New Hampshire Natural Heritage Bureau
DRED – Division of Forests & Lands
PO Box 1856 – 172 Pembroke Road, Concord, NH 03302-1856
(603) 271-2215

Comparison of Alternative Wetland Assessment Methods at Numerous Sites in New Hampshire

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A Quick Overview of the NH Natural Heritage Bureau's Purpose and Policies

The New Hampshire Native Plant Protection Act (RSA 217-A) declared that native plants should be protected and conserved for human need and enjoyment, the interests of science, and the economy of the state. The state maintains and enhances populations of native plants to insure their perpetuation as viable ecosystem components.

The Natural Heritage Bureau administers the Native Plant Protection Act. Natural Heritage collects and analyzes data on the status, location, and distribution of rare or declining native plant species and exemplary natural communities in the state.

The Natural Heritage database contains information about more than 7,000 plant, animal, and natural community occurrences in New Hampshire.

In addition, Natural Heritage develops and implements measures for the protection, conservation, enhancement, and management of native New Hampshire plants. State agencies assist and cooperate with the Natural Heritage Bureau to carry out the purposes of the Native Plant Protection Act. The Natural Heritage Bureau also assists and advises the private sector upon request.

Cover: Garland Pond, Ossipee, NH.
(Photo by Ben Kimball)

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INTRODUCTION

The number of wetland rapid assessment methods has increased in recent years due to their ability to provide information on wetland condition and function with a comparatively small investment in resources. These field driven methods characterize condition and function using metrics and stressors that are relatively simple to evaluate. Condition based methods assess the degree a wetland deviates (if at all) from reference (undisturbed) sites. Function based methods assess a wetland's ability to provide individual ecological and societal services (i.e., perform particular functions). These rapid methods are used to inform conservation, local land use planning, regulation, restoration success, and mitigation compliance.

The New Hampshire Natural Heritage Bureau (NHB) has been contracted by the New Hampshire Department of Environmental Services (DES) to help collect and analyze field data using 3-5 alternative wetland assessment methods and to summarize a comparison of the methods in collaboration with staff at DES and UNH Cooperative Extension (UNHCE). Most or all of the following criteria will characterize each of the methods selected: 1) applicable for use in New Hampshire, 2) measures condition and/or function, 3) a rapid method (i.e., taking one person half a day or less for pre-field preparation and post-field analysis and half a day or less collecting data in the field), and 4) requires on-site visit.

The population of New Hampshire is growing rapidly. The state anticipates a 28 percent increase in population between 2000 and 2025. Wetlands in southeast New Hampshire are under increasingly intense development pressure. Eight towns have more than 20 percent of their land area in wetlands (Society for the Protection of New Hampshire Forests 2005). Available information on wetland type and quality is too coarse to guide effective conservation action, and there is limited information available on wetland significance, vulnerabilities, and current condition. Significant knowledge gaps limit the successful protection of critical, at-risk, and other priority wetlands. Better understanding the strengths and weaknesses of alternative wetland assessment methods will allow users to choose the method most appropriate for their purposes and in the process, help to fill in some of the existing knowledge gaps regarding wetland status and condition. This report summarizes this comparison of methods.

METHODS

The principal goal of this project was a comparison of alternative wetland assessment methods. NHB, in coordination with the DES and UNHCE, achieved this goal by:

1. Selecting wetland assessment methods to study.
2. Assessing relevant existing data.
3. Identifying wetlands suitable for field-based data collection.
4. Conducting concurrent and coterminous field assessments of wetlands using multiple methods.
5. Summarizing and comparing the assessment method's protocols and results.
6. Disseminating information to end users.

Selecting Wetland Assessment Methods to Study

Methods for assessing the condition and values of wetlands have proliferated due to the inherent value of water resources and the variety of agencies and organizations engaged in protecting water quality. These methods differ based on specific goals as well as protocols and outcomes. There is a need for objective means of comparing and selecting the most appropriate method for individual projects.

This project focused on Rapid Assessment Methods (RAMs), defined as requiring one person half a day or less for pre-field preparation and post-field analysis and half a day or less collecting data in the field (Fennessy et al. 2004). These characterize wetlands using a combination of existing data (e.g., soil maps and remote sensing data) and field surveys that collect relatively basic data, so that the total time investment per wetland is limited. Important distinctions between methods inherent in their design include:

1. Purpose of the assessment (i.e., condition vs. function).
2. Availability of relevant existing data.
3. Field measurements needed.
4. Degree of expertise required.
5. Indices and assessments produced.

Other important distinctions that can best be determined by field-based comparisons are:

1. Accuracy and reliability of existing data compared to field observations.
2. Inter-observer variability.
3. Time investment.
4. Agreement between indices intended to measure the same features.

The wetland assessment methods chosen for this study during an April 2012 work plan meeting attended by project members from NHB, DES, and UNHCE were:

- The Method for Inventorying and Evaluating Freshwater Wetlands in New Hampshire (NHM) (Stone and Mitchell 2011).
- USA RAM (Environmental Protection Agency 2011; New Hampshire Department of Environmental Services 2012).
- Ecological Integrity Assessment method (EIA) (Nichols and Faber-Langendoen 2012).
- Floristic Quality Assessment (FQA) (Bried et al. 2012).

Training for Field Staff

Training on the different rapid assessment methods was provided by NHB, DES, and UNH Cooperative Extension staff. NHB personnel provided an overview of EIA during a webinar, then later at a field-based RAM workshop (offered by NEIWPCC in Newburyport, Massachusetts). Field training on EIA (and FQA) was also provided by shadowing NHB staff at 2-3 sites where EIA was applied and during follow-up communications. UNH Cooperative Extension personnel (NHM authors) provided classroom and field trainings on NHM. DES personnel provided classroom and field training on USA RAM on two dates and a third additional classroom session.

Assessing Relevant Existing Data

The four wetland assessment methods chosen (NHM, USA RAM, EIA, and FQA) all require or benefit from pre-field office-based preparation using existing data sources. The project team evaluated existing data currently available for each method relative to its currency, resolution, accuracy, accessibility, and cost (including software requirements). The accuracy assessments included scores recorded by field surveyors during the actual field assessments of the methods.

Identifying Wetlands Suitable for Field-Based Data Collection

The goal of field surveys to be conducted for this project was to make comparisons between different wetland assessment methods. Given limited funds and time, it was important to limit uncontrolled differences between wetlands surveyed to those that are the highest priority for the methods comparisons. The efficiency and effectiveness of the project were also increased by using some sites recently visited in

2009 and 2010 for EPA Grant Project CD-97193901-0. Sites from the previous and current EPA project were located in central and southern New Hampshire.

Selecting some of the bog and fen sites from EPA Grant Project CD-97193901-0 combined with several other know peatlands with straightforward access and logistics provided a suite of sites with a range of conditions (A-D; preliminary ranking) and sizes, from less than one to 78 ha (Table 1). Limiting the wetlands assessed for this project to bogs and fens minimized uncontrolled variability between sites and resulted in better comparisons of methods.

Other advantages to bogs and fens include:

- These systems are more sensitive than other wetland types to nutrient and hydrologic change.
- Most of the vegetation is relatively easy to identify.
- Many of the peatlands selected from sites associated with the EPA Grant Project CD-97193901-0 and from other locations are clustered, so travel time would be reduced.

Table 1. List of 27 assessment sites.

System*	Survey Site	Pre-field Rank**	Hectares
Kettle hole bog system			
	Silver Lake, East of	AB	4
	White Lake State Park	AB	2
	Heath Pond Bog	B+	21
	Parker Pond	B+	19
	Lost Ponds	B	7
	Cedar Swamp Pond	B	4.5
	Spruce Hole Bog	B	0.8
	Merrimack Technology Park	C+	7
	Pennichuck Water Works Kettle	D	2
Medium level fen system			
	Garland Pond	AB	77
	Spruce Swamp	AB	10.5
	Powwow River	B+	78
	Cooks Pond Outlet	B	18.5
	Hinsman Pond	B	16
	Hall Mountain Marsh	B	14
	Clay Pond	BC	54
	Lovewell Pond	C+	10
	Musquash Swamp	C	18
Poor level fen/bog system			
	Odiorne Pond	B+	14.5
	Turee Pond	B	53
	Rochester Heath Bog	B	23
	Smith’s Pond	B	14
	Country Pond NE	B	4.5
	Powwow Pond	B	3

System*	Survey Site	Pre-field Rank**	Hectares
	Country Pond NE - AWC	B	2.5
	Pennichuck Pond	BC	5
	Lee Town Hall Bog	C	3

*Pre-field classification of system type.
**Preliminary ranking of system viability made before site visits (to be adjusted based on field surveys).

Conducting Concurrent and Coterminous Field Assessments of Wetlands Using Multiple Methods
Comparisons of results between methods were based on field assessments designed to reveal differences between the methods that are relevant to the overall goals of the study, while minimizing differences that are not inherent in the methodology. Wetland systems studied were peatlands that are relatively sensitive to anthropogenic disturbance. Twenty-seven sites have been selected to include a range of wetland size and quality. Whenever feasible, preparatory field materials for each of the methods used the same existing data. Field surveyors using different methods worked independently in the same wetlands.

NHB, the agency with the most experience using EIA, applied this method at all of the 27 assessment sites. Two surveyors from DES applied EIA at the three replicate sites in Kingston, NH. These replicate sites were used to document information on inter-observer variability. DES, the agency with the most experience using USA RAM, applied this method at all of the 27 assessment sites. Staff from NHB applied USA RAM at the three replicate sites. UNHCE applied NHM at five sites; two of the five sites, Lee Town Hall Bog and Powwow Pond, were pre-survey training sites for NHM and USA RAM. After training, DES and NHB staff then applied NHM at the remaining sites. This sampling strategy allowed us to better understand minimum experience level and other variables that may affect application of these methods and provide feedback important when comparing the strengths and weaknesses of each method. NHB staff collected species richness data at all 27 sites for FQA. DES collected species richness data at three of the 27 sites (the three replicate sites).

In addition, data was collected at five wetland mitigation sites (Table 5) using the same four assessment methods. To broaden the context of our comparisons, these data were analyzed with the data collected at the 27 peatland sites that were the primary focus of this study, EPA Grant Project CD-96155701. The mitigation sites were the primary focus of a related and concurrent study, EPA Grant Project CD-96155401.

Summarizing and Comparing the Assessment Methods Protocols and Results
NHB compared alternative wetland assessment methods through a combination of field application and research. The final report herein summarizes the strengths and weaknesses of the selected wetland assessment methods. Comparisons have been compiled in digital tables (MS Access and/or MS Excel). Preliminary tables compiled by NHB were distributed to appropriate project team members to solicit additional information and for quality control. During field assessments, standardized data sheets were used to record information focused on the ease and accuracy of the recorded observations (e.g., total time to complete tasks, clarity of instructions in the field, and degree of certainty in the data recorded). Tables of results include these strengths and limitations of each method as well as the actual indices generated by the field data. NHB ran quantitative comparisons between indices when appropriate, but most of the comparisons were qualitative. The final products guide users in selecting an appropriate method given their particular goals and constraints.

Disseminating Information to End Users

Summary tables of data collected and of comparisons between methods were stored in digital format (MS Access and/or MS Excel) and distributed to partners. Guidelines suitable for end users to apply when selecting a method for a particular purpose were posted in digital format (pdf) on the DES website.

NHB entered all new and updated exemplary wetland records documented during field surveys into the Biotics database. These exemplary wetland records inform wetland protection activities in many ways, including use by non-governmental conservation organizations and the environmental review process run by DES and NHB. NHB distributed results from the project to partners in digital formats. NHB posted digital versions of the report (pdf) on its website (www.nhnaturalheritage.org). Any improvements to the NHB classification of natural communities and systems made as a result of this project will be distributed to the public through the NHB website and future workshops. DES entered site specific data in its EMD which serves as the repository for all site related chemical, physical, and biological data for water monitoring programs.

Sampling Design

The project team (staff from NHB, DES, and UNHCE) conducted field surveys at 27 wetland sites. Because NHM does not use a vegetation classification to identify the overall wetland type, the assessment area used in this study was a single wetland system (following Sperduto 2011) to make the results comparable to EIA. Wetland complexes with two or more systems occurred at 11 of these sites. Normally, NHM would be applied to the entire contiguous wetland complex. Wetlands at the 27 sites include nine examples each of medium level fen, poor level fen/bog, and kettle hole bog systems (pre-field classification of system type). Within each system type are a range of preliminary wetland quality ranks (A–D) and sizes (less than one to 78 ha).

NHB produced maps depicting each wetland system and distribute them to DES and UNHCE field staff. The maps included GIS layers, e.g., National Wetlands Inventory and conservation land polygons displayed on USGS topographic maps (1:12,000). NHB also produced land use index maps for each site for application of EIA. DES staff also used to GIS imagery and related data layers for desktop reviews.

On any given field day, at any one site, field surveyors collected data following standard protocols for one or more of the four chosen wetland assessment methods: NHM, USA RAM, EIA, and FQA. Surveyors worked independently when surveying the same site. The preferred approach was to have experienced field personnel to apply each of the four wetland assessment methods to each of the wetland sites. However, due to funding and time constraints, some of the surveys were conducted by field staff who (a) are experienced botanists and (b) have been trained in the use of the method they will apply, but (c) do not have previous experience with other RAMs they will apply. The surveys were planned so that systems assessed by experienced field personnel for each method included a range of system types and quality ranks. Three replicate sites in Kingston, NH were used to document information on inter-observer variability. To minimize scoring variability at the three replicate sites due to inter-observer experience levels, non-replicate sites were completed first for those surveyors with additional sites. See Table 2 for additional survey plan details.

Table 2. Comparative wetland assessment survey plan for the 27 peatland sites. Italic font indicates surveyor(s) with the most experience with a particular method.

METHOD	**NHM**		**USA RAM**		**EIA**		**FQA**		
Surveyor	**Replicate***	**Non-Replicate**	**Replicate***	**Non-Replicate**	**Replicate***	**Non-Replicate**	**Replicate***	**Non-Replicate**	**Totals**
Bill Nichols[1]	3	6	3		***3***	13	***3***	13	**44**

METHOD	**NHM**		**USA RAM**		**EIA**		**FQA**		
Surveyor	**Replicate ***	**Non-Replicate**	**Replicate***	**Non-Replicate**	**Replicate***	**Non-Replicate**	**Replicate ***	**Non-Replicate**	**Totals**
Pete Bowman[1]	3	5	3		3	11	3	11	**39**
Melissa Coppola[1]	3	1			3		3		**10**
Sandi Mattfeldt[2]		6	3	10	3		3		**25**
Jen Drociak[2]				4					**4**
Kirsten Pulkinnen[2]		4		6					**10**
Sandy Crystall[2]	1		***3***	4	3		3		**14**
Ted Walsh[2]	2		***3***						**5**
Frank Mitchell[3]	***3***	2							**5**
Total Sites	**3**	**24**	**3**	**24**	**3**	**24**	**3**	**24**	**156**
Observations	**15**		**15**		**15**		**15**		

*Three replicate sites in Kingston, NH (Cedar Swamp Pond and two nearby peatlands at Country Pond NE).
[1]NHB surveyor; [2]DES surveyor; [3]UNHCE surveyor.

