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 Five Restoration Sites in New Hampshire

March 2013

A report prepared by the
New Hampshire Natural Heritage Bureau
DRED Division of Forests & Lands, Concord, NH

Completed under EPA Grant # CD-96155401

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: Hillsboro Mitigation Site, Hillsboro, NH.
(Photo by Bill Nichols)

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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 condition. 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 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). For constructed mitigation sites and wetlands that have been degraded by human activities, targeted for restoration, and now in a "mature" restoration state, the need to provide regulatory agencies with a potential tool to measure the success of these projects is critical.

The principal goal of this project is to compare alternative wetland assessment methods at three to five restoration projects, focusing on the overall condition of wetlands at mature restoration or constructed mitigation sites. Better understanding the strengths and weaknesses of alternative wetland assessment methods will allow regulatory agencies and other users to choose the method most appropriate for measuring restoration success.

METHODS

The principal goal of this project was a comparison of alternative wetland assessment methods to determine their potential use as a tool to measure project success. The NH Natural Heritage Bureau (NHB), in coordination with the NH Department of Environmental Services (DES) and the University of New Hampshire Cooperative Extension (UNHCE), achieved this goal by:

1. Selecting wetland assessment methods to study.
2. Assessing relevant existing data.
3. Identifying mitigation 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 wetland restoration and mitigation projects.

This project focused on Rapid Assessment Methods (RAMs). 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 NH Natural Heritage Bureau (NHB), NH Department of Environmental Services (DES), and University of New Hampshire Cooperative Extension (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).

Most or all of the following criteria characterizes 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 one day or less to complete office preparation, field data collection, and data analysis), and 4) requires on-site visit.

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 Mitigation 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 at mature restoration or constructed mitigation sites to provide regulatory agencies with a potential tool to measure success of these projects. Given limited funds and time, it was important to limit uncontrolled differences between wetlands surveyed to those that were the highest priority for the methods comparisons. The most mature sites were chosen to improve the likelihood that restoration success was detectable by the selected assessment methods. Assessment methods were applied to five restoration or constructed mitigation sites in central and southern New Hampshire (Table 1).

Table 1. List of sites to evaluate using selected wetland assessment methods.

Survey Site	**Town**	**Hectares**	**Site Data**

Survey Site	Town	Hectares	Site Data
Speedway	Loudon	5	Compensation for filling 4 ha of forested wetlands for parking lot expansion includes 5 ha of wetland construction.
NH DOT	Brentwood	5	Compensation for filling 44.5 ha for highway includes creating 40.5 ha of wetland, preserving 84 ha, and conducting wetland enhancement of 5 ha.
NH DOT	Conway	5.4	Compensation for filling 14.5 ha for highway includes construction of wetlands in excavation sites with 5.4 ha adjacent to Pequawket Pond.
NH DOT	Hillsboro	5.5	Compensation for filling 5.6 ha for highway improvements includes 5.5 ha of wetland creation and enhancement, 6.6 ha of wetland preservation, and 13 ha of upland preservation and enhancement.
NH DOT	Peterborough	1.3	Compensation for filling 1.4 ha for highway improvements includes 1.3 ha of wetland construction and preservation of the wetland construction area and an additional 3.5 ha of upland preservation.

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 to be studied were mature restoration or constructed mitigation sites. Whenever feasible, preparatory field materials for each of the methods used the same existing data. Surveyors from NHB applied the selected methods at each of the five sites. Inter-observer variability was assessed at Conway and for the EPA Grant Project CD-96155701, a related and concurrent study with a larger sample size of sites (n=27). Surveyors had assessed multiple wetlands for EPA Grant Project CD-96155701 using the selected methods. To broaden the context of our comparisons, data from EPA Grant Project CD-96155701 was analyzed with the data collected at the five mitigation sites.

Summarizing and Comparing the Assessment Methods Protocols and Results
NHB and DES compared alternative wetland assessment methods through research and by applying the methods to five mature restoration or constructed mitigation sites. This report herein summarizes the strengths and weaknesses of the selected wetland assessment methods. In addition, the report specifically evaluates each method’s results relative to their use a potential tool to measure the success of restoration projects. Comparisons have been compiled in digital tables (MS Access and/or MS Excel). 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 the goal of assessing the success of restoration projects.

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 through 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

NHB conducted field surveys at five constructed mitigation sites in central and southern New Hampshire. NHB produced maps of each of the chosen wetland sites. The maps included GIS layers, e.g., National Wetlands Inventory and conservation land polygons displayed on USGS topographic maps (1:12,000). Two surveyors applied the four wetland assessment methods (NHM, USA RAM, EIA, and FQA) at the mitigation sites (Table 1). Each surveyor visited three of the five sites; the mitigation wetland in Conway served as a replicate site (independently assessed by the two surveyors).

