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Rating the Condition of Reference Wetlands Across States: NatureServe's Ecological Integrity Assessment Method

Rating the condition of reference wetland sites is an important step in the creation of a national Reference Wetlands Registry. The ecological integrity assessment method uses conceptual ecological models to develop a consistent and cost-effective way to classify wetlands. Examples of how it works are illustrated using outputs from several states.

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Reference sites provide an important way for scientists and resource managers to understand how ecosystems function, so that we can better conserve, restore, and benefit from the ecosystem services they provide. As described by Brooks et al. (2016), reference sites often represent areas that are intact or with minimal human disturbance. For example, reference standards in hydrogeomorphic (HGM) parlance (Smith et al. 1995) or exemplary ecosystem occurrences in core Heritage methodology terms (Stein et al. 2000). Reference sites can also represent a range of ecological conditions across a landscape, whether for rare or common types.

How do we select reference sites? That is, by what criteria do we know whether they are exemplary or not? Typically, the initial approach is to rely on a combination of factors, including naturalness, ecological integrity, and lack of evidence of human disturbances. Naturalness and integrity are often judged by historical fidelity (connectivity in time), a full complement of native species, characteristic species dominance and productivity, presence of typical ecological processes such as fire, flooding, and windstorms, and minimal evidence of anthropogenic stressors (Woodley 2010). These factors can be summarized in narrative form (Table 1). But at some point, these criteria need to be tested and validated, so that chosen reference sites are reliable.

Here, we describe our development of an indicator-based wetland assessment method that we use to reliably identify reference sites, both reference standards and the full range of reference conditions.

Background

Ecological integrity assessment (EIA) is defined as "an assessment of the structure, composition, function, and connectivity of an ecosystem as compared to reference ecosystems operating within the bounds of natural or historical disturbance regimes" (Faber-Langendoen et al. 2012). To have integrity, an ecosystem should be relatively unimpaired across a range of characteristics and spatial and temporal scales (Andreasen et al. 2001).

NatureServe and its network partners from state Natural Heritage Programs, in collaboration with a variety of agency partners, have developed methods to assess ecosystem condition, structured around the concept of ecological integrity (Faber-Langendoen et al. 2012). Our EIA method follows a multi-metric approach similar to the Index of Biotic Integrity (Karr & Chu 1999) and Tiered Aquatic Life Use (Davies & Jackson 2006) frameworks for aquatic systems, and a variety of state-based wetland rapid assessment methods (Fennessy et al. 2007; Wardrop et al. 2013). We developed the EIA method for various data sources practical at the state level, but repeatable across ecosystems, states, and wherever applied nationally (Faber-Langendoen et al. 2012).

Ecological Integrity Assessment Framework

Conceptual Models

Conceptual models provide a critical step in understanding how ecosystems function. They help us identify the major ecological factors that characterize the ecological drivers and dynamics of the ecosystem, and which we must address when making management decisions to maintain

Table 1. General narrative definitions of ecological integrity ratings. Adapted from Faber-Langendoen et al. (2012).

Rating	Description
A (intact, excellent)	Occurrence exhibits species composition, vegetation structure, and ecological dynamics that reflect its historical range of variability; resides in an essentially unfragmented landscape; and is believed, across the range of a type, to be functioning within the bounds of natural disturbance regimes.
B (minimally disturbed, good)	Occurrence is not among the highest quality examples, but nevertheless exhibits species composition, vegetation structure, and ecological dynamics that are near their historical range of variability; resides in a minimally fragmented landscape; and functions within minimally altered natural disturbance regimes.
C (moderately disturbed, fair)	Occurrence has moderately altered characteristics, such as exhibiting species composition, vegetation structure, and ecological dynamics that are fairly outside their historical range of variability; resides in a moderately fragmented landscape; and functions with moderately altered natural disturbance regimes.
D (severely disturbed, poor)	Occurrence has severely altered characteristics (but still meets minimum criteria for the type), such as exhibiting species composition, vegetation structure, and ecological dynamics that are well beyond their historical range of variability; residing in a highly fragmented landscape; and functions with severely altered natural disturbance regimes. There may be little long-term conservation value without substantial restoration, and such restoration may be difficult or uncertain.

ecological integrity. For rapid assessments, we include three primary factors and their associated major ecological factors: landscape context (landscape, buffer), condition (vegetation, hydrology, and soil), and size (Figure 1). These factors capture the structure, composition, processes, and connectivity of most terrestrial systems, and are relatively straightforward to assess. Other major ecological factors, such as animals (e.g., birds and fish), soil and water chemistry, or particular ecological processes (e.g., fire, flooding, or productivity), can also be assessed where resources, time, and field sampling design permit, or where more intensive indicators are desired. The model is fairly intuitive, but a key component is that the model includes both the "inner workings" (condition) and the "outer workings" (landscape context) of an ecosystem (Leroux et al. 2007), with size potentially playing a role in both.

