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AN EVALUATION OF RAPID METHODS FOR ASSESSING THE ECOLOGICAL CONDITION OF WETLANDS

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Abstract: We analyzed 40 existing wetland rapid assessment methods that were developed for a variety of purposes, including informing regulatory decisions and local land use planning, and reviewed them for their potential to assess ecological integrity or condition. Four evaluation criteria were used. We determined if the method 1) can be used to measure condition, 2) is truly rapid, 3) includes a site visit, and 4) can be verified. This resulted in six methods being selected for evaluation relative to a conceptual model describing the core elements of a wetland assessment method, including universal indicators of soil, hydrology, and biotic communities, as well as regional indicators. An additional nine methods were kept for ideas on indicators, scoring, or regionalization. From this review, we identified five general areas that need to be addressed when adapting existing methods or developing new methods to assess condition: 1) definition of the assessment area, 2) treatment of wetland type, 3) approaches to scoring, 4) consideration of highly valued wetland types or features, and 5) procedures for validation with comprehensive ecological data. With scoring in particular, we present the advantages of a method that produces a single integrative score. Development of a rapid assessment method can assist those interested in incorporating condition assessment into their programs because they require less time in the field and less taxonomic expertise than more quantitative methods, which can lead to significant cost savings and increased sample sizes.

Key Words: ecosystem integrity, ecosystem stressors, indicators, wetland bioassessment

INTRODUCTION

Wetland ecosystems are under increasing pressure from human activities the world over (van Dam et al. 1998, Finlayson and Rea 1999, Brinson and Malvarez 2002, Junk 2002, Kentula et al. 2004). This has generated considerable interest in methods designed to assess the ecological condition or integrity of wetlands as a means to document the extent of degradation, to provide early warning of ecosystem stress or degradation, to determine the effectiveness of management actions, and to track wetland condition for regulatory programs charged with wetland management, restoration, and mitigation. Further reflecting the need for effective wetland monitoring methodologies, the National Water Quality Inventory Report to the U.S. Congress (U.S. EPA 2002b) states that only 4% of U.S. wetlands have been monitored. This leaves insufficient data to evaluate the health of wetlands or to quantify the extent to which they are degraded.

The monitoring and assessment of wetland resources has been approached both through quantitative biological methods, such as indices of biotic integrity (Karr and Chu 1999) and hydrogeomorphic functional assessments (Brinson 1993, Smith et al. 1995), as well as through semi-quantitative, rapid assessment methods (e.g., Mack 2001). Rapid methods require less time in the field and less taxonomic expertise than more quantitative methods, which can lead to significant cost savings and increased sample sizes. Therefore, rapid assessment methods are increasingly seen as central to implementation of wetland monitoring and assessment programs that, in turn, are recognized as essential to effective management of the resource (U.S. EPA 2003, Carletti et al. 2004).

The principle goals of wetland monitoring and assessment programs in the U.S. are to report on the ambient condition of wetland resources, evaluate restoration success, and report on the success of management activities. The "three-tier framework" is a strategy for designing effective monitoring programs. This approach breaks assessment procedures into a hierarchy of three levels that vary in the degree of effort and scale, ranging from broad, landscape assessments using readily available data (known as Level 1 methods), to rapid field methods (Level 2), to intensive biological and physicochemical measures (Level 3) (Brooks et al. 2004, Fennessy et al. 2004, Wardrop et al. 2007a, Whigham et al. 2007). Each level can be used to validate and inform the others; for example, intensive assessments (Level 3) are often used to calibrate or validate rapid methods (Level 2) (e.g., Mack et al. 2000, Wardrop et al. 2007a).

We set out to identify rapid methods most suitable for assessing the ecological condition of wetlands (defined following) as a first step in determining how best to employ Level 2 assessments within the three-tier framework of a monitoring and assessment program. The assessment methods included in this analysis (Table 1) were developed for a variety of purposes, including use in regulatory decision making, local land use planning, and the evaluation of ambient ecosystem condition. This analysis will also help address calls to retire out-of-date methods and to strengthen and cross-calibrate those that are useful (Kusler and Niering 1998, Karr 1999, Innis et al. 2000). Our review is in no way meant to be a critique of each method for its intended use; rather, our goal was to evaluate each relative to its ability to ascertain ecological integrity or ambient condition. Despite the different program needs that sparked their development, many of these methods share common features. Throughout, we have highlighted the common ground, particularly the indicators or metrics that are used in multiple methods and in different parts of the country. These metrics are most likely to be transferable among states or regions and show promise for use outside of the U.S. (Carletti et al. 2004).

This review led us to recognize five common operational issues that are related to our criteria for evaluation (shown following). These must be addressed when developing a rapid assessment method to evaluate wetland condition. We discuss some of the advantages and disadvantages of how various methods address each issue. These issues are 1) how to define the assessment area when in the field; 2) how to incorporate different wetland types into the application of the method; 3) how scoring is handled; 4) whether or not certain wetland types or functions should be recognized for their value or the ecosystem services they provide, regardless of condition; and 5) the need for verification with comprehensive ecological data.

EVALUATION OF RAPID METHODS

Study Approach

We initially screened 40 methods, focusing on those reviewed by Bartoldus (1999) and others that were published or otherwise available through 2003. An initial assessment of each method was conducted; if it was obvious that the method was not at Level 2 of the three-tier system, it was eliminated from further consideration. For example, the original list included many Level 3 methods such as HGM functional assessments (*per* the approach described by Brinson 1993, Smith et al. 1995) and indices of biotic integrity (IBIs; see Karr and Chu 1999). Several landscape assessments (Level 1), such as the Synoptic Approach for Wetlands Cumulative Effects Assessment, which require detailed analysis using geographic information systems and no on-the-ground site assessment (Leibowitz et al. 1992, Abbruzzese and Leibowitz 1997), were also eliminated. After removal of these methods, 16 remained (Table 1).

We analyzed these methods in two steps. First, we established four criteria with which to evaluate each. The criteria were designed to identify methods that 1) measure ecological condition, 2) are truly rapid, 3) require a site visit, and 4) can be validated. Only the methods that met all four criteria were retained for a second, more detailed review. In the second step, the remaining methods were evaluated relative to a conceptual model describing the components of an ecologically sound wetland assessment method (Figure 1). All 16 methods were scrutinized for ideas on indicators, scoring, and regionalization.