Sampling Methods
The project team evaluated peatland systems in central and southern New Hampshire using sampling protocols associated with selected wetland assessment methods. Selected methods were the NH Method, USA RAM, NHB Level 2 EIA, and Floristic Quality Assessment.

<u>NH Method</u>
The following description is adapted from Stone and Mitchell (2011):

The NH Method (NHM) is designed to function as a practical method for several audiences, including public officials, community volunteers, and professionals (wetland and non-wetland specialists), to use for inventorying and evaluating wetlands. It is intended to be relatively simple to use but still scientifically defensible. Appropriate uses of this method include:

1) Educating the public about the functions and values of wetlands.
2) Informing local land use decisions such as prime wetland designation or watershed planning.
3) Identifying potential restoration sites.
4) Providing the basis for more thorough assessments.

It can be applied to a single wetland or used to make relative comparisons among multiple wetlands. For each wetland evaluated, it generates 12 function scores (Ecological Integrity, Wetland-Dependent Wildlife Habitat, Fish & Aquatic Life Habitat, Scenic Quality, Educational Potential, Wetland-Based Recreation, Flood Storage, Groundwater Recharge, Sediment Trapping, Nutrient Trapping-Retention-Transformation, Shoreline Anchoring, and Noteworthiness). These scores are not meant to be combined into a single index for the wetland.

The first step in conducting a wetland assessment using NHM is to prepare a large scale wetland inventory map and a wetland-specific evaluation map. These maps are used to break large wetland systems into separate evaluation units as well as for logistics planning. The wetlands are then field checked to confirm and adjust the map data as well as to collect on-site observations. Standard data sheets are filled out, with each sheet providing guidelines on how to answer the questions and convert observations into numerical scores. After the scores are entered into a MS Excel spreadsheet, formulae in the spreadsheet convert the data into an average score for each function. A narrative description is also part of the final product from NHM.

This project used the 2011 revision of the method (Stone and Mitchell 2011). Instructions in the NHM manual were followed to develop preparatory maps, plan surveys, collect data, and calculate the function scores.

<u>USA RAM</u>

USA RAM was developed in 2011 to provide a rapid assessment method appropriate for use nationwide (Environmental Protection Agency 2011), and that can be further developed and refined as needed and appropriate. It was initially developed to be used during the 2011 National Wetland Condition Assessment (NWCA), a Level 3 (intensive field-based) wetland assessment effort. USA RAM focuses on the form and structure of wetlands, assuming that wetlands with more complex form and structure, and less stress, tend to have higher levels of ecological integrity. Individual metrics within a condition index are selected and organized to reflect a set of four core wetland attributes describing ecosystem structure and form (Table 3). One attribute reflects wetland hydrology as represented by water level fluctuation and connectivity to the other aquatic resources. Another attribute reflects physical structure as represented by topographic complexity and patch mosaic complexity in a wetland assessment area. The third attribute is biological structure of the wetland as expressed in terms of the vertical complexity of the vegetation community and overall plant community complexity. A fourth attribute termed buffer is also part of the condition index.

Stressor metrics within USA RAM are based on an assessment framework that assumes wetland exposure to anthropogenic disturbance will affect ecosystem condition. The magnitude of those effects is related to the proximity, intensity, and duration of stressors acting on the wetland in a cumulative way. These influences and their interactions cannot be assessed with a known level of certainty using USA RAM. Instead, USA RAM relies on an approach that classifies the number of human caused stressors that cause wetland degradation. The overall stress on a wetland is assessed as the number of evident stressors and their intensity. As the number of stressors increase, overall wetland condition declines. This relationship is assumed to hold true regardless of wetland class.

USA RAM can be applied to assess overall condition and stress for a wetland, defined as the “Assessment Area” (AA). Condition and stress are assessed separately for each of four attributes (Buffer, Hydrology, Physical Structure, and Biological Structure), based on unique metrics and their field indicators. The same attributes, metrics, and indicators are applied to every AA. Details on the modified USA RAM field protocol can be found in USA RAM manual (New Hampshire Department of Environmental Services 2012).

Table 3. USA RAM attributes, condition metrics, and stressor metrics.

Attributes	**Condition Metrics**	**Stressor Metrics**
Buffer	Percent of AA Having Buffer	Buffer Stressors

Attributes	Condition Metrics	Stressor Metrics
	Buffer Width	
Hydrology	Water Level Fluctuation	Water Quality Stressors
	Hydrological Connectivity	Alterations to Hydroperiod
Physical Structure	Topographic Complexity	Habitat/Substrate Alterations
	Patch Mosaic Complexity	
Biological Structure	Vertical Complexity	Percent Cover of Invasive Plants
	Plant Community Complexity	Vegetation Disturbance

This rapid assessment method uses presence/absence checklists and other semi-quantitative and narrative metrics that rely on best professional judgment and onsite evidence to measure aspects of the landscape, hydrology, physical structure, and biological structure to generate individual attribute and aggregate scores to reflect condition on the site. No USA RAM data were sent to a laboratory for further analysis; all metrics are based on field observations and GIS-based information.

After consultation with wetland assessment experts (Josh Collins, San Francisco Estuary Institute, pers. comm. 2012; Richard Sumner, USEPA-Corvallis, pers. comm. 2012), minor changes were made to apply USA RAM outside of the NWCA context. These changes, reflected in the revised manual and score sheets (New Hampshire Department of Environmental Services 2012), include:

- Applying the buffer metrics to the 100 m buffer around the wetland system (rather than around a 40 meter assessment area).
- Using one to three randomly selected assessment areas (depending on wetland size) to assess the wetland.
- A nonvascular plant category has been added to the Vertical Complexity metric on Form 5. On the same form, a percent coverage category of "absent" has been added for each stratum. We applied Landscape Metrics 1 and 2 to the wetland system in a manner similar to the original USA RAM. However, we did not follow the specific field protocol to field check the buffers along the radials. We field checked any areas that seemed inconsistent with the imagery we had reviewed.

Control measures to minimize measurement error among surveyors and sites included the use of standardized field protocols, consistent training, field assistance visits, and availability of experienced technical personnel during the field season to respond to site-specific questions from surveyors as they arise. Upon completion of sampling, the field surveyor(s) reviewed all USA RAM forms for completeness, legibility, and errors. Tables for scoring each metric are provided in the USA RAM manual (New Hampshire Department of Environmental Services 2012). In addition, digital photographs with views in the four cardinal directions were taken from the center point of each assessment area. A photo log was maintained to document the images and what they represent.

<u>NHB Level 2 EIA</u>

NHB's ecological integrity assessment method (EIA) builds on the historic approaches of NatureServe and the Network of Natural Heritage Programs to assessing condition. Earlier methods have been adapted by building on the variety of existing wetland rapid assessment methods, and the 3-level approach of EPA and others. The NHB EIA method emphasizes metrics that are condition-based, distinct from stressor-based approaches.

Characteristics of the NHB EIA include:

- Reliance on a general conceptual model that:
    - Identifies the major ecological attributes – landscape context, size, and the condition of vegetation, soils, and hydrology.
    - Provides a narrative description of declining integrity levels based on changes to ecological attributes.
    - Uses a metrics-based approach to assess the levels of integrity.
- Use of ecological classifications at multiple scales to guide the development of the conceptual models, thereby enhancing attribute assessment.
- A Level 1 remote sensing approach for assessing landscape context using GIS prior to a site visit.
- Ecosystem stressors measured to inform evaluation of condition metrics.
- Ratings and thresholds for each metric based on "normal' or "natural range of variation" benchmarks.
- A scorecard matrix for rating and integrating metrics into an overall set of indices of ecological integrity.
- A mechanism for adapting metrics over time as new information and methods are developed.

The NHB EIA enables consistent and repeated assessment of biodiversity sites to determine if value is conserved, enhanced, or diminished. Application of the EIA method is described in Nichols and Faber-Langendoen (2012). Surveyors document the ecological context and classify natural community and system types first, in order that a basic understanding of the wetlands structure, composition, and function are established. This aids in properly assessing the ecological integrity of wetland systems.

The EIA method's utilization of a vegetation classification is also important to estimating wildlife value. NHB's natural community and system classifications draw on the "coarse-filter" approach to conservation biology as follows. Natural communities are recurring assemblages of plants and animals found in particular physical environments. Systems are particular associations of natural communities that repeatedly co-occur in the landscape and are linked by a common set of driving forces, such as landform, hydrology, soils, and nutrient regime. Since natural communities and systems often correspond closely to distinct assemblages of other types of organisms, they can be used as "coarse filters" that capture many of the species and processes in the community or system even if they have not been specifically identified. They are the natural arenas where populations of different plant and animal species interact, respond to selective pressures, and continue to evolve. If these natural contexts can be protected and maintained, wildlife and other biodiversity will benefit; if they cannot, the species they contain may be in jeopardy.

The EIA manual (Nichols and Faber-Langendoen 2012) provided detailed, field-by-field coding conventions for the primary data forms used in the field and office. Steps and forms involved in a Level 2 assessment in completion order included:

Pre-field:

- EIA Level 1 Land Use Index

Field:

- EIA Level 2 Rapid Recon Form

Post-field:

- EIA Level 2 General Form
- EIA Level 2 Stressor Checklist Form
- EIA Level 2 Metrics Rating Form

The original NatureServe manual (Faber-Langendoen 2009) and forms were adopted by NHB and adapted for New Hampshire based on extensive testing in 2009 and 2010.

Field sampling methods employed standard NHB survey methodology. At the start of an inventory project, NHB conducts an initial landscape analysis to identify areas that have greater potential to contain features of interest in the wetland. This process allows surveyors to prioritize survey areas to increase the efficiency of field visits. Information sources used during landscape analysis include NWI maps (Cowardin et al. 1979), surficial (Goldthwait 1950) and bedrock (Lyons et al. 1997) geologic maps, Natural Resource Conservation Service (2009) soil surveys, land cover data (NH GRANIT 2011), and US Geological Survey topographic quadrangles. Digital layers of some of these data, used with GIS computer mapping software, allow rapid comparison and integration of information from different sources. Surveyors also query the NHB database to identify specific locations of known rare species and exemplary natural communities within study areas. Then they review aerial photographs to determine vegetation patterns and conditions.

NHB consults NWI and soil maps to identify wetland locations, as well as broad vegetation types and hydrologic classifications. These maps, although not diagnostic, can be useful for predicting systems and natural communities. In addition to NWI maps, NHB uses topographic maps to determine wetland size, landscape position, and setting (e.g., degree of isolation, connectedness to streams, and association with water bodies). Aerial photography signatures are also used to predict system and natural community types.

NHB designs field survey routes to cover specific destinations and to maximize intersection with representative areas or polygons of medium and lower priority. During field surveys, NHB collects data at specific locations considered representative of the component natural communities, based on observations and interpretation of community composition and structure. NHB collects data whenever there is an apparent change in community type, or there are significant changes in apparent ecological condition, as evidenced by changes in physical structure or species composition. As the survey progresses, NHB ecologists use their knowledge and experience to identify the portions of the study area that are the most ecologically significant, and focus attention on these locations (i.e., rare or uncommon communities, or large, high-integrity examples). The specific route of travel is modified on the ground to investigate small-scale habitat conditions not apparent from landscape analysis. During site visits, the surveyor collects detailed plot data for communities that require classification refinement.

NHB collects the following data at observations points during field surveys:

1. Natural community system type (Sperduto 2011).
2. Natural community type (Sperduto and Nichols 2011).
3. Identification of all native and non-native plant species.
4. Percent coverage estimates for all plant species.
5. Other descriptive notes including information on soils and other physical site characteristics, evidence of human disturbance, size of the community, and evidence of wildlife.
6. Diagnostic natural community and rare species photographs.

NHB identifies most plants in the field during the inventory; others are collected, pressed, and keyed using the resources available at NHB. Vascular plant nomenclature follows Haines (2011). The University of New Hampshire Hodgdon Herbarium (NHA) is the depository for voucher specimens of rare plants. Digital photographs of representative and noteworthy features are stored in the NHB photographic archive. NHB determines the location of observation points in each natural community type, and the location of rare plant populations in the study area, with a Global Positioning System (GPS). The accuracy of the data collected by the GPS is generally within 10 meters. NHB catalogs and stores in the Biotics database field data and site locations of rare plant populations and exemplary natural communities and systems.

<u>Floristic Quality Assessment</u>
Most of the following description is adapted from Milburn et al. (2007) and Herman et al. (2001):

Floristic Quality Assessment (FQA) is a tool to assist users in assessing the condition of upland and wetland habitats. Following refinement of concepts and methodology (Swink and Wilhelm 1994; Taft et al. 1997), the use of FQA has rapidly expanded. Because a number of recent studies have shown FQA to be a responsive and reliable indicator of wetland condition, it has potential to be useful in a variety of monitoring and assessment applications.

A fundamental principle in FQA is the concept of individual plant species conservatism, or fidelity, to natural systems and communities. Through the evolutionary process, species develop life strategies and adaptations within communities or assemblages that better enable survival in relation to competition, stress, and disturbance (Grime 1974). It is assumed then that each plant species has a varying degree of tolerance to disturbance (either natural or anthropogenic in origin) and a varying fidelity to natural habitats. The Coefficient of Conservatism (C) value is simply a numerical rating of an individual species' conservatism and habitat fidelity in relation to disturbance (Wilhelm 1977; Swink and Wilhelm 1994; Taft et al. 1997). C-values range from 0 to 10 (i.e., 0 is a non-native species with a wide range of tolerance; 10 is a native species with a very narrow range of tolerance) and are assigned to each species in a flora typically by an expert panel of botanists using best professional judgment.

FQA is applied by calculating a mean coefficient of conservatism (Mean C) and a floristic quality index (FQI) from a comprehensive list of plant species obtained from a particular site. This is done by summing the coefficients of conservatism of an inventory of plants and dividing by the total number of plant taxa (n), yielding an average or the mean coefficient of conservatism (Mean C = ÓC /n). Mean C is then multiplied by the square root of the total number of plants to yield the FQI. The square root of n is used as a multiplier to transform the mean coefficient of conservatism and allow for better comparison of the FQI between large sites with a high number of species and small sites with fewer species. Sites with the same Mean C may have different FQIs, and sites with the same FQI may have different Mean Cs (Goforth et al. 2001; Taft et al. 1997). It remains unclear whether Mean C has a stronger or weaker relationship with human disturbance and stress compared to FQI (Milburn et al. 2007).