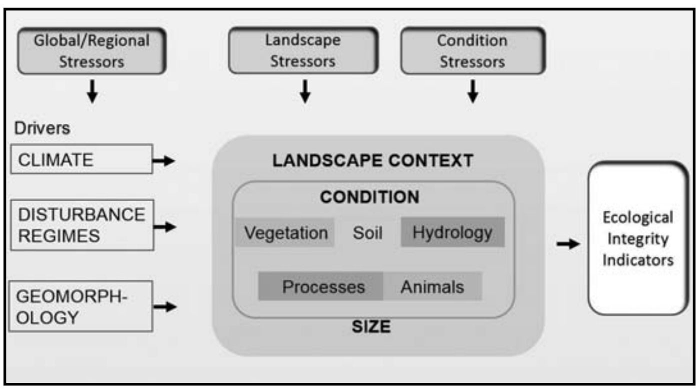

Figure 1: Conceptual ecological model for assessing ecological integrity. Size interacts with both landscape context and on-site condition. The major ecological factors of ecological integrity are shown for wetlands and uplands. The model can be expanded to include additional measures of ecological integrity, such as animals (birds, mammals, amphibians, macroinvertebrates, etc.) and ecological processes or functions (water quality, productivity, etc.).

The conceptual model guides our selection of specific indicators or metrics that can be rated in the field and office. These metrics are integrated into a multi-metric index or rating of "excellent" to "poor" for each major ecological factor and overall ecological integrity. This follows the same logic of indices of biotic integrity that have been developed for lakes and streams (e.g., Karr & Chu 1999).

Three-Tiered Approach to Metrics

Ecological integrity can be assessed at different levels, which can be applied on their own, or integrated into a landscape or watershed assessment (see EPA 2006; Wardrop et al. 2013):

- **Level 1:** Landscape Assessment relies primarily on remote sensing and indicators of landscape integrity. We use a number of Level 1 approaches, including a Landscape Condition Model (Comer & Faber-Langendoen 2013).
- **Level 2:** Rapid Field Assessment involves relatively simple semi-quantitative or quantitative wetland condition indicators that are readily observed in the field, supplemented by a stressor checklist (see *Ecological Integrity and Stressors* below).
- **Level 3:** Intensive Field Assessment requires detailed quantitative field measurements, and may include intensive versions of some of the rapid metrics. For example, a "Native Plant Species Cover" indicator can be measured rapidly by walking through an assessment area and visually estimating cover of native spe-

cies, or it can be measured intensively by estimating cover in one or more vegetation plots. Level 3 assessment data can also be used to calibrate Level 2 assessments (Stein et al. 2009).

Fine-Tuning the Model for Specific Ecosystem Types

Ecological classifications help wetland managers better understand natural variability within and among types, and thus can play an important role in distinguishing sites with good integrity and poor integrity. For example, the indicators of the hydrology of tidal salt marshes will be distinct from that of bogs or floodplain forests. The approach used in California by Collins et al. (2006) was particularly instructive in demonstrating how metrics could be adapted for different wetland types. For EIA purposes, we employ classification categories to the degree that they are needed for reliable rapid assessment of ecological integrity. Metric variants typically reflect either broad formation types of the U.S. National Vegetation Classification (USNVC) (e.g., marsh, floodplain forest, bog, salt marsh) or some combination of HGM classes (e.g., riverine vs. non-riverine, tidal vs. non-tidal).

Ecological Integrity and Stressors

Using our conceptual ecological model (Figure 1), we evaluate the role of stressors in altering ecological integrity. Stressor evaluations for wetland rapid assessments vary from being a complementary exercise to the wetland condition assessment, to being mixed in with the condition assessment, to essentially being a substitute for a condition assessment. We use the complementary approach because we are interested in a direct measure of ecological integrity. We provide a stressor checklist to systematically score the scope and severity of each stressor present at a site. The stressors are then integrated into a stressor index that can be used to rate the overall impact of stressors to the wetland (from Absent to Very High). The stressor checklist is not necessarily required; it is used as supporting evidence for assessing condition, and to guide management activities to reduce harmful stressors.

