metric are provided in Table 10B.

Major Attribute	Key Ecological Attribute	Metric Name	Tier	Metric Type	Metrics Definition
LANDSCAPE CONTEXT	Landscape Structure	Landscape Connectivity	1, 2	C	Non-riverine: A measure of the percent of unfragmented landscape within 500 m radius (non-riverine types). Riverine: A measure of the degree to which the riverine corridor above and below a floodplain area exhibits connectivity with adjacent natural systems (riverine types). Assessed segment is 500 m upstream and 500 m downstream.
		Buffer Index			An index of the overall area and condition of the buffer immediately surrounding the wetland, using three measures: Percent of Wetland with Buffer, Average Buffer Width (with slope correction), and Buffer Condition. Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.
	Landscape Composition	Surrounding Land Use Index	1, 2	S	A measure of the intensity of human-dominated land uses within a specific landscape area (such as a catchment) from the center of the occurrence. Each land use type occurring in the landscape area is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the target system.
	Landscape Context Stressors	Landscape Stressors Checklist	2	S	A checklist of stressors that could affect landscape context condition.
SIZE	Size	Patch Size Condition*	1, 2	C	A measure of the current size of the wetland (ha) relative to the original natural size. Assessed by dividing the best estimate of historic size by current absolute size, multiplied by 100.
		Patch Size (ha)	1, 2	C	A measure of the current size (ha) of the occurrence or stand. Assessed relative to reference stands of a type, globally.
VEGETATION (BIOTA)	Community Structure	Vegetation Structure	2	C	An assessment of the overall structural complexity of the vegetation layers, including presence of multiple strata, age and structural complexity of canopy layer, and evidence of disease or mortality.
		Organic Matter Accumulation (coarse and fine debris)	2	C	An assessment of the overall organic matter accumulation, whether both fine and coarse litter (non-forested wetlands) or coarse woody debris and snags (forested wetlands).
	Community Composition	Vegetation Composition	2	C	An assessment of the overall species composition and diversity, including by layer, and evidence of specific species diseases or mortality.
		Relative Total Cover of Native Plant Species	2	C	A measure of the relative percent cover of all plant species that are native to the region. Typically measured by estimating total absolute cover and subtracting total exotic species cover.

(Continued on next page.)

TABLE 10A (continued from previous page)

Major Attribute	Key Ecological Attribute	Metric Name	Tier	Metric Type	Metrics Definition
VEGETATION (BIOTA) (cont.)	Biotic Stressors	Invasive Exotic Plant Species	2	S	A measure of the percent cover of a set of exotic plant species that are considered invasive.
		Biotic Condition Stressors Checklist	2	S	A checklist of stressors that could affect biotic condition.
HYDROLOGY	Hydrological Regime	Water Source	2	C	An assessment of the extent, duration and frequency of saturated or ponded conditions within a wetland, as affected by the kinds of direct inputs of water into, or any diversions of water away from, the wetland.
		Hydroperiod	2	C	An assessment of the characteristic frequency and duration of inundation or saturation of a wetland during a typical year.
		Hydrologic Connectivity	2	C	An assessment of the ability of the water to flow into or out of the wetland, or to inundate adjacent areas.
	Hydrologic Stressors	Upstream Surface Water Retention	1	S	A measure of the percentage of the contributing watershed which drains into water storage facilities capable of storing surface water from several days to months. Applies to riverine systems.
		Upstream/Onsite Water Diversions	1	S	A measure of the number of water diversions and their impact in the contributing watershed and in the wetland. Applies to riverine systems.
		Groundwater Diversions	1, 2	S	Under development for non-riverine systems.
		Hydrologic Stressors Checklist	2	S	A checklist of stressors that could affect hydrologic condition.
SOILS (PHYSICO-CHEMISTRY)	Physical Structure	Physical Patch Types	2	C	A checklist of the number of different physical surfaces or features that may provide habitat for species.
		Water Quality	2	C	An assessment of water quality based on visual evidence of water clarity and eutrophic species abundance.
		Soil Surface Condition	2	S	An assessment of soil surface disturbances (e.g. bare soil, tracks).
	Soils (Physico-chemical) Stressors Checklist	On-Site Land Use Index	2	S	A measure of the intensity of human-dominated land uses within the site. Each land use type occurring within the site is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the target system.
		Soils (Physico-chemical) Stressors Checklist	2	S	A checklist of stressors that could affect soils and physicochemical condition.

* *optional metric*

(End of Table 10A.)

TABLE 10B

Summary of Ratings for Rapid Field-Based (Level 2) Metrics used to Assess Wetland Integrity.

Tier: 1 = Remote sensing-based metric, 2 = Rapid field-based metric. Metric Type: C = condition metric, S = stressor metric or checklist (grey cells). Shaded rows contain metrics that are not used directly to assess integrity, but are considered informative. Formations listed are all temperate and boreal wetland formations, except for Tropical Mangrove. References to "riverine," etc., follow standard HGM definitions. Detailed protocols for each metric are provided separately in Appendix II.

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria: Excellent (A)	Good (B)	Fair (C)	Poor (D)
Landscape Context	Landscape Connectivity–*Non-Riverine*	1	C	Intact: Embedded in 90–100% natural habitat of around wetland, preferably within the watershed	Variegated: Embedded in 60–90% natural habitat	Fragmented: Embedded in 20–60% natural habitat	Relictual: Embedded in <20% natural habitat
	Riverine	1		The combined total length of all non-buffer segments is less than 200 m (<10%) for wadable (2-sided) sites, 100 m (<10%) for non-wadable (1-sided) sites	Combined length of all non-buffer segments is between 200 m and 800 m (10-40%) for "2-sided" sites; between 100 m and 400 m (10–40%) for "1-sided" sites	Combined length of all non-buffer segments is between 800 and 1800 m (40–90%) for "2-sided" sites; between 400 m and 900 m (40–90%) for "1-sided" sites	Combined length of all non-buffer segments is greater than 1800 m for "2-sided" (>90%) sites, greater than 900 m for "1-sided" sites (>90%)
	Buffer Index–*Length*	1,2	C	Buffer is 75–100% of occurrence perimeter	Buffer is 50–74% of occurrence perimeter	Buffer is 25–49% of occurrence perimeter	Buffer is <25% of occurrence perimeter
	Width			Average buffer width of occurrence is >200 m, adjusted for slope	Average buffer width is 100–199 m, after adjusting for slope	Average buffer width is 50–99 m, after adjusting for slope	Average buffer width (m) is, after adjusting for slope: D: 10–49 | E: <10 m
	Condition			Buffer for occurrence is characterized by abundant (>95%) cover of native vegetation and little to no (<5%) cover of non-native plants, with intact soils, and little or no trash or refuse	Buffer for occurrence is characterized by substantial (75–95%) cover of native vegetation, low (5–25%) cover of non-native plants, intact or moderately disrupted soils, moderate or lesser amounts of trash or refuse, and minor intensity of human visitation or recreation	Buffer for occurrence is characterized by a moderate (25–50%) cover of non-native plants, and either moderate or extensive soil disruption, moderate or greater amounts of trash or refuse, and moderate intensity of human visitation or recreation	Buffer for occurrence is dominated by non-native plant cover (>50%) characterized by barren ground and highly compacted or otherwise disrupted soils, with moderate or greater amounts of trash or refuse, and moderate or greater intensity of human visitation or recreation; OR there is no buffer present

(Continued on next page.)