The New England Interstate Water Pollution Control Commission (NEIWPCC), with funding from EPA, used nine of the region's most experienced botanists to assign coefficient of conservatism scores to the complete vascular flora of each New England state and New York State. The botanists followed strict guidelines and criteria and communicated several times with each other and NEIWPCC staff to ensure that high quality standards were met (Bried et al. 2012).

For this project, comparing alternative wetland assessment methods, comprehensive vascular plant species checklists were collected in each wetland system and used to calculate floristic quality indices.

The survey methodology followed a specific protocol. Within each natural community type, an experienced botanist developed a list of all vascular plant taxa by searching intensively until no additional taxa with a cover >1% were found within a 10-minute interval (here defined as the point of diminishing returns), or until small areas were completely traversed. In portions of natural communities that had not been completely searched, at the point when 10 minutes had passed with no additional taxa with a cover >1% located, the remaining areas were surveyed at a higher rate of travel. This technique has been found to be effective in locating a minimum of 92% of the taxa actually present (Nichols et al. 1998).

For each natural community, percent cover estimates for all plant species were determined. The cover of each natural community in the system was also estimated. Together, these estimates were used to calculate the cover for all plant species within the wetland system. These cover values were then used to calculate weighted Mean C (Mean Cw) and weighted FQI (FQIw).

Landscape development index

A landscape development index (LDI) was used to provide an independent variable to compare against the four wetland assessment method scores. Recent 2010 statewide high resolution aerials (NH GRANIT 2011) were used to evaluate land use type and cover within the 500 m buffer surrounding each wetland system. The LDI was then calculated using land use cover and their associated land use coefficient (Table 4).

Table 4. Land use coefficient table.*

Current Land Use	**Coefficient**
Paved; buildings; mining	0
Unpaved roads; abandoned mines	0.1
Agriculture (tilled); intensively developed vegetation (golf courses, lawns, sport fields)	0.2
Clearcut	0.3
Heavy grazing on pasture lands	0.3
Heavy logging with 50-75% of trees >30 cm dbh removed	0.4
Intense recreation (ATV use, camping, popular fishing spot); training areas	0.4
Permanent crop (orchards, nurseries, berry production, introduced hay field and pastures)	0.4
Commercial tree plantations	0.5
Dam sites and flood disturbed shorelines around water storage reservoirs	0.5
Recent old field dominated by ruderal and exotic species	0.5
Moderate grazing on pasture lands	0.6
Moderate recreation (high-use trail)	0.7
Mature old field with natural composition	0.7
Selective logging with less than 50% of trees >30 cm dbh removed	0.8
Light grazing; light recreation (low-use trail); haying of native grassland	0.9
Natural area	1

* Modified from Hauer et al. (2002).

RESULTS

Nine surveyors from NHB, DES, and UNHCE completed a total of 180 wetland assessments at 32 sites (Table 5) using the four methods: NHM, USA RAM, EIA, and FQA. All mention of USA RAM in the Results and Discussion sections (unless otherwise specified) refers to the version of the method modified by New Hampshire Department of Environmental Services (2012). Five of the 32 sites were wetland mitigation sites (bottom of table), the primary focus of a related and concurrent study (EPA Grant Project CD-96155401).

Table 5. Wetland assessments (n = 180) completed at 32 sites. See Table 2 to interpret surveyor initials.

SURVEY SITE	NHM	USA RAM	EIA	FQA
Cedar Swamp Pond*	BN,PB,MC[1]	BN,PB,MC[1]	BN,PB,MC[1]	BN,PB,MC[1]
	TW[2]	TW,SM[2]	SC,SM[2]	SC,SM[2]
	FM[3]			
Country Pond NE*	BN,PB,MC[1]	BN,PB,MC[1]	BN,PB,MC[1]	BN,PB,MC[1]
	SC[2]	TW,SM[2]	SC,SM[2]	SC,SM[2]
	FM[3]			
Country Pond NE - AWC*	BN,PB,MC[1]	BN,PB,MC[1]	BN,PB,MC[1]	BN,PB,MC[1]
	TW[2]	TW,SM[2]	SC,SM[2]	SC,SM[2]
	FM[3]			
Clay Pond	KP[2]	SC[2]	BN[1]	BN[1]
Cooks Pond Outlet	BN[1]	SM[2]	BN[1]	BN[1]
Garland Pond	PB[1]	SC[2]	PB[1]	PB[1]
Hall Mountain Marsh	SM[2]	KP[2]	PB[1]	PB[1]
Heath Pond Bog	KP[2]	SM[2]	BN[1]	BN[1]
Hinsman Pond	KP[2]	SM[2]	BN[1]	BN[1]
Lee Town Hall Bog	FM[3]	SM[2]	PB[1]	PB[1]
Lost Ponds	MC[1]	SM[2]	PB[1]	PB[1]
Lovewell Pond	BN[1]	JD[2]	BN[1]	BN[1]
Merrimack Technology Park	SM[2]	KP[2]	BN[1]	BN[1]
Musquash Swamp	SM[2]	KP[2]	BN[1]	BN[1]
Odiorne Pond	SM[2]	KP[2]	PB[1]	PB[1]
Parker Pond	PB[1]	SM[2]	PB[1]	PB[1]
Pennichuck Pond	BN[1]	JD[2]	BN[1]	BN[1]
Pennichuck Water Works Kettle	BN[1]	JD[2]	BN[1]	BN[1]
Powwow Pond	FM[3]	SM[2]	BN[1]	BN[1]
Powwow River	PB[1]	SC[2]	PB[1]	PB[1]
Rochester Heath Bog	BN[1]	JD[2]	BN[1]	BN[1]
Silver Lake, East of	BN[1]	SM[2]	BN[1]	BN[1]
Smith’s Pond	PB[1]	SM[2]	PB[1]	PB[1]
Spruce Hole Bog	KP[2]	SM[2]	BN[1]	BN[1]
Spruce Swamp	SM[2]	KP[2]	PB[1]	PB[1]
Turee Pond	PB[1]	SC[2]	PB[1]	PB[1]

SURVEY SITE	NHM	USA RAM	EIA	FQA
White Lake State Park	SM[2]	KP[2]	PB[1]	PB[1]
Hillsboro Mitigation Site**	BN[1]	BN[1]	BN[1]	BN[1]
Peterborough Mitigation Site**	BN[1]	BN[1]	BN[1]	BN[1]
Conway Mitigation Site**	BN,PB[1]	BN,PB[1]	BN,PB[1]	BN,PB[1]
Brentwood Mitigation Site**	PB[1]	PB[1]	PB[1]	PB[1]
Loudon Mitigation Site**	PB[1]	PB[1]	PB[1]	PB[1]

*One of three replicate sites in Kingston, NH.
**One of five mitigation sites (Note: Conway is a replicate site for the mitigation study).
[1]NHB surveyor; [2]DES surveyor; [3]UNHCE surveyor.

NHM evaluates overall condition indirectly based on anthropomorphic stressors to the wetland in the Ecological Integrity Function. Two other functions, Wetland Wildlife Habitat and Fish & Aquatic Habitat, may indirectly relate to wetland condition but their scores were poorly correlated at 32 sites with Ecological Integrity scores (R^2 = 0.27 and 0.01, respectively) and were dropped in further analysis. NHM Ecological Integrity scores were compared to the three other wetland assessment methods (USA RAM, EIA, and FQA), which more directly evaluate wetland condition.

Landscape Development Index

LDI was compared to EIA land use index at the 32 wetland sites (Figure 1). On a scale of 0–10, LDI values averaged 0.6 lower than those from the EIA land use index. The indices were highly correlated (R^2 = 0.79). The land use index values were calculated with a raster developed by UNH largely using satellite imagery acquired by Landsat Thematic Mapper between 1990 and 1999, last revised (including augmentation from other data sources) in 2001, while the LDI values were estimated by visually inspecting 2010 high resolution aerial imagery.

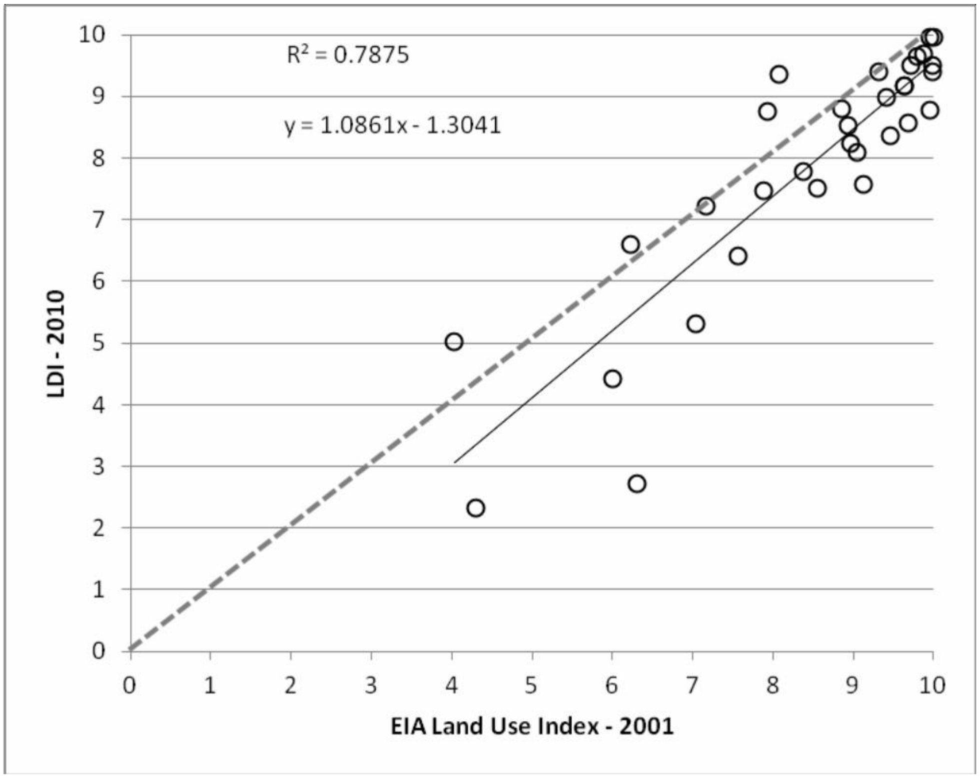


Figure 1. EIA land use index calculated based on pre-2001 aerial imagery vs. LDI using 2010 images at 32 wetland sites. Both indices were calculated within the 0–500 m area surrounding each wetland.

Questionnaire Responses
Each surveyor was asked to complete three questionnaires (Appendix 1):

1) Pre-season surveyor self-assessment after NHM, USA RAM, and EIA training.
2) Method assessment after each field survey (specific to combination of observer-method-date-site).
3) Comparison of methods after field season.

Surveyor responses to the questionnaires helped inform data interpretation. A summary of several responses is below.

<u>Experience of surveyors</u>
For each of the four methods compared in the study, eight to nine surveyors were asked to rate their experience level (i.e., low, medium, or high; Figure 2). Each method had 1-2 surveyors with a high degree of experience with that method. EIA had a relatively high proportion of surveyors with little to no experience (5 out of 8). The NHM and FQA methods had only two surveyors with little to no experience.

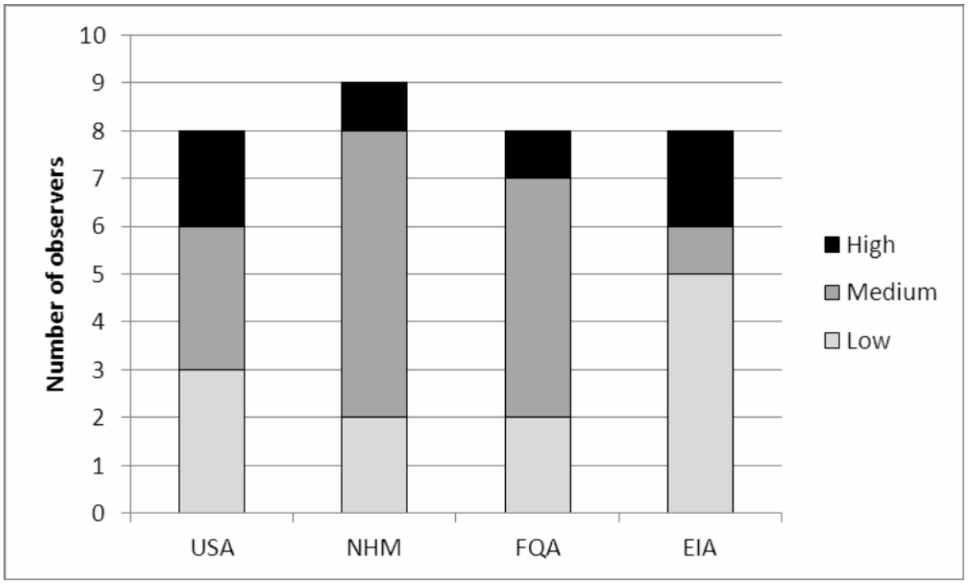


Figure 2. Experience of surveyors with each of the four assessment methods.

<u>Field time requirements</u>
FQA required the least time to complete, averaging around 1.5 hours (Table 6; Figure 3). The other three methods averaged around 2 hours for collecting data in the field. Field time ranged from a minimum of 25 minutes for all four methods to a maximum of 300 minutes for EIA at Powwow River. Powwow River, the largest site in the study (78 ha), also had significant access challenges. The maximum amount of time in the field for the other methods also took place at large sites, for example 270 minutes for NHM at Garland Pond, the second largest site at 77 ha. The 32 sites ranged in size from 0.8 ha to 78 ha.

Table 6. Total time (minutes) required for field data collection by method.

Method	**No. of Scores**	**Avg (min)**	**SD**	**Min**	**Max**
FQA	25	97	48	25	210
USA RAM	31	116	58	25	270
EIA	41	124	71	25	300
NHM	39	125	76	25	360

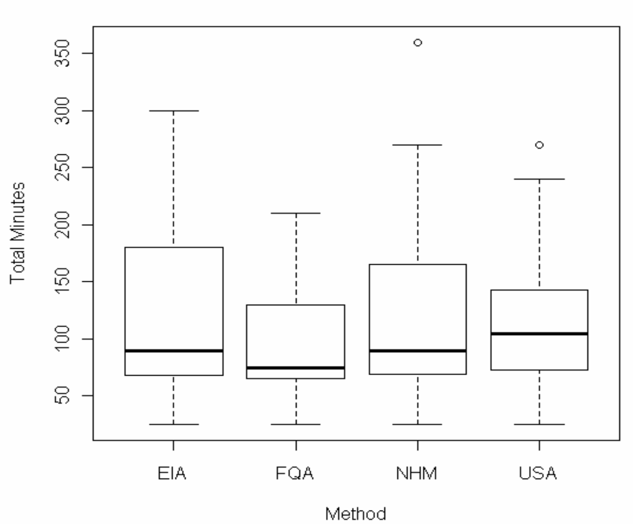


Figure 3. Total time required for field data collection by method at 32 sites, depicting minimum, lower quartile (25% of scores), median, upper quartiles (75%), maximum, and outliers (open circles).