Criteria Used to Evaluate Assessment Methods

In adopting or developing a rapid assessment method for use in ambient wetland monitoring and assessment programs, the following four criteria were deemed essential.

1) The method can be used to measure condition. A principal goal of the U.S. Clean Water Act is to maintain and restore the physical, chemical, and biological integrity of the waters of the United

Table 1. Citations and summary of the 16 rapid assessment methods reviewed including information on the method's suitability for assessing condition, the wetlands types the method was designed for, an estimate of how long a typical wetland assessment might take using the method, and a summary of the pros and cons for using each method to assess condition.

Procedure and Source	Method Assesses…	Wetland Types Assessed	Time to Perform[1]	Pros	Cons
Delaware Method v1.2 (Jacobs 2003)	Condition	Tidal and non-tidal wetlands in Delaware	< 0.5 day	• Can be used on all HGM subclasses • Easy to use	• May not work where stressors are not obvious • Stressor list would require regionalization
Florida Wetland Quality Index (FWQI) (Lodge et al. 1995)	Mitigation site compliance	Mitigation wetlands	Day +	• Combines indicators for an overall score • Weights indicators based on their importance • Easy to use	• Not a rapid assessment • Developed specifically for mitigation sites; may not be applicable for natural wetlands
Florida Wetland Rapid Assessment Procedure (FWRAP) (Miller and Gunsalus 1999)	Condition of mitigation projects with habitat emphasis. Provides a single score that may be interpreted as condition.	Designed for mitigation projects; may have broader applications	< day	• Easy to follow directions • Allows user to adjust scores based on the site conditions	• Narrative descriptions of variables combine many indicators into one score • Heavily weighted to evaluate wildlife habitat
Maryland Department of the Environment Method (MDE method) (Furgro East, Inc. 1995)	Functional capacity for each of eight functions. Includes opportunity metrics.	Non-tidal palustrine vegetated wetlands	Day +	• Comprehensive list of wetland indicators • Flow charts easy to read, providing a well-organized layout for scoring	• Not a rapid assessment • Few stressor indicators included
Massachusetts Coastal Zone Management Method (Hicks and Carlisle 1998)	Condition	Separate versions for freshwater wetlands and salt marshes	0.5 day	• Developed to evaluate macroinvertebrate habitat but metrics have wider applicability • Evaluates both tidal and non-tidal systems • Format is easy to follow • Flexible scoring allows observer to assign scores within a range	• Combines numerous metrics into one indicator • Combines all human stressors into one indicator

Table 1. Continued.

Procedure and Source	Method Assesses…	Wetland Types Assessed	Time to Perform[1]	Pros	Cons
Minnesota Routine Assessment Method (Minnesota Board of Water and Soil Resources 2003)	• Each of 12 functions, restoration potential, sensitivity to development, and storm-water treatment • Includes measures of value and opportunity	Freshwater wetlands	0.5 day	• Comprehensive list of indicators	• Some questions difficult to assess rapidly in the field and may require GIS • A computer program is required to score each function
Montana Wetland Assessment Method (Burglund 1999)	• 12 functions but provides single score that may be interpreted as condition • Score leads to regulatory category describing degree of disturbance and replacement potential	Freshwater wetlands	0.5 day	• Easy to use • Good ideas for rapid field indicators	• Some indicators not rapid and may be difficult to determine in the field • Emphasis is on identifying unique and high value wetlands
New Hampshire Coastal Method (Cook et al. 1993)	• Each of 12 functions	Tidal marshes of New Hampshire	Day +	• Good list of indicators • Ideas for adapting non-tidal methods to tidal systems	• Not a rapid assessment • No overall score produced
New Hampshire Method (Ammann and Stone 1991)	• Each of 14 functional values	Non-tidal wetlands of New Hampshire	Day +	• Good list of indicators	• Not a rapid assessment • No overall score produced
Ohio Rapid Assessment Method (ORAM) (Mack 2001)	• Condition	Freshwater wetlands	$<$ 0.5 day	• Questions are clearly stated • Rapid • Provides an overall rating • Easy to calculate final score	
Oregon Freshwater Wetlands Assessment Method (Roth et al. 1996)	• Each of nine functions • Weighted heavily on measures of value and opportunity	Freshwater wetlands	Day +	• Comprehensive list of value-added indicators	• Not a rapid assessment • Function category descriptions are vague (e.g., provides habitat for some wildlife species)

Table 1. Continued.

Procedure and Source	Method Assesses…	Wetland Types Assessed	Time to Perform[1]	Pros	Cons
Penn State Stressor Checklist (Brooks et al. 2002)	• Condition • Weights all stressors as equal	Freshwater wetlands	> 0.5 day	• Field portion of method is easy to use	• Method required landscape analysis to calculate score • Stressor list would require regionalization
Virginia Institute of Marine Science Method (VIMS) (Bradshaw 1991)	• Each of seven functions • Weighted heavily on measures of opportunity	Freshwater wetlands, primarily streams	Day +		• Not a rapid assessment • Primarily a desktop evaluation • Evaluates opportunity not condition • Complex data needs
Washington State Wetland Rating System (Eastern) (Washington State Department of Ecology, Draft revision)	• Evaluates functions and special characteristics • Weighted heavily on opportunity	Freshwater wetlands in eastern Washington	0.5 day	• Questions clearly stated • Easy to perform • Provides overall score	• Includes some value measurements • Rates wetlands higher based on opportunity
Washington State Wetland Rating System (Western) (Washington State Department of Ecology 1993)	• Condition • Also evaluates sensitivity to disturbance, rarity, and irreplaceability	Freshwater wetlands in western Washington	0.5 day	• Rapid • Easy to use • Includes measures of condition	• Includes some value measurements • Certain types of wetlands score higher because of opportunity • Not all wetlands receive a numerical score
Wisconsin Rapid Assessment Method (Wisconsin Department of Natural Resources 1992)	• Each of seven functions and values • Weighted heavily on measures of value and opportunity	Freshwater wetlands	Day	• Questions clearly stated • Easy to perform	• Scoring functions based on indicators relies solely on best professional judgment • Includes opportunity and value measures

[1] See Methods for explanation.