TABLE 10B (continued from previous page)

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Landscape Context (cont.)	Surrounding Land Use Index–*Non-Tidal*	1, 2	S	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
	Tidal		S	Land use index = 85–100	Land use index = 65–84	Land use index = 45–64	Land use index <44
	Landscape Stressors Checklist	2	S				
Size	Patch Size Condition	1, 2	S	Occurrence is at, or only minimally reduced from, its full original, natural extent (<95%), and has not been artificially reduced in size. Reduction can include destroyed or severely disturbed (e.g., large changes in hydrology due to roads, impoundments, development, human-induced drainage; or changes caused by recent clearcutting).	Occurrence is only modestly reduced from its original, natural extent (80–95% or more). Reduction includes...(see A).	Occurrence is substantially reduced from its original, natural extent (50–80%). Reduction includes... (see A).	Occurrence is heavily reduced from its original natural extent (>50%). Reduction includes... (see A).
	Patch Size	1, 2		Patch size is very large compared to other examples of the same type (e.g., top 10% based on known and historic occurrences, or area-sensitive indicator species very abundant within occurrence)	Patch size is large compared to other examples of the same type (e.g. within 10–30%, based on known and historic occurrences, or most area-sensitive indicator species moderately abundant within occurrence)	Patch size is moderate compared to other examples of the same type, (e.g., within 30–70% of known or historic sizes; or many area-sensitive indicator species are able to sustain a minimally viable population, or many characteristic species are but present)	Patch size is too small to sustain full diversity and full function of the type. (e.g., smallest 30% of known or historic occurrences, or both key area-sensitive indicator species and characteristic species are sparse to absent)

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Vegetation (Biota)	Vegetation Structure– *Bog & Fen*	2	C	Peatland is supporting vegetation to its reference standard condition. Some very wet peatlands may not have any woody vegetation or only scattered stunted individuals. Woody vegetation mortality is due to natural factors and is not being influenced by anthropomorphic factors. Tree diameters and heights are near reference standard condition.	Generally, peatland vegetation has only minor anthropogenic influences present or the site is still recovering from major past human disturbances. Mortality or degradation due to grazing, limited timber harvesting or other anthropomorphic factors may be present although not widespread. The site can be expected to meet reference standard condition in the near future if negative human influence does not continue.	Peatland vegetation has been moderately influenced by anthropogenic factors. Expected structural classes or species are not present. Human factors may have diminished the standard condition for woody vegetation. The site will recover to reference standard condition only with the removal of degrading human influences and moderate recovery times.	Expected peatland vegetation is absent or much degraded due to anthropogenic factors. Woody regeneration is minimal and existing vegetation is in poor condition, unnaturally sparse, or depauperate in expected species. Recovery to reference standard condition is questionable without restoration or will take many decades.
	Floodplain & Swamp Forest, Mangrove [east U.S. versus west U.S.]?			Canopy a mosaic of small patches of different ages or sizes, including old trees and canopy gaps containing regeneration. Overall density moderate and average tree cover generally greater than 25%.	Canopy largely heterogeneous in age or size, but with some gaps containing regeneration or some variation in tree sizes AND overall density moderate and greater than 25% tree cover.	Canopy somewhat homogeneous in density and age, AND extremely dense or very open. Canopy cover may be very high or very low (>90%, <25%).	Canopy extremely homogeneous, sparse or absent (<10% cover).
	Freshwater Marsh [separate out vernal pools, prairie potholes]			Vegetation is at or near reference standard condition in structural proportions. No structural indicators of degradation evident.		Vegetation is moderately altered from reference standard condition in structural proportions. Several structural indicators of degradation evident.	Vegetation is greatly altered from reference condition in structural proportions. Many structural indicators of degradation evident.

(Continued on next page.)

TABLE 10B (continued from previous page)

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Vegetation (Biota) (cont.)	*Aquatic Vegetation*			Vegetation is at or near reference standard condition in structural proportions. No structural indicators of degradation evident.		Vegetation is moderately altered from reference standard condition in structural proportions. Several structural indicators of degradation evident.	Vegetation is greatly altered from reference condition in structural proportions. Many structural indicators of degradation evident.
	Organic Matter Accumulation (coarse and fine debris)– *Floodplain & Swamp Forest, Mangrove*	2	C	A wide size-class diversity of downed coarse woody debris (logs) and standing snags, with 5–9 or more logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay. [An Excellent rating could be based on: with >10 logs and snags exceeding 30 cm dbh and 2 m in length.]		A moderately wide size-class diversity of downed coarse woody debris (logs) and standing snags, with 1–4 logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay.	A low size-class diversity of downed coarse woody debris (logs) and standing snags, with logs and snags absent to rarely exceeding 30 cm dbh and 2 m in length, and logs in mostly early stages of decay (if present).
	Bog & Fen			The site is characterized by an accumulation of peaty, hummocky, organic matter. There is some matter of various sizes, some very old.		The site is characterized by some areas lacking an accumulation of peaty hummocky, organic matter. Size of materials does not vary greatly, nor do any appear old.	The site is characterized by large areas without peaty, hummocky organic matter (e.g., peat mining). Size of materials does not vary greatly, nor do any appear old.
	Freshwater Marsh, Salt Marsh, and Aquatic Vegetation	2		The site is characterized by a moderate amount of fine organic matter. There is some matter of various sizes, but new materials seem much more prevalent than old materials. Litter layers, duff layers and leaf piles in pools or topographic lows are thin. In North American Pacific Salt Marsh, with 5–9 or more logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay. [An Excellent rating could be established using: >10 logs and snags exceeding 30 cm dbh and 2 m in length.]		The site is characterized by occasional small amounts of coarse organic debris, such as leaf litter or thatch, with only traces of fine debris, and with little evidence of organic matter recruitment, or somewhat excessive litter. In North American Pacific Salt Marsh, with 1–4 logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay.	The site contains essentially no significant amounts of coarse plant debris, and only scant amounts of fine debris. OR too much debris. In North American Pacific Salt Marsh, with logs and snags absent to rarely exceeding 30 cm dbh and 2 m in length, and logs in mostly early stages of decay.

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Vegetation (Biota) (cont.)	Vegetation Composition	2, 3	C	Vegetation is at or near reference standard condition in species present and their proportions. Lower strata composed of appropriate species, and regeneration good. Native species sensitive to anthropogenic degradation are present, functional groups indicative of anthropogenic disturbance (ruderal or "weedy" species) are absent to minor, and full range of diagnostic/indicator species are present.	Vegetation is close to reference standard condition in species present and their proportions. Upper or lower strata may be composed of some native species reflective of past anthropogenic degradation (ruderal or "weedy" species). Some indicator/diagnostic species may be absent.	Vegetation is different from reference standard condition in species diversity or proportions, but still largely composed of native species characteristic of the type. This may include ruderal ("weedy") species. Regeneration of expected native trees may be sparse. Many indicator/diagnostic species may be absent.	Vegetation severely altered from reference standard in composition. Expected strata are absent or dominated by ruderal ("weedy") species, or comprised of planted stands of non-characteristic species, or unnaturally dominated by a single species. Regeneration of expected native trees minimal or absent. Most or all indicator/diagnostic species are absent.
	Relative Total Cover of Native Plant Species	2, 3	C	>99% relative cover of native plant species	97–99% relative cover of native plant species	90–96% relative cover of native plant species	D: 50–89% relative cover of native plant species E: <50% relative cover of native plant species
	Invasive Exotic Plant Species	2, 3	C	No key invasive exotic species present in area	Total abundance of key invasive exotic species less than 3%	Total abundance of key invasive exotic species 3–5%	Total abundance of key invasive exotic species greater than 5%
	Biotic Condition Stressors Checklist	2	S				

(Continued on next page.)

TABLE 10B (continued from previous page)

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Hydrology	Water Source	2		Water source for site is precipitation, groundwater, tidal, natural runoff from an adjacent freshwater body, or system naturally lacks water in the growing season. There is no indication of direct artificial water sources. Land use in the local drainage area of the site is primarily open space or low density, passive uses. No large point sources discharge into or adjacent to the site.	Water source is mostly natural, but site directly receives occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic input include developed land or agricultural land (<20%) in the immediate drainage area of the site, or the presence of small stormdrains or other local discharges emptying into the site, road runoff, or the presence of scattered homes along the wetland that probably have septic systems. No large point sources discharge into or adjacent to the site.	Water source is primarily urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology. Indications of substantial artificial hydrology include >20% developed or agricultural land adjacent to the site, and the presence of major point sources that discharge into or adjacent to the site.	Water flow exists but has been substantially diminished by known impoundments or diversions of water or other withdrawals directly from the site, its encompassing wetland, or from areas adjacent to the site or its wetland, OR water source has been several altered to the point where they no longer support wetland vegetation (e.g., flashy runoff from impervious surfaces).
	Hydroperiod–*All Non-riverine wetlands, except Bog & Fen*	2		Hydroperiod of the site is characterized by natural patterns of filling or inundation and drying or drawdown	The filling or inundation patterns in the site are of *greater* magnitude (and greater or lesser duration than would be expected under natural conditions, but thereafter, the site is subject to *natural drawdown or drying.*	The filling or inundation patterns in the site are characterized by *natural* conditions, but thereafter are subject to *more rapid or extreme drawdown or drying*, as compared to more natural wetlands, OR the filling or inundation patterns in the site are of substantially *lower magnitude or duration* than would be expected under natural conditions, but thereafter, the site is subject to *natural drawdown or drying*	Both the filling/inundation and drawdown/drying of the site deviate from natural conditions (either increased or decreased in magnitude and/or duration)