<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 towns to use for inventorying and evaluating their 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.
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 and 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 should not 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, 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 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 2). 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 2. USA RAM attributes, condition metrics, and stressor metrics.

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

NHB Level 2 EIA

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. EIA emphasizes metrics that are condition-based, distinct from stressor-based approaches.

Characteristics of 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 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 ($C = \Sigma C / n$). The 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 C may have different FQIs, and sites with the same FQI may have different Cs (Goforth et al. 2001; Taft et al. 1997).

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 3).

Table 3. Land use coefficient table.*

Current Land Use	**Coefficient**
Paved; buildings; mining	0
Unpaved roads; abandoned mines	0.1

Current Land Use	Coefficient
Agriculture (tilled); intensively developed vegetation (golf courses, lawns, sport fields)	0.2
Clearcut Heavy grazing on pasture lands	0.3 0.3
Heavy logging with 50-75% of trees >30 cm dbh removed Intense recreation (ATV use, camping, popular fishing spot); training areas Permanent crop (orchards, nurseries, berry production, introduced hay field and pastures)	0.4 0.4 0.4
Commercial tree plantations Dam sites and flood disturbed shorelines around water storage reservoirs Recent old field dominated by ruderal and exotic species	0.5 0.5 0.5
Moderate grazing on pasture lands	0.6
Moderate recreation (high-use trail) Mature old field with natural composition	0.7 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

Two surveyors from NHB completed a total of 24 assessments at five wetland mitigation sites (Table 4) using the four methods: NHM, USA RAM, EIA, and FQA.

Table 4. Wetland assessments (n = 24) completed at five wetland mitigation sites.

SURVEY SITE	NHM	USA RAM	EIA	FQA
Brentwood Mitigation Site	Surveyor 1	Surveyor 1	Surveyor 1	Surveyor 1
Loudon Mitigation Site	Surveyor 1	Surveyor 1	Surveyor 1	Surveyor 1
Conway Mitigation Site*	Surveyor 1 Surveyor 2	Surveyor 1 Surveyor 2	Surveyor 1 Surveyor 2	Surveyor 1 Surveyor 2
Hillsboro Mitigation Site	Surveyor 2	Surveyor 2	Surveyor 2	Surveyor 2
Peterborough Mitigation Site	Surveyor 2	Surveyor 2	Surveyor 2	Surveyor 2

* Conway is a replicate site for the mitigation study.

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 (including the five mitigation 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.

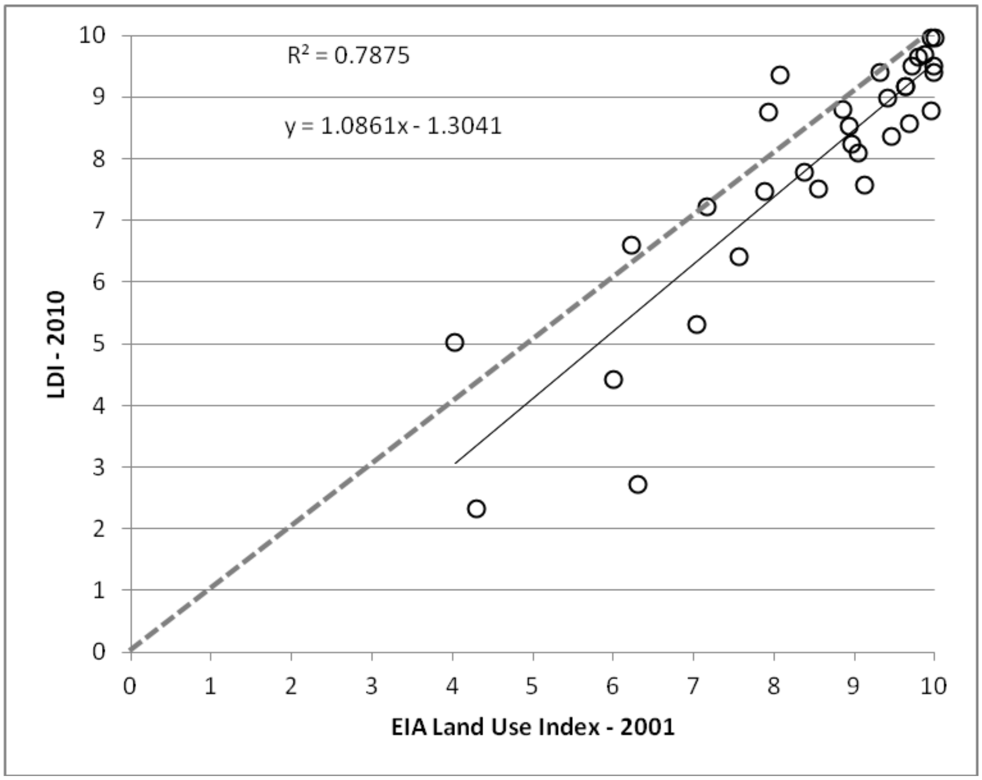


Figure 1. EIA land use index calculated based on pre-2001 aerial imagery vs. LDI using 2010 images at 32 wetland sites. Both indices were calculated within the 0–500 m area surrounding each wetland.