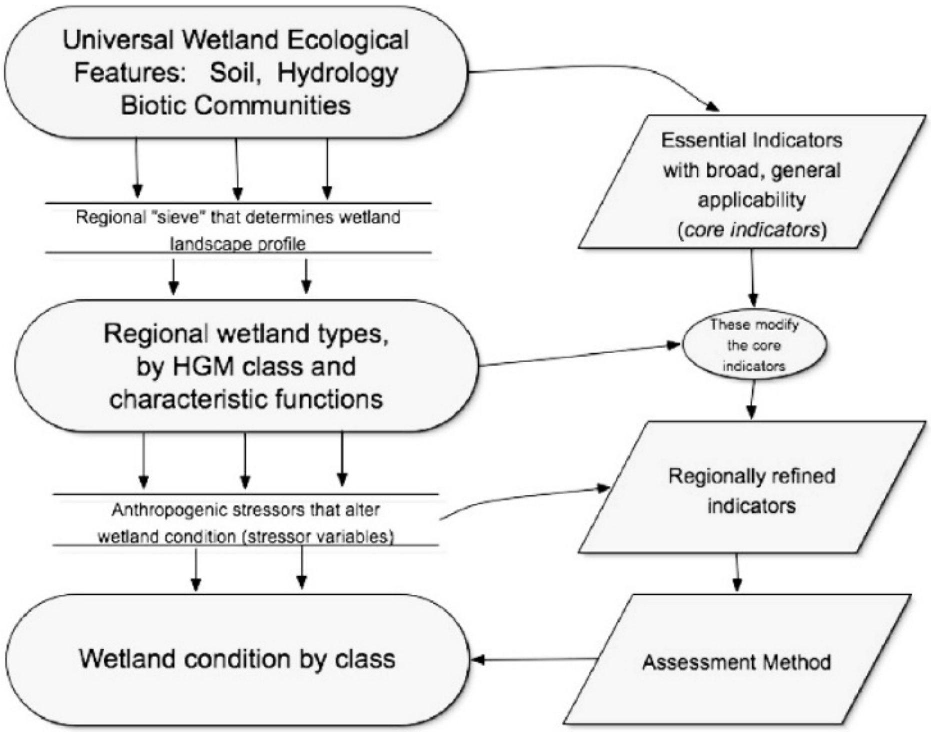

Figure 1. Conceptual model showing the links between the wetlands being evaluated and the core elements of a rapid assessment method. The model is hierarchical with respect to the ecological features that define wetlands (ovals on the left) and the indicators that can be adapted to evaluate the resulting wetland condition (boxes on right).

States. According to 33 U.S.C. §1251(a), integrity can be defined as the ability of a system to support and maintain a "…balanced integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to the natural habitat of the region" (Karr and Dudley 1981, U.S. EPA 2002a). By contrast, ecological condition describes the extent to which a given site departs from full ecological integrity (if at all). Condition can be defined as the ability of a wetland to support and maintain its complexity and capacity for self-organization with respect to species composition, physico-chemical characteristics, and functional processes as compared to wetlands of a similar type without human alterations (*sensu* Karr and Dudley 1981). Ultimately, ecological condition results from the integration of the chemical, physical, and biological processes that maintain the system over time. Methods best suited to measure condition reflect this by providing a quantitative measure describing where a wetland lies on the continuum ranging from full ecological integrity (i.e., the least impacted or reference condition) to highly degraded (poor condition). A single numeric score is the result. This score is not meant to measure absolute value or have intrinsic meaning, but allows comparisons between wetlands to be made relative to reference condition.

Methods that evaluate condition and provide a single integrative score for each site effectively serve many monitoring needs because data on the ambient condition of the wetland resource provide an essential benchmark to determine the effectiveness of management actions. Relative to the requirements of the U.S. Clean Water Act, information derived from monitoring programs can also be used to develop and support aquatic life use designations for the implementation of wetland water quality standards. Because condition can describe the relative ability of a waterbody to support its designated uses, the adoption of a rapid method that assesses condition is a key in the implementation of such standards on a state-wide or national level. Assessing condition also alleviates the difficulty of quantifying multiple functions of wetlands at a single site and avoids the issues associated with combining multiple functions into a single score.

2) The method must be rapid. Consideration was given to the level of effort needed, as well as how much time a method would take to complete. A rapid method must be able to provide an accurate assessment of condition in a relatively short time period. For this reason, we defined "rapid" as taking no more than two people a half day total in the field and requiring no more than another half day of office preparation and data analysis to obtain a result. We estimated the time needed to use the methods through a combination of 1) personal experience with the methods, 2) input from others who had experience with the methods, and 3) best professional judgment based on the type of data required to complete a given method.

3) The method must be an on-site assessment. An accurate evaluation using a rapid method requires a site visit to ensure that the method captures the current condition of the wetland and does not infer condition based, for example, on characteristics of the surrounding landscape or on the potential of a wetland to perform certain functions.

4) The validity of the method can be determined. The validity of a Level 2 method can be determined using data gathered in empirical studies that employ more intensive wetland monitoring activities (i.e., Level 3 assessments). However, producing results that are comparable to those from an intensive method is not in itself sufficient in evaluating a rapid method. Clear and complete documentation of the assumptions behind the rapid method is essential to identify and fix problems, to calibrate the rapid method with the intensive method, and to interpret the results. Because there was little information on the extent of validation with intensive methods, we gauged a methods ability to be validated based on the use of metrics that could be supported by more intensive data, the process for calculating a final score, and the thoroughness of the documentation. The calculation of the final score was evaluated based on whether it was a clear and repeatable process for arriving at a final score. If the final score is assigned based on the best professional judgment of each user, then the validity of the method cannot be determined. We were conservative in making this determination in that we excluded methods only when final scores were arrived at using some form best professional judgment.