<u>Clarity of instructions</u>
For each of the four methods applied at the 32 sites, surveyors (n = 9) were asked about clarity of instructions on a scale of 1 (clear) to 5 (ambiguous). Median responses ranged from 1 (clear) for FQA, 1.5 for EIA, and 2 for both NHM and USA RAM (Figure 4).

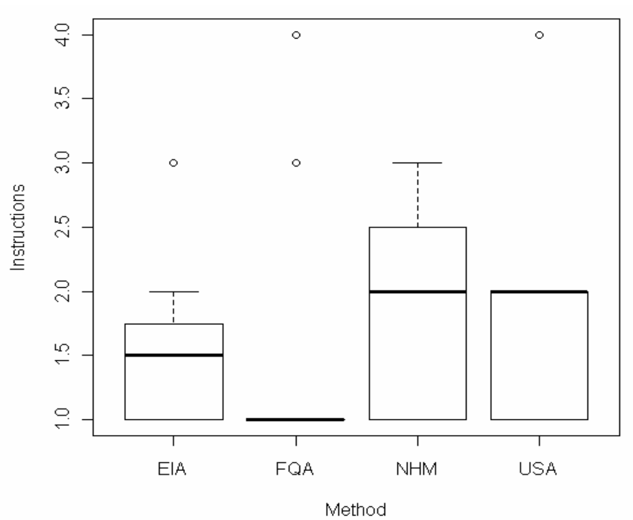


Figure 4. Surveyor (n = 9) responses to clarity of instructions by method (1–clear to 5–ambiguous). Depicts minimum, lower quartile (25% of scores), median, upper quartiles (75%), maximum, and outliers (open circles).

<u>Ability to make scoring decisions</u>
For each of the four methods applied at the 32 sites, surveyors (n = 9) were asked about difficulty in making decisions on how to score metrics or answer questions (1–easy to 5–difficult). Median responses ranged from 1 (easy) for FQA, 1.5 for EIA, and 2 for both NHM and USA RAM (Figure 5).

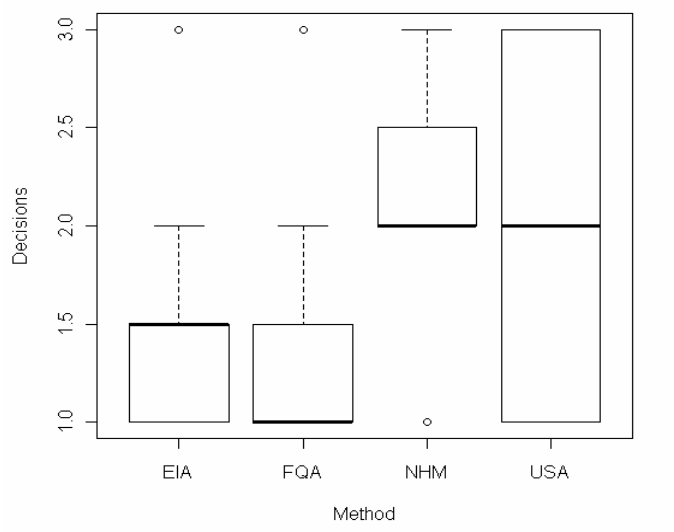


Figure 5. Surveyor (n = 9) responses to difficulty in making decisions on how to score metrics or answer questions (1–easy to 5–difficult). Depicts minimum, lower quartile (25% of scores), median, upper quartiles (75%), maximum, and outliers (open circles).

<u>Likelihood of similar scores from a similarly qualified surveyor</u>

For each of the four methods applied at the 32 sites, surveyors (n = 9) were asked if another similarly qualified observer did the same survey, would their scoring likely be "1–very similar to yours" to "5–very different." Median responses ranged from 1 (very similar) for FQA, 1.5 for EIA, and 2 for both NHM and USA RAM (Figure 6).

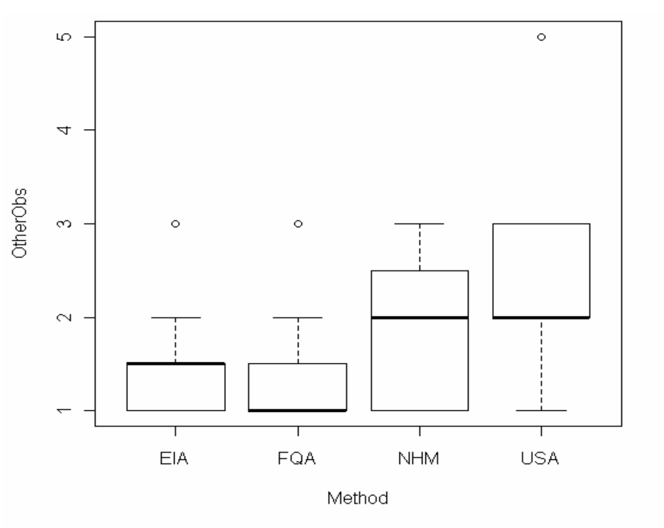


Figure 6. Surveyor (n = 9) responses when asked if another similarly qualified observer did the same survey, would their scoring likely be "1–very similar to yours" to "5–very different." Depicts minimum, lower quartile (25% of scores), median, upper quartiles (75%), maximum, and outliers (open circles).

<u>Percent of wetlands surveyed</u>

For each of the four methods applied at the 32 sites, surveyors (n = 9) were asked about the percent of the wetland (entire system as mapped) they observed in the field. Distant observations were included only if surveyors were able to assess condition. The median percent of wetlands observed in the field were similar for EIA, NHM, and USA RAM (around 60%; Figure 7). FQA median percent of wetlands observed was around 50%.

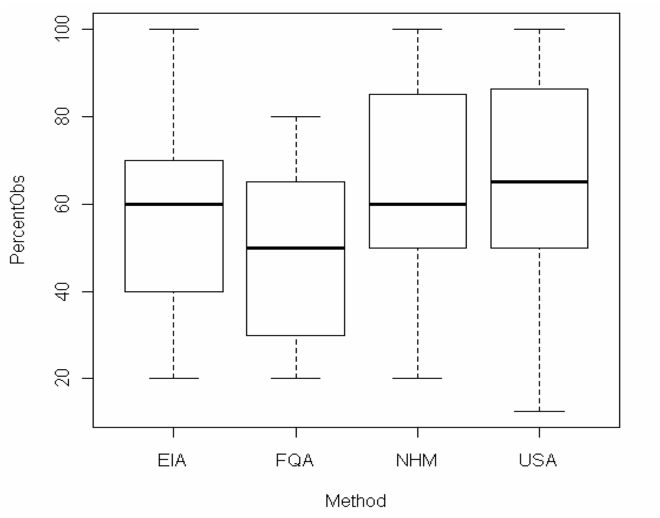


Figure 7. Surveyor (n = 9) responses when asked about the percent of wetland observed. Distant observations were included only if surveyors were able to assess condition. Depicts minimum, lower quartile (25% of scores), median, upper quartiles (75%), and maximum.

Range of Assessment Method Scores

The range of scores assigned at 32 sites (including five mitigation sites) by surveyors for each method is summarized in Table 7. Including replicate scores, the results are based on 45 scores per method. The maximum possible range of scores varied from 0–5 for EIA to 0–144 for USA RAM. FQA is here represented by four indices: Mean C, weighted Mean C (Mean Cw), FQI, and weighted FQI (FQIw).

Table 7. Range of scores assigned by surveyors for each method for 32 sites (including five mitigation sites).

Method	Min Score	Max Score	Avg Score	Range	Max Range
EIA	3.2	4.7	4.3	1.5	5
FQI	16.1	41.5	29.4	25.4	N/A
FQIw	20.5	43.8	32.6	23.3	N/A
Mean C	3.1	6.1	4.8	3.0	10
Mean Cw	3.1	7.5	5.4	4.4	10
NHM	5.8	10.0	8.6	4.2	10
USA RAM	93.0	126.0	113.7	33.0	144
LDI	2.3	10.0	7.9	7.7	10

Inter-Observer and Inter-Method Variability at Replicate Sites

To allow direct comparisons between methods with different maximum values, standardized scores were calculated. The actual score was turned into a percent of the total range observed over all 32 sites for that method (Table 8; Figure 8), then multiplied by 5. The standardized scores thus include at least one site with a score of 0, and one or more with a score of 5 for each method, if calculated for all 32 sites.

Table 8. Standardized scores (0–5 for each method over all 32 sites) at the three non-mitigation replicate sites (n = 5 scores at each site for each method). Sorted by site and then by range.

Replicate Site	Method	Range	Mean Score	Min Score	Max Score
Cedar Swamp Pond					
	USA RAM	1.36	3.82	3.18	4.55
	NHM	0.89	4.70	4.11	5.00
	Mean C	0.73	4.50	4.27	5.00
	FQI	0.73	2.89	2.62	3.35
	EIA	0.32	4.67	4.48	4.79
	LDI	0.00*	4.05	4.05	4.05
Country Pond NE					
	NHM	2.86	3.50	2.14	5.00
	USA RAM	1.82	3.09	2.27	4.09
	FQI	1.58	1.89	0.86	2.45
	EIA	1.39	4.10	3.19	4.58
	Mean C	0.52	2.56	2.31	2.83
	LDI	0.00*	4.48	4.48	4.48
Country Pond NE - AWC					
	USA RAM	2.27	2.91	1.82	4.09
	NHM	2.26	3.80	2.74	5.00
	EIA	1.33	4.45	3.67	5.00
	FQI	1.14	1.68	0.94	2.08
	Mean C	0.72	3.41	3.11	3.82
	LDI	0.00*	4.48	4.48	4.48

*Recorded by a single observer (inter-observer variability not applicable).

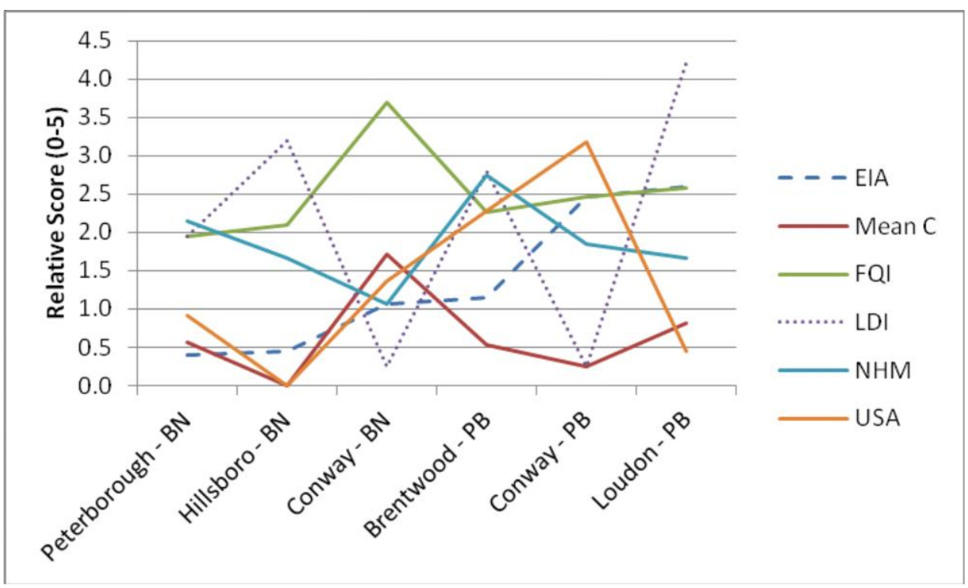
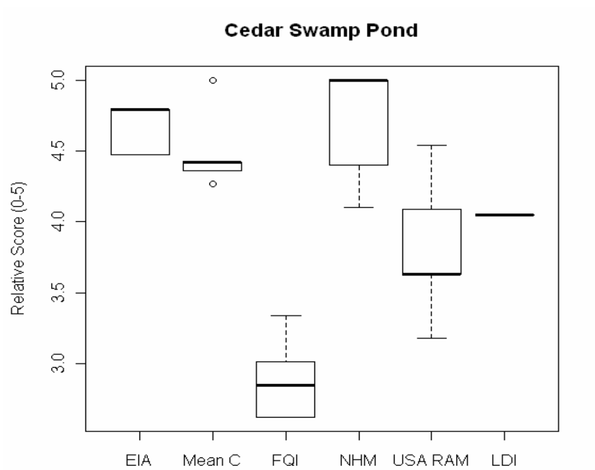
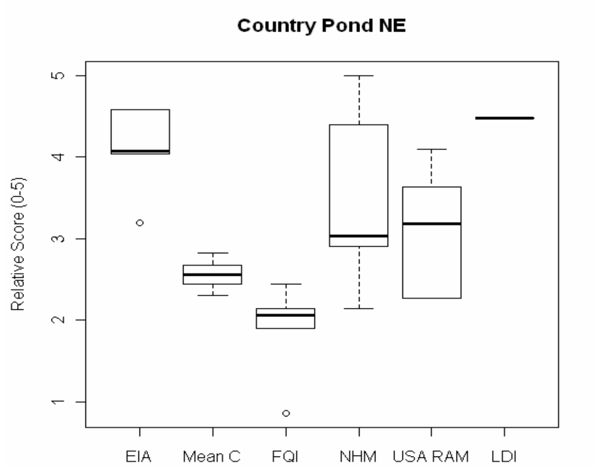


Figure 8. Standardized scores (0–5 for each method) at the five mitigation sites. EIA scores trend from lower to higher from left to right (see dashed blue line). Note: Conway Mitigation Site was scored twice, by two different surveyors (see Table 2 to interpret surveyor initials).

Range was used as an index of inter-observer variability: it is more easily interpreted than standard deviation, and when calculated, standard deviations were highly correlated with range ($R^2 = 0.98$). Outliers were not a problem with these replicate scores.

Ignoring LDI, which was recorded by a single observer, NHM and USA RAM had the highest inter-observer variability at all three non-mitigation replicate sites, while Mean C or weighted Mean C scores had the lowest (Table 8; Figure 9). The five indices varied considerably within each site (Figure 9), with FQI consistently assigning the lowest scores and EIA assigning the highest (or next-to-highest) median score.





