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Freshwater Wetlands Monitoring and Assessment Framework for the Northeast Temperate Network

Natural Resource Report NPS/NETN/NRR—2009/143

ON THE COVER
Freshwater marsh at Acadia National Park:
Photograph by: Kevin Hop

Freshwater Wetlands Monitoring and Assessment Framework for the Northeast Temperate Network

Natural Resource Report NPS/NETN/NRR—2009/143

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Abstract

The Northeast Temperate Network (NETN) of the National Park Service is developing a freshwater wetland monitoring program as part of the overall development of its vital signs monitoring program. This report presents a prototype of a rapid assessment method based on an ecological integrity assessment perspective that is compared with a prototype intensive assessment method.

The major components of the rapid assessment proposed include 1) using a standardized classification of wetland types, 2) identifying key ecological attributes and indicators for each wetland type that reflect composition, structure and function, 3) identifying practical metrics with ratings and thresholds based on "normal" or "natural" benchmarks; and 4) providing a reporting scorecard by which the indicators/metrics are rated and integrated into an overall wetland index of ecological integrity (IEI).

We compiled a list of 15 indicators/metrics of condition for freshwater wetlands that cover the five major attributes of our wetland conceptual model: landscape context, size, biota, hydrology, and soils/physicochemistry. Each metric is described in full, and protocols are provided for its consistent measurement in the field. Guidance on assessing stressors is also provided. We compared the set of rapid metrics to a possible set of intensive wetland metrics.

We developed an index of ecological integrity from these metrics using a scorecard format. The table is structured so that the score for each metric and major attribute is provided along with the overall index.

The report is concluded by noting the need for a sampling design and briefly discussing a set of field protocols, topics that extend beyond the scope of this report.

Acknowledgements

I am grateful for financial assistance from the National Park Service to develop this freshwater wetland assessment method for the Northeast Temperate Network (NETN) of parks. Brian Mitchell provided valuable coordination and advice throughout the project, including peer review of this report. Geri Tierney provided much input on the initial conceptual modeling that was part of the overall NETN Vital Signs monitoring program (Mitchell et al. 2006).

The design of this wetland assessment and monitoring scorecard is based on an extensive effort by NatureServe and the Natural Heritage Network to improve that core methodology by using an ecological integrity framework. These improvements draw on the experience and collaboration with partners, including The Nature Conservancy, and with federal partners, particularly the Environmental Protection Agency (EPA), which provided funds to NatureServe to work on ecological integrity assessments for all wetland types in the U.S. Other support comes from the National Park Service, the Army Corps of Engineers, and the U.S. Forest Service.

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Overview of Wetland Assessment and Monitoring

Introduction

The Northeast Temperate Network (NETN) of the National Park Service is developing a freshwater wetland monitoring program as part of the overall development of its vital signs monitoring program (Mitchell et al. 2006). Two approaches are being considered. First, an intensive field-based monitoring program is being developed, currently applicable to wet meadows and alkaline fens (Neckles et al. 2007). Second, a rapid field method is being developed for all wetlands. The two methods will be designed to complement each other. Here we present the rapid assessment method.

Wetland assessments, whether intensive or rapid, are increasingly using an indicators-based approach to assessing and reporting on ecological condition (Harwell et al. 1999, Young and Sanzone 2002, U.S. EPA 2002). Assessing the current ecological condition or integrity of an ecosystem requires developing measures of the structure, composition, and function of an ecosystem, as compared to reference or benchmark ecosystems operating within the bounds of natural or historic disturbance regimes (Lindenmayer and Franklin 2002, Young and Sanzone 2002). However, selection and development of indicators can be challenging, given the diversity of organisms and systems, the large number of ecological attributes that could be measured, and concerns over cost effectiveness and statistical rigor.

Indicators of meaningful change can be developed in multiple ways. There is increasing recognition that some change can be detected using remote sensing information, other changes using rapid assessments, and others only by detailed, intensive assessments. Together these form what has been called a 3-level approach to wetland monitoring and assessment (Brooks et al. 2004, Tiner 2004, USEPA 2006). Working at multiple levels can give managers more flexibility for assessing changes in ecological integrity. It also requires a greater variety of tools to identify the metrics at each level. For example, for intensive metrics statistical screening tools can be used (Barbour et al. 1996, Blocksom et al. 2002). For rapid metrics, which are more semi-quantitative to qualitative, a combination of graphical and simple categorical tools can be used (Karr and Chu 1999, Mack 2001).

Ideally, information at the three levels of assessment will also provide relatively consistent information about ecological integrity, with improved interpretations as the level of intensity increases. To achieve this, the various levels need to be calibrated against one another. Where rapid assessment metrics have a corresponding intensive metric, the rapid metric can be calibrated against the intensive metric. For example, a rapid vegetation metric may require that the overall percent-cover of native species versus exotic species be compared, whereas an intensive metric may be based on a Floristic Quality Index or Vegetation Index of Biotic Integrity that scores each species or group of species based on sensitivity to human stressors. By measuring both metrics in the same wetland, the thresholds for the rapid metrics can be calibrated against those of the intensive metric.

To ensure that the 3-level approach is consistent among levels, various studies have recommend using a standard framework or model for choosing metrics (e.g., Harwell et al. 1999, Young and Sanzone 2002, Parrish et al. 2003, Faber-Langendoen et al. 2006). The framework identifies a common set of key ecological attributes and categories (such as landscape context, size hydrology, soils and biota) for all three levels. Choosing metrics or indicators within this framework ensures that a comparable set of wetland characteristics are being assessed. This guiding framework can be used to evaluate and integrate the growing list of wetland metrics and indices that are being developed for use in wetland condition assessments, including by many states (see review by Fennessy et al. 2004, 2007).

The NETN program has already made substantial progress on creating an intensive (level 3) field-based monitoring program for upland forests (Tierney et al. 2009), though some rapid level 2 metrics are included. The protocol uses an indicators or metrics-based approach, and provides a scorecard that presents ratings at the level of each metric. That program is commencing its third year of sampling. A landscape (level 1) set of metrics for forests will be developed based on guidance from the national Vital Signs landscape program.

Wetlands, although less common on the park landscapes, are in some ways more complex and diverse than forests in terms of their structure, composition, and dynamics. There are a greater variety of intensive metrics that might be needed to cover all wetland types, and measuring them all could be cost prohibitive. In order to initiate the process of selecting metrics and assessing wetlands, we first developed a rapid field-based (level 2) monitoring and assessment program for NETN wetlands, intended to complement an intensive field based assessment developed by Neckles et al. (2007), including alkaline fens and wet meadows. As with forests, a landscape (level 1) set of metrics for wetlands will be developed from guidance provided by the national Vital Signs landscape program.

The major components of the rapid assessment being proposed include (1) using a standardized classification of wetland types, (2) identifying key ecological attributes and indicators for each wetland type that reflect composition, structure and function (pattern and process), with protocols for measuring those indicators to ensure consistent field measurements and documentation, (3) identifying practical metrics with ratings and thresholds based on "normal' or "natural" benchmarks; and (4) providing a reporting scorecard by which the indicators/metrics are rated and integrated into an overall wetland index of ecological integrity (IEI).

Our rapid assessment methods are a prototype intended for further testing and refinement. They should be validated through comparisons with a reference set of wetland sites in the NETN region. They should also be calibrated through cooperative intensive studies, where both rapid and intensive metrics are measured at the same site.

A Conceptual Model for Wetlands

Wetlands can be defined based on hydrology, soils and physicochemistry, and biota (Mitsch and Gosselink 2000). These three components form the basis for the development and functioning of wetland ecosystems (Figure 1). Water is present in all wetlands at one time or another but the depth and duration of flooding (i.e., hydrology), varies substantially among wetland types. *Hydrology* is the defining physical parameter that separates wetland ecosystems from terrestrial and deep water aquatic systems. Hydrology is thus a most important factor in the establishment and maintenance of characteristic types of wetlands and wetland processes. In turn, the starting point for the hydrology of a wetland is the climate and basin geomorphology (Mitsch and Gosselink 2000). The diverse climatic, hydrologic, and geomorphologic settings of wetlands influence the *physicochemical* environment of the wetland, which is defined as the soils, chemical properties, and processes that interact with the hydrology to influence the biota. The physicochemical environment also includes the cycling of and transformation of biochemicals through the wetland. Soils are both the medium in which many of these transformations occur and the source (i.e., storage) of available chemicals for plants. In turn, wetland *biota* both respond to and control, through feedback loops, the hydrology and biogeochemistry of wetlands (e.g., coarse woody debris, beavers, muskrats, geese) (Mitsch and Gosselink 2000).

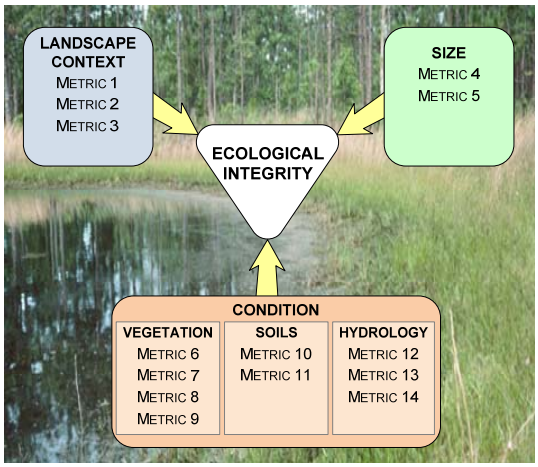

Figure 1. General conceptual diagram showing the major ecological attributes of wetland integrity: hydrology, soils , vegetation (summarized as "condition"), and the influence of wetland size and landscape context. The surrounding geomorphic landscape and climate exert controls over these attributes.

Many of these processes are strongly influenced by coupling with adjacent ecosystems, which form the *landscape context* of the wetland. "Open" wetlands (i.e., riverine, lacustrine, or coastal) regularly exchange water, chemicals, and biota with adjacent systems. In contrast, "closed" systems, such as bogs, have little material exchange. All wetland types are affected to varying degrees by alterations to adjacent ecosystems.

A fifth attribute, wetland size, is closely related to landscape context. Size is an important attribute because it limits the abundance of area-dependent species and influences the level of heterogeneity and diversity of wetland composition. There is an interaction between size and landscape context. With increasing size, wetlands are more likely to be buffered from adjacent stressors. A small wetland in a large, natural, landscape may retain many important aspects otherwise found in large wetlands, whereas that same wetland would not in a fragmented landscape.

Thus, a full set of core major ecological attributes of wetland ecosystems include hydrology, soils/physicochemistry, vegetation, size, and landscape context. The first three attributes can be combined into an overall "condition" factor, to form a triad of landscape context, size, and condition factors (Fig. 1 and Faber-Langendoen et al. 2008b). This general conceptual model can be refined into a more specific model using figures and a narrative that describes the current understanding of wetland system attributes and their interactions (Figure 2). A detailed narrative of the model is provided in Mitchell et al. (2006). The specific model includes the effects of drivers and stressors that affect the major attributes. Additional attributes, such as focal taxa (birds, mammals, amphibians, rare plants) are difficult to monitor as part of a rapid assessment at a site level, but can be monitored selectively. Their data can then be linked to the results of the core assessments.