Conceptual Model for Rapid Method Evaluation

All methods that met the preceding four criteria were then evaluated relative to a conceptual model (Figure 1). The model illustrates components that are central to many rapid methods and defines categories of indicators that can be used in developing a method. The primary components of the model are the ecological attributes of wetlands (i.e., hydrology, soil, biota) and the regional hydrogeologic factors that determine wetland types (often described by HGM class). In the absence of anthropogenic stressors, these regional wetland types represent the reference condition. The model then accounts for the effects of anthropogenic stressors. Stressors are an important component of an assessment method because they act to degrade ecological condition. Knowledge of the stressors present in and around a wetland is also valuable in determining what measures are needed to improve condition. We evaluated if and how each of the methods addressed these components.

RESULTS OF EVALUATION

Analysis Relative to the Evaluation Criteria

Of the 16 methods evaluated (Table 1), only six met the four criteria we established: the Delaware Method, the Florida Wetland Rapid Assessment Procedure (FWRAP), the Massachusetts Coastal Zone Management Method, the Montana Method, the Ohio Rapid Assessment Method (ORAM), and the Washington State Wetland Rating System for Western Washington (Table 2). Of the 10 methods eliminated, six were dropped because we estimated that they would take a day or more to complete, in large part due to the complexities of the data required. For example, the Oregon Freshwater Wetlands Assessment Method (Oregon method) evaluates nine functions, each of which is assessed and assigned to a category (high, medium, low) of functional performance. Gathering the information needed for the indicators, such as "flashy water level response to storms" or "contribution to base flow," can be quite time-consuming. A lengthy list of indicators also increases the time required to gather information. For example, the Minnesota method provides an evaluation of 12 functions that, in turn, are calculated based on a list of 72 indicators (Table 1).

Most of the methods we eliminated gave no means to aggregate scores to reflect the integrated condition of the site. In addition, several of the eliminated methods had very limited documentation, with no clear means to reach a final score. Another common problem was that complex formulas or models were used to generate a final score, but no information was provided as to the reasoning behind such calculations.

Analysis Relative to a Conceptual Model of Assessment

In the second stage of the analysis, each of the six methods remaining were evaluated relative to the

Table 2. A comparison of the six methods that may be used to assess condition relative to the conceptual model of wetland assessment summarizing how each method addresses the ecological features that define wetland ecosystems.

Method	Hydrology	Soils	Biotic Communities
Delaware Method v1.2	Incorporated into method by evaluation of stressors that affect hydrologic processes	Incorporated into portion of the method evaluating biogeochemical cycling and the stressors that affect soil processes	Incorporated into the method by the evaluation of stressors that affect the biotic communities
Florida Wetland Rapid Assessment Procedure	Considers evidence that hydrologic regime is a adequate to maintain a viable wetland system	Not considered	Considers wildlife utilization in terms of habitat, disturbance, food sources; tree and shrub canopy in terms of likelihood of providing habitat; herbaceous plants in terms of cover, disturbance, native vs. exotic
Massachusetts Coastal Zone Management Rapid Habitat Assessment Method	Evaluates in terms of stressors and degree of alteration, e.g., restriction of inlets and outlets	Ranks by type with rocks and gravel with little organic matter rated the lowest	Considers number of Cowardin vegetation classes (more is better), number and types of food sources, presence of buffer
Montana Wetland Assessment Method	Considers duration of surface water Rates flood attenuation as amount of site subject to periodic flooding Rates surface water storage as area of site subject to periodic flooding or ponding relative to frequency and duration of flooding Rates ground-water discharge/recharge based on presence of indicators (e.g., springs, seeps, inlet but no outlet)	Not considered	Rates structural diversity as number of Cowardin vegetation classes present and relates to general wildlife habitat Considers habitat for federally listed or proposed threatened or endangered species Considers fish/aquatic habitat relative to duration and frequency of flooding, cover (e.g., rocks, logs), and shading Rates food chain support relative to vegetation cover and structural diversity, and hydrologic characteristics
Ohio Rapid Assessment Method	Considers source; maximum water depth, duration of inundation (the more permanent and deeper the water the higher the score); and connectivity to other surface waters and upland	Rates in terms of disturbance	Rates overall habitat development and also degree of alteration (see stressors) Vegetation ranked as to: number of communities present, degree of interspersion Considers microtopography — presence of hummocks, woody debris, standing dead, pools

Table 2. Continued.

Method	Hydrology	Soils	Biotic Communities
Washington State Wetland Rating System, Western Version	Considers amount of inundation and flow	Gives extra points to wetlands with a deep organic layer	Considers plants, mosses, woody vegetation; plant diversity; structural diversity; degree of interspersion; habitat features (nests, snags, open water), connection with a stream; part of a corridor; cover of vegetation types, proximity to priority habitats

conceptual model (Figure 1) showing the relationship between the ecological features that define wetlands (ovals on the left), anthropogenic stressors that degrade sites, and the indicators used to evaluate the resulting wetland condition (boxes on right). The model illustrates how method development involves an understanding of 1) the ecological factors that create and sustain wetlands, 2) how regional hydrogeologic conditions such as geomorphology and the pathways of water flow drive the formation of regional wetland classes with characteristic structure and functions, and 3) how wetland types respond to anthropogenic disturbance (stressors). In other words, effective rapid assessment techniques are based on indicators of wetland condition derived from an understanding of the factors that create, maintain, and degrade wetlands on the landscape.

Wetlands, by definition, are characterized by three parameters: hydrology (e.g., hydroperiod, mean water depth), the presence of hydric soils, and the resulting biotic communities, particularly the presence of hydrophytic vegetation. Hydrology is considered the master variable of wetland ecosystems, driving the development of wetland soils and leading to the development of the biotic communities (Mitsch and Gosselink 2000). We term these the *universal features* of wetlands and were interested to see if and how each method addressed these fundamental ecosystem components (Table 2). Of the three parameters, we found that indicators based on soils are the least well developed and are entirely absent in some methods, such as the Florida and Montana methods. In contrast, all methods place considerable emphasis on hydrology indicators, both from the standpoint of characterizing hydrology (e.g., the duration of surface water in the Montana Method) to identifying hydrologic stressors (e.g., the degree of hydrologic alteration in the Massachusetts method, more detail on stressors follows). Indicators based on the structure of the biotic communities are perhaps the most extensive, with the bulk of these focused on vegetation community types (including the extent of invasive species) as a proxy for overall community diversity. Wildlife and amphibian habitat features are considered directly in five of the methods; only the Delaware Method that is made up solely of stressor indicators does not include wildlife indicators directly.