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Hydrology (cont.)	*Bog & Fen (non-riverine)*			Hydroperiod of the site is characterized by stable, saturated hydrology, or by naturally damped cycles of saturation and partial drying	Hydroperiod of the site experiences minor altered inflows or drawdown/ drying, as compared to more natural wetlands (e.g., ditching)	Hydroperiod of the site is somewhat altered by greater increased inflow from runoff, or experiences moderate drawdown or drying, as compared to more natural wetlands (e.g., ditching)	Hydroperiod of the site is greatly altered by greater increased inflow from runoff, or experiences large drawdown or drying, as compared to more natural wetlands (e.g., ditching)
	Salt Marsh, Mangrove			Estuary: Area is subject to the full tidal prism, with two daily tidal minima and maxima. Lagoon: Area subject to natural interannual tidal fluctuations (range may be severely muted or vary seasonally), and is episodically fully tidal by natural breaching due to either fluvial flooding or storm surge.	Estuary: Area is subject to reduced, or muted, tidal prism, although two daily minima and maxima are observed. Lagoon: Area is subject to full tidal range more often than would be expected under natural circumstances, because of artificial breaching of the tidal barrier.	Estuary: Area is subject to muted tidal prism, with tidal fluctuations evident only in relation to extreme daily highs or spring tides. Lagoon: Area is subject to full tidal range less often than would be expected under natural circumstances due to management of the breach to prevent its opening.	Estuary: Area is subject to muted tidal prism, plus there is inadequate drainage, such that the marsh plain tends to remain flooded during low tide. Lagoon: Area probably has no episodes of full tidal exchange.
	Riverine			Most of the channel through the site is characterized by equilibrium conditions, with no evidence of severe aggradation or degradation (based on the field indicators listed in metric protocol).	Most of the channel through the site is characterized by some aggradation or degradation, none of which is severe, and the channel seems to be approaching an equilibrium form (based on the field indicators listed in metric protocol).	There is evidence of severe aggradation or degradation of most of the channel through the site (based on the field indicators listed in metric protocol)	Concrete, or otherwise artificially hardened, channels through most of the site (based on the field indicators listed in metric protocol).

(Continued on next page.)

TABLE 10B (continued from previous page)

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Hydrology (cont.)	Hydrologic Connectivity– *All non-riverine wetlands, excluding Bogs and other isolated wetlands, Salt Marsh and Mangrove (see below)*	2	C	Rising water in the site has unrestricted access to adjacent upland, without levees, excessively high banks, artificial barriers, or other obstructions to the lateral movement of flood flows	Lateral excursion of rising waters in the site is partially restricted by unnatural features, such as levees or excessively high banks, but less than 50% of the site is restricted by barriers to drainage. Restrictions may be intermittent along the site, or the restrictions may occur only along one bank or shore. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment.	Lateral excursion of rising waters in the site is partially restricted by unnatural features, such as levees or excessively high banks, and *50-90%* of the site is restricted by barriers to drainage. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment.	All water stages in the site are contained within artificial banks, levees, sea walls, or comparable features, or *greater than 90%* of wetland is restricted by barriers to drainage. There is essentially no hydrologic connection to adjacent uplands.
	Bogs and other isolated wetlands				No connectivity	Partial connectivity. (e.g., ditching or where duripan is intentionally broken by drilling or blasting	Substantial to full connectivity
	Salt Marsh			Average tidal channel sinuosity >4.0; absence of channelization. Marsh receives unimpeded tidal flooding. Total absence of tide gates, flaps, dikes culverts, or human-made channels.	Average tidal channel sinuosity = 2.5–3.9. Marsh receives essentially unimpeded tidal flooding, with few tidal channels blocked by dikes or tide gates, and human-made channels are few. Culvert, if present, is of large diameter and does not significantly change tidal flow, as evidenced by similar vegetation on either side of the culvert.	Average tidal channel sinuosity = 1.0–2.4. Marsh channels are frequently blocked by dikes or tide gates. Tidal flooding is somewhat impeded by small culvert size, as evidenced by obvious differences in vegetation on either side of the culvert.	Average tidal channel sinuosity <1.0. Tidal channels are extensively blocked by dikes and tide gates; evidence of extensive human channelization. Tidal flooding is totally or almost totally impeded by tidal gates or obstructed culverts.

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Hydrology (cont.)	*Mangrove*			Excellent connectivity to other estuarine communities (e.g., marsh-mangrove, lagoon-bay estuaries, freshwater marshes) to ensure wide salinity gradients. Tidal flow is unimpeded.	Good connectivity to other estuarine communities (e.g., marsh-mangrove, lagoon-bay estuaries, freshwater marshes), with minimally reduced salinity gradients. Tidal flow is only minimally impeded by un-natural barriers.	Fair connectivity to other estuarine communities (e.g., marsh-mangrove, lagoon-bay estuaries, freshwater marshes) with moderately reduced salinity gradients. Tidal flow is moderately impeded by un-natural barriers.	Poor connectivity to other estuarine communities (e.g., marsh-mangrove, lagoon-bay estuaries, freshwater marshes) with little gradient in salinity. Tidal flow is extensively impeded by unnatural barriers.
	Riverine–Unconfined		C	Entrenchment ratio is >4.0. Completely connected to floodplain (backwater sloughs and channels).	Entrenchment ratio is 1.4–2.2. Minimally disconnected from floodplain by dikes, tide gates, elevated culverts, etc.	Entrenchment ratio is <1.4. Moderately disconnected from floodplain by dikes, tide gates, elevated culverts, etc.	Extensively disconnected from floodplain by dikes, tide gates, elevated culverts, etc.
	Riverine–Confined		C	Entrenchment ratio is >1.4	Entrenchment ratio is 1.0 –1.4	Entrenchment ratio is <1.0	—
	Upstream Surface Water Retention–*Riverine wetlands only?*	1	S	<5% of drainage basin drains to surface water storage facilities	>5–20% of drainage basin drains to surface water storage facilities	>20–50% of drainage basin drains to surface water storage facilities	>50% of drainage basin drains to surface water storage facilities
	Upstream/On-site Water Diversions–*Riverine wetlands only?*	1	S	No upstream, on-site or nearby downstream water diversions present	Few diversions present or impacts from diversions minor relative to contributing watershed size. On-site or nearby downstream diversions, if present, appear to have only minor impact on local hydrology.	Many diversions present or impacts from diversions moderate relative to contributing watershed size. Onsite or nearby downstream diversions, if present, appear to have a major impact on local hydrology.	Water diversions are very numerous or impacts from diversions high relative to contributing watershed size. Onsite or nearby downstream diversions, if present, have drastically altered local hydrology.
	Groundwater Diversions	1	S	Under development	Under development.	Under development	Under development
	Hydrologic Stressors Checklist	2	S				

(Continued on next page.)

TABLE 10B (continued from previous page)

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Soils (Physico-chemistry)	Physical Patch Types		C		Physical patch types typical of reference standard condition are present (see checklist).	Some physical patch types typical of reference standard condition are lacking (see checklist).	Many physical patch types typical of reference standard condition are lacking (see checklist).
	Water Quality	2	C	There is no visual evidence of degraded water quality. Wetland species that respond to un-naturally high nutrient levels are minimally present, if at all. Water is clear with no strong green tint or sheen.	Some negative water quality indicators are present, but limited to small and localized areas within the wetland. Wetland species that respond to unnaturally high nutrient levels may be present but are not dominant. Water may have a minimal greenish tint or cloudiness, or sheen.	Negative water quality indicators or wetland species that respond to unnaturally high nutrient levels are common. Wetland is not dominated by these vegetation species. Sources of water quality degradation are typically apparent. Water may have a moderate greenish tint, sheen or other turbidity with common algae.	Wetland is dominated by vegetation species that respond to unnaturally high nutrient levels or there is widespread evidence of other negative water quality indicators. Algae mats may be extensive. Sources of water quality degradation are typically apparent. Water may have a strong greenish tint, sheen or turbidity. The bottom will be difficult to see during the growing season. Surface algal mats and other vegetation block light to the bottom.
	Soil Surface Condition–*All freshwater wetlands*	2	C, S	Bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails	Some amount of bare soil due to human causes is present but the extent and impact is minimal. The depth of disturbance is limited to only a few inches and does not show evidence of ponding or channeling water. Any disturbance is likely to recover within a few years after the disturbance is removed.	Bare soil areas due to human causes are common and will be slow to recover. There may be pugging due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts. Damage is not excessive and the site will recover to potential with the removal of degrading human influences and moderate recovery times.	Bare soil areas substantially degrade the site due to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock pugging and/or trails are widespread. Water will be channeled or ponded. The site will not recover without restoration and/or long recovery times.