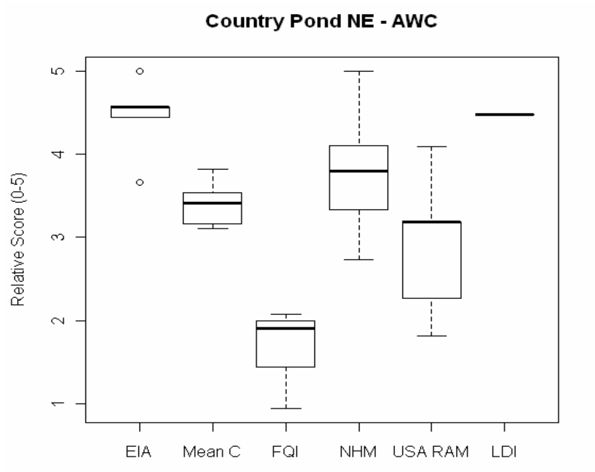


Figure 9. Boxplots (median, quartiles, minimum, and maximum) for six assessment methods at three sites with replicate data (n = 5 surveyors at each site except that LDI was scored remotely by a single person).

Agreement Between EIA and FQA (Mean C and FQI) Scores

In our study, EIA scores from 32 sites (including five mitigation sites) were compared with Mean C and FQI scores (Table 9). For EIA, the "B–C" threshold separate sites with higher ecological integrity from those with lower ecological integrity. Most Mean C scores above the EIA "B–C" threshold are >3.5, a Mean C threshold used in the Midwest to separate wetlands with higher floristic quality from those with lower quality (Milburn et al. 2007; US Fish & Wildlife Service 2012; Wilhelm 1992). Musquash Swamp and Brentwood Mitigation Site were the only wetlands with a "B" EIA grade and a Mean C =3.5 (3.47 and 3.39, respectively). Merrimack Technology Park was the only wetland with a "C" EIA grade and a Mean C above 3.5.

Table 9. Comparison of EIA scores from 32 sites (including five mitigation sites) with Mean C and FQI scores. Scores for each method were averaged at replicate sites. Mean C scores in italic font are anomalously lying above or below the EIA "B–C" threshold (red line).

Survey Site	EIA Grade	Mean C	FQI
Hinsman Pond	A	5.23	35.88
Cedar Swamp Pond*	A	5.81	30.79
Lost Ponds	A	6.10	36.09
Smith's Pond	A	5.38	28.97
Parker Pond	A	4.94	35.64
Odiorne Pond	A	4.74	38.53
Hall Mountain Marsh	A	4.52	32.59
Country Pond NE – AWC*	A	5.15	24.62
White Lake State Park	A	5.92	29.60
Turee Pond	B	5.31	41.48
Clay Pond	B	3.93	26.39
Spruce Swamp	B	4.59	28.66
Garland Pond	B	4.67	34.29

Survey Site	EIA Grade	Mean C	FQI
Spruce Hole Bog	B	5.76	31.01
Silver Lake, east of	B	5.61	38.04
Powwow River	B	4.32	27.64
Country Pond NE*	B	4.63	25.69
Pennichuck Pond	B	4.33	16.78
Heath Pond Bog	B	5.63	40.63
Cooks Pond Outlet	B	5.33	36.12
Musquash Swamp	B	***3.47***	26.69
Powwow Pond	B	4.66	28.71
Lee Town Hall Bog	B	5.03	28.46
Loudon Mitigation Site**	B	3.57	29.20
Lovewell Pond	B	3.74	24.23
Conway Mitigation Site**	B	3.67	31.76
Rochester Heath Bog	B	4.44	28.42
Brentwood Mitigation Site**	B	***3.39***	27.57
Hillsboro Mitigation Site**	C	3.07	26.73
Peterborough Mitigation Site**	C	3.41	26.00
Merrimack Technology Park	C	***4.70***	32.24
Pennichuck Water Works Kettle	C	3.29	16.13

*One of three replicate sites in Kingston, NH.
**One of five mitigation sites (Note: Conway is a replicate site for the mitigation study).

Mean C and FQI are expected to have different floristic quality thresholds (e.g., for high quality and degraded examples) for different systems, related to varying patterns of vascular plant species richness and their associated CoC values (Herman et al. 2001; Bourdaghs 2012). EIA was a fairly good predictor of Mean C and FQI scores for the kettle hole bog system (R^2 = 0.71 and 0.37, respectively; Figure 10) and the drainage marsh - shrub swamp system (R^2 = 0.53 and 0.54, respectively), but less so for other system types.

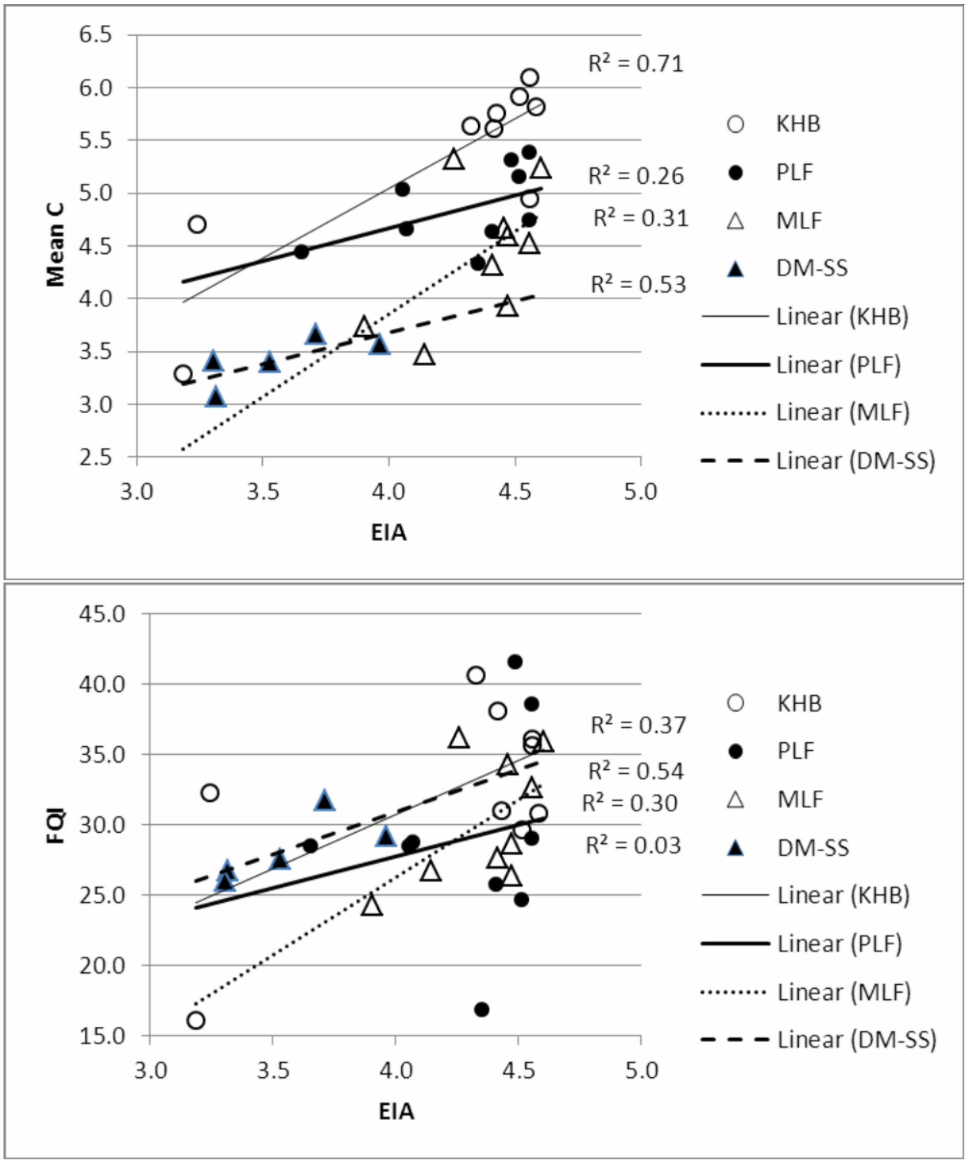


Figure 10. Relationship of EIA scores to Mean C and FQI scores by system type at 32 wetlands (including five mitigation sites). Scores are averaged for sites with replications. DM-SS = drainage marsh - shrub swamp system; MLF = medium level fen system; PLF = poor level fen/bog system; KHB = kettle hole bog system.

Linear regression showed Mean C scores were moderately correlated with EIA scores (R^2 = 0.48, Table 10) and somewhat less correlated to USA RAM and NHM scores (R^2 = 0.42 and 0.37, respectively). A weaker relationship exists between FQI scores and the other three methods. EIA was moderately correlated with USA RAM and NHM (R^2 = 0.56 and 0.52, respectively). USA RAM was less correlated with NHM (R^2 = 0.35).

Table 10. Coefficient of determination (R^2) for average scores of 32 wetlands (lower diagonal; below cells with the number "1"). Upper diagonal (above cells with the number "1") equals significance level of the coefficients. Correlations in italic font are significant at a "p" value of 0.05.

	EIA	Mean C	FQI	Mean Cw	FQIw	LDI	NHM	USA RAM
EIA	1	0.000	0.017	0.026	0.150	0.000	0.000	0.000
Mean C	*0.48*	1	0.000	0.000	0.002	0.002	0.000	0.000
FQI	*0.18*	*0.32*	1	0.388	0.000	0.053	0.132	0.012
Mean Cw	*0.10*	*0.53*	0.03	1	0.000	0.227	0.216	0.009
FQIw	0.07	*0.27*	*0.52*	*0.38*	1	0.400	0.945	0.031
LDI	*0.64*	*0.28*	0.12	0.05	0.02	1	0.000	0.000
NHM	*0.52*	*0.37*	0.07	0.05	0.00	*0.56*	1	0.000
USA RAM	*0.56*	*0.42*	*0.19*	*0.21*	*0.14*	*0.35*	*0.35*	1

Assessment Method Scores at Mitigation Sites

Two surveyors applied the four wetland assessment methods (NHM, USA RAM, EIA, and FQA) at five mitigation sites (Table 11). Each surveyor visited three of the five sites; the mitigation wetland in Conway served as a replicate site (independently assessed by the two surveyors). Conway FQA scores, influenced by the vascular plant species and their associated CoC values documented by each surveyor, were significantly different by surveyor (Mean C 3.22 vs. 4.11; FQI 28.6 vs. 34.9).

The other three methods do not require a comprehensive list of vascular plant species as part of the assessment. For these methods, there was a consistent difference in scoring between the two surveyors at the Conway replicate site. The scores from one surveyor for each method were higher than the other observer (EIA 3.92 vs. 3.50; NHM 7.35 vs. 6.70; USA RAM 114 vs. 102), in an opposite manner from FQA results.

Table 11. Wetland assessment scores at the five mitigation sites sorted by EIA. Italic scores indicate the highest-rated wetland for that method. Note: Conway Mitigation Site was scored twice, by two different surveyors.

Mitigation Site	Surveyor	EIA	Mean C	FQI	NHM	USA RAM	LDI*
Loudon	Surveyor 1	*3.96*	3.57	29.2	7.20	96	*8.77*
Conway	Surveyor 1	3.92	3.22	28.6	7.35	*114*	2.71
Brentwood	Surveyor 1	3.53	3.39	27.6	*8.10*	108	6.61
Conway	Surveyor 2	3.50	*4.11*	*34.9*	6.70	102	2.71
Hillsboro	Surveyor 2	3.32	3.07	26.7	7.20	93	7.22
Peterborough	Surveyor 2	3.30	3.41	26.0	7.60	99	5.31

*Recorded by Surveyor 2.

DISCUSSION

Multiple comparisons are needed to describe the differences between wetland assessment methods. Possible comparisons vary from the logistics of how data are collected to the overall goal of what wetland feature(s) are being measured. This discussion will focus on some important contrasts between the methods used in this study, with a more detailed comparison presented in tabular format.

Wetland Assessment Area

Clearly defining the assessment area prior to field surveys is critical to how data are collected, interpreted, and utilized. Important factors to consider when defining the area to be assessed include: sample design and site selection; effective field application; ecological significance of results; and ability of results to meet project objectives (Fennessy et al. 2004).

Wetlands can be defined geographically and/or based on distinct suites of characteristic vegetation (systems). One major difference between NHM and the other three methods used in this study is that NHM is typically applied to the entire wetland complex (i.e., geographically defined and potentially including multiple systems), whereas USA RAM and EIA generate a separate score for each system. FQA can be applied to any defined area, but care has to be taken to collect data within each system in order to generate a complete species list.

- The basic assessment area evaluated using NHM is a single wetland consisting of one or more systems. The method recommends not breaking a wetland complex into two or more assessment areas unless there is a compelling reason to do so.

- USA RAM targets a single wetland system and considers the entire system the assessment area when 20 ha or less in size. Larger wetland systems require at least a second assessment area. If the difference between the condition scores from the two assessment area is greater than 15%, then a third assessment area is required. Scores for each assessment area would then be combined to generate a score for the system.

- For EIA, the assessment area is defined as a single wetland system, regardless of size. Data collection (observation points) is conducted at one or more sites within each natural community in the system.

- FQA can be applied to sites that vary in the number and types of upland and wetland systems. However, FQA indices are more interpretable when comparing data among similar systems, especially when using a standardized sampling design (Herman et al. 2001).

Each method has a different protocol to select sampling sites within the assessment area, but the end goal is the same: to characterize the condition and functions of the entire assessment area.

Assessing Function vs. Condition
Wetland assessment methods differ in whether they measure individual functions, or provide a measure of overall condition. Functional assessments evaluate each function separately from the others (see Table 19). This allows specific problems or exceptional traits to be identified, but renders it difficult to assess overall ecological integrity (Faber-Langendoen et al. 2006). Overall condition can be considered an indirect measure of wetland functions: when wetland condition is exceptional, then both ecological integrity and the functions associated with the wetland type occur at levels comparable to reference sites.

NHM evaluates the performance of 12 separate wetland functions at a site. This degree of sensitivity to individual functions is not possible for condition assessments with a single score, such as FQA. However, the function scores should not be combined for an overall wetland condition score. On the one hand this encourages/requires users of NHM to explicitly think about the variety of functions provided by each wetland. On the other hand, it makes it difficult to compare multiple wetlands except on a function-by-function basis.

EIA results in an overall wetland condition score based on (in addition) scores for five Major Ecological Attributes (Size, Landscape Context, Vegetation, Hydrology, and Soils). Each Major Ecological Attribute score is calculated from metric scores associated with the attribute. Pre-defined thresholds exist for translating numeric EIA scores into ranks on an "A to D" scale. Multiple wetlands can thus readily be ranked and compared on their overall condition. EIA does not measure specific wetland ecological services and functions, potentially making it difficult to use to justify wetland protection in terms of monetary value to the community. However, all ecological functions can be inferred to be in good shape for highly ranked wetlands, while one or more can be inferred to be impaired at low-ranked sites.

USA RAM is comprised of 12 individual condition or stressor metric scores that roll into an overall score for the assessment area. The overall score permits comparisons between multiple wetlands. However, its condition and metric scores do not include the cultural functions measured by NHM, and the overall score lacks some of the insight that EIA gains by integrating into the method a system and natural community classification (see next section).