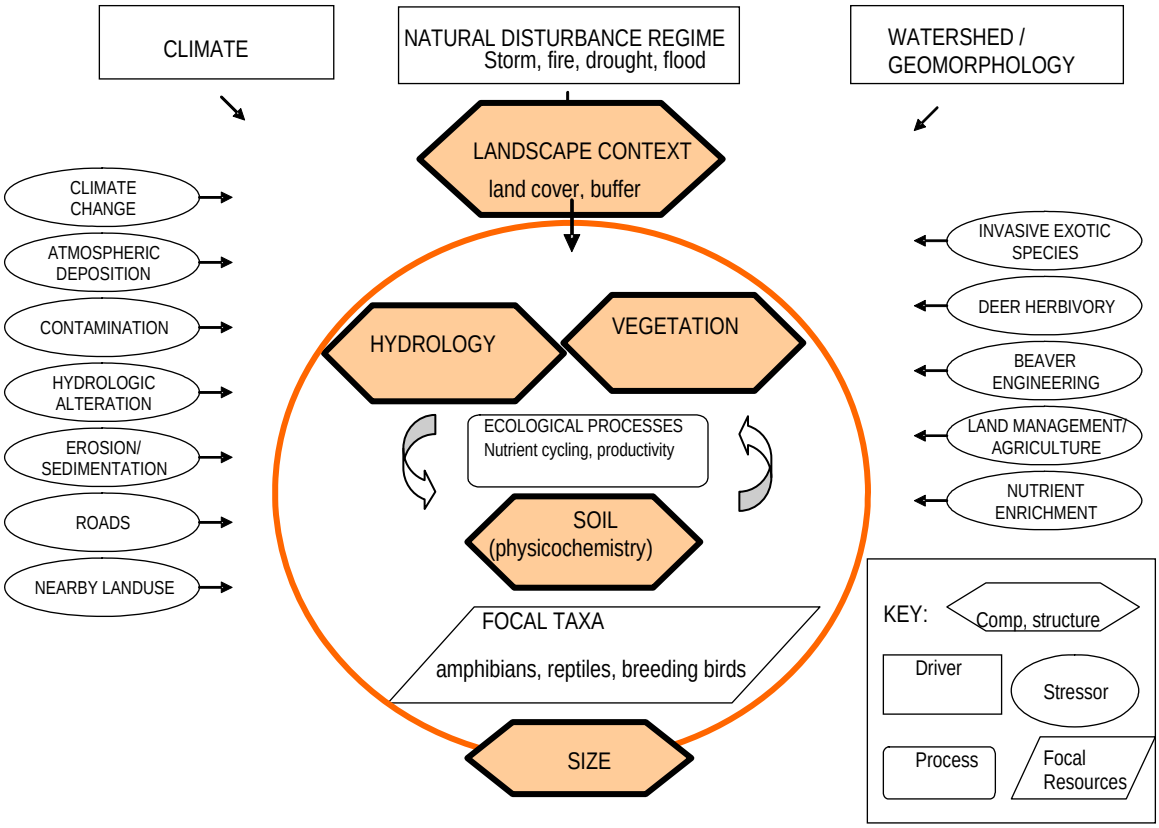

Figure 2. Detailed conceptual model for wetland systems in the Northeast Temperate Network, showing the relation of drivers and stressors to the five major ecological attributes of wetlands – landscape context, size, hydrology, physicochemistry, and biota.

Ecological Integrity

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 and others). The concept of "ecological integrity" provides a useful framework for selecting monitoring variables and assessing progress towards ecologically-based management goals (Harwell et al. 1999). The notion of naturalness depends on an understanding of how the presence and impact of human activity relates to natural ecological patterns and processes (Kapos et al. 2002). Identification of reference or benchmark conditions based on natural or historic ranges of variation, although challenging, can provide a basis for interpretation of natural and historic ranges of variation (Swetnam et al. 1999).

Several approaches can be taken to assess wetland integrity (Kapos et al. 2002). First, *indicators* can be used to assess key aspects of wetland structure, composition and/or function. This strategy has the advantage of directly addressing the primary concern, which is the state of the ecosystem. Identification of a suite of reference or benchmark sites is an important component of such an approach to avoid some of the difficulties concerning effects of human-induced changes in ecosystems (Brooks et al. 2004, Stoddard et al. 2006). Second, the *stressors* (negative human impacts) and ecological *drivers* (climate, geology, natural disturbances) can be assessed separately from the *responses*—ecological integrity and change. Separation of the drivers and stressors (causes) and responses (ecological effects) provides a valuable analytical tool (Kapos et al. 2002, Tierney et al. 2009).

Selection of Wetland Integrity Metrics

Rapid Field-Based Metrics

The metrics presented here are part of a national effort to select metrics for rapid assessment and monitoring of ecological integrity of wetlands. A core ecology team of NatureServe and Natural Heritage Network staff have reviewed the literature on wetland assessments. This review helped us reach agreement on the models that were presented above, including the decision to work with the major attributes identified in the conceptual models—landscape context, size, biota, hydrology, and soils/physicochemistry (see Fennessy et al. 2004, 2007).

We then reviewed a variety of existing rapid wetland assessment and monitoring materials, particularly that of the California Rapid Assessment Manual (CRAM, Collins et al. 2006, 2007), the Ohio Rapid Assessment Manual (Mack 2001), as well as a variety of others from North Carolina, Montana, and Delaware. We also consulted a variety of Hydrogeomorphic assessment manuals. Some of these materials have already been summarized in previous work by NatureServe (Faber-Langendoen et al. 2006). From the list of metrics provided by those assessments, we attempted to narrow down the list of metrics using the following criteria (Andreasen et al. 2001, Kapos et al. 2002, Faber-Langendoen et al. 2006):

- Useful at multiple spatial scales
- Inclusive across ecological attributes of composition, structure and function
- Grounded in natural history and ecologically relevant
- Practically relevant to managers, decision-makers, and the public—not just scientists
- Flexible
- Feasible to implement and measure, with relevant target or threshold settings
- Responsive, including to changes from stressors

Multiple Spatial Scales: We identify metrics that address issues of the individual plot or assessment area, the full wetland patch, and the surrounding landscape. In this way, ecological factors that vary in their spatial characteristics can be tracked.

Inclusive of a Range of Ecological Attributes: We work with an ecosystem model of wetlands that includes the major attributes of vegetation, soils, hydrology, size, and landscape context. We review metrics that address these major attributes.

Natural History and Ecological Relevance: Our overall concern is to measure ecological integrity or condition; that is, the overall naturalness/normalcy of ecological patterns and processes operating in a wetland. We have ensured that the metrics are broadly applicable, both geographically and for as wide a set of freshwater wetlands as possible. We have ensured the ecological relevance of the metrics by evaluating them by the major ecological attributes (Figure 2). In addition, we have looked for linkages between metrics. For example, landscape context metrics, such as buffer, provide information on changes to the surrounding landscape that will also affect metrics that are directly assessing hydrological and biotic changes within a wetland.

Practical Relevance: We have also sought to make any thresholds relative to determining quantitative or qualitative thresholds for condition as meaningful for managers as possible; that is, changes in a metric should be helpful to making management decisions. Thus, in so far as ecological integrity or condition is part of management goals, the metrics will be significant. But further input is needed to be sure that specific management goals for NETN have not been omitted.

Flexibility: Metrics need to be available to answer questions with varying degrees of resolution, depending on manager's needs and shifting priorities, and available funding,

Feasibility: We sought to ensure feasibility in several ways. First, we chose, wherever possible, to rely on metrics already tested and in use by various state wetland programs. Second, several members of the NatureServe team are actively testing these metrics (e.g., Rocchio 2007). Third, we relied on our own professional judgment, based on experiences with similar kinds of field assessments in other projects. Thus, we are confident that these metrics are well-documented, rapid, cost-effective, often have baseline data available from other projects outside of NETN, easily measured with little equipment or specialized knowledge, and have a large sampling window (i.e., can be sampled throughout much of the growing season).

Responsivity: Because rapid metrics rely on a combination of qualitative and quantitative metrics, they can be more challenging to apply consistently than strictly quantitative metrics, which can introduce some measurement error or lack of repeatability. We sought to minimize these issues by ensuring that, for each of the four major attributes, at least some metrics were simple quantifiable ones. For the more qualitative metrics, an expansive narrative was provided for guidance. We are less concerned about statistical power in rapid assessments, and more concerned with a qualitative discrimination of wetland integrity that is open to validation through quantitative assessments. In some ways, the qualitative metrics are better able to control for temporal and spatial variability, because they often ask the field observer to integrate a variety of observations. For example, when assessing soil disturbance, the metric relies on visual evidence of trampling, including ATV or ORV tracks and trails that are readily observed and persistent throughout the season.

Intensive Metrics

At this time, the development of intensive metrics for NETN wetlands is still preliminary, based in part on the work of Neckles et al. (2007) for wet meadows and alkaline fens. There are other studies developing intensive metrics for a variety of wetlands (e.g., Miller et al. 2006a, b). Intensive metrics should be far more accurate and informative about wetland patterns and processes than Level 2 metrics, but they may only be measurable in a select set of wetlands, whereas Level 2 metrics could be measured across a wider set of wetlands. Ensuring that the two levels of metrics are coordinated should allow for greater interpretive value of both (Mack 2006).

Ecological Integrity Metrics and Reference Condition

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 (Faber-Langendoen et al. 2008a). 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 (Swetnam et al. 1999). It is this practical concept that we apply to evaluating wetland integrity.

Reference wetlands (or the *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), and 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, providing 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). 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 are also 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.

Reference Condition and NETN

Much work has already been done throughout the Northeast to locate hundreds of exemplary ('A' or 'B' ranked) wetland sites on both managed and protected lands (Anderson et al. 2006). But assessments of

these sites need to be validated. By using a series of known reference sites across a range of management activities, and with partners who have already begun to implement some aspects of ecological integrity assessments, we fully expect that a series of wetland sites of the same types found at NETN can be visited and measured using the set of ecological metrics below. To be an effective network of reference wetlands we suggest the following steps:

1) Engage the Partners: Form an advisory team among partners that are already working on measuring various aspects of ecological integrity and wetland condition to identify shared goals, common sampling designs, and compatible reporting structures.