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
Soils (Physico-chemistry) (cont.)	*Salt marsh and Mangrove*			Excluding mud flats, bare soils are limited to salt panes	Limited exposure of bare soils caused by erosion of marsh and channel banks due to excavation or marine traffic	Frequent exposure of bare soils caused by erosion of marsh and channel banks due to excavation by marine traffic [heavy animal grazing?]	Extensive bare soils caused by erosion of marsh and channel banks due to excavation by marine traffic [heavy animal grazing?]
	On-Site Land Use	2	S	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
	Soils (Physico-chemical) Stressors Checklist	2	S				

(End of Table 10B.)

Stressor Checklists

Stressor checklists can be useful as additional information when evaluating the ecological integrity of an occurrence. Typically, they are an aid to further understanding the overall condition of the wetland. In some cases, where stressors appear to be having a negative impact on the site, but the condition metrics do not reflect these impacts, it may lead to changes in the overall ecological integrity rank of a wetland. This should be done only in exceptional circumstances. The need for manual over-rides may suggest that the current condition metrics may be insensitive to degradation of certain stressors, and future adjustments to the metrics used may be needed. See also Appendix II for protocols in using the checklist.

TABLE 11

Stressor Checklist Worksheets for Assessment Area (site). Checklist adapted from Collins et al. (2006).

LANDSCAPE CONTEXT STRESSORS CHECKLIST	Present, but at low levels (<10% of stand or polygon)	Present at high levels (>10% of stand or polygon)
Urban residential		
Industrial/commercial		
Military training/air traffic		
Transportation corridor (paved roads, highways)		
Dryland farming		
Intensive row-crop agriculture		
Orchards/nurseries		
Dairies		
Commercial feedlots (high-density livestock)		
Ranching, moderate-density livestock (enclosed livestock grazing or horse paddock)		
Rangeland, low-density livestock (livestock rangeland also managed for native vegetation)		
Sports fields and urban parklands (golf courses, soccer fields, etc.)		
Passive recreation (bird-watching, hiking, etc.)		
Active recreation (off-road vehicles, mountain biking, hunting, fishing)		
Physical resource extraction, mining, quarrying (rock, sediment, oil/gas)		
Biological resource extraction (aquaculture, commercial fisheries, horticultural and medical plant collecting)		
Lack of appropriate treatment of invasive plant species in surrounding area		
Comments		

VEGETATION (BIOTA) STRESSORS CHECKLIST	Present, but at low levels (<10% of stand or polygon)	Present at high levels (>10% of stand or polygon)
Mowing, grazing, excessive herbivory (within occurrence)		
Excessive human visitation		
Predation and habitat destruction by non-native vertebrates, including feral introduced naturalized species, such as feral livestock, exotic game animals, pet predators (e.g., Virginia possum, oryx, pigs, goats, burros, cats, dogs)		
Tree/sapling or shrub removal (cutting, chaining, cabling, herbiciding)		
Removal of woody debris		
Lack of appropriate treatment of invasive plant species in the area		
Damage caused by treatment of non-native and nuisance plant species		
Pesticide application or vector control		
Lack of fire or too frequent fire		
Lack of floods or excessive floods for riparian areas		
Biological resource extraction or stocking (e.g., aquaculture, commercial fisheries, horticultural and medical plant collecting)		
Excessive organic debris (for recently logged sites)		
Other lack of vegetation management to conserve natural resources [please specify]		
Comments		

(Continued on next page.)

TABLE 11 (continued from previous page)

SOIL/SUBSTRATE STRESSORS CHECKLIST	Present, but at low levels (<10% of stand or polygon)	Present at high levels (>10% of stand or polygon)
Filling or dumping of sediment or soils (N/A for restoration areas)		
Grading/compaction (N/A for restoration areas)		
Plowing/discing (N/A for restoration areas)		
Resource extraction (sediment, gravel, mineral, oil and/or gas)		
Impact of vegetation management on soils/ substrate (e.g., terracing, pitting, drilling seed, chaining, root plowing)		
Excessive sediment or organic debris (e.g., excessive erosion, gullying, slope failure)		
Physical disturbance of soil/substrate by recreational vehicle tracks, livestock, logger skidding, etc.		
Pesticides or toxic chemicals (PS or non-PS pollution) (on-site evidence)		
Trash or refuse dumping		
Comments		

HYDROLOGY STRESSORS CHECKLIST	Present, but at low levels (<10% of stand or polygon)	Present at high levels (>10% of stand or polygon)
Point Source (PS) Discharges (POTW, other non-stormwater discharge)		
Non-point Source (Non-PS) Discharges (urban runoff, farm drainage onto site)		
Flow diversions or unnatural inflows (restrictions and augmentations)		
Dams (reservoirs, detention basins, recharge basins)		
Flow obstructions (culverts, paved stream crossings)		
Weir/drop structure, tide gates		
Dredged inlet/channel		
Engineered channel (riprap, armored channel bank, bed)		
Dike/levees		
Groundwater extraction (water table lowered)		
Ditches (borrow, agricultural drainage, mosquito control, etc.)		
Actively managed hydrology (e.g., lake levels controlled)		
Comments		

Scorecard Protocols for Level 2 Assessments

Point-Based Approach

Individual metrics can be aggregated to provide a rating of the condition of each major attribute — landscape context, vegetation, hydrology and soils (aggregating by key ecological attribute is typically not needed, as they often have only one or two metrics). The major attributes can be further aggregated into an overall Index of Ecological Integrity (IEI) rank. IEIs can be calculated at multiple scales (e.g., sample plot, polygon, occurrence, site, jurisdictional area), depending on the sampling design and the scale of the question. Here we focus on an assessment of an occurrence of a wetland type at a site.

A number of approaches for aggregating, or "rolling up" rapid-based field metrics are available, each with a variety of strengths and weaknesses. In a point-based approach, each metric is assessed independently, assigned a rating of a metric a consistent weight, regardless of the scores of other metrics (e.g., A = 5 points, B = 4 points, etc.), then added up the points across all metrics. In this sense it is a *non-interaction approach* (common to point-based methods).[1] Rules and weights can be added to account for some interactions. Point-based approaches have been widely used in biotic integrity assessments, and are appropriate when the scaling of the metrics is standardized to equate to have the same meaning based on use of reference condition (i.e., all D ratings for metrics equate to a system that is well outside the natural range of variation) (Karr and Chu 1999). Although many of our metrics are based on ordinal scales, which make it harder to combine metrics, they are more easily justified in terms of biological, ecological and mathematical criteria. That is, as stated by Sutula et al. (2006), "ordinal scales require only the ability to rank wetlands based on their relative similarity to the desired assessment endpoint without knowing precisely how close the condition is to that endpoint or to the next highest rating category." The key is to scale the ordinal values so that the full range of each of the metrics is indicating something comparable in terms of ecological integrity. Given that premise, it can be acceptable to use a relatively simple, point-based approach to both score and aggregate the metrics together, without developing any statistical applications. The overall interpretation should remain focused on the general ratings of A–D and not on the details of the points themselves (i.e., whether an A of 96 is better than an A of 90). In addition, the original metrics themselves are available to further explain the reasons for the aggregated scores.

When aggregating metrics or categories, one can simply calculate an arithmetic mean, which assumes that all categories have an equal weight and contribution to the overall integrity index. But, one could weight some metrics or categories more than others, so that they contribute an overall higher proportion of the total points to the final index. As noted above, another approach is to add some rules, so that specific combinations of metrics or categories define a particular level of integrity. The limitations of aggregating scores should always be kept in mind.