Use of Wetland Classifications

Wetland assessment methods should be able to account for a wide range of wetland types (Faber-Langendoen et al. 2012a, 2012b), utilizing diagnostic indicators of condition specific to each type. Using some form of wetland classification to guide sampling and analysis reduces variability of scores within wetland types and improves the ability to differentiate ecological integrity over a range of wetland conditions (Fennessy et al. 2004). Using a wetland classification is also important because the susceptibility of different wetland types to a particular stressor may differ (Fennessy 2004). For example, nutrient runoff on average will affect a kettle hole bog system to a greater degree than it will a drainage marsh - shrub swamp system.

EIA uses a wetland classification (Sperduto 2011; Sperduto and Nichols 2011) that is based on vegetation composition and structure as well as a specific combination of physical conditions (e.g., water, light, soil, nutrient levels, and climate). Applying the classification improves EIA's sensitivity in estimating condition by refining ecological context and increasing the surveyor's ability to evaluate EIA metrics and the scope and severity of stressors to the system.

NHM and USA RAM both utilize Cowardin et al. (1979) but only to identify assessment areas, not to improve the sensitivity of assessments to estimate condition. For FQA, indices are more interpretable when using a vegetation classification to compare data among similar systems.

Use of Stressors

NHM, USA RAM, and EIA all evaluate stressors known to negatively impact function and/or condition. They differ in which stressors are focused on, and whether stressors are explicitly measured or simply noted as part of the process of generating other scores.

NHM's three biological-based functions (Ecological Integrity, Wetland-Dependent Wildlife Habitat, and Fish & Aquatic Life Habitat) are largely evaluated in the context of human-induced stressors to the wetland and surrounding landscape. For each of these functions, one or more questions address a stressor that could negatively affect the system (e.g., human activity, invasive plants, and land use in the watershed). Wetlands little impacted by stressors have higher scores for these three functions.

USA RAM uses stressor-based metrics to evaluate each of the four attributes of ecological integrity (Buffer, Hydrology, Biological Structure, and Physical structure). Condition metrics are also used to evaluate all but Hydrology (this attribute is assessed only in terms of stressors).

For EIA, stressors are used to inform assessment of metrics and to help interpret a wetland system's condition. The focus is on "stressors that have caused or are causing impacts, whenever the effects of the stressors are evident. For example, a stressor may be recent tree removal or mowing. Less recent mowing or tree removal would be included only if the effect of those stressors is still currently evident (e.g., old tree stumps)" (Faber-Langendoen et al. 2012b). The scope and severity of stressors in the nearby watershed and to vegetation, soils, and hydrology in the wetland are recorded, but they are not rolled into the overall score.

Repeatability and Minimum Experience Requirements of Assessment Methods

Variations between observers in how wetlands are measured reduces the value of condition and function scores. At a given place and time all observers should be estimating the value of the same 'true' ecological integrity and functions of a wetland. Methods that result in wide variations between observers cannot be used with the same confidence as methods that consistently produce similar results even when applied by different field personnel.

Inter-observer variability was examined in this study primarily by having multiple observers score the same wetland using multiple methods. At other wetlands, variability due to factors other than the observer and the method being used was reduced by (a) completing all the surveys in a single field season (primarily July and August) and (b) limiting the type of wetlands used in the study to those with similar, relatively simple vegetation.

Based on questionnaires, observers indicated that they expected similarly experienced observers should have similar results to their own for all four methods, with EIA and FQA slightly more likely to have low inter-observer variation. This expectation was partially borne out at the three wetlands where five observers took replicate measures for each of the methods: EIA and FQA had less variation between observers than NHM and USA RAM. However the absolute differences for NHM and USA RAM were fairly high, e.g., differing by more than two points on a five-point scale.

Inter-observer variability is affected by training and experience. In one study (Herlihy et al. 2009), researchers found training had a greater impact on observer to observer repeatability compared to experience. In our study, these two factors were not compared directly, but the importance of experience is likely heightened relative to training for EIA and FQA compared to NHM and USA RAM. The recommended minimum background for EIA and FQA application is a professional wetland scientist with competent botany and plant community ecology skills. Although NHM is often used by wetland scientists, by design a background in wetland ecology is not required. The minimum background needed to use USA RAM probably lies somewhere between NHM and EIA/FQA to achieve reasonable repeatability.

For a given wetland, a nearly complete species list is recommended for FQA. Assuming a reasonable level of botanical competence between observers, the primary factor contributing to inter-observer variation is likely to be survey effort. There is a well-documented relationship between number of species observed at a site and the area searched. It is therefore particularly important with FQA that sampling methods be similar in design and intensity. When sampling methods differ, contrasts should be clearly stated (Rentch and Anderson 2006).

Applicability of Methods to Different Uses

<u>Water quality standards</u>

Water quality standards are established for a number of reasons including: promoting improved water quality; pollution prevention; protection of drinking water supplies; wildlife conservation; and for agricultural, industrial, recreational, and other uses. Level 3 (intensive field-based) assessments are required to make meaningful water quality evaluations. Level 2 rapid assessment methods can be used as initial screening tools for evaluating water quality but they are no substitute for more detailed site-specific studies.

NHM, USA RAM, and EIA all address water quality to some extent as Level 2 methods. Two functions in NHM with direct bearing on water quality are Sediment Trapping and Nutrient Trapping-Retention-Transformation. Functions indirectly addressing water quality are Ecological Integrity, Wetland-Dependent Wildlife Habitat, and Fish & Aquatic Life Habitat. For USA RAM, one of the twelve metrics, Stressors to Water Quality, provides a rapid assessment of water quality. Other USA RAM metrics include some stressors that affect water quality. EIA protocols originally included a Level 2 water quality metric. After field testing and data analysis, this metric was dropped because of the degree of subjectivity in the evaluation and acknowledgement of the need for a Level 3 assessment to adequately address water quality. Several of the stressors listed (e.g., evidence of herbicides/pesticides, point source discharge, or non-point source discharge) in the EIA Stressors Checklist directly or indirectly relate to water quality and in this way, water quality is addressed in the method.

<u>Wildlife value</u>

A thorough evaluation of a wetland system's wildlife value requires Level 3 assessments, similar to evaluating water quality standards. Each of this study's four methods evaluates a system's importance to wildlife at Level 2 to some degree. For NHM, three of the 12 functions address wildlife either directly or indirectly (Ecological Integrity, Wetland-Dependent Wildlife Habitat, and Fish & Aquatic Life Habitat). Wetlands with higher scores for the Ecological Integrity Function are more likely to support better quality wildlife habitat than wetlands with low Ecological Integrity scores. The Wetland-Dependent Wildlife Habitat Function looks at some of the species that depend on wetlands for all or part of their life cycles. The Fish & Aquatic Life Habitat Function provides a general assessment of habitat conditions for fish and other aquatic life.

For USA RAM, several of the 12 primary metrics address wildlife. "Non-buffer land covers" in Buffer Metrics 1 & 2 include any roadway dangerous to wildlife (e.g., railroads, busy streets, highways, etc.). Buffer Metric 3 includes stressors that could affect wildlife in and around the wetland system. The physical structure attributes (Metrics 4 & 5) and biological structure attributes (Metrics 6 & 7) help evaluate topographic relief, patch diversity, vertical structure, and plant strata complexity, all of which can affect habitat quality and diversity for animals. Metrics 8-12 assess stressors in the wetland system, including those that could affect wildlife.

Like USA RAM, EIA assesses wildlife value indirectly based on stressors and habitat. The Land Use Index evaluates land uses and their impacts in three zones surrounding a wetland system (Buffer, Core Landscape, and Supporting Landscape). Collectively, these zones evaluate landscape connectivity out to 500 m from the wetland edge. Landscape connectivity addresses ecological dynamics and species that depend on the larger landscape beyond the immediate buffer. Landscapes retaining more connectivity between habitat patches are more likely to maintain populations of various wildlife species that inhabit the patches. The Stressors Checklist, which informs completion of metric evaluations, considers several stressors that could affect wildlife in and around the system. By explicitly classifying the assessment area to system type, EIA allows the user to directly identify key wildlife habitat types and thus wildlife species of conservation concern by referencing New Hampshire's Wildlife Action Plan (New Hampshire Fish & Game 2011).

FQA measures wetland condition using floristic quality. To a certain extent, one can assume that FQA indirectly measures the condition of wildlife habitat in and around the wetland system. Wetlands with higher Mean C and FQI scores (higher floristic quality) are likely to support better habitat for native species compared with wetlands with lower scores.

Regulatory decisions / permit review

The ecological condition and functions of wetlands, along with a variety of other factors, affect regulatory and permit decisions. High-quality wetlands may have additional regulatory requirements, in order to protect water quality and other wetland values. Each of the assessment methods studied in this project has the potential to contribute to a meaningful understanding of either a wetland's ecological condition or functions. In New Hampshire, wetland assessment methods currently affect the regulatory process through two avenues: 1) checking for "exemplary" wetlands in a project area as identified by the NH Natural Heritage Bureau (NHB) using EIA and 2) checking for "prime" wetlands as identified (mostly) by NHM.

Many agencies and organizations at the local, state, and federal levels currently require that permit applicants include an assessment of potential impacts to rare plants and animals and exemplary natural communities in the project area. This requirement is typically met by checking the project's location against records maintained by the NH Natural Heritage Bureau (NHB); when there are potential impacts to rare species or exemplary wetlands, NHB recommends ways to avoid, reduce, or mitigate these impacts. Any wetland judged by NHB to be "exemplary" is included in this review process. The New Hampshire Native Plant Protection Act (RSA 217-A) defines an "exemplary natural community" as a viable occurrence of a rare natural community type or a high quality example of a more common community type as designated by NHB based on community size, ecological condition, and landscape context. Applying the EIA method to a wetland and evaluating the five major ecological attributes associated with size, condition, and landscape context is the process now used by NHB to determine if a wetland natural community or system is exemplary.

Individual municipalities, under RSA 482-A:15 and administrative rules Env-Wt 700, may choose to designate wetlands as "prime wetlands" after high value examples are identified. Characteristics of prime wetlands may include large size, exceptional ecological integrity (e.g., NHB's exemplary natural communities and systems), and the presence of rare plant and animal species. After prime wetland candidates have been identified, a public hearing is held to vote on the designation. If the municipality supports the designation as prime, relevant documentation is sent to the DES Wetlands Program for review. If approved, DES will apply the applicable law and rules to proposed projects within the prime wetland or the 100' prime wetland buffer. Wetlands designated as prime are provided more protection in DES's review of permit applications. For the purpose of prime wetlands designation, the function-based NHM has been recommended by the NH DES Wetlands Bureau Prime Wetlands Regulations since 1991. The three other methods compared in this study (USA RAM, EIA, and FQA) could also be used to inform prime wetland decisions. Each method has different strengths and weaknesses, which are summarized in Table 19.

Mitigation compliance

Mitigation offers a way to offset unavoidable wetland impacts through the restoration or creation of other wetlands (Mitsch and Gosselink 2000). Faber-Langendoen et al. (2008) state that "compensatory mitigation involves a process in which the ecological integrity, function, and/or services created-restored-enhanced from a mitigation wetlands is compared to the ecological integrity, function and/or services lost from an impacted wetland." No national guidelines exist for developing performance standards. Kihslinger (2008) recommends that…

> "Permits should define performance standards that are based on ecological criteria such as community structure, soil, hydrology, amphibian communities, and vegetation (Fennessy et al. 2007). Currently, many permits simply require a certain percentage of herbaceous cover as a criterion for assessing the success of a mitigation site because it is easily measured and may quickly reach required thresholds. However, percent herbaceous cover may not be a sufficient surrogate for most wetland functions (Cole and Shafer 2002)."

Rapid assessment methods have the potential to provide consistent, science-based goals for mitigation sites and criteria for judging their success. See New Hampshire Natural Heritage Bureau (2013) for additional information on a concurrent study comparing the same four assessment methods at five wetland mitigation sites (EPA Grant Project CD-96155401).

Ability to assess condition and identify ecologically significant wetlands

The foundation for successful biodiversity protection is to identify and protect a series of representative, high quality examples of all the state's ecosystem types (natural communities and systems), with their constituent species and underlying ecological processes. NHB and other Natural Heritage programs use two ranks to prioritize examples of natural communities and systems for protection. The first is based on the type (classification) of wetland: is it a rare type, or a common one? The second is based on the quality of the particular example: is it relatively undisturbed, in good condition, or have some of its features been degraded?

EIA, USA RAM, and FQA all estimate overall ecological integrity or condition for wetland systems (NHM estimates individual ecological functions and societal values). FQA is not necessarily meant to be used as a stand-alone method. Herman et al. (2001) state it should be used to supplement or validate other assessment methods. In the future, FQA will be combined with other Vegetation Condition metrics in NHB's EIA protocols and used as an optional metric. USA RAM is under development but its stressor and condition based metrics evaluate key components important in assessing a wetland system's overall condition.

In their current form, EIA is the only one of the four methods that requires classification of the wetland system (Sperduto 2011; Sperduto and Nichols 2011) and thus allows factors such as the rarity of the type and its sensitivity to different stressors to be considered. The sensitivity of several USA RAM metrics to differences in condition would likely improve if they were more specific to wetland type.

Interpreting Scores

To enhance their usefulness, the numeric scores generated by wetland assessment methods need to be translated into ranks (e.g., A-D) and/or have a threshold value that separates high-quality from low-quality wetlands.

Previous studies applying FQA used a Mean C >3.5 (FQI >35) to separate higher-quality from lower-quality sites (Wilhelm 1992; US Fish & Wildlife Service 2012). For EIA, the dividing line between sites with an A or B rank vs. those with a C or D rank is 3.5. In this study, FQA and EIA scores agreed on which were the higher-quality sites for 29 of the 32 wetlands (Table 9). Two of the disagreements were borderline (Mean C of 3.39 and 3.47 rather than >3.5 for sites that EIA ranked as B). Only the 4.7 Mean C score at Merrimack Technology Park was noticeably anomalous relative to the EIA "C" grade. The low EIA grade is largely due to a degraded landscape context. Mean C values appeared to be relatively insensitive to landscape context at this site. In addition, nutrient-poor bogs and fens typically support a relatively low number of species (47 species at Merrimack Technology Park) and several species with a high fidelity to these system types. The presence of nine species with high CoC values (ranging from 7 to 9) had a disproportionate effect on the site's Mean C at Merrimack Technology Park. Similarly in West Virginia, acidic nutrient-poor bogs support several species with high CoC values and Mean C scores tend to be relatively high in this system even though species richness is relatively low (Herman et al. 2001; Bourdaghs 2012).