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.

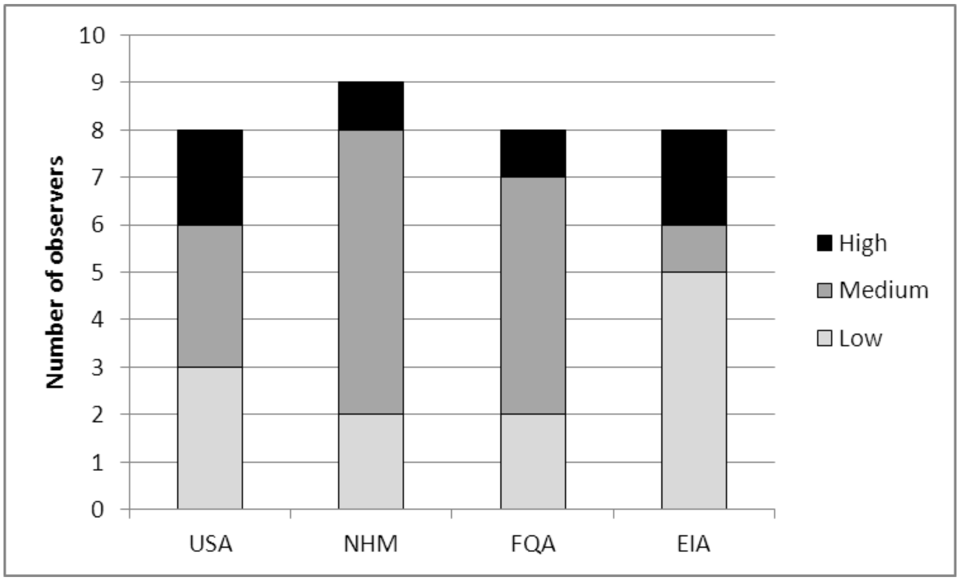


Figure 2. Experience of surveyors with each of the four assessment methods.

Field time requirements

FQA required the least time to complete, averaging around 1.5 hours (Table 5; 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 5. 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

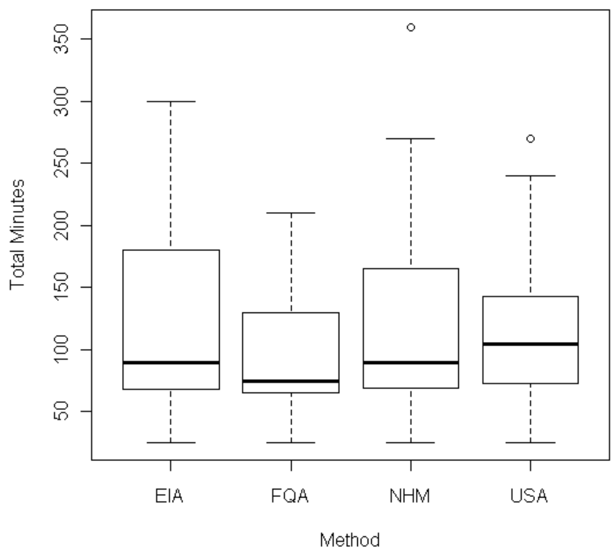


Figure 3. Total time required for field data collection by method at 32 sites, depicting minimum, lower quartile (25% of scores), median, upper quartiles (75%), maximum, and outliers (open circles).

<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).

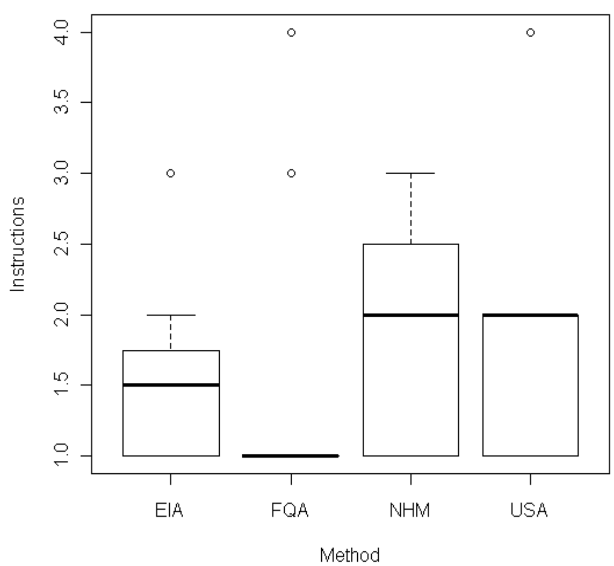


Figure 4. Surveyor (n = 9) responses to clarity of instructions by method (1–clear to 5–ambiguous). Depicts minimum, lower quartile (25% of scores), median, upper quartiles (75%), maximum, and outliers (open circles).