For the point-based approach developed here, the default set of points for the basic four category rating scheme are A = 5, B = 4, C = 3, D = 1. The weights are derived from Karr's Index of Biotic Integrity approach) (Karr and Chu 1999), where 5 (good),

---

[1] An *interaction approach* allows the role of a metric to vary depending on other metrics. A set of combination rules or tables are established based on our best knowledge of the ecological interactions among metrics. The interactive approach typically uses a series of Boolean logic statements throughout (e.g., if metric 1 = A, metric 2 = B, etc., then the category rating = B). For example, in a forested system, the Vegetation attribute may be assessed using two metrics — ground layer plant species composition and canopy structure. Using the non-interactive, point-based approach, if the ground layer is rated B and canopy structure is rated D, the points might be added and averaged to give an overall category rating of C. Using the combination rule approach, the canopy structure metric may only count when ground layer composition has at least a C rating. That is, when the ground layer is dominated by exotics and assigned a D rating, the overall vegetation rating is based solely on the ground layer metric, regardless of whether the canopy structure is pole stage or old growth. Such approaches require good knowledge of the ecological relations among the metrics and their effect on ecological integrity.

3 (fair) and 1 (poor) points were used. Distinctions between excellent (A) and good (B) can be subtle, compared to the C/D break, so only a single point separates them. Some metrics have a five- or six-point rating scheme (A–E or A–F), and the points are then spread out evenly from 5 to 1. The metrics are rolled up into four categories (landscape context, biota, hydrology and physicochemistry condition), and in turn, these categories are rolled up into an overall Index of Ecological Integrity (see "Landscape Integrity of the Watershed" on page 6, and Table 5 on page 22).

Use of Range-Ratings when Assessing Metrics

The metrics may also be scored using "range ratings." That is, an assessor may not be able to decide between an A or a B rating for a metric. In this case, it may be best to assign an AB rating (that is, the rating may be either A or B). The low and high scores (e.g., A = 5, B = 4) will both be used in the calculation. When roll-ups to the four categories are completed, both the total low scores and high scores across the metrics are calculated, and if the final low and high score span two ratings, a range rating is assigned to the category. A similar approach can be used for the overall IEI. The use of range ratings should only be applied in cases of great uncertainty. Exact ratings are encouraged. But the range rating is helpful whenever rating proves challenging because of unusual situations in the field or assessor inexperience with a metric.

Role of Stressor Checklists

Typically, stressor checklists are used only for informative purposes, as an aid to further understanding the overall condition of the wetland. In some cases, where stressors appear to be having a negative impact on the site, but the condition metrics do not reflect these impacts, it may be important to over-ride the calculated IEI. This should only be done in exceptional circumstances. The need for manual over-rides may suggest that the current condition metrics may be insensitive to degradation of certain stressors, and future adjustments to the metrics used may be needed.

Weighting Metrics by Formation

Not all metrics are equally relevant to each formation. A metric such as Vegetation Structure has greater interpretive value for forested wetlands, where changes in structure can be linked to ecological integrity, than it does to freshwater marshes, where changes in structure are more subtle. Thus the rating protocols specified below may need to be varied by formation.

Landscape Context Rating Protocol

Rate the Landscape Context metrics according to their specified ratings (see Table 10B). Use the scoring table below to roll up the metrics into an overall Landscape Context rating.

Rationale for Scoring: Three factors are judged equally important.

Thus, the following weights apply to the Landscape Context metrics:

Landscape Context Rating Calculation						
Measure	A	B	C	D	Weight	Score (sum of weighted scores/ sum of weights)
Landscape Connectivity	5	4	3	1		
Buffer Index	5	4	3	1		
Surrounding Land Use	5	4	3	1		
Landscape Context 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

Size Rating Protocol

Rate the Size metrics according to their specified ratings (see Table 10B). Use the scoring table below to roll up the metrics into an overall Size rating.

Rationale for Scoring: Absolute Size is always used as a metric, but Relative Size is optional. Even when used, it does not carry the same weight as absolute size. The focus is on current condition, not historic patterns per se.

Thus, the following weights apply to the Size metrics:

Size Rating Calculation						
Measure	A	B	C	D	Weight	Score (sum of weighted scores/ sum of weights)
Patch Size (ha)	5	4	3	1		
Patch Size Condition*		5	3	0.25		
Size 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

* *optional metric*

Vegetation (Biota) Rating Protocol

Rate the Vegetation metrics according to their specified ratings (see Table 10B). Use the scoring table below to roll up the metrics into an overall Vegetation rating.

Rationale for Scoring: Each of the metrics is judged to be equally important as a measure of biotic integrity. Further work is needed to improve their evaluation in a rapid assessment.

Vegetation (Biota) Rating Calculation							
Measure	A	B	C	D	E	Weight	Score (sum of weighted scores/ sum of weights)
Vegetation Structure	5	4	3	1			
Organic Matter Accumulation (coarse and fine debris)		5	3	1			
Vegetation Composition	5	4	3	1			
Relative Total Cover of Native Plant Species	5	4	3	2	1		
Vegetation (Biota) 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

Hydrology Rating Protocol

Rate the measures according to the metrics protocols (see Table 10B). Use the scoring table below to roll up the metrics into an overall Hydrology rating.

Rationale for Scoring: Each of the hydrologic metrics is judged to be equally important to the overall measure of hydrologic integrity.

Hydrology Rating Calculation						
Measure	A	B	C	D	Weight	Score (sum of weighted scores/ sum of weights)
Water Source	5	4	3	1		
Hydroperiod	5	4	3	1		
Hydrologic Connectivity	5	4	3	1		
Hydrology 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

Soils (Physicochemistry) Rating Protocol

Rate the Physicochemistry metrics according to their specified ratings (see Table 10B). Use the scoring table below to roll up the metrics into an overall Physicochemistry rating.

Rationale for Scoring: The three metrics are judged to be equally important to the overall measure of physicochemistry integrity.

Soils (Physicochemistry) Rating Calculation						
Measure	A	B	C	D	Weight	Score (sum of weighted scores/ sum of weights)
Physical Patch Types		5	3	1		
Water Quality	5	4	3	1		
Soil Surface Condition	5	4	3	1		
Soils (Physicochemistry) 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

Overall Index of Ecological Integrity Rank

Rate the overall ecological integrity of the occurrence based on the major categories (Landscape Context, Size, Biota, Hydrology and Physicochemistry Attributes). Use the scoring table below to roll up the metrics into an overall rating.

Overall EIA Rating Calculation						
Category	A	B	C	D	Weight	Score (sum of weighted scores/ sum of weights)
Landscape Context	5	4	3	1	1	
Size	5	4	3	1	0.5	
Vegetation (Biota)	5	4	3	1	1	
Hydrology	5	4	3	1	1	
Soils (Physico-chemistry)	5	4	3	1	0.5	
EIA 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

Level 3 (Intensive Field-Based) Metrics for Wetlands

Based on the conceptual model developed above, we are in the early stages of compiling a list of indicators/metrics of integrity for each wetland type that covers the major attributes of hydrology, landscape context, size, vegetation, hydrology and soils (physicochemistry) (see Fig. 1). We have reviewed a variety of existing rapid and intensive wetland assessment and monitoring materials as well as draft reports for intensive wetland monitoring in the National Park Service Northeast Temperate Network (Mack 2001, Collins et al. 2006, Neckles et al. 2006, Faber-Langendoen et al. 2006).

Many researchers have approached the development of Level 3 assessments by focusing primarily on the vegetation. A vegetation index of biotic integrity is developed by sampling various attributes of the vegetation assemblage in wetlands exposed to varying degrees of human disturbance. An important component to VIBI is that it moves beyond the simple diversity approach to assessing the status of a vegetation community, which has been criticized as a method for assessing ecological condition.

The underlying assumption of the VIBI approach to wetland assessment is that vegetation effectively integrates the hydrological, physical, chemical and biological status of a wetland and thus provides a cost-effective and efficient method of assessing wetland integrity. Because of their ability to reflect current and historical ecological condition, plants are one of the most commonly used taxa for wetland bioassessment. In other words, if the chemical, physical and/or biological processes of an ecosystem have been altered, vegetation composition and abundance will reflect those alterations. In summary, the ecological basis for using vegetation as an indicator in wetlands is as follows (U.S. EPA 2002a, b, Rocchio 2007):

- Vegetation is known to be a sensitive measure of human impacts;
- Vegetation structure and composition provide habitat for other taxonomic groups such as waterbirds, migratory songbirds, macroinvertebrates, fish, large and small mammals, etc.;
- Strong correlations exist between vegetation and water chemistry;
- Vegetation influences most wetland functions;
- Vegetation supports the food chain and is the primary vector of energy flow through an ecosystem;
- Plants are found in all wetlands and are the most conspicuous biological feature of wetland ecosystems; and
- Ecological tolerances for many plant species are known and could be used to identify specific disturbances or stressors that may be responsible for a change in wetland biotic integrity.