Ecological Integrity and Reference Sites

Our model is based on characteristics of ecosystems known from historical conditions and as found on existing high-quality reference sites, spanning the variety of ecosystem types. We refer to the full range of reference sites, sometimes called the "reference gradient"; that is the gradient of ecosystem condition across a region varying from least disturbed (reference standard) to highly impaired. When testing our model, we identify sites that span the full range of stressor levels (Faber-Langendoen et al. 2016).

Landscape Context	**Rating**
Landscape	
Contiguous Natural Cover Metric	A
Land Use Index Metric	C
Buffer	
Perimeter with Natural Buffer Metric	A
Width of Natural Buffer Metric	A
Condition of Natural Buffer Metric	C
Condition	
Vegetation	
Native Plant Species Cover Metric	C-
Invasive Nonnative Plant Species Cover Metric	D
Native Plant Species Composition Metric	D
Vegetation Structure Metric	C
Woody Regeneration Metric	D
Coarse Woody Debris Metric	A
Hydrology	
Water Source Metric	C
Hydroperiod Metric	D
Hydrologic Connectivity Metric	C
Soil	
Soil Condition Metric	A

Figure 2: Example of scorecard, showing metric ratings for a floodplain forest site along the lower Arkansas River in Bent Co, Colorado. The individual metric ratings can be aggregated into an overall EIA rating.

Indicator/Metric Calibration and Validation

Over the past 10 years, we have tested our methodology to identify and evaluate metrics (specific indicators) that are informative of the ecological integrity of wetlands (e.g., Lemly & Rocchio 2009; Faber-Langendoen et al. 2012; Nichols & Faber-Langendoen 2012; Comer & Faber-Langendoen 2013; Nichols 2013; Lemly & Gilligan 2015; NJDEP 2010-2016 in prep.). These tests help us select the current set of metrics now in use (Figure 2). We recently completed a rigorous evaluation of these metrics from 220 sites across six states (CO, IN, MI, NH, NJ, WA), testing for both the discriminatory power of the metrics and major ecological factors and the levels of redundancy (Faber-Langendoen et al. 2016). All metrics and factors, except for soils, had good to very good ability to discriminate various levels of stressors, and only two vegetation metrics had strong levels of redundancy. Our analyses support the use of a suite of 12-15 rapid metrics to assess the ecological integrity of wetlands.

EcoObs—Reference Sites Database

We use the Ecological Observation database (EcoObs) to manage basic site information, rapid and intensive data on vegetation, soils, and hydrology, and information on indicators and metrics, including floristic quality indices. EcoObs is currently managed by NatureServe staff, is in use in a number of states, and is linked to NatureServe's Biotics database.

The Scorecard

After metrics are rated in the field and office, and data entered into EcoObs, their ratings can be incorporated into a scorecard that displays the ratings for each metric (Figure 2). This scorecard brings information together in a transparent way, allowing users to understand the status of various components of ecological integrity. Metric ratings are aggregated into major ecological factors ratings, which in turn generate ratings for Landscape Context and (on-site) Condition, and ultimately, an Ecological Integrity rating. This information can be further summarized into "dashboard" or other types of scorecards.

EIA and the Reference Wetlands Registry

State and Regional Wetland Reference Gradients

Our EIA method provides a reliable and cost-effective way to identify wetland reference sites for a national Reference Wetlands Registry (RWR). The method is now being implemented in nine states (AR, CO, IN, ME, MI, NH, NJ, PA, and WA), with other states conducting additional testing or review (e.g., MO, MT, NM, and WI). By applying the method in conjunction with wetland classifications, such as the USNVC and HGM, we can begin to build up a series of wetland reference gradients that systematically document the range of conditions for particular wetland types within and across states (Figure 3). These reference gradients can become an important source of information for conservation, restoration, and mitigation. For example, the Michigan EIA wetland reference dataset is now being used by the U.S. Fish and Wildlife Service's Natural Resources Damage Assessment program as part of a pilot project to assess restoration and monitoring goals for impaired wetlands in the Saginaw Bay area.