<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).

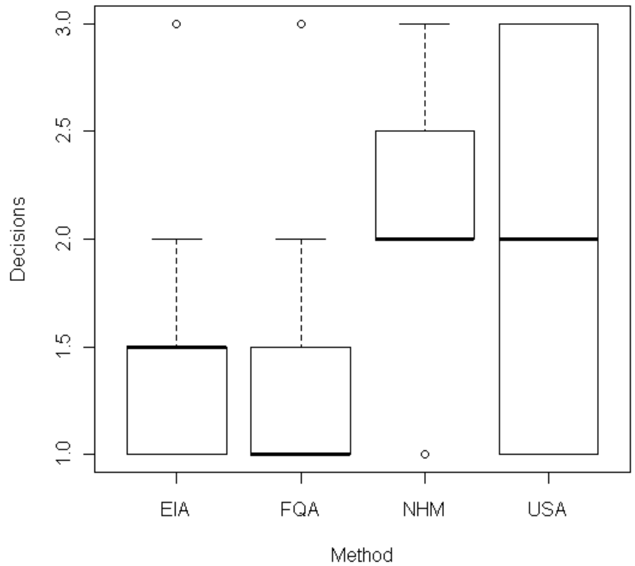


Figure 5. Surveyor (n = 9) responses to difficulty in making decisions on how to score metrics or answer questions (1–easy to 5–difficult). Depicts minimum, lower quartile (25% of scores), median, upper quartiles (75%), maximum, and outliers (open circles).

<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).

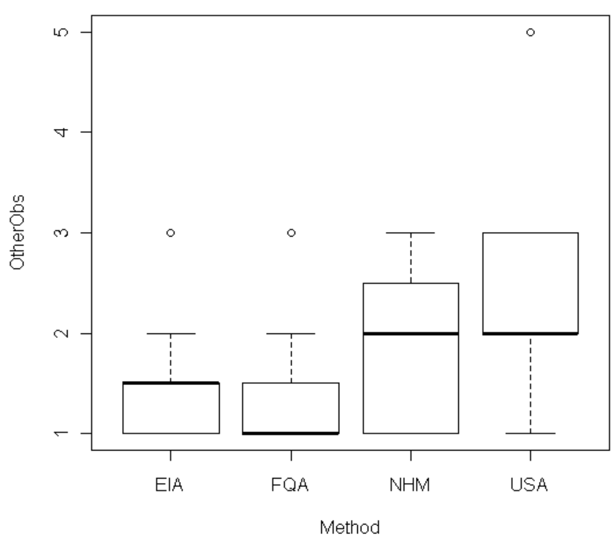


Figure 6. Surveyor (n = 9) responses when asked if another similarly qualified observer did the same survey, would their scoring likely be "1–very similar to yours" to "5–very different." Depicts minimum, lower quartile (25% of scores), median, upper quartiles (75%), maximum, and outliers (open circles).

Percent of wetlands surveyed

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%.

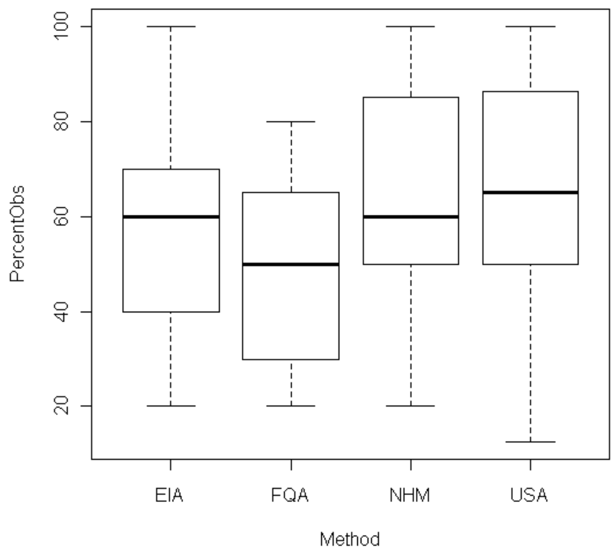


Figure 7. Surveyor (n = 9) responses when asked about the percent of wetland observed. Distant observations were included only if surveyors were able to assess condition. Depicts minimum, lower quartile (25% of scores), median, upper quartiles (75%), and maximum.