Typical field methods to develop a Vegetation Index of Biotic Integrity include (Rocchio 2007):

- Developing a sampling design to assess all major wetlands types across varying degrees of human-induced disturbance.
- Scoring human disturbances at each site according to the type, severity and duration of human-induced alterations to the wetland and surrounding area's ecological processes.
- Choosing vegetation attributes which had strong discriminatory power and were strongly correlated to the human disturbance gradient as metrics for the VIBI.
- Scaling each metric's field values to a numeric score resulting in a standardized scoring system across all metrics.

The total VIBI score is derived by summing scores for all the metrics. There are an increasing number of VIBI studies being conducted. The increased precision and accuracy of these studies also makes them more applicable only within the region of study.

It is important to collect some hydrologic or soils data, in order to validate the integrative role that the VIBI has. Moreover, it is not always necessary to have the VIBI serve as a surrogate for the other major attributes. Metrics can also be developed for hydrology and soils. In these cases the VIBI's major function is to serve as an indicator of the biotic attributes of the wetland, rather than the entire set of ecological attributes.

Metrics for Level 3 Assessment

A synopsis of the ecological metrics and ratings is presented in Table 12. Our list is still preliminary but further development is beyond the scope of this report.

Protocols describing some of these metrics are provided in Appendix III.

TABLE 12

Examples of metrics applicable to intensive (Level 3) metrics for wetlands.

Major Attribute	Proposed Metric	Description
Landscape Context	Landscape connectivity Landscape integrity index	• Percent area of natural ecosystems in surrounding landscape • Anthropogenic stressor index based on % agriculture, % urban, human population density, road density, and % impervious surface
Size	Patch size	The area in hectares occupied by a wetland type
Vegetation	Vegetation Structure Vegetation Composition, Invasive Exotic Species Floristic Quality Assessment Vegetation Index of Biotic Integrity	Transect establishment and vegetation sampling
Hydrology	Groundwater level	Level of water in monitoring wells
	Surface water level	Level of water at deepest point in the wetland surrounding the monitoring wells
Soil (Physicochemistry)	Groundwater Conductivity Surface Water Conductivity	Conductivity for ground and surface water chemistry
	Temperature	Temperature for ground and surface water chemistry
	Groundwater pH Surface water pH	pH for ground and surface water chemistry

Procedures for Conducting Ecological Integrity Assessments

At this time we have not developed a formal set of procedures for conducting an ecological integrity assessment as it relates to mitigation. Further study is needed to provide such guidance. We provide a brief overview below of how such an assessment can be conducted.

The general procedure for using EIA Assessment consists of a series of steps (adapted from Collins et al. 2006, see Chapter 3):

Step 1: Assemble background information about the management and history of the wetland.
Step 2: Classify the wetland using the U.S. National Vegetation Classification, the NatureServe Ecological Systems, the Hydrogeomorphic Classification, and an appropriate state classification. State classifications that are crosswalked to the above classifications may give a ready answer for all classifications.
Step 3: Establish the landscape context boundary for the occurrence.
Step 4: Determine wetland size.
Step 5: Verify the appropriate season and other timing aspects of field assessment.
Step 6: Determine the boundary and estimate the size of the assessment area (if it is not the same as the wetland) and allocate observation points or plots, if plots or points are to be used.
Step 7: Conduct the office assessment of stressors, landscape context and on-site conditions of the wetland or assessment area.
Step 8: Conduct the field assessment of stressors and on-site conditions of the wetland or assessment area.
Step 9: Complete assessment scores and QA/QC procedures.
Step 10: Upload results into Biotics Database or other regional and statewide information systems.

Some Guidelines for Field Methods

At this time we have not developed a formal set of field methods for conducting an ecological integrity assessment as it relates to mitigation. Further study is needed to provide such guidance. We do provide a few guidelines below of how such an assessment can be conducted.

A few guidelines are provided for conducting Ecological Integrity Assessments:

1. Determine where the assessment areas or sites of a wetland type are and classify them using the NVC.

Wetlands will be classified using the U.S. National Vegetation Classification (FGDC 2007), Ecological Systems (Comer et al. 2003, NatureServe 2008), the Hydrogeomorphic type, and a state classification. For example, a local marsh occurrence along a river is identified as a Temperate & Boreal Freshwater Marsh formation. Knowing the formation will determine which metrics and ratings are used, and knowing the HGM class will determine which metric variant to use. That is, assessing the Landscape Connectivity metric of a freshwater marsh found along a river corridor (riverine HGM) requires a different form of the metric than for marshes found in depressions (depressional HGM).

2. The field data collection protocols should be fairly standard, regardless of the intent of the survey, since the fundamental metrics of the EIA need to be included. Protocols for how to measure the metrics are briefly described in Appendix II. These documentations will help inform the field data collection protocols. In many cases the metrics can be documented from remote sensing/aerial photo imagery; in other cases,

by walking an assessment area (site); yet in others, by taking a few relatively simple field measures.

3. Rapid field assessments should be able to be completed within two hours, plus two hours preparation time assessing the imagery (see #4 below). By and large, once the crew leaves the field, the field forms are essentially complete.

Field crew expertise should be akin to that needed for wetland delineation; that is, field crews should have some knowledge of hydrology, soils, and vegetation, sufficient to assess hydrologic dynamics, perhaps examine a soil core for mottling, and be able to identify all prominent exotic species in a region.

4. Field methods for applying ecological integrity assessments vary, depending on the purpose of the assessment. But several general comments can be provided, in the context of a rapid assessment.

First, it must be established what the "unit of observation" is. Most commonly, for ecological surveys, this is an occurrence of a wetland, at the scale of a site. We refer to this as the Ecological Assessment Area (EAA). Accordingly we may define the EAA as "the entire area, sub-area, or point of an occurrence of a wetland type."

If the occurrence at a site is the focus, then a sampling design could still vary as follows:

a) conduct an assessment survey of the entire area of the occurrence, e.g., a rapid qualitative assessment;
b) conduct an assessment survey of a typical sub-area(s) of the occurrence, or
c) collect a series of plots, placed either in representative or un-biased locations, throughout the entire area or sub-area occurrence.

In all three cases, the intent is to assess the ecological integrity of a particular wetland occurrence.

The focus of an EIA for mitigation purposes is primarily to assess the integrity of an occurrence at a site, irrespective of the property or management regime it may be found on, and however large it is. This area may be equivalent to a Project Assessment Area, (Hauer et al. 2002), or a Wetland Assessment Area, by many HGM manuals (Hauer et al. 2002), though those areas are determined by property lines or management areas.

5. Many of the metrics can be assessed, at least preliminarily, in the office, using remote sensing imagery. Many other additional sources of information can help determine the condition and threats to a site (see Rocchio 2007):

- Digital orthophoto quadrangles (1 m resolution)
- GIS layers (roads, utility lines, trails, mines, wilderness areas, National Land Cover Dataset, irrigation, ditches, groundwater wells, etc.)
- Element occurrence records from Natural Heritage Programs
- State or Federal agency surveys
- Soils map, etc,

6. It is usually helpful to map the extent of the occurrence as part of the field survey (see Rocchio 2007), using the following steps.

a) *Estimation of Wetland Boundaries*
The first step is to map the wetland area. Readily observable ecological criteria such as vegetation, soil and hydrological characteristics were used to define wetland boundaries, regardless of whether they met jurisdictional criteria for wetlands regulated under the Clean Water Act.

b) *Delineating Formation and Ecological System Boundaries*
The second step is to delineate the targeted type present within the wetland boundary. Formation and Ecological System descriptions can be used to guide a subjective determination of the target system's boundaries in the field. A minimum map size criteria should be specified, and each patch of a wetland type would be considered separate potential EAA or sub-EAA and thus as an independent sample. If a patch was less than its minimum size then it would be considered to be associated with internal variation of the type in which it is embedded.

c) *Size and Land Use Related Boundaries*
Once the targeted type boundaries are delineated, then size and land use can be used to further refine EAA boundaries. For example, depending on the size or variation of the wetland area, the EAA may consist of the entire site or only a portion of the wetland/riparian area. For small wetlands or those with a clearly defined boundary (e.g., isolated fens or wet meadows) this boundary was almost always the entire wetland. In very large wetlands or extensive and contiguous riparian types, a sub-sample of the area can be defined as the EAA for the project. For other project purposes such as regulatory wetland projects, there may be multiple EAAs in one large wetland.