2) Identify a Suite of Reference Sites: Extensive work has already been done in the region to identify the highest quality landscape-scale sites across the region, including work by The Nature Conservancy to identify its priority 'matrix blocks'. Within these landscape scale sites, many 'benchmark' or reference wetland sites exist, such as those found within the Maine Ecological Reserves and known wetland sites in the Adirondacks and Catskills. A set of sites could be identified that cover the ecological variation across the region, as well as adjacent sites where stressor levels are higher and management history differs. A screening process should be developed that assesses independent abiotic (e.g., landscape stressor models based on land use and other human disturbance factors) and biotic stressors on these sites. Measures of ecological integrity can then be assessed and compared to these stressores.

3) Review and Analyze Quantitative Data: Large amounts of data has already been gathered at many wetland sites. An effort should be made to compile and collect data on wetland structure and composition from a variety of sources, prioritizing the collection of data at three scales—site, large landscape, and region-wide. Provided compatible data can be found across a range of sites, comparison across the full range of 'A' to 'D' conditions could be developed. In addition, where sites exist that have data comparable to level 3 metrics (e.g., detailed species composition or hydrology information), sites could be visited and sampled using level 2 metrics.

4) Develop and Refine Attributes, Metrics, and Thresholds: The reference data sets can be used to calibrate the specific ranking attributes, metrics, and thresholds for poor, fair, good, and excellent wetland conditions, using both level 2 and level 3 metrics. Where data are sufficient to test the statistical significance of the metrics, they could be analyzed to gauge variability among measures of each indicator metric, document redundancy among selected metric ratings, and recommend a minimum set of metrics for effective assessment of forest integrity at multiple scales. Statistical screening tools, such as those outlined by Blocksom et al. (2002), can be used to test the discriminatory power between minimally disturbed and degraded conditions. In addition, the rapid assessment metrics can be calibrated against the intensive metrics.

Although the establishment of a series of reference sites per se outside of the National Park System is beyond the mandate of NETN, it is feasible through a partnership with other organizations and agencies interested in documenting wetland reference conditions (e.g., Brooks et al. 2004, Faber-Langendoen et al. 2008b). It may be similar to the regional network of sites that have been developed for assessing salt marsh restoration (Konisky et al. 2006). Such a study will also permit a greater refinement of the qualitative narratives used for some of the metrics proposed here.

Wetland Classification for NETN

Ecological Systems and Formations

We have been discussing general issues in selecting ecological metrics for wetlands. But the success of developing indicators of wetland ecological integrity depends on an understanding of the structure, composition, and processes that differ across 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. Here we rely on two major classifications approaches: Ecological Systems (Comer et al. 2003) and the U.S. National Vegetation Classification (USNVC) (FGDC 2008, Faber-Langendoen et al. 2009).

Our primary classification, also used by NETN for forest monitoring, is NatureServe's Ecological Systems (Comer et al. 2003). Ecological Systems provide a spatial-ecologic perspective on the relation of associations and alliances (fine-scale plant community types), 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).

Our secondary classification is the USNVC, which is the primary classification used for mapping the vegetation of the national parks, including all wetlands (e.g., for Acadia National Park, see Lubinski et al. 2003). The USNVC is a conceptual/taxonomic hierarchy of vegetation, ranging from broad-scale formations to fine-scale alliances and associations. It provides an organizing framework for Ecological Systems, using the NVC formation level (see Table 1).

Currently two other major classifications are widely used for wetlands work, the National Wetlands Inventory (NWI), as summarized in Cowardin et al. (1979), and the Hydrogeomorphic (HGM) classification (Brinson 1993). A comparison of these classifications with the USNVC and Ecological Systems is provided in Faber-Langendoen et al. (2008a). The Systems and USNVC Formation types share with the HGM approach the use of hydrogeomorphic criteria, but the first two approaches also use biota, soils, climate and other criteria to define types. An important benefit of using the USNVC and Ecological Systems classifications for NETN monitoring is that they are comprehensive for all ecosystems, not just wetlands. They provide a framework for all ecological integrity or condition assessments, and also a comprehensive classification and mapping approach for park landscapes.

Wetland Types in NETN Parks

Freshwater wetlands are present in all NETN parks (Table 1). Acadia (ACAD), the largest park in the Northeast Temperate Network, contains 2,233 acres (904 ha) of wetlands, followed by Minute Man (MIMA) with 261 acres (106 ha), and Saratoga (SARA) with 91 acres (37 ha). All other parks contain less than 37 acres (15 ha) of wetlands. Salt marsh wetlands are found at ACAD and Boston Harbor Islands (BOHA), but are not included in Table 1.

Table 1. Approximate extent (hectares) of NatureServe freshwater wetland ecological systems present within NETN parks. This information will be updated and improved after completion of the Inventory & Monitoring mapping inventory of these parks. Area listed in larger boxes spanning more than one ecological type indicates that current information does not distinguish between related types. Adapted from Mitchell et al. (2006).

USNVC Formation	NatureServe Ecological System Type	Northeast Temperate Network Parks									
		ACAD	BOHA	MABI	MIMA	MORR	ROVA	SAGA	SAIR	SARA	WEFA
Floodplain & Swamp Forest	Laurentian-Acadian Floodplain Forest	-	-	-	4	-	-	-	-	30	-
	Central Appalachian Floodplain	-	-	-	-	-	-	-	-	-	-
	Eastern Boreal Semi-Treed Bog/Acidic Swamp	146	-	-	-	-	-	-	-	-	-
	Laurentian-Acadian Acidic Swamp	214	-	4	58	-	-	-	-	3	-
	North Central Appalachian Acidic Swamp	-	-	-	-	6	9	-	-	-	1
Bog & Fen	Acadian Maritime Bog	37	-	-	-	-	-	-	-	-	-
	Laurentian-Acadian Acidic Basin Fen	216	-	-	2	-	-	-	-	-	-
	Laurentian-Acadian Alkaline Fen	68	-	-	-	-	-	-	-	-	-
Freshwater Marsh	Laurentian-Acadian Wet Meadow-Shrub Swamp & Marsh	223	12	0.2	42	9	3	5	2	4	3

Freshwater wetlands in NETN parks are comprised of nine different types of wetland ecological systems (NatureServe 2003) and vernal pools. These types are summarized below (from Mitchell et al. 2006):

Temperate Floodplain & Swamp Forest

Laurentian-Acadian Floodplain Forest: These systems encompass north-temperate floodplains in the northeastern and north-central U.S. and adjacent parts of Canada at the northern end of the range of silver maple. They occur along medium to large rivers where topography and process have resulted in the development of a complex of upland and wetland temperate alluvial vegetation on generally flat topography. This complex includes floodplain forests, with silver maple (*Acer saccharinum*) characteristic, as well as herbaceous sloughs and shrub wetlands. Most areas are underwater in spring, with microtopography determining how long the various habitats are inundated. Associated trees include red maple (*Acer rubrum*) and American hornbeam (*Carpinus caroliniana*), the latter frequent but never abundant. On terraces or in more calcareous areas, sugar maple (*Acer saccharum*) or red oak (*Quercus rubra*) may be locally prominent, with yellow birch (*Betula alleghaniensis*) and ash (*Fraxinus* spp.). Black willow (*Salix nigra*) is characteristic of the levees adjacent to the channel. Common shrubs include silky dogwood (*Cornus amomum*) and viburnum (*Viburnum* spp). The herb layer in the forested portions often features abundant spring ephemerals, giving way to a fern-dominated understory in many areas by mid-summer. Non-forested wetlands associated with these systems include shrub-dominated and graminoid-herbaceous vegetation.

Central Appalachian Floodplain Forest: These systems encompass floodplains from New England to Virginia. Mostly forested, these occur on floodplains of medium to large rivers where topography and process have resulted in the development of a relatively flat floodplain with a complex of upland and wetland temperate alluvial vegetation. This complex includes floodplain forests in which silver maple, Eastern cottonwood (*Populus deltoids*), and American sycamore (*Platanus occidentalis*) are characteristic, as well as herbaceous sloughs and shrub wetlands. Most areas are underwater in spring with microtopography determining how long the various habitats are inundated. Depositional and erosional features may both be present depending on the particular floodplain, although there is a history of deposition in the floodplain formation.

Laurentian-Acadian Acidic Swamp: These forested wetlands are found in the temperate northeastern and north-central U.S., primarily in glaciated regions in the Laurentian-Acadian region. They occur on mineral soils that are nutrient-poor. There may be an organic epipedon, but the substrate is not deep peat. These basin wetlands remain saturated for all or nearly all of the growing season, and may have standing water seasonally. There may be some seepage influence, especially near the periphery. Red maple, ash species, red spruce (*Picea rubens*), balsam fir (*Abies balsamea*), and rarely black spruce (*Picea mariana*) are the most typical trees. The herbaceous and shrub layers tend to be fairly species-poor. Mountain holly (*Nemopanthus mucronatus*) and fern (*Osmunda* spp.) are typical shrub and herb species.

Eastern Boreal Semi-Treed Bog: These peatlands are found at the higher temperate and near-boreal latitudes of the northeastern and north-central U.S. and adjacent parts of Canada. Climate allows the rate of peat accumulation to exceed its decomposition, resulting in ombrotrophic and acidic peatlands in which the bog surface is raised above the water table. The surface morphology of the bog may be more-or-less level, domed, or eccentric. The vegetation is dominated by low ericaceous shrubs, including Sheep laurel (*Kalmia angustifolia*), bog laurel (*Kalmia polifolia*), Labrador tea (*Ledum groenlandicum*), and leatherleaf (*Chamaedaphne calyculata*), with patches of conifers, graminoids and bryophyte lawns.

Secondary bog pools may be present. While the raised portion defines these bogs, fen vegetation is usually present along the perimeter. At Acadia, where this type is listed, the stands may more accurately be defined as Laurentian-Acadian Acidic Swamp (see above). Further review is needed.
*North-Central Appalachian Acidic Swamp***:** These swamps are distributed through the Central Appalachians south to Virginia. They are found in basins, or on gently sloping seepage lowlands. The acidic substrate is mineral soil, often with a component of organic muck; if peat is present, it usually forms an organic epipedon over the mineral soil rather than a true peat substrate. Eastern hemlock (*Tsuga canadensis*) is usually present and may be dominant. It is often mixed with deciduous wetland trees such as red maple or blackgum (*Nyssa sylvatica*). *Sphagnum* is an important component of the bryoid layer. Basin swamps tend to be more nutrient-poor and less species-rich than seepage swamps; in some settings, the two occur adjacent to each other with the basin swamp vegetation surrounded by seepage swamp vegetation on its upland periphery.

Temperate & Boreal Bog & Fen

Acadian Maritime Bog: These ombrotrophic acidic peatlands occur along the northern Atlantic coast from Downeast Maine east into the Canadian maritimes. When these systems form in basins, they develop raised plateaus with undulating sedge and dwarf-shrub vegetation. Tufted leafless-bullrush (*Trichophorum caespitosum*) may form sedge lawns on the raised plateau. The system may also occur as "blanket bogs" over a sloping rocky substrate in extreme maritime settings; here, dwarf-shrubs and *Sphagnum* are the dominant cover. Species characteristic of this maritime setting include common crowberry (*Empetrum nigrum*) and cloudberry (*Rubus chamaemorus*). Typical bog heaths such as sheep laurel, bog laurel, black huckleberry (*Gaylussacia baccata*), Labrador tea, and dwarf huckelberry (*Gaylussacia dumosa*) are also present. Morphological characteristics and certain coastal species distinguish these from more inland raised bogs. The distribution is primarily Canadian, and these peatlands are rare in the U.S.