This study indicates that EIA is the most rigorous method for assessing wetland system condition while being fairly easy to understand and apply for experienced wetland scientists (Table 18). Basic results from surveyor questionnaire responses for EIA compared to NHM and USA RAM include:

- EIA instructions were fairly clear (median 1.5 for EIA vs. 2 for NHM and USA RAM on a scale of 1–5; Figure 4).
- Even though the EIA method had a relatively high proportion of surveyors with little to no experience (5 out of 8; Figure 2), the ability of surveyors to make decisions on how to score metrics or answer questions was judged by observers to be fairly easy (median 1.5 for EIA vs. 2 for NHM and USA RAM on a scale of 1–5; Figure 5).
- The likelihood that another similarly qualified observer surveying the same site would have a similar score was judged to be somewhat more likely with EIA (median 1.5 vs. 2 for NHM and USA RAM on a scale of 1–5; Figure 6).
- The percent of wetlands observed in the field (only including distant observations if able to assess condition for those distant areas) for EIA were similar to NHM and USA RAM (median around 60%; Figure 7).
- EIA field time was comparable to NHM and USA RAM (Table 5; Figure 3).

Range of Assessment Method Scores

The range of scores assigned at 32 sites (including five mitigation sites) by surveyors for each method are summarized in Table 6. 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 6. 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 7; 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 7. 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

Replicate Site	Method	Range	Mean Score	Min Score	Max Score
	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).

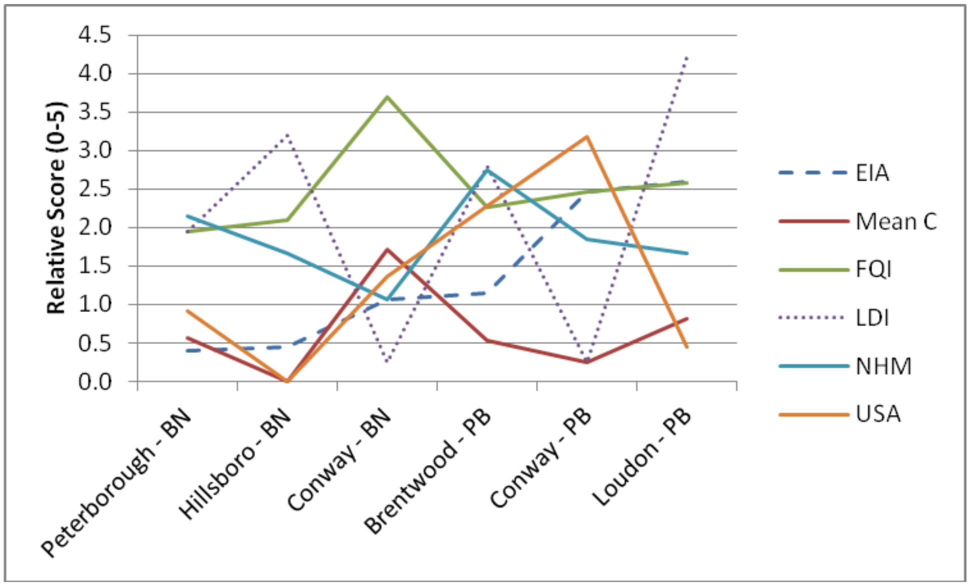
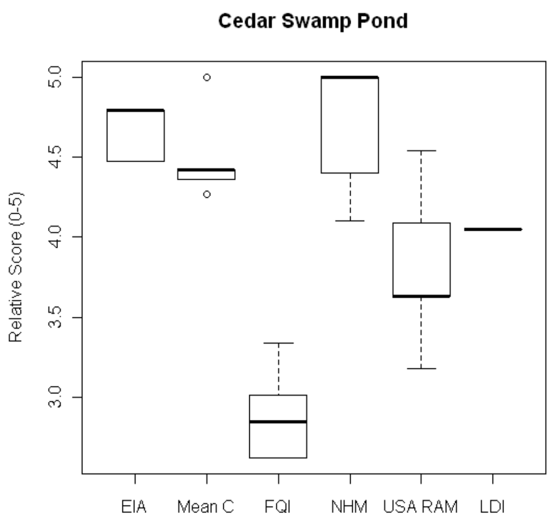
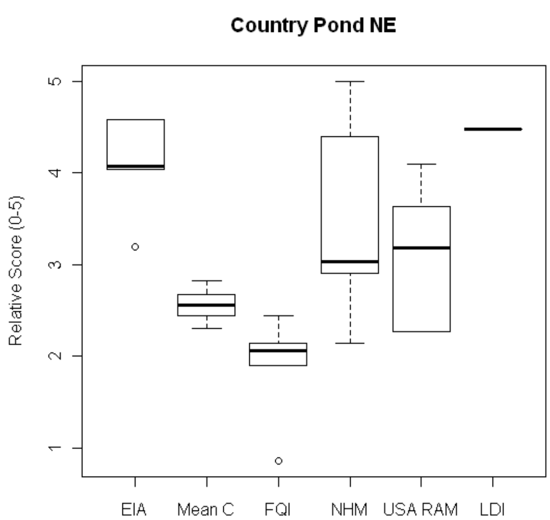


Figure 8. Standardized scores (0–5 for each method) at the five mitigation sites. EIA scores trend from lower to higher from left to right (see dashed blue line). Note: Conway Mitigation Site was scored twice, by two different surveyors.