Significant change in management or land use can result in distinct ecological differences. Some examples follow:

i. A heavily grazed wetland on one side of a fence line and ungrazed wetland on the other would result in two subunits of EAAs.
ii. Natural changes in hydrology could also be the basis for a separate assessment. For example, a drastic change in water table levels or fluctuations, confluence with a tributary, etc., would dictate at least a separate set of sub-EAAs.
iii. Anthropogenic changes in hydrology. For example, ditches, water diversions, irrigation inputs, roadbeds, etc., that substantially alter a site's hydrology relative to adjacent areas would dictate at least a separate set of sub-EAAs.

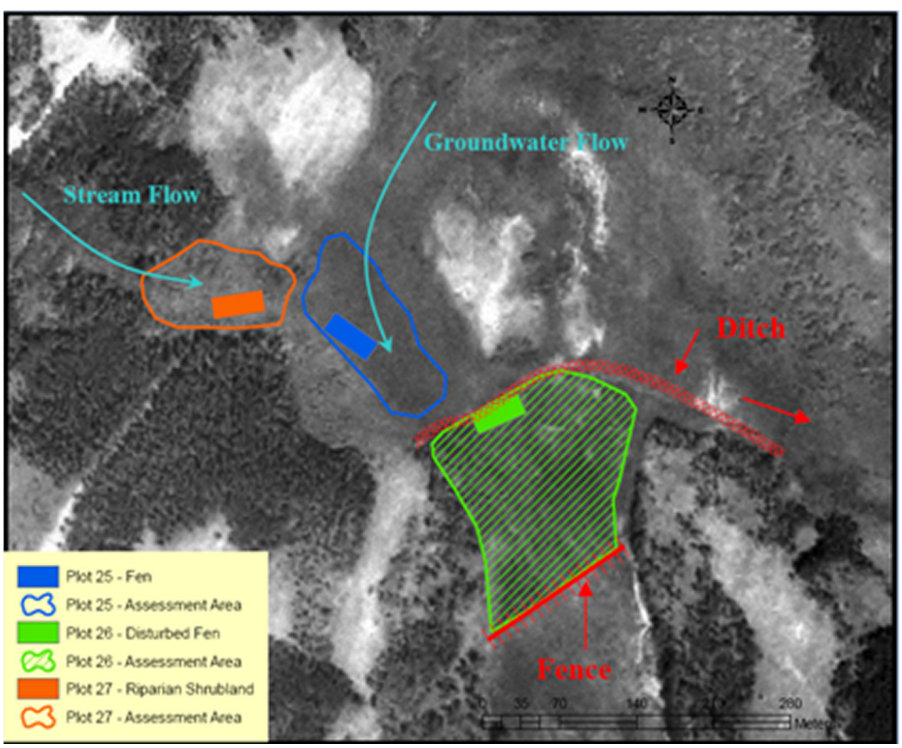


FIGURE 7
Examples of delineated Ecological Assessment Areas (EAAs). Although contiguous with each other, the fen and the riparian shrubland were delineated as distinct EAAs because they were distinct ecological system types (i.e., fen vs. riparian shrubland). The fen was divided into sub-EAAs due to a human-induced disturbance (e.g., ditch) which significantly altered a large portion of an otherwise contiguous wetland type (e.g., intact vs. disturbed fen) (adapted from Rocchio 2007).

7. Vegetation plots can be subjectively placed within the EAA to maximize abiotic/biotic heterogeneity within the plot. Capturing heterogeneity within the plot ensures adequate representation of local, micro-variations produced by such things as hummocks, water tracks, side-channels, pools, wetland edge, micro-topography, etc., in the floristic data. Plots can also be placed objectively, if enough plots are laid.

The following guidelines can be used to determine plot locations within the EAA (adapted from Mack 2004, Rocchio 2007).

- The plot can be located in a representative area of the EAA which incorporated as much micro-topographic variation as possible; or a series of unbiased plots can be located in the EAA or sub-EAA.
- If a small patch of another wetland type is present in the EAA (but not large enough to be delineated as a separate ecological system type), a plot can be placed so that at least a portion of the patch is in the plot.
- Uplands should be excluded from plots; however, mesic micro-topographic features such as hummocks, if present, can be included in the plots.
- Localized, small areas of human-induced disturbance can be included in the plot according to their relative representation of the EAA. Large areas of human-induced disturbance should be delineated as a separate sub-EAA.

References

Andreasen, J.K., R.V. O'Neill, R. Noss, and N. C. Slosser. 2001. Considerations for the development of a terrestrial index of ecological integrity. Ecological Indicators 1: 21–35.

Barbour, M.T., J. Gerritsen, G.E. Griffith, R. Frydenborg, E. McCarron, J.S. White, and M.L. Bastian. 1996. A framework for biological criteria for Florida streams using benthic macroinvertebrates. Journal of North American Benthological Society 15(2): 185-211.

Bedford, B. L. 1996. The need to define hydrologic equivalence at the landscape scale for freshwater wetland mitigation. Ecological Applications 6:57–68.

Blocksom, K. A., J. P. Kurtenbach, D. J. Klemm, F. A. Fulk, and S. M. Cormier. 2002. Development and Evaluation of the Lake Macroinvertebrate Integrity Index (LMII) for New Jersey Lakes and Reservoirs. Environmental Monitoring and Assessment 77:311-333.

Brooks, R.P., D.H. Wardrop, and J.A. Bishop. 2004. Assessing wetland condition on a watershed basis in the Mid-Atlantic region using synoptic land-cover maps. Environmental Monitoring and Assessment 94:9-22.

Brinson, M. M. 1993. A Hydrogeomorphic Approach to Wetland Functional Assessment. Technical Report WRP-DE-4. Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, MS.

Brown, N., L. Master, D. Faber-Langendoen, P. Comer, K. Maybury, M. Robles, J. Nichols and T. B. Wigley. 2004. Managing elements of biodiversity in sustainable forestry programs: Status and utility of NatureServe's information resources to forest managers. Technical Bulletin No. 885. Research Triangle Park, N.C.: National Council for Air and Stream Improvement, Inc.

Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2006. California Rapid Assessment Method (CRAM) for Wetlands and Riparian Areas. Version 4.2.3. 136 pp.

Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2007. California Rapid Assessment Method (CRAM) for Wetlands and Riparian Areas. Version 4.5.2. Riverine Field Book.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems. NatureServe, Arlington, VA.

Comer, P., and K. Schulz. 2007. Standardized Ecological Classification for Meso-Scale Mapping in Southwest United States. Rangeland Ecology and Management 60 (3) 324-335.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of the wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington, DC.

Dahl, T. E. 1990. Wetland losses in the United States, 1780s to 1980's. US Department of the Interior, Fish and Wildlife Service, Washington, DC.

Dahl, T.E. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. U.S. Department of the Interior; Fish and Wildlife Service, Washington, DC, 112 pp.

DeKeyser, E.S., D.R. Kirby, and M.J. Ell. 2003. An index of plant community integrity: development of the methodology for assessing prairie wetland plant communities. Ecological Metrics 3: 119-133.

De Leo, G. A., and S. Levin. 1997. The multifaceted aspects of ecosystem integrity. Conservation Ecology [online] 1:3: Available from http://www.consecol.org/vol1/iss1/art3.

Environmental Law Institute (ELI). 2004. Measuring Mitigation: A Review of the Science for Compensatory Mitigation Performance Standards. Environmental Law Institute, Washington, DC. 271 pp.

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 to US Environmental Protection Agency - Office of Wetlands, Oceans and Watersheds, NatureServe, Arlington, VA.

Faber-Langendoen, D, J. Rocchio, P. Comer, G. Kudray, L. Vance, E. Byers, M. Schafale, C. Nordman, E. Muldavin, G. Kittel, L. Sneddon, M. Pyne and S. Menard. 2008. Overview of Natural Heritage Methodology for Ecological Element Occurrence Ranking based on Ecological Integrity Assessment Methods [Draft for Network Review]. NatureServe, Arlington, VA.

Federal Geographic Data Committee. 1997. Vegetation Classification Standard, FGDC-STD-005. Washington, DC.

Federal Geographic Data Committee. 2008. Vegetation Classification Standard, version 2 FGDC-STD-005, v2. Washington, DC (in press).