Mean C scores for the five mitigation sites (ranging from 3.07–3.67; Table 11) were among the lowest of the 32 sites surveyed (Table 9). All five of these sites also had an EIA score below 4 (range 3.30–3.96; Table 11). A possible reason for the relatively low Mean C scores is that the mitigation sites may need more time to improve their floristic quality even if the potential for higher floristic quality exists at each site (ages range from 7 to 12 years since created). Another possible reason is that system type was different for the five mitigation sites (drainage marsh - shrub swamp system vs. nutrient poor bogs to weakly minerotrophic medium level fens for all but two of the other sites). Peatland systems are expected to have lower species richness and a higher proportion of species with moderate to strong fidelities compared to drainage marsh - shrub swamps (NH Natural Heritage Bureau, pers. comm. 2013). Therefore, the FQA threshold for higher floristic quality examples of drainage marsh - shrub swamp systems should be lower compared to bogs and fens, as other studies have shown (Bourdaghs 2012; Figure 11). Two other sites, classified pre-field as medium level fen systems, were determined in the field to be drainage marsh - shrub swamp systems (pre-field misclassification based on limitations of landscape analysis). Musquash Swamp had a Mean C (3.47) comparable to the average score (3.46) from the five mitigation sites. Clay Pond had the highest EIA score (4.47) and the second highest Mean C (3.93) for the seven drainage marsh - shrub swamp systems sampled (including the five mitigation sites). Clay Pond's Mean C (3.93) is likely near or above the threshold that separates higher-quality drainage marsh - shrub swamp systems from lower-quality examples but below that same threshold for nutrient poor bogs.

Mean C had a relatively strong correlation with the EIA, USA RAM, and NHM methods (R^2 = 0.48, 0.42, and 0.37, respectively; Table 10). A weaker relationship was observed between FQI and EIA, USA RAM, and NHM (R^2 = 0.18, 0.19, and 0.07 respectively). Other studies (Francis et al. 2000) suggest Mean C may be a better predictor of floristic quality compared to FQI when assessing similar wetland types (as is the case in this study). FQI scores are influenced by species richness (Andreas et al. 2004; Miller and Wardrop 2006; Taft et al. 1997). For example, a wetland with a low Mean C but high species richness may have a higher FQI than a wetland with a higher Mean C but a lower number of species. Some studies have shown FQI may be best applied to comparing sites with large numbers of species with those supporting small numbers (Haering and Galbraith 2010).

As expected at the 32 sites, a comparison of Landscape development indices (LDI)from different time periods (Figure 1) showed a trend toward increased land use around the wetlands from the 1990s (pre-2001) to 2010. Coefficient values used in both indices are based on documented impacts of different land uses on wetland condition (Hauer et al. 2002), but different numbers of categories used in the pre-2001 vs. 2010 analyses may further contribute to differences between the two indices. LDIs do not precisely measure wetland system condition but they have been shown to be strongly correlated with floristic metrics (Cohen et al. 2004; Mack 2006). Whereas Mean C was moderately correlated in this study with LDI (R^2 = 0.28), neither of the weighted versions of FQA (Mean Cw and FQIw) were significantly correlated. Poling et al. (2003) and Bourdaghs et al. (2006) have shown non-weighted FQA indices outperformed weighted indices with between site comparisons. Other studies (Cohen et al. 2004; Rooney and Rogers 2002) suggest that weighted Mean C may be better applied to comparisons of unrelated wetland systems of various sizes. Based on these relationships, coupled with the additional resources required to assess each species' cover compared to just presence-absence data at each site, using non-weighted Mean C may be most applicable for comparing similar system types.

Accurate interpretation of FQA scores for a given wetland requires identification of the system involved and studies to determine what threshold values apply to that system. In Minnesota, Bourdaghs (2012) analyzed FQA scores in 14 wetland systems using relevé data from both relatively undisturbed wetlands and those determined to be severely impacted (i.e., strong evidence of both the former type and severe anthropogenic impacts present). They compared average FQA scores among system types and showed significantly different scores for different types (Figure 11). In this study, weighted Mean C was chosen as the primary FQA assessment metric because it was more responsive than Mean C in wetland systems with a significant cover of non-native invasive species (Michael Bourdaghs, Minnesota Pollution Control Agency, pers. comm. 2013). These data indicate that it is essential to classify wetland systems when interpreting FQA results (Bourdaghs 2012).

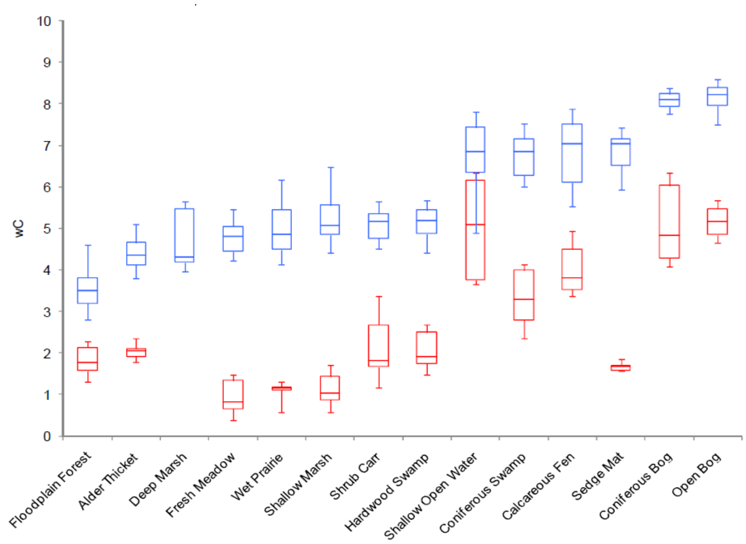


Figure 11. Weighted Mean C (wC) box and whisker distribution plots from all system types in Minnesota. Blue plots = pre-settlement and minimally impacted examples; red plots = severely impacted examples. Arranged from left to right according to increasing median wC scores for the pre-settlement/minimally impacted plots (from Bourdaghs 2012).

In our study, even though sample size was small, the average Mean C scores for relatively undisturbed examples (EIA rank of A or B) of the four surveyed system types followed the same pattern (Table 18; Figure 12) as seen in Minnesota (Figure 11).

Table 18. Average Mean C scores for relatively undisturbed examples (EIA rank of A or B) of the four system types surveyed in our study.

Mean C by System Type		
System Type	**Mean C**	**Sampled**
Drainage marsh - shrub swamp system	3.70	2
Medium level fen system	4.63	7
Poor level fen/bog system	4.86	9
Kettle hole bog system	5.29	9

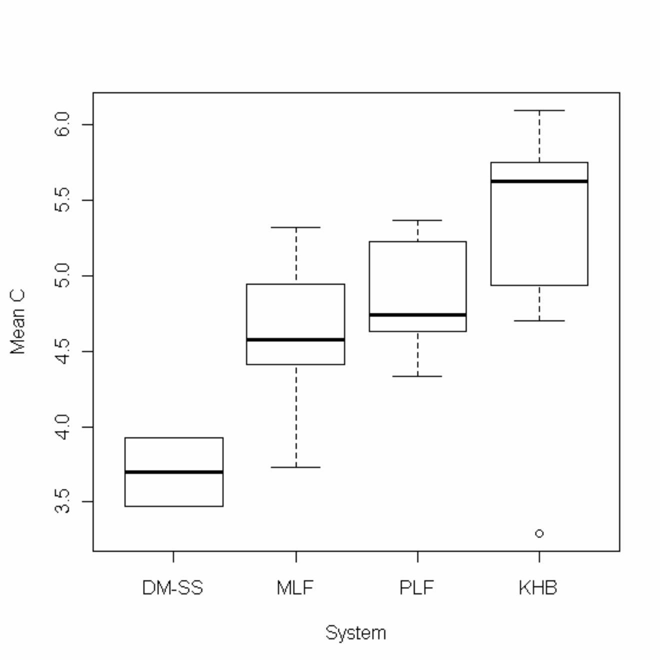


Figure 12. Boxplot of Mean C scores by system type for relatively undisturbed examples (EIA rank of A or B) in our study. Depicts median, quartiles, minimum, and maximum. DM-SS = drainage marsh - shrub swamp system (n = 2); MLF = medium level fen system (n = 7); PLF = poor level fen/bog system (n = 9); KHB = kettle hole bog system (n = 9).

Additional research would clarify FQA floristic quality thresholds among different wetland system types in the Northeast. Other potential FQA research topics include understanding which indices best predict condition given differences in disturbance, wetland size, and sampling approach.

Comparison of Strengths and Weaknesses

Given the diversity of goals possible for wetlands assessments, no one method can be considered to be superior to others. The choice of method for a particular situation will depend on the overall goal, the resources available, and the expected uses of the results. The combination of field application and literature research conducted for this study allows a detailed comparison of the strengths and weaknesses of the four rapid assessment methods used (Table 19). These results can be used to assist users in selecting an appropriate method given their particular goals and constraints.

Table 19. Comparison of selected wetland assessment methods (some information from Langendoen et al. 2006).

	METHOD			
Feature	**NHM**	**USA RAM (modified)**	**EIA**	**FQA**
Reference	Stone and Mitchell 2011	Environmental Protection Agency 2011; New Hampshire Department of Environmental Services 2012	Nichols and Faber-Langendoen 2012	Bried et al. 2012
	Protocol and Field Based Comparisons			
Purpose	Function: Estimate individual ecological functions (and societal values)	Condition: Estimate wetland's overall ecological integrity	Condition: Estimate wetland's overall ecological integrity	Condition: Estimate wetland's overall ecological integrity
Application	Non-tidal wetlands	Tidal & non-tidal wetland systems	Tidal & non-tidal wetland systems	All wetland and upland systems
Usage	Informing local land use decisions Identifying potential restoration sites Providing basis for more thorough field assessments Developing performance standards and mitigation criteria Identifying high quality wetlands Evaluating a wetland's functions and potential functions Education	Informing local land use decisions Identifying potential restoration sites Monitor changes at restoration and mitigation sites Developing performance standards and mitigation criteria Identifying high quality wetlands Long term status and trend monitoring	Informing local land use decisions Identifying potential restoration sites Monitoring changes at restoration and mitigation sites Developing performance standards and mitigation criteria Identifying high quality wetlands Long term status and trend monitoring Field surveys for threatened and endangered plant species Field surveys for exemplary natural communities and systems (Natural Heritage sites)	Informing local land use decisions Identifying potential restoration sites Monitoring changes at restoration and mitigation sites Developing performance standards and mitigation criteria Identifying high quality wetlands Long term status and trend monitoring Field surveys for threatened and endangered plant species
Approach	Compartmental: Multiple functions assessed individually	Holistic: Ecological integrity = "integrating super function"	Holistic: Ecological integrity = "integrating super function"	Botanical: Fidelity of plant species to specific habitats and condition of habitat
Features evaluated	12 Functions: ♦Ecological Integrity ♦Wetland-Dependent Wildlife Habitat ♦Fish & Aquatic Life Habitat ♦Scenic Quality ♦Educational Potential ♦Wetland-Based Recreation ♦Flood Storage ♦Groundwater Recharge ♦Sediment Trapping ♦Nutrient Trapping-Retention-Transformation ♦Shoreline Anchoring ♦Noteworthiness	4 Major Attributes of Ecological Integrity: ♦Buffer ♦Hydrology ♦Biological Structure ♦Physical Structure	5 Major Attributes of Ecological Integrity: ♦Landscape Context ♦Hydrology ♦Vegetation ♦Soil ♦Size	Floristic Quality: ♦Species richness and species-specific coefficients of conservatism
Use of wetland classification	Identifies NWI class types in the wetland and counts them	Identifies NWI class types in the wetland and counts them	Identifies system and natural community classification and uses them to inform stressors and metric assessment and biodiversity value (rarity) of the wetland	Not directly used but more interpretable when indices compared between similar systems
Use of stressors	Evaluates stressors known to negatively impact biological based functions (i.e., Ecological Integrity, Wetland-Dependent Wildlife Habitat, and Fish & Aquatic Life Habitat) For a given function, stressor scores rolled up with other scores to determine individual function score	Evaluate stressors known to negatively impact condition Stressor and condition metric scores rolled up to determine overall wetland condition score	Evaluate stressors known to negatively impact condition Stressor scores are used to inform assessment of metrics and to help interpret a wetland system's condition, but they are not rolled into the overall score EIA Stressor Checklist may be utilized to evaluate whether a wetland system is a candidate for restoration	Not used
Assessment area	Contiguous wetland complex (although not formerly classified, wetland may support more than one system)	Single wetland unit if <20 ha; a larger wetland requires at least a second assessment area (although not formerly classified, assessment area typically one system)	Single wetland system regardless of size (following Sperduto 2011)	Usually a single wetland unit (although not formerly classified, assessment area typically one system)

METHOD				
Feature	**NHM**	**USA RAM (modified)**	**EIA**	**FQA**
Buffer evaluated: width from wetland's edge	0–152 m (0–500 ft.)	0–100 m	0–100 m 100–250 m 250–500 m	None
Assessing wildlife value	Four of the 12 functions address wildlife either directly or indirectly: Ecological Integrity, Wetland-Dependent Wildlife Habitat, Fish & Aquatic Life Habitat, and Noteworthiness	Several of the 12 primary metrics indirectly address wildlife habitat: buffers and stressors, patch types/physical structure, plant community complexity, and stressors to water quality	Land Use Index metric evaluates landscape connectivity for wildlife out to 500 m from the wetland's edge Stressors Checklist considers the extent and scope of stressors that could affect wildlife in and around the system Classifying assessment area to system type allows the user to directly identify key wildlife habitat types and wildlife species of conservation concern	Indirectly measures the condition of wildlife habitat in and around the wetland system; wetlands with higher Mean C scores are more likely to support better habitat for native wildlife species compared to wetlands with lower Mean C scores
Current regulatory decisions / permit review	Recommended by NH DES for Prime Wetlands designation since 1991 (Env-Wt 700; see Discussion for more information)		NH DES considers impacts to exemplary natural communities and systems per RSA 217-A in regulatory review; exemplary status for wetlands is now based on an EIA analysis	
Potential use in regulatory process	Identifying candidate wetlands for restoration due to low functional scores that resulted from human causes Use by permittees to respond to the "20 Questions" in Env-Wt 302.04 (i.e., potential impact of the proposed project on the values and functions of the wetland)	Could be used to inform permitting, mitigation, and prime wetland designation (see Discussion for more information)	Could be used to inform permitting, mitigation, and prime wetland designation (see Discussion for more information)	Could be used to inform permitting, mitigation, and prime wetland designation (see Discussion for more information)
Existing data required	♦ GIS software and readily available data layers ♦ Alternatively, uses the web-based GIS tool designed for NHM (NH Wetlands Mapper) ♦ An information request to NHB on known rare species and exemplary natural communities ♦ FEMA Flood Insurance Rate map (available online) ♦ Stratified drift aquifer data from DES or Society for the Protection of NH Forests (available online) ♦ Soil survey data to interpret soil relevant characteristics of soils in and surrounding wetland ♦ Wetland gradient determination using DRG Topographic Map, Google Earth, Terrain Navigator, (or ground survey) ♦ Local or region conservation plans ♦ Historical/Archaeological information from a town's historic resources or contacting the state archaeological office ♦ Information from NH Rivers Management & Protection Program or from the National Wild & Scenic Rivers Program on State Designated Rivers and Federally Designated Wild & Scenic Rivers (available online) ♦ Wildlife Action Plan for information regarding critical wildlife habitats and highest- ranked habitats	♦ GIS software and readily available data layers	♦ GIS software and readily available data layers ♦ System and natural community classification (Sperduto 2011; Sperduto and Nichols 2011; available online)	♦ Readily available mapped data (i.e., aerials, NWI, and conservation lands) ♦ Table of CoC values for NH developed in 2011;may need updates/additions (available online)