The conceptual model also recognizes that wetlands vary regionally and that this variability must be accounted for when developing reliable indicators of condition. Regionalization, in this case, is described in terms of the hydrogeologic settings and the hydrogeomorphology that dictate wetland form and function and that influence the selection or calibration of indicators (Table 3). Regionalization can also refer to the incorporation of values placed on specific wetland classes or ecosystem services that influence how a site is rated. Hydrogeologic settings are defined as the position of wetlands relative to surface- and ground-water flows, climate, and the characteristics of the surficial geology that control water movement (Winter 1988, 1992, 2001, Bedford 1996). The specific landscape settings that support development of various wetland types are termed "templates" by Bedford (1999). Templates are the result of physical variables operating at the landscape scale that generate and maintain different wetland types. The diversity of wetland types (kinds, numbers, relative abundance, and spatial distribution) can be summarized in a wetland landscape profile (e.g., Gwin et al. 1999). In this way, regional hydrogeologic and hydrogeomorphic characteristics act as a sieve, selecting for the wetland types and locations (i.e., the profile) that are sustainable in a particular landscape. Several of the methods shown in Table 3 categorize sites as either freshwater or saltwater (Washington and Massachusetts methods), while others employ the HGM classification (Brinson 1993). The Delaware Method includes

Table 3. A comparison of the six methods relative to how each method addresses regional factors including the wetland types specific to the region as well as any consideration given to the ecosystem services provided by and/or special values placed on some wetlands.

Method	Wetland Types	Services and Values
Delaware Method v1.2	• HGM Classes; Regionalizes by changing the thresholds for interpretation of the assessment relative to HGM class	• Not included
Florida Wetland Rapid Assessment Procedure	• Does not consider wetland type in the assessment • Designed for use in a wide range of systems, but is not intended to be used to compare types	• Primary focus of the assessment is habitat, also considers water treatment
Massachusetts Coastal Zone Management Rapid Habitat Assessment Method	• Has a form for all freshwater wetlands and another for salt marshes	• Not included
Montana Wetland Assessment Method	• Uses regional versions of the national HGM classes and vegetation classes (aquatic bed, emergent, scrub-shrub, forested, moss-lichen) • Rates relative abundance of similarly classified sites within the basin	• Considers habitat for Montana Natural Heritage Program listed species • Flood attenuation – considers residences or businesses downstream of wetland • Sediment/nutrient/toxicant retention and removal – opportunity (i.e., probable or actual source); presence and amount of vegetation, of flooding and ponding, and of restriction of outlet • Sediment/shoreline stabilization – cover and flooding of plant species with deep, binding roots • Uniqueness – rareness of wetland type or species present, and amount of disturbance • Recreation or education – potential for use, ownership, and amount of disturbance
Ohio Rapid Assessment Method	• Considers HGM class within the assessment as a means to compare like kinds of sites and recognizes some types as having special value	• Gives extra points to wetlands of special significance and wetlands that are habitat for threatened or endangered species or are migratory bird habitat
Washington State Wetland Rating System, Western Version	• Tidal and non-tidal evaluation is not type specific	• The office form of the assessment focuses on determining the regulatory category of the wetland based on whether it has been designated by the state, heritage program, federal agency, or local government as having sensitive or endangered species, or is considered significant locally for functions such as shoreline protection and water storage.

a provision to place wetlands in the HGM classes *a posteriori* (i.e., following assessment), for the purposes of reporting or interpreting scores (i.e., ecological condition can be reported by HGM class). ORAM requires users to compare the wetland in question to high quality wetlands in the same HGM class to gauge its departure from the reference condition. Four methods recognize the value of specific wetland types or ecosystem services and award points to boost scores accordingly. For instance, the Montana, Ohio, and Washington methods all give extra points to sites that are known to support sensitive or endangered species.

Finally, wetlands are subject to human activities (e.g., changes in land use or hydrology) that stress the system and degrade its ecological integrity (Table 4). One of the assumptions underlying any condition assessment method is that wetlands re-

Table 4. A comparison of the six methods relative to how each method addresses the stressors that act to degrade wetland condition.

Method	Stressors
Delaware Method v1.2	• Entire method scores stressors relative to their potential effect on hydrology, biogechemical cycling, and habitat/plant community • Also includes potential for effects (positive and negative) of what is in the area 100 m around the wetland
Florida Wetland Rapid Assessment Procedure	• Hydrologic modification • Adjacent land use as ameliorated by a buffer
Massachusetts Coastal Zone Management Rapid Habitat Assessment Method	From the surrounding landscape: • Land use – commercial, industrial, transportation rated lowest; forestry and open space rated highest • Amount impervious cover – > 20% rated lowest; < 5% rated highest • % natural vegetation – < 10% rated lowest; > 50% rated highest • Ratio wetland/drainage basin area – < 2% rated lowest; > 10% rated highest • Possible sources of pollution – industrial, commercial effluent, and urban storm water rated lowest; no source rated highest Onsite: • Hydrology – variability in water levels (altered or human controlled ranked lower); restriction of outlet (presence gets lower rating); degree of tidal flushing for tidal systems • Soils – high sedimentation given lowest rating; high erosion gets lowest rating for tidal systems. • Human activities – rated lowest if human activities severely degrade the wetland
Montana Wetland Assessment Method	• Disturbance – considers the site and area adjacent (within 500 feet); categories considered are natural; not cultivated but moderately grazed, hayed or selectively logged, minor clearing, fill, or hydrologic alteration, few roads or buildings; cultivated or heavily grazed or logged, substantial grading, fill, clearing, or hydrologic alteration, high road or building density • Vegetation alteration – predominant weedy, alien, and introduced species, degree of disturbance to vegetation • Hydrology – culverts, dikes, and other structures, restriction of outlets if present
Ohio Rapid Assessment Method	• Vegetated buffers scored as an ameliorating factor • Intensity of land use scored; score decreases with increasing land use intensity • Modifications to hydrology, with highest score for none and lowest for recent or no recovery • Substrate disturbance rated • Habitat modification rated • Rates coverage of invasive plants
Washington State Wetland Rating System, Western Version	• Hydrologic modifications • Grazing • Impervious surface > 12% in upstream watershed • Exotic plants • Runoff from roads or parking lots • Dumping • Vegetated buffers scored as an ameliorating factor