Laurentian-Acadian Acidic Basin Fen: These peatland systems range over a broad geographic area across the glaciated northeast to the Great Lakes and upper Midwest. The fens have developed in open or closed, relatively shallow basins with nutrient-poor and acidic conditions. Many occur in association with larger lakes or streams. The substrate is *Sphagnum*, and vegetation typically includes areas of graminoid and dwarf-shrub dominance. Leatherleaf is usually present and often dominant. Scattered stunted trees may be present. These fens often develop adjacent to open water. They lack the ribbed or reticulate microtopographical patterning of the patterned fen system.

Laurentian-Acadian Alkaline Fen: These fens, distributed across glaciated eastern and central North America, develop in open basins where bedrock or other substrate influence creates circumneutral to calcareous conditions. They are most abundant in areas of limestone bedrock, and widely scattered in areas where calcareous substrates are scarce. The vegetation may be graminoid-dominated, shrub-dominated, or a patchwork of the two; shrubby cinquefoil (*Dasiphora fruticosa ssp. floribunda*) is a common diagnostic shrub. The herbaceous flora is usually species-rich, and includes calciphilic graminoids and forbs. *Sphagnum* dominates the substrate; star campylium moss (*Campylium stellatum*) is an indicator bryophyte. The edge of the basin may be shallow to deep peat over a sloping substrate, where seepage waters provide nutrients.

Temperate & Boreal Freshwater Marsh

Laurentian-Acadian Wet Meadow-Shrub Swamp and Marsh: These systems encompass shrub swamps and herbaceous emergent to submergent mineral-soil wetlands of the Northeast and upper Midwest. They are often associated with lakes and ponds, but are also found along streams, where the water level does not fluctuate greatly. The size of occurrences ranges from small pockets to extensive acreages. The emergent wetlands often have a patchwork of shrub and graminoid dominance; typical species include speckled alder (*Alnus incana*), white meadowsweet (*Spiraea alba*), sweetgale (*Myrica gale*), bluejoint (*Calamagrostis Canadensis*), tall sedge (*Carex* spp.), and *Juncus effusus*. Trees are generally absent and, if present, are scattered. Submergent wetlands include a variety of macrophytes, often with a border of non-persistent emergent vegetation dominated by pickerelweed (*Pontederia cordata*). The submergent vegetation zones may be severely impacted by non-native invasive aquatics including Eurasian water milfoil (*Myriophyllum spicatum*) and others.

Northeast Vernal Pools: Vernal pools are temporary bodies of fresh water inhabited by many species of wildlife, some of which are totally dependent on the pools for their survival. They are often smaller than 2 ha in size, and difficult to map because they typically occur as depressions within upland forests. These temporary freshwater pools provide critical habitats for breeding populations of amphibians and invertebrates dependent upon fishless environments for successful recruitment. Periodic drying of vernal pools eliminates fish populations and breeding populations of other predators such as bullfrogs (*Rana catesbeiana* Shaw) and green frogs (*Rana clamitans* Latreille). Thus, vernal pools provide an unusual low predation environment for many amphibians. In northeastern North America, vernal pools are typically found in upland forest and floodplain depression systems that are filled by spring rains, snowmelt, or seasonally raised water tables. Candidate systems within the Northeast Temperate Network where vernal pools may occur include the following: Laurentian-Acadian Floodplain Forest, Central Appalachian Floodplain, Acadian Lowland Spruce-Fir-Hardwood Forest, Laurentian-Acadian Northern Hardwood Forest, Laurentian-Acadian Pine-Hemlock-Hardwood Forest, and Appalachian Hemlock-Hardwood Forest.

Field-Based Metrics for Assessing Wetland Ecological Integrity

Overview of Rapid Metrics

We compiled a list of indicators/metrics of condition for freshwater wetlands that covered the five major attributes: landscape context, size, biota, hydrology, and soils/physicochemistry (Figures 1 and 2), and which should reflect wetland composition, structure, and function (pattern and process). Because the same metrics apply to salt marshes, we retain information about metric variants appropriate to them in order to document metrics appropriate for monitoring all park wetlands.

We first developed the criteria for the metrics at the broadest possible level: all freshwater wetlands. We then assessed whether some metrics needed "variants" based on the special characteristics of certain wetland formations, such as bogs and fens versus marshes. Finally, we asked whether certain systems might need more specific versions of these metrics. We are still reviewing this final step.

A synopsis of the ecological metrics and ratings for freshwater wetlands is presented in Table 2, which is adapted from Faber-Langendoen et al. (2008a). Table 2 provides a brief overview and definition of each metric. Table 3 provides the details on the ratings for each metric, including variants for the metrics based on wetland types. For example, when rating Hydroperiod, three separate ratings are provided: (1) Non-riverine wetlands (excluding Bog and Fen), (2) Bog and Fen, and (3) Riverine.

Metrics are 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). They should also show a known response to anthropogenic stressors. *Stressor metrics* are used to measure activities or structures which are known or hypothesized to degrade the condition of the system. For example, measuring changes in water quality is a condition metric, whereas measuring the number of water diversions in the watershed of a wetland is a stressor metric. In addition to stressor metrics, we provide a *stressors checklist* that can help field crews assess the overall set of stressors found at a site. As noted in the section on Ecological Integrety, and as reflected in the conceptual model for wetlands, we keep condition and stressor metrics separate in order to be able to assess stressor-ecological response relationships (Kapos et al. 2002).

The background, methods, and rationale for each metric are provided in the Protocols Section. A rating is developed, from excellent to poor, usually in a 4-category scale from A (Excellent) to D (Poor). Sometimes, a 3- or 5-category scale is used, depending on how sensitive the metric is to the effects of various stressors. Ratings and thresholds are provided as prototypes, and will be refined as the metrics are field tested and validated. Some metrics, such as vegetation structure, rely on knowledge of *reference standard condition* (see Section on Selection of Wetland Integrity Metrics).

For each metric, data are collected based on field or office observation data, and those data are recorded. These metrics are designed to be rapid; that is, it should be possible to assess a wetland within two hours, plus two hours preparation time assessing the imagery. 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. Usually, once the crew leaves the field, the field forms are essentially complete. Unlike intensive metrics, there rarely are samples that require further analysis, and the data analysis is built into the rating system. There is never any need for intensive equipment-based measures.

Table 2. Overview of rapid field-based (Level 2) metrics for assessing wetland integrity.

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	1,2	C	An index of the overall area and condition of the buffer immediately surrounding the wetland, using 3 measures: (1) Percent of Wetland with Buffer, (2) Average Buffer Width (with slope correction), and (3) 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 (ha)	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.
		Absolute 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	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.

Table 2. Overview of rapid field-based (Level 2) metrics for assessing wetland integrity (continued).

Major Attribute	Key Ecological Attribute	Metric Name	Tier	Metric Type	Metrics Definition
	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.
		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).
	Soil (Physicochemical) Stressors	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 (Physicochemical) Stressors Checklist	2	S	A checklist of stressors that could affect soils and physicochemical condition.

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 3. Adapted from Faber-Langendoen et al. (2008a) to show only wetland types found at NETN.

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity.

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 f or "1-sided" sites (>90%).
	Buffer Index:	1,2	C				
	Length			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.

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
	Surrounding Land Use Index	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
	Non-tidal 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 changed from, its current natural extent (<95%). Changes 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 clear cutting)	Occurrence is only modestly changed from its current extent (80-95% or more). Changes can include (see A).	Occurrence is substantially changed from its natural extent (50-80%). Changes can include (see A).	Occurrence is heavily changed from its original extent (>50%). Changes can include (see A).
	Absolute 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).

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

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			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.

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
	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)	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).
	Floodplain & Swamp Forest						
	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, & 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 littler. 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

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
	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	S	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				

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

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 storm drains 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. 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).

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
	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						
	Estuary			Area is subject to the full tidal prism, with two daily tidal minima and maxima.	Area is subject to reduced, or muted, tidal prism, although two daily minima and maxima are observed.	Area is subject to muted tidal prism, with tidal fluctuations evident only in relation to extreme daily highs or spring tides.	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 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.	Area is subject to full tidal range more often than would be expected under natural circumstances, because of artificial breaching of the tidal barrier.	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.	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 Section II.E.4).	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 Section II.E.4).	There is evidence of severe aggradation or degradation of most of the channel through the site (based on the field indicators listed in Section II.E.4)	D: Concrete, or otherwise artificially hardened, channels through most of the site (based on the field indicators listed in Section II.E.4).

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
	Hydrologic Connectivity All non-riverine wetlands, excluding Bogs & other isolated wetlands, Salt Marsh (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 in 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.

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
	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, onsite, or nearby downstream water diversions present	Few diversions present or impacts from diversions minor relative to contributing watershed size. Onsite 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.
	Hydrologic Stressors Checklist	2	S				
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).

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
	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.
	Salt marsh			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. (Excessive animal grazing?)	Extensive bare soils caused by erosion of marsh and channel banks due to excavation by marine traffic. (Excessive animal grazing?)

Table 3. Summary of ratings for rapid field-based (Level 2) metrics used to assess wetland integrity (continued).

Major Attribute	Metric Name	Tier	Metric Type	Metric Rating Criteria			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
	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 (Physicochemical) Stressors Checklist	2	S				

Tier: 1 = Remote sensing based metric, 2 = Rapid field based metric. Metric Type: C = condition metric, and S = stressor metric or checklist (grey cells). Shaded rows contain metrics that are not used directly to assess integrity, but are considered informative). References to "riverine" etc follow standard HGM definitions. Detailed protocols for each metric are provided separately in the Section on Rapid Field Metric Descriptions. Adapted from Faber-Langendoen et al. (2008a) to show only wetland types found at NETN.

Stressor Checklist

Stressor checklists can be useful as additional information when evaluating the ecological integrity of an occurrence (Kapos et al. 2002). 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 only be done in exceptional circumstances. The need for manual over-rides may suggest that the current condition metrics may be insensitive to degradation due to certain stressors, and future adjustments to the metrics used may be needed.

Stressors are listed if they are observed or inferred to occur, but are not included if they are projected to occur in the near term, but do not yet occur. Stressors may be characterized in terms of scope and severity. **Scope** is defined as the proportion of the occurrence of an ecosystem that can reasonably be expected to be affected (that is, subject to one or more stresses) by the threat with continuation of current circumstances and trends. Within the scope (as defined spatially and temporally in assessing the scope of the threat**), severity** is the level of damage to the ecosystem from the threat that can reasonably be expected with continuation of current circumstances and trends by excluding potential new threats). For ecosystems, severity is typically assessed by known or inferred degree of degradation or decline in integrity to one or more key ecological attributes.