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 7; 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.


Cedar Swamp Pond
Relative Score (0-5)
5.0
4.5
4.0
3.5
3.0
EIA
Mean C
FQI
NHM
USA RAM
LDI


Country Pond NE
Relative Score (0-5)
5
4
3
2
1
EIA
Mean C
FQI
NHM
USA RAM
LDI

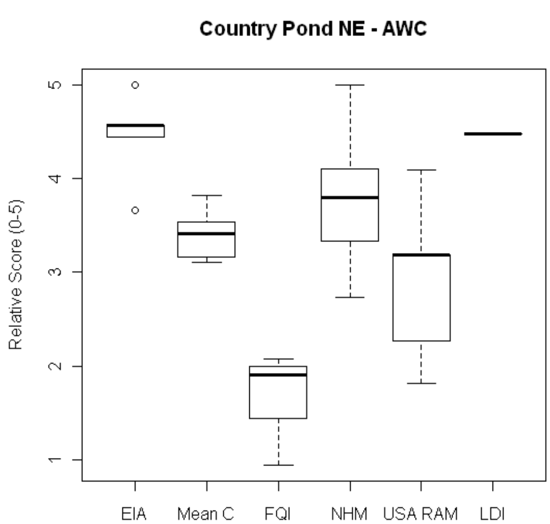

Country Pond NE - AWC
Relative Score (0-5)
5
4
3
2
1
EIA
Mean C
FQI
NHM
USA RAM
LDI

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 8). 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.

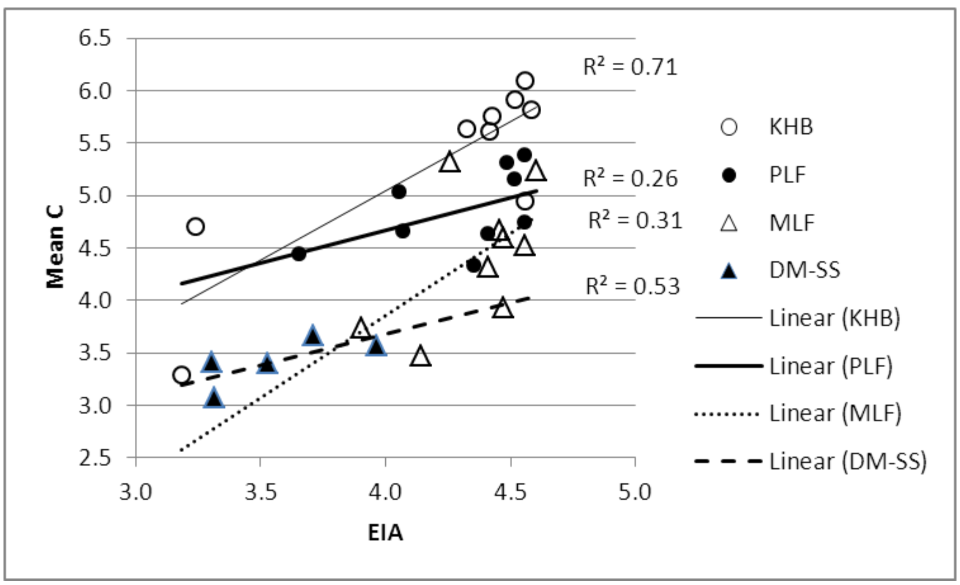
Table 8. Comparison of EIA scores from 32 sites (including five mitigation sites) with Mean C and FQI scores. Scores for each method were averaged at replicate sites. Mean C scores in italic font are anomalously lying above or below the EIA "B–C" threshold (red line).

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
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

Survey Site	EIA Grade	Mean C	FQI
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.