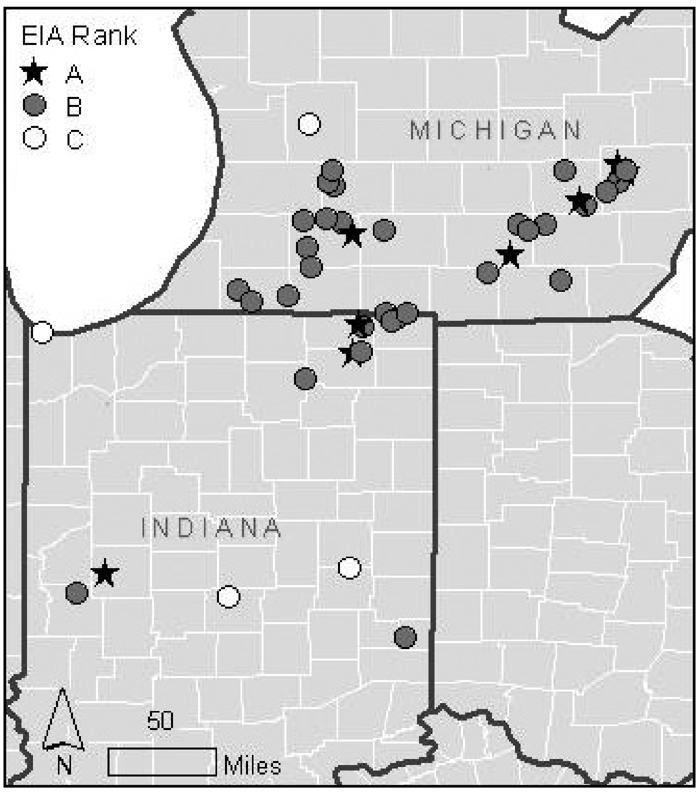

Figure 3: Reference wetland sites for Midwest Prairie Alkaline Fen (NVC G183 on usnvc.org). Forty-four sites were visited (A=9, B=31, C= 4). The overall EIA rating (Table 1) is based on metrics shown in Figure 2. Sites are "element occurrences" in Natural Heritage databases in Indiana and Michigan (adapted from Faber-Langendoen et al. 2012).

Integration Into a National Reference Wetlands Registry

Our EIA method is one of a number of methods to establish wetland condition (Brooks et al. 2016). When integrated into a national RWR, it will be helpful to users if the database can establish the degree of equivalencies among the methods (e.g., assessing whether a wetland that is rated A (excellent or intact) by NatureServe's EIA method also has a similar rating by other methods). Comparative analysis of the various datasets in the wetlands registry would be desirable.

It will take time to build up a robust network of sites with good characterizations and well-validated indicators. Given that wetlands continue to be lost or face a wide range of stressors, it will be important to identify candidate reference wetlands using remote-sensing (Level 1) methods with limited ground-truthing, so that these sites can be flagged as potentially important for an RWR. Then, as opportunities arise, further assessments can be conducted. In this way, the RWR can both encourage identification of new reference wetlands and provide the needed perspective on assessing, restoring, and conserving existing wetlands. ■

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Reference Wetlands as Benchmarks for Assessing Climate Change Effects

Reference wetland data provide a starting point from which to measure wetland condition as well as changes to these aquatic ecosystems over time. Wetland characteristics are expected to change as a result of a changing climate. There is uncertainty regarding what those changes may be (e.g., wetter winters, drier summers in the East; drought in the Southwest) and how individual wetland types will respond. That uncertainty, coupled with the variety of wetland types, variable hydrology, and ecoregional differences, make it difficult to generalize about wetlands in a changing climate. EPA and state partners, however, have been working for over 20 years to build the science of wetland monitoring and assessment in order to forge a better scientific understanding of the quality or condition of wetland resources across the nation. We need widespread geographic distribution of reference wetlands, such as the National Wetlands Condition Assessment, so that regional differences in responses to climate change can be documented and tracked over time. Reference wetlands can provide benchmarks as starting points in time for trend analyses (e.g., long-term successional studies, impact analyses, and climate change patterns). Temporal data gains value over time and provides critically important signals to shifting patterns.

Wetland research has been focused on advancing the science and building state wetland monitoring programs to be on par with other aquatic resource monitoring programs (e.g., streams and lakes). Integral to that work has been the concept of using reference standard sites to set benchmark expectations for condition. This is a well-known and scientifically valid approach to condition assessment not only for wetlands, but for other natural resources including streams. As a result, many state wetland monitoring programs have developed statewide wetland reference networks. Building on these existing reference networks and developing a standard suite of climate indicators for wetlands can provide a baseline for the current status of wetlands to measure against future changes as a result of climate change. The challenge will be to identify that set of metrics that best indicate climate change effects. ■

—Regina Poeske and Robert P. Brooks