Instructions for assessing Stressors are provided in the Table 4. A The stressor checklists are provided in Table 5.

Table 4. Instructions for using the Stressors Checklists (the following guidance is under review, and is adapted from Master et al. (2009)).

1. Record an estimate of the scope and severity for applicable individual stressors/threats to the ecosystem.[see Stressors Checklist]	Threat Scope (typically assessed within a 10-year time frame)	*Pervasive* = Affects all or most (71-100%) of total occurrence *Large* = Affects much (31-70%) of the total occurrence *Restricted* = Affects some (11-30%) of the total occurrence *Small* = Affects a small (1-10%) proportion of the total occurrence
	Threat Severity (within the scope; *assessed within max of 10 yrs)*	*Extreme* = likely to extremely degrade/destroy or eliminate occurrence (71-100%) *Serious* = likely to seriously degrade/reduce occurrence (31-70%) *Moderate* = likely to moderately degrade/reduce occurrence (11-30%) *Slight* = likely to only slightly degrade/reduce occurrence (1-10%)

2. The Impact of each Stressor/Threat is calculated automatically from the Scope and Severity values (*right*), and a letter grade is assigned (*below, right*).

Threat Impact Calculation		Scope			
		Pervasive	Large	Restricted	Small
Severity	Extreme	Very High	High	Medium	Low
	Serious	High	High	Medium	Low
	Moderate	Medium	Medium	Low	Low
	Slight	Low	Low	Low	Low

Threat Impact

A = Very High
B = High
C = Medium
D = Low

Table 4. Instructions for using the Stressors Checklists (the following guidance is under review, and is adapted from Master et al. (2009)) (continued).

3. After Impact has been recorded for all applicable stressors/threats, use these impact values to calculate an overall threat impact for the major ecosystem attribute (landscape context, vegetation, soils, hydrology) according to the categories below. Professional judgment is used to assign an Overall Threat Impact for each Major Ecological Attribute [an automated procedure may be made available in the future].

If the value for one or more impacts is a range, evaluate the highest (single and range) values for every threat and then evaluate the lowest values to determine the range of overall threat impact. For example, three Medium-Low impacts could indicates an overall threat impact of High–Low, and four Medium-Low impacts indicates an overall threat impact of High-Medium.

Impact Values of Stressor Categories	1 or more Very High, OR
	2 or more High, OR
	1 High + 2 or more Medium
	1 High, OR
	3 or more Medium, *OR*
	2 Medium + 2 Low, *OR*
	1 Medium + 3 or more Low
	1 Medium, or 4 or more Low
	1 to 3 Low

4. After Impact has been recorded for the major ecological attributes, use these impact values to calculate an overall threat impact to the occurrence, [guidance is needed].

If the value for one or more major ecological attributes is a range, evaluate the highest (single and range) values for every major attribute and then evaluate the lowest values to determine the range of overall threat impact. For example, three Medium-Low impacts indicates an overall threat impact of High–Low, and four Medium-Low impacts indicates an overall threat impact of High-Medium.

Table 5. Stressor Checklist Worksheets for Assessment Area (site). Checklist adapted from Collins et al. (2006).

HYDROLOGY	**Scope**	**Severity**	**Impact**
Point Source (PS) Discharges (POTW, other non-stormwater discharge)			
Non-point Source (Non-PS) Discharges (urban runoff, farm drainage)			
Flow diversions or unnatural inflows			
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			
Ditches (borrow, agricultural drainage, mosquito control, etc.)			
Actively managed hydrology			
Comments			
SOILS (PHYSICOCHEMISTRY)	**Scope**	**Severity**	**Impact**
Filling or dumping of sediment or soils (N/A for restoration areas)			
Grading/compaction/road (N/A for restoration areas)			
Plowing/Discing (N/A for restoration areas)			
Resource extraction (sediment, gravel, oil and/or gas, peat, logging)			
Vegetation management			
Excessive sediment (erosion) or organic debris from watershed			
Excessive runoff from watershed			
Nutrient impaired (PS or Non-PS pollution)			
Heavy metal impaired (PS or Non-PS pollution)			
Pesticides or trace organics impaired (PS or Non-PS pollution)			
Bacteria and pathogens impaired (PS or Non-PS pollution)			
Trash or refuse			
Comments			
VEGETATION	**Scope**	**Severity**	**Impact**
Mowing (within site)			
Livestock grazing			
Excessive herbivory (within site)			
Excessive human visitation			
Predation and habitat destruction by non-native vertebrates (e.g., domestic predators, such as feral pets)			
Tree cutting/sapling removal			
Removal of woody debris			
Treatment of non-native and nuisance plant species			
Pesticide application or vector control			
Evidence of fire			
Evidence of flood			
Biological resource extraction or stocking (fisheries, aquaculture)			
Excessive organic debris in matrix (for vernal pools)			
Lack of vegetation management to conserve natural resources			
Invasives (animals, pathogens) [see also Invasive Exotics metric for plants] *			
Lack of appropriate treatment of invasive plant species adjacent to site or buffer			
Comments			
ADJACENT LAND USE	**Scope**	**Severity**	
Urban residential			
Industrial/commercial			
Military training/Air traffic			
Dryland farming			
Intensive row-crop agriculture			
Orchards/nurseries			
Commercial feedlots			
Dairies			
Ranching (enclosed livestock grazing or horse paddock or feedlot)			
Transportation corridor			
Distance to nearest transportation corridor or road (measure)	**Distance**		
Rangeland (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 (rock, sediment, oil/gas)			
Biological resource extraction (aquaculture, commercial fisheries)			
Boat traffic (frequency and distance from site)			
Comments			

Overview of Intensive Metrics

At this time, intensive metrics are still under development. Neckles et al. (2007) provide a series of metrics focused on wet meadows and fens. These metrics will need to be extended to cover all wetlands. A summary of possible metrics is provided in Table 6.

Table 6. Overview of a draft set of intensive field based metrics for assessing freshwater wetland integrity. Metric Type: C = condition based metric, and S = stressor metric.

Category	Key Ecological Attribute	Metric Name	Tier	Metric Type	Metrics Definition
Landscape Context & Size		(Metrics could be taken from Level 2 assessment)			
Biota	Community Structure	Vegetation Structure	3	C	A measure of the overall structural complexity of the vegetation layers, including presence of multiple strata, age and structural complexity of canopy layer.
		Organic Matter Accumulation (coarse and fine debris)	3	C	A measure 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	Floristic Quality Index	3	C	A measure of the mean conservatism of all the native species growing in the wetland. The index reflects increasing sensitivity of plant species to human disturbance.
		Invasive Exotic Plant Species	3	S	A measure of the percent cover of a set of exotic plant species that are considered invasive. Similar to rapid assessment metric, but measured quantitatively
Hydrology	Hydrological Regime	Index of Hydrological Alteration	3	C	This metric uses daily stream flow data to determine trends at one site or determine differences between pre- and post-impacts of sites.
		Surface Water Level	3	C	A measure of the change in surface water level over time.
		Groundwater Level	2	C	A measure of the changes in ground water level over time.
Soils/ Physicochemestry	Physical Structure	Bank Stability	3	C	This metric assesses the stability and condition of the streambanks.
		Soil Bulk Density		C	Soil bulk density is a ratio of the mass/volume of the soil. This metric measures compaction of soil horizons.
	Water Chemistry	Water Quality	3	C	Consult with Freshwater Team.
		pH (surface water, groundwater)	3	C	A measure of the status and trend in acidity of both the surface water and the ground water.
		Conductivity (surface water, groundwater)	3	C	A measure of the status and trend in conductivity of both the surface water and the ground water.
	Soil Chemistry	Soil Organic Carbon	3	C	This metric measures the amount of soil organic carbon present in the soil.

Wetland Integrity Scorecard

Introduction

It is challenging to integrate or summarize indicators into indices that highlight the overall condition of ecosystems and help guide management decisions. This challenge is part of a larger need to develop meaningful indices of terrestrial and wetland ecological integrity (Andreasen et al. 2001), akin to Karr's Index of Biotic Integrity (IBI) for aquatic systems (Karr and Chu 1999). Properly constructed, such indices can be useful as an early warning system for ecological degradation and for priority setting among degraded systems, or for protection of those in more pristine condition. These indices should be useable both for assessments, where a snapshot of the current condition is taken, and for monitoring, where changes in condition are tracked over time (Andreasen et al. 2001).

Individual metrics can be aggregated to provide a rating of the condition of each the major ecological attributes - landscape context, size, biota, hydrology, and physicochemical condition (aggregating by key ecological attribute is typically not needed, as they often have only one or two metrics). The categories 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 (see Section F).

A Point-Based Approach

In our point-based approach, the following assumptions are made: each metric is treated independently and assigned a rating, which is then converted to a score. For each metric, the scaling is attempting to establish a rating for degree of degradation. Essentially, every A rating means the same thing – the ecological attribute is well within its natural or acceptable range of variation. Thus, a rating of A is reflective of a "higher" score than a rating of B, even though a letter rating does not indicate the magnitude of the difference between A or B (i.e., if instead of A we said "95" and instead of C, we stated "71," we would know they were 24 units apart). Since the exact mathematical distribution of the A or B ratings is not defined, the values cannot meaningfully be added, subtracted, etc. None-the-less, in a well constructed set of metrics, we have explicitly attempted to scale what is meant by A, B, C and D within and across metrics.

Thus, although ordinal scales provide less resolution and, to some degree, make it harder to combine metrics, they are more easily justified in terms of biological, ecological, and mathematical criteria. 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 aggregation helps provide users with a readily interpretable set of indices that highlight the integrity of major attributes of the system. 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 95 is better than an A of 89). In addition, the original metrics themselves are available to further explain the reasons for the aggregated scores.

When aggregating metrics or categories, an arithmetic mean can be calculated which assumes all categories have an equal weight and contribution to the overall integrity index. One could also weight

some metrics or major attributes 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 attributes define a particular level of integrity.

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 (IBI) approach (Karr and Chu 1999), where 5 (good), 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 by major ecological attribute, and in turn, these attributes are rolled up into an overall Index of Ecological Integrity (IEI).

Addressing Uncertainty when Assessing Metrics

There are times when it may be difficult to assign a rating value to a metric. Rather than be forced to assign an exact value, it may be valuable to record the level of uncertainly by using a "range-rating." That is, an assessor may not be able to decide between an A and 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 major attribute. A similar approach can be used for the overall IEI. The use of range-ranks 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

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 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 adjusted by wetland formation (see Table 1).