spond predictably to stressors. Indicators of wetland condition can be based either on the response of the wetland to these stressors (e.g., the percent cover of invasive species, the number of vegetation communities present) or on the stressors themselves (hydrologic modification). Stressor indicators can be very robust since the stressors have a negative effect on condition regardless of wetland type; for instance, hydrologic modification has a negative impact in a coastal marsh or a riparian forest. Some stressors can be used to refine methods regionally because the occurrence of stressors varies by region and wetland type. Methods range in their use of stressor indicators from those that only use stressor indicators (Delaware) to those that have very few stressor-based indicators (FWRAP).

Table 5. Major categories of indicators used in the 16 rapid assessment methods reviewed, the characteristic(s) on which the indicator is based, and a tally of methods using that indicator (from high to low).

Core Element	Indicators Developed for or Based on:	Number of Methods Employing Indicator (16 Maximum)
Hydrology:	Hydrologic alterations (stressors)	14
	Hydroperiod	9
	Type of outlet restriction	8
	Water quality	8
	Surface water connectivity	7
	Flood storage potential	7
	Ground-water recharge and/or discharge	4
	Water source(s)	3
	Degree of water level fluctuation	3
	Maximum water depth	1
	Total	**64**
Soils/substrate:	Soil type	4
	Substrate disturbance	2
	Presence of mottles	1
	Depth of A horizon	1
	Munsell color (matrix/mottles)	1
	Microtopography	1
	Sediment composition	1
	Total	**11**
Vegetation:	Number of vegetation classes	12
	Degree of interspersion (community types or open water)	8
	Extent of invasive species	8
	Vegetation alterations	6
	Habitat value to wildlife	5
	Endangered/threatened species, their habitat or communities	4
	Coarse woody debris	3
	Dominant vegetation	2
	Plant species diversity	2
	Area of open water	1
	Total	**51**
Landscape setting:	Surrounding land use cover	14
	Connectivity to other wetlands or corridors	8
	Extent of and/or vegetation type in buffer	7
	Extent of human land use in buffer	5
	Wetland size	5
	Ratio of wetland to watershed size or watershed size	3
	Land use in watershed	3
	Wetland morphology	2
	Position of wetland in watershed	1
	Total	**48**

Tally of Indicators

We sorted the indicators used in the 16 methods into major categories to determine the extent to which they focus on the three parameters that define wetlands (hydrology, soils, biota) and on the landscape setting of the site (Table 5). All sixteen methods reviewed address hydrology; many emphasize the stressors that affect hydrologic processes (e.g., ditching and culverts; Table 5). Hydroperiod is another important consideration; half of the methods use the duration of flooding and the sources of water to the wetland. Soils received the least attention, with several methods not addressing soils at all. Features of the biotic communities, particularly vegetation, were the basis for many indicators. Most methods rely on the structural characteristics of the plant community (number of communities present, degree of interspersion, vegetation cover) as indicators of overall biotic richness. Plants are considered "one of the best indicators of the factors that shape wetlands within their landscape" (Bedford 1996). Wetland vegetation provides critical habitat structure for other taxonomic groups, such as epiphytic bacteria, phytoplankton, and some species of algae, periphyton, macroinvertebrates, amphibians, and fish; therefore, the composition and diversity of the plant community influences diversity in these taxonomic groups.

OPERATIONAL CONSIDERATIONS AND CONCLUSIONS

Our review of existing rapid assessment methods led us to identify issues that must be faced when adopting or developing such methods for wetland monitoring and assessment programs. These relate to operationalizing methods for use in the field: how the assessment area is defined, how wetlands of different types are handled by the method, how the method will be scored (e.g., will some indicators be weighted more heavily than others), how the values that we place on certain wetland functions or characteristics can be recognized, and how method verification can be approached.

Definition of Assessment Area

The requirement of a site visit to do the assessment implies that field protocols must be developed to ensure consistency and repeatability among users. One important decision in designing the protocol is how to define the area of wetland to be included in the assessment. This is referred to as the "wetland assessment area" or sometimes as the area within a "scoring boundary." In many instances, it is a simple matter of assessing the entire wetland. For example, when assessing a relatively small wetland the scoring boundaries will generally coincide with ecological or jurisdictional boundaries. When dealing with very large wetlands or a smaller area that is part of a larger wetland complex, decision rules to identify what area to include in the assessment must be clear. Misidentification of the assessment area can result in either the under- or overscoring of a given wetland (e.g., Mack 2001).

The definition of the wetland assessment area varies by method, ranging from sampling a fixed area around a point (for instance, a 0.5-ha area; the Delaware Method), to sampling the wetland as a whole (the New Hampshire Coastal Method). The latter approach can be problematic when large complexes made up of different wetland types are encountered, making it difficult to define a single wetland, or when very large wetlands require sampling. Some methods use a combination of approaches; for instance, the ORAM defines the assessment area using a "scoring boundary," which can be based either on the wetland's natural (jurisdictional) boundary (i.e., the whole site) or on boundaries defined by natural breaks in hydrology (much as stream sampling is done by a defined stream reach). This can mean that "whole" wetlands are not being sampled in the traditional sense, but the data collected will be consistent and provide an assessment of the ambient condition of the resource. The six methods that we applied to our model of assessment could all be easily adapted for use in whole wetlands or a defined assessment area within a wetland, depending on the user's objectives.