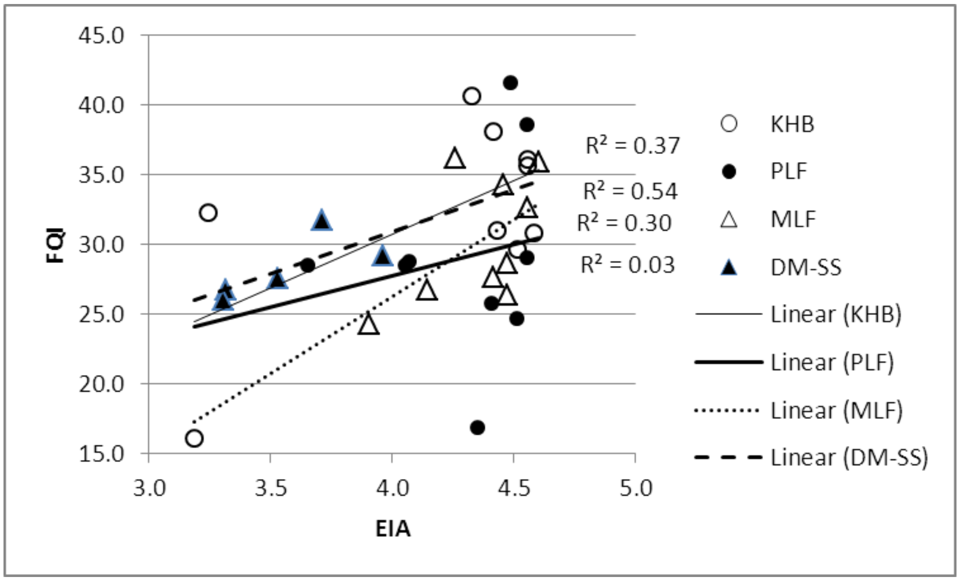


Figure 10. Relationship of EIA scores to Mean C and FQI scores by system type at 32 wetlands (including five mitigation sites). Scores are averaged for sites with replications. DM-SS = drainage marsh - shrub swamp system; MLF = medium level fen system; PLF = poor level fen/bog system; KHB = kettle hole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

Linear regression showed Mean C scores were moderately correlated with EIA scores (R^2 = 0.48, Table 9) 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 9. 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 10). 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 10. 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). Similar to functional assessments, the individual metrics and attributes associated with EIA and USA RAM can be used as mitigation tools, measuring compensational adequacy.

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(s). 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 scope and severity of multiple stressors 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 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

Water quality standards

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 at Level 2. 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 effect 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 in the EIA Stressors Checklist directly or indirectly relate to water quality and in this way, water quality is addressed in the method.

Wildlife value

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 18.

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)."

Gale (2003) describes key measures of successful mitigation, common pitfalls, and ways to improve the likelihood of success (Appendix 2). There is a need to use such guidelines to improve the current approach to evaluating mitigation sites in NH. For example, the following account of the Conway Mitigation Site seems to apply to the other four sites as well: "Although the approval conditions in the USACE and NHDES Wetland Permits do provide some general guidance on mitigation goals for the site (e.g., create a functioning wetland capable of providing flood storage, water quality renovation, and habitat values similar to those of the impacted wetlands), these conditions do not address specific standards of success and performance criteria to be reviewed on a long-term basis" (NH Department of Transportation 2012). Table 11 summarizes the mitigation project goals documented for each of the five sites included in this study. Rapid assessment methods have the potential to provide a set of consistent, science-based goals for mitigation sites and criteria for judging their success.

Table 11. Project goals for each of the five wetland mitigation sites.

Mitigation Site	**Year Created**	**Prior Use**	**Mitigation Design Goals**
Brentwood	1996	Gravel area and recreational camp sites	Overall: Replace principal functions and values lost (i.e., water quality, flood storage, and wildlife habitat)

Mitigation Site	Year Created	Prior Use	Mitigation Design Goals
			Other: ♦Replace wetland acreage impacted ♦Replace approximate acreage of wetland vegetation types impacted ♦Natural regeneration emphasized in two zones ♦Create/restore predetermined acreage amounts by wetland vegetative class ♦Replace flood storage lost ♦Replace principal valuable functions lost (i.e., wildlife habitat, flood storage, and nutrient/sediment retention) ♦Provide additional water quality treatment of stormwater runoff ♦Enhance/restore wildlife habitat along the Lamprey River and stabilize unvegetated slopes
Conway	2006	Sand & gravel excavation	Overall: Construction and enhancement to create functioning wetland areas similar to those of the wetlands destroyed by the project (e.g., create a functioning wetland capable of providing flood storage, water quality renovation, and habitat values similar to those of the impacted wetlands) Other: ♦Topsoil in wetland with organic content of 10-30% ♦≥75% successful establishment of wetland vegetation after two growing seasons ♦2% downed woody debris (standard ACOE condition that "promotes macro-invertebrate species development and provides a more natural appearance" ♦Size ratio equal to or greater than impacts
Hillsboro	2002	Farm field	Overall: Establish wetland functions and values that include flood storage, water quality improvement, groundwater recharge, wildlife habitat, recreational opportunity, and aesthetics
Loudon	2000	Sand pit	Overall: Compensate for loss of ground water recharge, wildlife habitat, and water quality functions provided by the destroyed wetland Other: ♦≥75% successful establishment of wetland vegetation after two growing seasons ♦Wetland creation and enhancement areas shall be properly constructed, landscaped, monitored, and remedial actions taken that may be necessary to create functioning wetland areas similar to those of the wetlands destroyed by the project
Peterborough	2006	Canal and former mill	Overall: Principal function of impacted wetlands was sediment and toxicant retention; intended goal of mitigation site is to provide sediment and toxicant retention, as well as wildlife habitat and flood storage Other: ♦Is the proposed hydrology met at the site? ♦Are the proposed vegetation diversity and/or density goals for woody plants met? ♦Does the mitigation site have at least 80% areal cover, excluding planned open water areas or planned bare soil area, by non-invasive species?