The Rapid Assessment Ecological Integrity Scorecard

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. Second, each rating for a metric is assigned a point value with A = 5 points, B = 4 points, etc. 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 1 = 4). The weighted scores for all metrics within a major attribute (e.g., Landscape Context) are then summed and divided by the sum of the weights, giving a weighted average score. Finally, the weighted average of each attribute can be summed and divided by the total number of attributes (or if the attributes themselves are also weighted, then the division would be based on the weighted sum of those attributes). The point-based approach is consistent with that of many IBI scoring methods (e.g., Karr and Chu 1999).

Landscape Context

Rate the Landscape Context metrics according to their specified ratings (see Table 3). Use the scoring table below (Table 7) to roll up the metrics into an overall Landscape Context rating.

Rational for Scoring: Three metrics are judged equally important.

Size

Rate the size metrics according to their specified ratings (see Table 3). Use the scoring table below (Table 7) 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 carries less weight than current absolute size. The focus is on current condition, not historic patterns per se.

Table 7. Landscape Context rating calculation for wetlands in the Northeast Temperate Network.

Metric	A*	B	C	D	Weight	Weighted Score
Landscape Connectivity	5	4	3	1	1	
Buffer Index	5	4	3	1	1	
Surrounding Land Use	5	4	3	1	1	
					∑ = sum of weights	∑ = sum of weighted scores Score = (sum of weighted scores / sum of weights)

* Landscape Context Rating: A = 4.5 – 5.0; B = 3.5 – 4.4, C = 2.5 – 3.4; D = 1.0 – 2.4

Table 8. Size rating* calculation for wetlands in the Northeast Temperate Network.

Metric	A	B	C	D	Weight	Weighted Score
Absolute Patch Size (ha)**	5	4	3	1	1	
Patch Size Condition (ha)**		5	3	1	0.5	
					∑ = sum of weights	∑ = sum of weighted scores Score = (sum of weighted scores/sum of weights)

* Size Rating: A = 4.5-5.0; B = 3.5-4.4; C = 2.5-3.4; D = 1.0-2.4
** optional metric

Vegetation (Biota)

Rate the vegetation metrics according to their specified ratings (see Table 3). The scoring table below (Table 9) is used 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 (vegetation) integrity.

Hydrology

Rate the metrics according to their specified ratings (see Table 3). Use the scoring table below (Table 10) 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 hydrologic integrity.

Soils (Physicochemistry)

Rate the physicochemistry metrics according to their specified ratings (see Table 3). Use the scoring table below (Table 11) to roll up the metrics into an overall physicochemistry rating.

Rationale for Scoring: *Physical patch types* is weighted less heavily than the other two metrics because it is not yet clear how much diversity of patch types is an inherent property of ecological integrity. Water quality may be difficult to observe in the field for floodplain and for bog and fen systems, where standing water is often not present.

Table 9. Vegetation (Biota) rating* calculation for wetlands in the Northeast Temperate Network.

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

*Vegetation (Biota) Rating: A = 4.5–5.0; B = 3.5–4.4; C = 2.5–3.4; D = 1.0–2.4

Table 10. Hydrology rating* calculation for wetlands in the Northeast Temperate Network.

Metric	A	B	C	D	Weight	Score
Water Source	5	4	3	1	1	
Hydroperiod	5	4	3	1	1	
Hydrologic Connectivity	5	4	3	1	1	
					∑ = sum of weights	∑ = sum of weighted scores Score = (sum of weighted scores / sum of weights)

*Hydrology Rating: A = 4.5–5.0; B = 3.5–4.4; C = 2.5–3.4; D = 1.0–2.4

Table 11. Soils (Physicochemistry) rating* calculation for wetlands in the Northeast Temperate Network.

Metric	A	B	C	D	Weight	Weighted Score
Physical Patch Types		5	3	1	0.5	
Water Quality**	5	4	3	1	1	
Soil Surface Condition	5	4	3	1	1	
					∑ = sum of weights	∑ = sum of weighted scores Score = (sum of weighted scores / sum of weights)

* Soils (Physicochemistry) Rating: A = 4.5–5.0; B = 3.5–4.4; C = 2.5–3.4; D = 1.0–2.4
**optional metric

Overall Index of Ecological Integrity (IEI) Rank

The *overall index of ecological integrity* is based on a roll-up of the scores for each of the major ecological attributes (see scorecard metrics above). The table (Table 12) used to calculate overall ecological integrity is structured so that the score for each of the major attributes is provided, along with the overall index. Managers may find trends at both levels helpful when assessing the integrity of wetlands in their park.

Rationale for Scoring: Each of the major attributes is given a specific weight. In the current model, we weight size and soils less heavily than the other factors. Soils and size are down-weighted because at this time we are not as confident that the rapid metrics for these attributes can be as readily used to assess ecological integrity as metrics for the other attributes. In addition, consideration is being given to a rule for interactions between size and landscape context scores, whereby when landscape context scores are high (i.e., the wetland is found in an intact natural landscape), less weight is given to size, whereas as landscape context decreases in integrity, increasing weight is given to size.

An example is provided in Table 13. In this example, the Weighted Attribute Score column multiplies the attribute score (e.g., for size the attribute score is 6.5 / 1.5 = 4.3 by the weight (e.g. for size the weight is 0.5) to get a Weighted Attribute Score (e.g., for Size = 2.2). The weighted score is summed, as are the weights. The "Score" column is calculated by dividing the total sum of weighted attribute scores (in this example: 4.3+2.2+3.6+4.0+2.0 = 16.1) by the total sum of attribute weights (1+0.5+1+1+0.5 = 4).

The Intensive Assessment Ecological Integrity Scorecard

At this time, the development of intensive metrics is still preliminary, based in part on the work of Neckles et al. (2007) and others (Miller et al. 2006a, 2006b). Thus, the scorecard cannot yet be fully developed. Once the intensive metrics are agreed on and ratings for them are established, a scorecard can be generated. If the scorecards for the rapid and intensive metrics are structured in similar ways, it will be possible to evaluate the two sets of scores for comparable metrics and by major attribute to see how they compare.

Adapting the Methods Over Time

It is important to remember that our efforts to assess ecological integrity are approximations of our current understanding of these systems. In reality, ecosystems are far too complex to be fully represented by a suite of metrics and attributes. Moreover, our rapid 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 possible methods used in conducting our assessments, so that communication and understanding is fostered among people with different backgrounds, goals, and points of view.

Table 12. Overall IEI rank* calculation for wetlands in the Northeast Temperate Network.

Category	A	B	C	D	Weight	Weighted Score
Landscape Context	5	4	3	1	1	
Size	5	4	3	1	0.50	
Vegetation	5	4	3	1	1	
Hydrology	5	4	3	1	1	
Soils (Physicochemistry)	5	4	3	1	0.50	
					∑ = sum of weights	∑ = sum of weighted scores Score = (sum of weighted scores / sum of weights)

*IEI Rating: A = 4.5–5.0; B = 3.5–4.4; C = 2.5–3.4; D = 1.0–2.4

Table 13. Example of scores and ranks for metrics, factors, and the overall ecological integrity for a Level 2 Rapid Field-based Assessment.

	Major Attributes						
Metric	**Assigned Metric Rating**	**Assigned Metric Points**	**Weight (W)**	**Metric Score (M)**	**Weighted Attribute Score (WAS)**	**Rank Factor Score Rank**	**Index of Ecological Integrity**
Landscape Context					4.3 (4.3*1)	B	
Landscape Connectivity	A	5	1	5			
Buffer Index	B	4	1	4			
Surrounding Land Use	B	4	1	4			
			∑ = 3	∑ = 13			
Size					2.2 (4.3*0.5)	B	
Patch Size Condition	A	5	0.5	2.5			
Absolute Size	B	4	1	4			
			∑ = 1.5	∑ = 6.5			
Vegetation					3.6 (3.6*1)	B	
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 (4.0*1)	B	
Water Source	C	3	1	3			
Hydroperiod	B	4	1	4			
Hydrologic Connectivity	A	5	1	5			
			∑ = 3	∑ = 12			
Soils (Physicochemistry)					2.0 (4.0*0.5)	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			
∑ = 16.1 (4)							
Rating A = 4.5-5.0, B = 3.5-4.4, C = 2.5-3.4, D = 1.0-2.4						4.0	B

Sampling Design and Field Methods

Sampling Design

A sampling design is needed to implement both a rapid and an intensive wetland monitoring program; however, creating such a design is beyond the scope of this report. At this time, there is no established sampling design or field survey methods for NETN wetlands. It is possible that the rapid assessment protocol will be completed for all NETN wetlands–essentially a comprehensive survey. Otherwise a sampling design will be needed. What follows below are a series of observations and guidelines that may be helpful for designing a field survey protocol for NETN wetlands.

Overview of Sampling Methods

Field methods for applying ecological integrity assessments vary depending on the purpose of the assessment. Several general comments can be provided in the context of a rapid assessment. First, the level of inference must be established. There are perhaps three options: 1) Treat the entire set of wetland area as one population; 2) Treat all wetland polygons as one population; or 3) Stratify either 1 and 2 by some important variable, such as wetland type or ecoregion.

From a monitoring perspective, the first option is perhaps the most straightforward. A comprehensive map of the areas of wetland is required. A sampling design is used to select a set of points for monitoring. This approach would be the most similar to the forest sampling design. The level of inference is then most directly about "wetlands" overall, and one may not be able to infer much about particular wetland types or wetland areas.

The second and third options are commonly used for ecological surveys, where an occurrence of a wetland is defined for a site, either the entire wetland or a specific wetland type (e.g., Acadian Maritime Bog). Within the site or type, either the entire area or a subset is surveyed. They surveyed area is the Ecological Assessment Area (EAA). Accordingly, EAA can be defined as "the entire area, sub-area, or point of an occurrence of a wetland type." The level of inference may be about both wetlands overall and particular wetland types or wetland areas, but the analyses may be more complicated by the use of strata.

Regardless of the option chosen, there are multiple strategies for sampling the point or the occurrence: 1) conduct an assessment survey of the entire area of the occurrence (e.g., using a rapid qualitative assessment); 2) conduct an assessment survey of a typical sub-area(s) of the occurrence; or 3) collect data at a point (with specified radius) using one or more plots, placed in representative or unbiased locations. In all three cases, the intent is to assess the ecological integrity of a particular wetland occurrence.

Here, we discuss our methods using the third option (above), identifying particular wetland types within a wetland, and surveying the entire area of that wetland type within a particular wetland (i.e., a wetland occurrence);. The goal is to assess the integrity of this occurrence, irrespective of the property or management regime it may be found on, or its size. Note however that these methods can be easily adapted to the first option above[1].

[1] When combining a rapid assessment approach with an intensive approach, one method of sampling would be select points for monitoring, then use a 0.5 ha area around the point (equivalent to the EAA) for the rapid assessment (Jacobs 2003). To conduct an intensive assessment, a single 0.1 ha plot, with 4 or more subplots, could be used. Not all points may need intensive plots, reducing the cost of monitoring.