The definition of the assessment area is important because it influences how the data are collected and how the results are reported (e.g., by area of wetland resource, by wetland), understood, and, therefore used. An evaluation of what assessment area to use should consider 1) how well the definition can be applied in sample design and site selection (e.g., does it correlate with available mapped or GIS information), 2) how well and consistently the definition can be applied in the field (e.g., are boundaries easy to distinguish), 3) how ecologically meaningful the results will be, and 4) how useful the results will be in achieving the objectives of the monitoring or management program. A rationale can be made for using ecologically based units (i.e., wetlands, hydrogeomorphic units) as the assessment area, but this can make conducting the assessment and reporting the results problematic. For example, if the goal of the program is to assess the population of wetlands as a whole (in a watershed or region), then using a fixed area facilitates describing the characteristics of the population because drawing a sample from mapped data, locating the sample in the field, and reporting the results can easily be done in a manner that is consistent through all parts of the assessment (e.g., Wardrop et al. 2007a, Whigham et al. 2007). In our experience, it is difficult to establish a definition of a wetland site or related ecological unit that can be used to both draw a sample from mapped data and be consistently applied in the field. In addition, there is the problem of how to combine the data from wetlands of various sizes into a population estimate.

Assessment of Different Wetland Types

Recognition of different wetland types is an important consideration in the development and

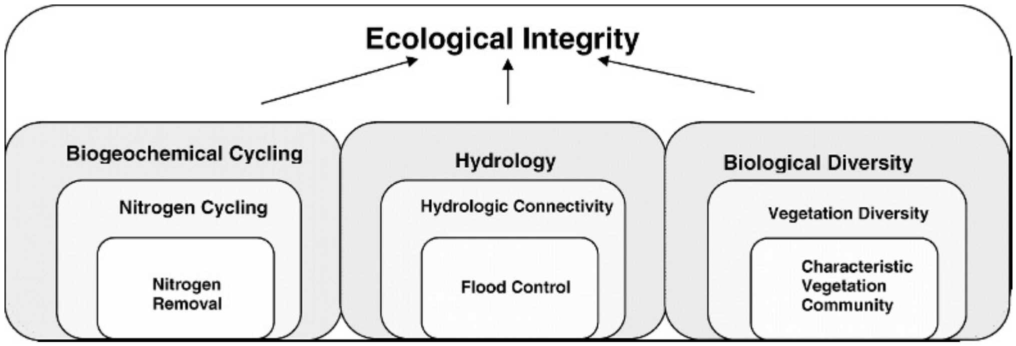

Figure 2. A schematic to illustrate the concept of ecological integrity as the integrating function of wetlands encompassing both ecosystem structure and processes. In this case, integrity is shown to include biogeochemical processes that lead to functions such as nitrogen removal, hydrologic processes that lead to the flood-control function, and habitat functions (based on Smith et al. 1995).

use of a rapid method because different classes of wetlands may be subject to different stressors and may vary in their relative susceptibility to particular stressors. The reference condition for a given class, defined by wetlands least impacted by human activities, is used to set the benchmark for the attainable ecological condition within a class.

Assessment of different wetland types can be accomplished in several ways: 1) develop a method for each class (e.g., HGM assessment), 2) weight the indicators according to wetland type within the method itself (e.g., ORAM) or in the calculation of the result (e.g., Delaware Method), or 3) have sets of indicators in the method that are used with particular wetland types (e.g., Washington State Wetland Rating System for Western Washington). The first approach allows for the use of type-specific field indictors, potentially increasing precision. This can be problematic, however, because each version will have to be validated separately and some wetlands, or some mosaics of wetlands, cannot be cleanly placed into a category.

The second and third approaches allow the creation of a single method for use in all wetland types and are, therefore, broadly applicable. Some methods using this approach embed the issues of class within the method itself; for instance, in the ORAM, the rater is asked to evaluate the wetland being assessed relative to other wetlands of similar type and hydrology (i.e., to other sites of the same HGM class). The result is that wetlands of different classes but with the same relative level of human impact should receive relatively similar scores (Mack et al. 2000).

The costs in time and resources needed to develop different versions of a method are important considerations. For instance, the sample size needed to detect differences (or lack thereof) between classes or other groupings statistically is influenced by the variability of the parameter(s) being measured. The U.S. Environmental Protection Agency's (U.S. EPA's) Environmental Monitoring and Assessment Program has arrived at a "rule of thumb" that, absent any information on the variability of what is being measured, 50 sites *per class* should be assessed during method development to increase the likelihood that the sample will be adequate. (See www.epa.gov/nheerl/arm/surdesignfaqs.htm for information on sample size and other monitoring design issues.) Therefore, a single method can be brought on line, evaluated, and developed more quickly than a suite of methods.

It is important to note that some methods are blind to wetland type (e.g., Delaware Method). The assumption behind such methods is that wetlands may differ in terms of their HGM class or floristic composition, but all are degraded by stressors. We have found that most of these methods track the type of wetland being assessed for uses such as ground-truthing wetland inventories, or for post-stratification of the data for analysis and reporting (e.g., Wardrop et al. 2007a).

Issues Associated with Scoring

A major focus of our analysis was to identify those methods that could assess the ecological condition of a site and in doing so provide a single, integrative score. We took this approach for a variety of practical reasons (discussed following) that are supported by the ecological relationship between function and condition. Wetlands perform a wide variety of functions at a hierarchy of scales ranging from specific (e.g., nitrogen retention) to extensive (e.g., biogeochemical cycling) as a result of their specific physical, chemical, and biological attributes.

At the highest level of this hierarchy is the maintenance of ecological integrity, the function that encompasses all ecosystem structure and processes (Figure 2) (Smith et al. 1995). If condition is excellent (i.e., equal to reference condition), then the ecological integrity of the wetland is intact and the functions typical of that wetland type should also occur at reference levels.