METHOD				
Feature	**NHM**	**USA RAM (modified)**	**EIA**	**FQA**
Field data gathered	Assessment of field-based questions associated with 10 of 12 functions: ♦ Ecological Integrity ♦ Wetland-Dependent Wildlife Habitat ♦ Fish & Aquatic Life Habitat ♦ Scenic Quality ♦ Educational Potential ♦ Wetland-Based Recreation ♦ Sediment Trapping ♦ Nutrient Trapping-Retention-Transformation ♦ Shoreline Anchoring ♦ Noteworthiness Field check important in establishing a wetland evaluation unit	Assessment of field-based stressor and condition metrics: ♦ Metric 3: Stress to the Buffer Zone ♦ Metric 4: Topographic Complexity ♦ Metric 5: Patch Mosaic Complexity ♦ Metric 6: Vertical Complexity ♦ Metric 7: Plant Community Complexity ♦ Metric 8: Stressors to Water Quality ♦ Metric 9: Alterations to Hydroperiod ♦ Metric 10: Habitat / Substrate Alterations ♦ Metric 11: Percent Cover of Invasive Species ♦ Metric 12: Vegetative Disturbance	Assessment of field-based condition metrics: ♦ Vegetation Structure ♦ Relative Cover of Native Species ♦ Cover of Invasive Plant Species ♦ Vegetation Regeneration ♦ Vegetation Composition ♦ Water Source ♦ Hydroperiod ♦ Hydrologic Connectivity ♦ Soil Condition ♦ Physical Patch Type Diversity ♦ Size Condition Stressor Checklist ground truthed Land Use Index map ground truthed (as needed) System and natural communities assessed Diagnostic list of vascular plant species completed for each natural community type present in system	A fairly thorough list of vascular plant species, completed by surveying each natural community type present in the system In addition, for weighted FQA indices, percent cover of each vascular plant species in the system
Average estimated time to complete evaluations (office and field time combined for 32 sites)	8+ hours	7 hours	8 hours	6 hours
Estimated time breakdown for 32 sites: **Preparation/research** **Field data collection** **Data entry and analysis**	 3+ hrs. 2 hrs. 3+ hrs.	 2 hrs. 2 hrs. 3 hrs.	 2 hrs. 2 hrs. 4 hrs.	 2 hrs. 2 hrs. 2 hrs.
Minimum expertise required	Good skills interpreting maps for desktop evaluation; background in wetland ecology not required, but good field experience extremely useful	Professional wetland scientist with skill identifying plant species, natural features, and vegetation classes	Professional wetland scientist with competent botany and plant community ecology skills and knowledge	Professional wetland scientist with competent botany skills and some plant community ecology knowledge
Numeric score produced	Numeric index (0–10) for each of 12 functions	Numeric index (0–144)	Numeric index (1–5) with associated ranks (A–D)	Mean C: numeric index (0–10) FQI: numeric index, undefined upper bound
Estimated inter-observer variability	Moderate	Low-Moderate	Low-Moderate	Low
Other Comparisons				
Strengths	Diverse list of function indicators including several with societal value Wetland functions with high scores may identify valuable features, regardless of overall wetland condition	Condition indicators combined for an overall score Relatively easy to use	Condition indicators combined for an overall score Indicators weighted based on their importance Identifies occurrences of threatened and endangered plant species and exemplary natural communities and systems Identifying the wetland system and natural communities based on a published classification (Sperduto 2011; Sperduto and Nichols 2011) improves EIA's sensitivity in estimating condition and makes further analyses possible (e.g., comparisons to reference sites or to the Wildlife Action Plan)	Overall score produced Most rapid and straightforward to use (if surveyor has competent skills in botany and some plant community ecology knowledge Identifies occurrences of threatened and endangered plant species

METHOD				
Feature	**NHM**	**USA RAM (modified)**	**EIA**	**FQA**
Potential limitations	Extensive office-based research requires enough additional time that the method may not be considered a "rapid assessment" Overall score not produced Some functions are evaluated based on the wetland's potential in performing them, irrespective of whether or not it is doing so More clarity and consistency needed in descriptions and questions between field hardcopy data forms, digital scorecard, and manual; in manual, more clarity needed between stated questions, background information associated with questions, and information associated with "how to answer the question" Does not utilize a vegetation classification: adding metrics on dominant plant species and community structure would improve the ability of the Ecological Integrity Function to assess condition Limited assessment of Ecological Integrity (condition)	Requires surveyor with skill identifying dominant plant species Does not utilize a vegetation classification: sensitivity of several metrics to differences in condition would improve if they were more specific to wetland type The use of some metric stressors may not be appropriate for condition assessments; other stressors may be insensitive as a condition measure Stressor assessment does not separate out stressor scope from extent; doing so may reduce inter-observer variability Does not use wetland size as one of the major ecological attributes evaluated Does not evaluate functions / services	Requires surveyor with competent botany and plant community ecology skills and knowledge Stressor checklist does not directly affect the final condition score (informs completion of condition metrics) Physical patch type metric can be challenging to evaluate Does not evaluate functions / services	Requires surveyor with competent botany skills and some plant community ecology knowledge Requires a well-justified Coefficient of Conservatism value for all plant species identified Requires regional evaluation to define vegetation quality thresholds by referencing established wetland condition gradients by wetland system type FQI scores influenced by species richness; a wetland with a low mean C but high species richness may have a higher FQI than a wetland with a higher mean C but a lower number of species Not intended to be a stand-alone indicator; should be used with other condition metrics Does not evaluate functions / services

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Appendix 1. Three Questionnaires for Surveyors.

Each surveyor will complete the following:

1) Pre-season surveyor self-assessment after NHM, USA RAM, and EIA field training.

2) Method assessment after each survey (specific to combination of observer-method-date-site).

3) Comparison of the methods after field season.

1. PRE-SEASON SURVEYOR SELF-ASSESSMENT AFTER NHM, USA RAM, AND EIA FIELD TRAINING (RANK SCALE OF 1–HIGH TO 5–LOW):

A. ***Ability in each area***:

_______ Interpreting topographic maps

_______ Interpreting aerial photographs

_______ Identifying plant species

_______ Identifying natural community types using NHB classification key

_______ Identifying natural community system types using NHB classification key

Comments:____

B. ***Familiarity with relative undisturbed examples of each system type***:

_______ Kettle hole bog systems

_______ Poor level fen/bog systems

_______ Medium level fen systems

_______ Open peatlands in general

Comments:____

C. ***Familiarity with using***:

_______ NH Method

_______ USA RAM Method

_______ EIA Method

_______ FQA Method (assess ability to collect a thorough species richness list for wetland systems)

Comments:____

2. METHOD ASSESSMENT AFTER EACH SURVEY (SPECIFIC TO COMBINATION OF OBSERVER-METHOD-DATE-SITE):

A. ***General information***:

Date:		Method:	NHM USA RAM EIA FQA
Observer(s):		Start Time:	
Wetland Site:		End Time:	

B. ***Score each on the scale indicated based on your experience <u>today</u> at <u>this wetland</u>*** (the score you give for this wetland may or may not be the same score you give to other wetlands during your surveys as you gain experience):

***<u>Today</u>* at *<u>this wetland</u>*…**		**Score**	**Please Comment**
Were the instructions generally…	1–Clear to 5–Ambiguous		
Was making decisions (how to score)…	1–Easy to make to 5–Difficult		
If another similarly qualified observer did the same survey, would their scoring likely be…	1–Very similar to yours to 5–Very different		
Were there any aspects of the method applied that need clarification to ensure its consistent application?			

C. ***List any specific limitations or sources of error in the data you collected at this site***:

How many plant species with a cover of 5% or more were difficult to identify:
What percent of the wetland (entire system as mapped) was observed? Note: Only include distant observations if you were able to assess condition for those distant areas.
Is there a portion of the wetland or buffer that could not be field-checked/observed and where its condition remained unknown even after reviewing aerial imagery? To what degree does this portion of the wetland or buffer have the potential to change the conclusions of the survey if it HAD been visited?
List any ecological features of the wetland (potential metrics) relevant to wetland condition or functions that were not captured by this assessment:
Note any time-consuming activities that in your judgment did not add much to the overall goal of assessing the condition or functions of the wetland:
Other comments:

3. COMPARISON OF THE METHODS AFTER FIELD SEASON:

A. ***General information***:

Surveyor:	
Date Form Completed:	

B. ***Total wetland sites surveyed (by Method)***:

Assessment Method	**# Sites Surveyed**	**Comments**
NHM		
USA RAM		
EIA		
FQI		

C. ***Ease of use for field surveys***: Were the methods you used particularly easy or difficult to apply under certain settings/circumstances? Specify what setting/circumstance, e.g., if a method was particularly difficult for large wetlands, add "large" to the **Specific Setting or Circumstance** column. For each method, complete additional rows for separate sites as needed:

USA RAM			
Survey Site Name		**Specific Setting or Circumstance**	**Ease of Use:** **1–Easy to 5–Difficult**
Site:			
Site:			
Site:			
Site:			
Site:			

NHM			
Survey Site Name		**Specific Setting or Circumstance**	**Ease of Use:** **1–Easy to 5–Difficult**
Site:			
Site:			
Site:			
Site:			
Site:			

EIA			
Survey Site Name		**Specific Setting or Circumstance**	**Ease of Use:** **1–Easy to 5–Difficult**
Site:			
Site:			
Site:			
Site:			
Site:			

FQA			
Survey Site Name		**Specific Setting or Circumstance**	**Ease of Use:** **1–Easy to 5–Difficult**
Site:			
Site:			
Site:			
Site:			
Site:			

D. ***Based on your experience conducting field surveys, please provide any other comments comparing the different methods you used***:

Method	**Comments**

Appendix 2. Explanation of Global and State Conservation Status Ranks.

These rank codes describe the degree of vulnerability of an element of biodiversity (species, natural community, or natural community system) to extirpation, either throughout its range (global or “G” rank) or within a subnational unit such as a state (subnational or “S” rank). For species, the vulnerability of a sub-species or variety is indicated with a taxon (“T”) rank. For example, a G5T1 rank for a sub-species indicates that the sub-species is critically imperiled (T1) while the species is secure (G5).

Code	Examples		Description
1	G1	S1	Critically imperiled because of extreme rarity (e.g., one to five occurrences), very restricted range, very steep recent declines, or other factors making it extremely vulnerable to extirpation.
2	G2	S2	Imperiled due to very few occurrences (e.g., six to 20), restricted range, steep recent declines, or other factors making it very vulnerable to extirpation.
3	G3	S3	Vulnerable due to relatively few occurrences (e.g., 21 to 80), relatively restricted range, recent declines, or other factors making it vulnerable to extirpation.
4	G4	S4	Apparently secure due to having more than a few occurrences (e.g., >80) and/or an extensive range, but possible cause for long-term concern due to local recent declines or other factors.
5	G5	S5	Secure; widespread and abundant.
U	GU	SU	Status uncertain. More information needed.
H	GH	SH	Known only from historical records (e.g., a species not reported as present within the last 20 years or a community or system that has not been reported within 40 years).
X	GX	SX	Believed to be extinct. May be rediscovered, but habitat alteration or other factors indicate rediscovery is unlikely.

Modifiers are used as follows:

Code	Examples		Description
Q	G5Q	GHQ	Questions or problems may exist with the element’s taxonomy or classification, so more information is needed.
?	G3?	3?	The rank is uncertain due to insufficient information at the global level, so more inventories are needed. When no rank has been proposed the global rank may be “G?” or “G5T?”.

When ranks are somewhat uncertain or the element’s status appears to fall between two ranks, the ranks may be combined. For example:

G4G5	The element rank is either 4 or 5, or its rank is near the border between the two.
G5T2T3	For a plant or animal, the species is globally secure (G5), but the sub-species is vulnerable or imperiled (T2T3).
G5?Q	The element seems to be secure globally (G5), but more information is needed to confirm this (?). Further, there are questions or problems with the element’s taxonomy or classification (Q).
G3G4Q S1S2	The element is globally vulnerable or apparently secure (G3G4), and there are questions about its taxonomy or classification (Q). In the subnation, the element is imperiled or critically imperiled (S1S2).

Appendix 3. Explanation of State Rarity Status Categories.

The New Hampshire Native Plant Protection Act (RSA 217-A) mandates that the New Hampshire Natural Heritage Bureau develop and maintain a list of plant species that are rare in the state. Each species on the rare plant list is assigned a category that reflects its degree of rarity. These categories are described below.

Endangered (E): Native plant taxa vulnerable to extirpation based on having five or fewer natural occurrences in the state observed within the last 20 years, or taxa with more than five occurrences that are, in the judgment of experts, vulnerable to extirpation due to other important rarity and endangerment factors (population size and trends, area of occupancy, overall viability, geographic distribution, habitat rarity and integrity, and/or degree of protection). A rare native plant taxon that has not been observed in over 20 years is considered endangered unless there is credible evidence that all previously known occurrences of the taxon in the state have been extirpated. For plant species, this status is equivalent to a rank of S1.

Threatened (T): Native plant taxa vulnerable to becoming endangered based on having 6–20 natural occurrences in the state observed within the last 20 years, or taxa that are, in the judgment of experts, vulnerable to becoming endangered due to other important rarity and endangerment factors (population size and trends, area of occupancy, overall viability, geographic distribution, habitat rarity and integrity, and/or degree of protection). For plant species, this status is equivalent to a rank of S2.

Watch (W): Native plant taxa vulnerable to becoming threatened based on having 21–100 natural occurrences in the state observed within the last 20 years, or taxa that are, in the judgment of experts, vulnerable to becoming threatened due to other important rarity and endangerment factors (population size and trends, area of occupancy, overall viability, geographic distribution, habitat rarity and integrity, and/or degree of protection). For plant species, this status is equivalent to a rank of S3.

Indeterminate (Ind): Plant taxa under review for listing as endangered, threatened, or watch, but their rarity, nativity, taxonomy, and/or nomenclature are not clearly understood.