Some Guidelines for Field Methods

Six basic guidelines are provided below for conducting wetland assessments (from Faber-Langendoen et al. 2008a):

1) Determine where the occurrences of a wetland type are and classify them using the UNSNVC. Wetlands will be classified using the U.S. National Vegetation Classification (FGDC 2008), as well as using Ecological Systems (Comer et al. 2003) (see Table 1). Knowing the Formation and System will determine which metrics are used and the rating scheme for the metrics, in so far as these vary by formation. For example, assessing the Buffer metric of a freshwater marsh found along a river corridor requires a different form of the metric than for marshes found in depressions.

2) The field data collection protocols should be fairly standard, regardless of the intent of the survey, since the fundamental metrics of the IEI need to be included. Protocols for how to measure the metrics are briefly described in "Rapid Field Metrics". This documentation 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, (either the site or a fixed area); and recording qualitative or relatively simple semi-quantitative or quantitiatve measures (Jacobs 2003, Fennessey et al. 2007).

3) A field crew (two people) should be able to complete a rapid field assessment within two hours, plus two hours preparation time assessing the imagery (see #4 below). Once the crew leaves the field, the field forms are essentially complete.

   Field crew expertise should be akin to that needed for wetland delineation. In other words, 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) 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) including Digital Orthophoto Quadrangles (1 m resolution), GIS layers (e.g., 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 maps.

5) Vegetation plots can be subjectively or objectively 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.

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 (though the NPS vegetation maps may already provide this info, and field crews would be verifying the accuracy of the maps):

   i. Estimation of Wetland Boundaries. The first step is to map the wetland area. Readily observable ecological criteria such as vegetation, soil, and hydrological characteristics are

used to define wetland boundaries, regardless of whether they meet jurisdictional criteria for wetlands regulated under the Clean Water Act.

ii. 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 the delineation of the type boundaries in the field. Minimum map size criteria should be specified, and each patch of wetland type would be considered separate potential EAA or sub-EAA. If a patch is less than the minimum map size then it would be considered to be associated with internal variation of the type in which it is embedded.

i. 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 is 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 may result in distinct ecological differences. Some examples follow:

1) A heavily grazed wetland on one side of a fence line and ungrazed wetland on the other would result in two subunits of EAAs.

2) 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.

3) 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.

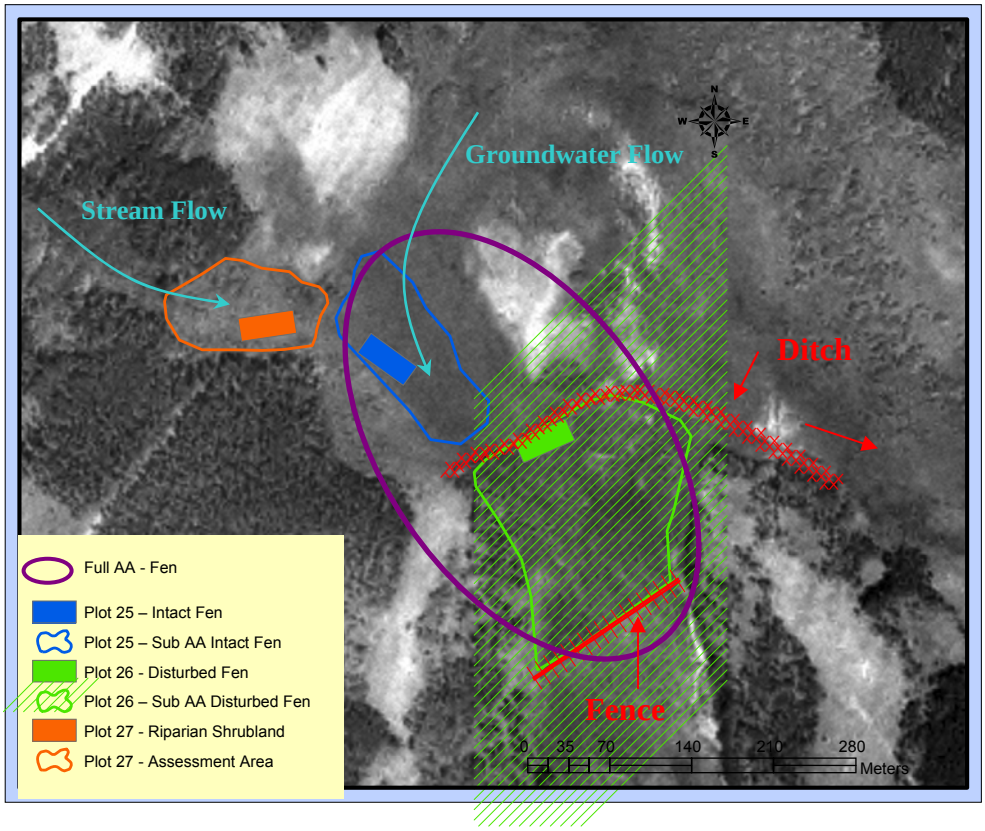

Figure 3. Example of Delineated Ecological Assessment Areas (EAAs). Although contiguous with each other, the fen and the riparian shrubland were delineated as distinct EAAs because either they were distinct ecological system types (e.g. fen vs. riparian shrubland). The fen was divided into sub-EAAs due 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.

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Rapid Field Metric Descriptions

Detailed descriptions are avalible for each metric in Faber-Langendoen et al. (2008a, Appendices), on the NatureServe website (www.natureserve.org). Note that a full set of protocols including plot design layout, sampling design, data management, etc. are beyond the scope of this report. Instead the descriptions for the metrics provide a foundation for a comprehensive protocol.

Appendix A. Field Form Requirements

Example Field Form

Biotic Composition—Vegetation Form

Table A.1. Field information needed to evaluate Vegetation Structure and Vegetation Composition.

Layer	Total Cover (%)	Exotic Cover (%)	Height*(m)	Most abundant species, and % cover of each (e.g., Acer rubrum (60%), etc.). In each layer, list all species or surfaces greater than 5**%,** including unknowns. *If tree layer, list ALL species.*	Live Stem: # ≥30(?) cm dbh			Snags: # ≥30 (?) cm dbh		
					30	40	≥50	30	40	≥50
Tree Layer										
Shrub Layer										
Sapling Layer										
Herb/Field Layer										
Non-vascular Layer (Moss, Lichen, Alga)										
Floating/Submerged Layer										
Unvegetated Surface										
Coarse Woody Debris				List # of large fallen stems by size classes in column to the right. Note # large stems > 30 cm in advanced** stages of decay:_____						

*Height is the predominant height of the main canopy, not of the tallest emergent.
**Advance decay =

Appendix B. Template for Metric Description

Metric A

Definition:

Background:

Metric Type:

Tier:

Rationale for Selection of the Variable:

Measurement Protocol:

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating			
Excellent	Good	Fair	Poor

Data:

Scaling Rationale:

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

Appendix C. Draft Set of Intensive Metrics for NETN Wetlands

In the course of compiling a rapid, level 2 assessment protocol, a number of intensive metrics were identified that may be relevant to a wide variety of wetlands in NETN. These could be considered along with the intensive metrics identified by Neckles et al. (2007) for assessing wet meadows and alkaline fens. Below are examples of such metrics.

Vegetation Metrics

Floristic Quality Assessment (Mean C)

Definition: The mean conservatism of all the native species growing in the wetland.

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

Metric Type: Condition

Tier: 3 (intensive field method)

Rationale for Selection of the Variable: Plants grow in habitats in which they are adapted to, including biotic and abiotic fluctuations associated with that habitat (Wilhelm and Masters 1995). However, when disturbances to that habitat exceed the natural range of variation (e.g. many human-induced disturbances), only those plants with wide ecological tolerance will survive and conservative species (e.g. those species with strong fidelity to habitat integrity) will decline or disappear according to the degree of human disturbance (Wilhelm and Masters 1995).

These observations can be combined into a "conservatism" (or C) index, whereby species with strong fidelity to habitat integrity are scored 10 and those with a very low integrity are scored 1. Exotics are either scored 0 or excluded. The average C value (xC) is then multiplied by the square root of site or total plot (or native) richness ($\sqrt{S}$) to produce the Floristic Quality Assessment Index (FQA) index, (also called the Floristic Quality Index, or FQI). The FQA index, originally developed for the Chicago region (Swink and Wilhelm 1979, 1994) is a plant community index designed to assess the degree of "naturalness" of an area based on the presence of species whose ecological tolerance are limited. FQA methods have been developed and successfully tested in Illinois (Swink and Wilhelm 1979), Missouri (Ladd 1993), Ohio (Andreas and Lichvar 1995), southern Ontario (Oldham et al. 1995), Michigan (Herman et al. 1996), Indiana (Coffee Creek Watershed Conservancy 2001), and North Dakota (Northern Great Plains Floristic Quality Assessment Panel 2001), but the exact form of the equation is still debated. Various authors have criticized the approach of combining the C value with the square root of richness (Bowles and Jones 2006), and recommend treating each separately, as done here.

Measurement Protocol: Species presence/absence data need to be collected from the wetland. Although quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the wetland system and make notes of each species encountered. A thorough search of each macro- and micro-habitat is required. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5

arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g., 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Peet et al. 1998, Mack 2004).

The metric is calculated by referencing only native species C value from a given state FQA Database, summing the C value, and dividing by the total number of native species (Mean C).

The Mean C is then used to determine the metric status in the scorecard.

Metric Rating: Specify the narrative and numerical ratings for a metric, from Excellent to Poor.

Metric Rating			
Excellent	Good	Fair	Poor
> 4.5	3.5-4.5	3.0 – 3.5	< 3.0

Data: Various state and provincial FQA Databases (*in development*)

Scaling Rationale: In the Midwest, field studies using FQA have determined that a site with a Mean C of 3.0 or less is unlikely to achieve higher C values, thus this value was used as the Restoration Threshold (between Fair and Poor) (Wilhelm and Masters 1995). In other words, those sites have been disturbed to the degree that conservative species are no longer able to survive and or compete with the less conservative species as a result of the changes to the soil and or hydrological processes on site. Sites with a Mean C of 3.5 or higher are considered to have at least marginal quality or integrity, thus this value was used as the Minimum Integrity Threshold (between Good and Fair) (Wilhelm and Masters 1995). The threshold between Excellent and Good was assigned based on best scientific judgment upon reviewing the FQA literature. As the FQA is applied in this region, the thresholds may change.

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

Vegetation Index of Biotic Integrity

Rather than being a specific metric, the Vegetation Index of Biotic Integrity draws on a series of measures of vegetation, including the floristic quality index, to assess Biotic Integrity. 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. Further details on the measure protocols are best described in Mack (2004).

Hydrological Metrics

Index of Hydrological Alteration

Definition: This metric uses daily streamflow data to determine trends at one site or determine differences between pre- and post-impacts of sites.