Many of the existing functional assessment methods provide information in terms of a separate "answer" for each function assessed (methods reviewed here include between eight and 14 functions), making them difficult to employ in ambient monitoring programs. Functional assessment results are presented either as a matrix of sites versus score by function or as a list of averages for each function. Either way results in a group of scores for each site that makes it difficult to compare their relative ecological status, the extent of anthropogenic impacts, or to make statements about the health of the resource as a whole. For example, the results of the Minnesota Routine Assessment Method (Version 1.0) and the Oregon Freshwater Wetlands Assessment Method are expressed as a series of ratings for each of nine functions. The Oregon method uses qualitative scores to indicate that the wetland "has the function" (earning a high score), that the "function is impacted or degraded" (mid), or that the "function is lost or not present" (low). The Minnesota Method assigns one of four ratings ranging from "exceptional" to "low" for each function. In a test of both methods to assess 10 depressional wetlands (Fennessy et al. 1998), approximately 40% of the functions evaluated by the Minnesota method scored "medium," while 65% of the functions received a score of "mid" using the Oregon method. It should be noted that the 10 wetlands included in that study (Fennessy et al. 1998) were selected to represent the full gradient of human disturbance (least impacted to highly impaired), so despite the large apparent differences in condition, all 10 wetlands received very similar scores, making it difficult to distinguish among them. This illustrates the problem in interpreting their results in ambient monitoring and assessment programs.

Another concern is that in some functional methods defining the highest level of a function does not necessarily equate with high ecological condition. Scoring by the highest degree of functionality can be a trap because maximizing one function (e.g., water quality improvement) may cause a reduction in others (e.g., supporting characteristic diversity) (Zedler 2005). Ultimately, if a wetland is functioning as an integrated system with a high degree of ecological integrity, it will perform all of its characteristic functions at the full levels typical of its class (i.e., at the level of the reference condition). If, in adopting a method, there is a desire to recognize wetlands that provide valuable functions despite moderate to high levels of degradation, points could be awarded to acknowledge this value after the score for condition has been determined.

A common approach used for scoring a rapid method is to assign scores by placing the "answers" to assessment questions into different categories and then assigning a score by category. For example, an assessment of the average buffer width around a wetland could be scored using categories such as "narrow" (e.g., 10–25 m), "medium" (25–75 m), or "wide" (greater than 75 m). Different points would be awarded for each of the three categories. This approach tends to dampen the variability in scoring, resulting in less measurement error (i.e., different people are more likely to get the same answer making results repeatable and the method robust).

Several methods included in this review (e.g., New Hampshire method, Minnesota Routine Assessment Method) calculate the level of a function assigned to a wetland using simple equations that combine different variables. This makes the functional scores more difficult to validate (more variables, as well as their interactions, must be validated for each function). We also note that in arriving at a final score, several of the methods reviewed lead the person doing the assessment through a relatively detailed analysis requiring a lot of specific information, but then leave the ultimate result of the assessment to the "best professional judgment" of the user that appeared hard to defend (for example, the Wisconsin Rapid Assessment Method). We recommend a transparent and documented process for coming to a result for the assessment.

Consideration of Highly Valued Wetlands or Features

Some of the methods reviewed include what might be termed "value-added metrics." These are metrics that provide the opportunity for points to be added for a specific wetland type or feature that is deemed particularly valuable in the region, regardless of condition. For instance, wetlands in urban settings may have a high degree of human disturbance and therefore be of low condition, but they may be highly valued as green space or for the educational opportunities they provide. Metric 5 in the ORAM addresses regional values by adding points for wetland types that are rare and support a high level of plant diversity, such as the Oak Openings wetlands on the sand plains of Lake Erie. The Western Washington Method (from which ORAM was developed) does the same for eelgrass beds. Enhancing scores in this manner might be done for several reasons: 1) if the results of the rapid assessment are considered in regulatory decisions then more weight can be given to valued wetland types that are felt to be deserving of protection regardless of their condition; 2) some stakeholders who have a say in the development and use of such a method may feel more satisfied about its validity if scores are enhanced for wetlands or habitat features that they view as particularly important; or 3) addressing differences among wetland classes that other indicators are not capturing. If this approach is taken, it is important that such "value-added metrics" be kept separate from the metrics that indicate condition or stressors. By keeping condition metrics and value-added metrics separate, the metrics that reflect ecological condition can be combined for a condition score that can be used to track the status of the site or to report on the ambient condition of the resource, then the "value-added metrics" can be factored in to get an overall score to be used in the regulatory process. This approach can substantially increase the flexibility of the method to meet program needs.

Verification with Comprehensive Ecological Data

A central component in the development of a rapid method is to determine its accuracy with more comprehensive ecological assessment data (Level 3 assessments such as IBI or HGM type data). The relationship between the rapid method and comprehensive data must be established so that the rapid method, with careful sampling design, can be used to extrapolate the more detailed results to the resource base as a whole (i.e., through probability-based sample design). It will also allow confidence limits on the use of a rapid assessment to be determined, increasing the reliability and defensibility of the method. The papers by Wardrop et al. (2007 a,b) on the assessment of the wetlands in the Upper Juniata watershed illustrate how the three-tiered approach can be applied and how the results from each tier can be used to verify and inform the others. For example, the cumulative distribution functions for the wetland resource produced from the landscape, rapid, and intensive (HGM) assessments are very similar, indicating that all three methods generate comparable distributions of condition scores for the population. Further examination of the results using classification and regression tree (CART) analysis demonstrated that the landscape and rapid methods group sites along a condition gradient supported by Level 3 ecological data.

SUMMARY

This paper serves as a first step in providing guidance on how to develop a rapid assessment method or to adapt an existing method for use in wetland monitoring. From an initial review of 40 methods, 16 were selected for further analysis, and six were selected for an in-depth evaluation. We used four criteria to select these methods: 1) the method must measure the current condition of the wetland, 2) its use requires a site visit to complete the assessment, 3) the method is truly rapid, and 4) the assumptions that underlie the method can be verified. A necessary next step is to determine how these methods perform in the field through systematic field-testing across multiple regions. Several questions arise. Which indicators provide the most accurate and useful information across regions and among different wetland types? Should stressors be included in any method? Do the methods adequately characterize ecological condition? Are the results from such methods repeatable with different users? Answers to such questions are beyond the scope of this analysis and can only be reached through a rigorous field test of rapid assessment methods like those we have identified.

The wetland assessment methods reviewed have multiple uses, including ambient condition monitoring, mitigation planning and establishment of performance criteria, monitoring status and trends, local land-use planning to protect the ecological integrity of wetlands, and for use in regulatory decision making. These uses highlight the fact that a scientifically sound rapid assessment method can serve as a cornerstone for wetland protection programs.

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