Fennessy, M.S., A.D. Jacobs, and M.E. Kentula. 2007. An evaluation of rapid methods for assessing the ecological condition of wetlands. Wetland 27:543-560.

Grossman, D.H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: Terrestrial vegetation of the United States.

Volume I: The vegetation classification standard. The Nature Conservancy, Arlington, VA.

Harwell, M.A., V. Myers, T. Young, A. Bartuska, N. Gassman, J. H.Gentile, C. C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean, R. Smola, P. Templet, and S. Tosini. 1999. A framework for an ecosystem integrity report card. BioScience 49: 543-556.

Hauer, F.R., B.J. Cook, M.C. Gilbert, E.J. Clairain Jr., and R.D. Smith. 2002. A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains. U.S.Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS. ERDC/EL TR-02-21.

Hruby, T. 2001. Environmental auditing: testing the basic assumption of the hydrogeomorphic approach to assessing wetland functions. Environmental Management Vol. 27, No. 5, pp. 749–761.

Jennings, M.D., D. Faber-Langendoen, R.K. Peet, O.L. Loucks, M.G.Barbour, and D. Roberts. 2008. Guidelines for characterizing associations and alliances of the U.S. National Vegetation Classification. Ecological Monographs (accepted).

Johnson, J. B. 2005. Hydrogeomorphic Wetland Profiling: An Approach to Landscape and Cumulative Impacts Analysis. EPA/620/R-05/001. U.S. Environmental Protection Agency, Washington, DC.

Karr, J.R. and E.W. Chu. 1999. Restoring life in running waters: better biological monitoring. Washington, DC. Island Press, 206 pp.

Klimas, Charles V., Elizabeth O. Murray, Jody Pagan, Henry Langston, Thomas Foti. 2004. A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley (ERDC/EL TR-04-16) U.S. Army Engineer Research and Development Center. Vicksburg, MS.

Klimas, Charles V., Elizabeth O. Murray, Henry Langston, Theo Witsell, Thomas Foti, Rob Holbrook. 2006. A Regional Guidebook for Conducting Functional Assessments of Wetland and Riparian Forests in the Ouachita Mountains and Crowley's Ridge Regions of Arkansas. ERDC/EL TR-06-14 U.S. Army Engineer Research and Development Center. Vicksburg, MS.

Lindenmayer, D.B., and J.F. Franklin. 2002. Conserving forest biodiversity: A comprehensive multiscaled approach. Island Press, Washington, DC. 351 pp.

Mack, J.J., 2001. Ohio rapid assessment method for wetlands v. 5.0, user's Manual and scoring forms. Ohio EPA Technical Report WET/2001-1. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, OH.

Mack, J. J. 2004. Integrated wetland assessment program, part 4: Vegetation Index of Biotic Integrity (VIBI) and Tiered Aquatic Life Uses (TALUs) for Ohio wetlands. Ohio EPA Technical Report WET/2004-4, Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, OH.

Mack, J. J., M. S. Fennessy, M.Micacchion and D. Porej. 2004. Standardized monitoring protocols, data analysis and reporting requirements for mitigation wetlands in Ohio, v. 1.0. Ohio EPA Technical Report WET/2004-6. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, OH.

Mack, J.J. 2006. Landscape as a predictor of wetland condition: an evaluation of the Landscape Development Index (LDI) with a large reference wetland dataset from Ohio. Environmental Monitoring and Assessment 120: 221–241.

Miller, S. J. and D. H. Wardrop. 2006. Adapting the Floristic Quality Assessment Index to Reflect Anthropogenic Disturbance in Central Pennsylvania Wetlands. Ecological Indicators 6:313–26.

Miller, S.J., D.H. Wardrop, W.M. Mahaney, R. P. Brooks. 2006. A plant-based index of biological integrity (IBI) for headwater wetlands in central Pennsylvania. Ecological Indicators 6:290–312.

Mita, D., E. DeKeyser, D. Kirby, and G. Easson. 2007. Developing a wetland condition prediction model using landscape structure variability. Wetlands 27:1124-1133.

Mitsch, W.J. and J. G. Gosselink. 2000. Wetlands, 3rd edition. J.Wiley & Sons, Inc. 920 pp.

National Research Council (NRC). 1995. Wetlands: Characteristics and Boundaries. National Academy Press, Washington, DC.

National Research Council (NRC). 2001. Compensating for Wetland Losses under the Clean Water Act. Washington, DC, National Academy of Sciences: 322.

NatureServe. 2002. Element Occurrence Data Standard. On-line at http://whiteoak.natureserve.org/eodraft/index.htm.

NatureServe. 2008. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA.

Neckles, H.A., A. T. Gilbert, G. R. Guntenspergen, N. P. Danz, T. Hollenhorst, A. Little, J. Olker. 2007 (in prep). Protocol for Monitoring Freshwater Wetlands in National Parks of the Northeast Temperate Network. Prepared for the National Park Service. U.S. Department of the Interior. U.S. Geological Survey, Reston, VA.

Noon, B. R. 2002. Conceptual issues in monitoring ecological systems. Pages 27-71 in D. E. Busch and J. C. Trexler, editors. Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington, DC.

Oakley, K.L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin 31(4):1000–1003

Parrish, J.D., D. P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. BioScience 53: 851-860.

Pyle, C. and M.M. Brown. 1998. A rapid system of decay classification for hardwood logs of the eastern deciduous forest floor. Journal of the Torrey Botanical Society 125:237-245.

Rocchio, J. 2007. Assessing Ecological Condition of Headwater Wetlands in the Southern Rocky Mountain Ecoregion Using a Vegetation Index of Biotic Integrity. Unpublished report prepared for Colorado Department of Natural Resources, and U.S. Environmental Protection Agency, Region VIII. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. Online: http://www.cnhp.colostate.edu/reports.html.

Saunders, D. L., J. J. Meeuwig, and A. C. J. Vincent. 2002. Freshwater protected areas: Strategies for conservation. Conservation Biology 16:30-41.

Science Applications International Corporation (SAIC). 2000. Summit County wetland functional assessment. Report prepared for the Summit County Community Development Division.

Smith, R. D., A. Amman, C. Bartoldus, and M. M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. Technical report TR WRP-DE-10, and operational draft. US Army Engineers Waterways Experiment Station, Vicksburg, MS.

Stein, B.A., L.S. Kutner, and J.S. Adams (eds.). 2000. Precious Heritage: The status of biodiversity in the United States. The Nature Conservancy and Association for Biodiversity Information [now NatureServe]. Oxford University Press.

Stoddard, J.L., D.P. Larsen, C.P. Hawkins, R.K. Johnson, and R.H. Norris. 2006. Setting expectation for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4): 1267-1276.

Sutula, M.A., E.D. Stein, J.N. Collins, A.E. Fetscher, and R. Clark. 2006. A practical guide for development of a wetland assessment method: the California experience. J. Amer. Water Resources Associationpp.157-175

Swetnam, T.W., C.D. Allen, and J.L. Betancourt. 1999. Applied historical ecology: using the past to manage for the future. Ecological Applications 9:1189-1206.

Tierney, GL, D Faber-Langendoen, BR Mitchell et al. 2008. Monitoring and evaluating the ecological integrity of forest ecosystems. Frontiers in Ecology and the Environment (accepted).

Tiner, R.W. 2004. Remotely-sensed indicators for monitoring the general condition. Ecological Indicators 4 (2004) 227–243.

Tuffly, M. and P. Comer. 2005. Calculating landscape integrity: A working model. Internal report for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder, CO.

U.S. EPA. 2002a. Methods for evaluating wetland condition: developing metrics and indexes of biological integrity. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-016.

U.S. EPA. 2002b. Methods for evaluating wetland condition: wetlands classification. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-017.

U.S. EPA. 2006. Application of Elements of a State Water Monitoring and Assessment Program For Wetlands. Wetlands Division, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, DC, April 2006.

U.S. EPA. 2008. Report on the Environment. U.S. Environmental Protection Agency, Washington, DC.

Wilkinson, J. and J. Thompson. 2006. A 2005 Status Report on Compensatory Mitigation in the United States. Environmental Law Institute. Washington, DC. 104 pp.

Young, T.F. and S. Sanzone (editors). 2002. A framework for assessing and reporting on ecological condition. Prepared by the Ecological Reporting Panel, Ecological Processes and Effects Committee. EPA Science Advisory Board. Washington, DC. 142 pp.

Appendices are provided in a separate document.

NatureServe

A Network Connecting Science With Conservation

www.natureserve.org