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

Metric Type: Condition

Tier: 3 (intensive field method)

Rationale for Selection of the Variable: The Index of Hydrological Alteration (IHA) is a readily available tool for calculating the characteristics of natural and altered hydrologic regimes using any type of daily hydrologic data, such as streamflows, river stages, ground water levels, etc. Rather than review the entire method here, please refer to http://www.freshwaters.org/tools to download the IHA software as well as supporting documentation, including numerous published papers.

Measurement Protocol: Long-term daily streamflow data are required for this metric. If those are not available daily flow data may be generated using a hydrologic model or other simulation method (see Richter et al. 1997). The IHA statistics will be meaningful only when calculated for a sufficiently long hydrologic record. The length of record necessary to obtain reliable comparisons is currently being researched, however it is recommended that at least twenty years of daily records be used (see Richter et al. 1997).

Some lake level and ground water well data are also available from the USGS, but much of this type of data is collected and managed by other local governmental entities.

Metric Rating: Specify the narrative and numerical ratings for a metric, from Excellent to Poor.

Metric Rating			
Excellent	Good	Fair	Poor
No significant change from Reference Hydrographs	Slight change from Reference Hydrographs	Moderate change from Reference Hydrographs	Large change from Reference Hydrographs

Data: The websites listed below provide data on hydrological metrics.

Index of Hydrologic Alteration Software and Supporting Documentation:
http://www.nature.org/initiatives/freshwater/conservationtools/

U.S. Geological Survey Streamflow Data: http://water.usgs.gov/usa/nwis. (data can be imported directly in the IHA).

The U.S. Forest Service, U.S. Bureau of Land Management, and local government agencies may have streamflow data for some of the streams located on the lands they manage.

Scaling Rationale: The scaling is based on best scientific judgment of deviation from the reference standard. Additional research may suggest changes to the scaling criteria.

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

Physiochemical Metrics

Bank Stability

Definition: This metric assesses the stability and condition of the streambanks.

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

Metric Type: Condition

Tier: 3 (intensive field method)

Rationale for Selection of the Variable: Unstable or eroding banks are often the results of local and/or upstream impacts associated with channel incision induced by over grazing and/or upstream alterations in the hydrological and/or sediment regimes. The local impact from eroding or unstable banks is typically a drop in the local water table along with a change in composition of plant species growing along the streambanks.

Measurement Protocol: This metric is measured by walking along the streambanks in the riparian area and observing signs of eroding and unstable banks. These signs include crumbling, unvegetated banks, exposed tree roots, exposed soil, as well as species composition of streamside plants (Prichard et al. 1998, Barbour et al. 1999). Stable streambanks are vegetated by native species that have extensive root masses (*Alnus incana*, *Salix* spp., *Populus* spp., *Betula* spp., *Carex* spp., *Juncus* spp., and some wetland grasses) (Prichard et al. 1998). In general, most plants with a Wetland Indicator Status of OBL (obligate) and FACW (facultative wetland) have root masses capable of stabilizing streambanks while most plants with FACU (facultative upland) or UPL (upland) do not (Reed 1988, Prichard et al. 1998).

Each bank is evaluated separately then averaged to assign the metric rating.

Metric Rating: Specify the narrative and numerical ratings for a metric, from Excellent to Poor.

Metric Rating			
Excellent	Good	Fair	Poor
Banks stable; evidence of erosion or bank failure absent or minimal; < 5% of bank affected. Streambanks dominated (> 90% cover) by Stabilizing Plant Species (OBL & FACW)	Mostly stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion. Streambanks have 75-90% cover of Stabilizing Plant Species (OBL & FACW)	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods. Streambanks have 60-75% cover of Stabilizing Plant Species (OBL & FACW)	Unstable; many eroded areas; "raw". Areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars. Streambanks have < 60% cover of Stabilizing Plant Species (OBL & FACW)

Data:
Wetland Indicator Status: U.S. Fish and Wildlife Service, National Wetlands Inventory website: http://www.nwi.fws.gov/plants.htm or USDA PLANTS Database: http://plants.usda.gov/

The Colorado Floristic Quality Assessment Database will also have Wetland Indicator Status information.

Scaling Rationale: The scaling is based on Barbour et al. (1999), Prichard et al. (1998), and best scientific judgment of deviation from the reference standard. Additional research may suggest changes to the scaling criteria.

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

Soil Organic Carbon

Definition: This metric measures the amount of soil organic carbon present in the soil.

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

Metric Type: Condition

Tier: 3 (intensive, field-based)

Rationale for Selection of the Variable: Soil organic matter or carbon generally refers to the organic fraction of the soil, including plant and animal residues at various stages of decomposition, as well as substances synthesized by the soil organisms (Neue 1984). Organic matter plays an extremely important role in the soil environment, including increasing water holding capacity, encouraging soil structure, plus it has a high cation exchange capacity and supplies essential nutrients (Brady 1990).

Soil organic carbon is a strong metric of soil quality due to its sensitivity to environmental disturbance (NRC 2000 *in* Fennessy et al. 2004). Given that soil organic carbon contributes to critical hydrologic, biogeochemical, and physical processes, a reduction in soil organic carbon from reference conditions serves as a strong indicator of loss of soil quality.

Measurement Protocol: Multiple soil pits should be dug in the wetland to a depth of at least 40 cm. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located within each of the intensive modules. At least five replicate soil samples should be taken within the top 10 cm of the soil surface in each pit. The replicates are mixed together as “one” sample from the site. Each soil sample should be placed in its own individual plastic bag, packed on ice, and sent to a laboratory for analysis of soil organic carbon.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating			
Excellent	Good	Fair	Poor
Soil C is equivalent to natural range of variability	Soil C is nearly equivalent to natural range of variability	Soil C is significantly lower than natural range of variability	Soil C is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference soil organic carbon levels need to be established in undisturbed wetlands. Thereafter, the scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established. Alternatively, if "baseline" soil organic carbon levels are known (from "pre-impact" conditions or from adjacent unaltered sites) then this metric can be used to determine change of soil organic carbon with time.

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

Soil Bulk Density

Definition: Soil bulk density is a ratio of the mass/volume of the soil. This metric is a measure of the compaction of the soil horizons.

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

Rationale for Selection of the Variable: Bulk density is a measure of the weight of the soil divided by its volume and provides an indication of the level of compaction. Compaction can result from any activity which compresses soil particles, thereby increasing the weight to volume ratio. This can reduce the soil's water holding capacity, infiltration rate, water movement through the soil, and limit plant growth by physically restricting root growth (NRCS 2001). Bulk density of organic soils are typically much less than those of mineral soils, however as decomposition increases and/or organic soils are compacted from human activity, bulk density of organic soils will increase. This has corresponding negative impacts on ecological processes such as water movement through the peat body, decomposition, and nutrient cycling.

Measurement Protocol: Multiple soil pits should be dug in the wetland to a depth of at least 40 cm. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located and samples collected within each of the intensive modules.

The samples are collected by taking a core sample within the top 15 cm of the soil. A cylinder of known volume should be used to collect samples. A PVC pipe of known dimensions will suffice. The cylinder is simply inserted into the soil profile, extracted, then shaved to eliminate any soil which is not contained within the cylinder. The soil remaining in the cylinder can then be placed into a plastic bag and then sent to a laboratory for analysis. Bulk density and soil texture (e.g., particle distribution) should be analyzed. Alternatively, texture can be determined in the field using the "field hand method;" however, lab analysis is preferable.

Once texture and bulk density are determined, use the information below to determine whether the soil's bulk density is less than, equal to, or greater then the minimum root-restricting bulk density values listed for the corresponding texture of the soil and assign the metric rating accordingly in the scorecard.

There are no root restricting values given for organic soils, thus if the wetland is dominated by organic soil, reference bulk density measurements need to be established in undisturbed areas.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating			
Excellent	Good	Fair	Poor
Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland.	Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. (same as Very Good)	Bulk density for wetland is between 0.2 to 0.1 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland.	Bulk density for wetland is = or > than Root Restricting Bulk Density value for the soil texture found in the wetland.

Data: The data below are derived from a Natural Resource Conservation Service, Soil Quality Information Sheet—Compaction which can be found online at: http://soils.usda.gov/sqi/publications/sqis.html, http://www.urbanext.uiuc.edu/soil/sq_info/RSQIS4.pdf, and http://soils.usda.gov/sqi/management/files/RSQIS4.pdf.

Theses texture classes have the following Root Restricting Bulk Density values (g/cm3):

1) Coarse, medium, and fine sand AND loamy sand other than loamy very fine sand = 1.8 g/cm3
2) Very fine sand, loamy very find sand = 1.77 g/cm3
3) Sandy loam = 1.75 g/cm3
4) Loam, sandy clay loam = 1.7 g/cm3
5) Clay loam = 1.65 g/cm3
6) Sandy clay = 1.6 g/cm3
7) Silt, silt loam = 1.55 g/cm3
8) Silty clay loam = 1.5 g/cm3
9) Silty clay = 1.45 g/cm3
10) Clay = 1.4 g/cm3

Scaling Rationale: The scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. However, no distinction was made between Excellent and Good as there is no information to suggest that threshold. Alternatively if "baseline" bulk density levels are known (from "pre-impact" conditions or from adjacent unaltered areas) then this metric can be used to determine change of bulk density with time.

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

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Appendix D. Vegetation Field Sampling

Although plot-based or area-based measurements are preferred, depending on time and financial constraints, this metric can also be measured using plot-less techniques. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the community type at the site and make notes on vegetation strata, their cover, and exotic species. (2) Quantitative Plot Data: Use a fixed area method. A variety of techniques are available, including line transects, transects with 20 or more small 0.25 – 1 m^2 quadrats laid along them, or fixed-area plot methods of 100 to 1000 m^2. Studies by Yorks and Dabydeen (1998) and Rocchio (2006) found that the transect method did not pick up most non-dominant species and therefore was biased toward dominant species and resulted in biased proportions for some guilds (graminoids, forbs, low levels of exotics, etc.). This can result in metrics which are less sensitive to changes resulting from human disturbances. Thus, the plot (or reléve) method is preferred.

The plot method may either be a "rapid plot" or a more intensive plot, following the 0.1 ha modular approach of Peet et al. (1998). The rapid plot incorporates some aspects of the intensive plot. For the rapid plot 1 or more 10 x 10 or 20 x 20 m plots may be systemically or randomly placed within the assessment area.

The plot method described by Peet et al. (1998) is a recommended approach for collecting quantitative vegetation data. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules, and provides a standard 0.1 ha sample area, a widely used standard for assessing species richness. However, the array of modules can be rearranged or reduced to meet site conditions (e.g., 1 x 5 for linear areas or 2 x 2 for small, circular sites). Species presence and cover is recorded in each of four modules. If time permits, the reset of the 50 x 20 m area can be surveyed for additional species to obtain a 0.1 ha sample. The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Peet et al. 1998, Mack 2004).

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