Mitigation Site	Year Created	Prior Use	Mitigation Design Goals
			♦ Are invasive species at the mitigation site being controlled? ♦ Are all slopes, soils, substrates, and constructed features within and adjacent to the mitigation site stable?

Ideally, a thorough evaluation of the five impacted wetlands would have been completed prior to their destruction. Classifying the wetlands to system type and identifying the natural communities they supported, together with an evaluation of the condition of their vegetation, hydrology, and soils, is essential to subsequent comparisons to the mitigation sites. The lack of this data limits our ability to more fully compare the strengths and weaknesses of the four wetland assessment methods in measuring mitigation compliance and success.

For the five mitigation sites in our study, the EIA method could have been used to develop specific success standards and long-term performance criteria, as well as to monitor mitigation progress (Appendix 3). Faber-Langendoen et al. (2008) provide several examples to illustrate how EIA can 1) set ecological performance standards for mitigated sites and 2) determine whether or not the ecological goals of mitigation have been met. EIA's suitability for developing performance standards is due in part to its diverse structural and functional measures. It also benefits from its use of reference wetlands as a model for the expected dynamics of created or restored sites. Table 19 in Appendix 3 outlines performance standards developed in Ohio for wetland mitigation and presents a list of EIA metrics relevant to measuring progress on those performance standards. Table 20 shows how EIA metrics can track progress at a mitigation site over time.

With further development and testing, USA RAM likely could be used in a similar fashion as EIA, particularly if it utilizes a vegetation classification to enhance metric assessment.

NHM functions could also be used in developing standards and measuring mitigation success, focusing on functions in need of restoration for a given wetland. To the extent that mitigation goals include or focus on ecological services and cultural values, NHM has the advantage of explicitly scoring different functions. Assessing mitigation success will require comparisons between different wetlands (lost vs. created) and different times (mitigation success over time). This may require additional guidelines for how to reduce inter-observer variability, e.g., by recommending a minimum level of observer expertise for studies of mitigation sites.

FQA has been used in other states to make permit decisions and to develop performance standards and mitigation criteria (Wilhelm 1993; Swink and Wilhelm 1994; Andreas and Lichvar 1995; Herman 1994). The US Army Corps of Engineers in the Chicago District uses FQA to measure mitigation success (Milburn et al. 2007). To be in compliance, mitigation wetlands are required to have a Mean C ≥ 3.5 or FQI ≥ 20 within five years of establishment. FQA is also used in Illinois to establish regulatory mitigation ratios. For a permitted impact, wetlands with relatively high Mean Cs and FQIs often require greater mitigation ratios; the permit could also be denied if the impact is considered unmitigable. For example, administrative rules to the Illinois Wetland Policy Act of 1989 (20 ILCS 830, 17 Ill. Adm. Code 1090) require a 5.5:1 mitigation replacement ratio for loss of wetlands with a Mean C ≥ 4.0 or a native FQI $\geq$ 20. In the Chicago region, Wilhelm (1992, 1993) proposes wetlands with high floristic quality (FQI ≥ 35) are unmitigable because of the unlikelihood of restoration achieving the original floristic quality; sites that are likely mitigable have lower floristic quality with FQI in the teens and twenties (Herman et al. 2001).

Bourdaghs (2012) developed FQA condition thresholds for all 14 wetland system types occurring in Minnesota by analyzing existing and newly sampled Natural Heritage relevé data for pre-settlement, minimally impacted, and severely degraded wetlands. Pre-settlement and minimally impacted examples were identified from sites visited by Natural Heritage with overall condition ranks of "A" and "AB." Preliminary examples of severely degraded sites were identified through landscape analysis and then confirmed and sampled in the field. In NH, FQA thresholds can be developed in a similar fashion through analysis of NHB relevé data across condition gradients for the 28 wetland systems in the state. FQA condition thresholds can then be used for evaluating mitigation success and to trigger certain actions in mitigation compliance, regulatory decisions, and management.

As this study suggests and other studies have shown, non-weighted FQA indices outperform weighted indices for between-site comparisons (Table 9; Poling et al. 2003; Bourdaghs et al. 2006). However, some studies reveal that weighted FQA indices can "increase performance-tracking changes within a particular site over time" (Bourdaghs et al. 2006) and in wetlands with significant cover of invasive species (Bourdaghs 2012).

Mean C scores for the five mitigation sites (ranging from 3.07–3.71, the latter an average of scores from two surveyors) were among the lowest of the 32 sites surveyed in the concurrent EPA study (Table 8). The Mean C at two mitigation sites (Conway and Loudon) was above the 3.5 threshold used to indicate relatively high floristic quality elsewhere. Using Midwest FQA standards for measuring mitigation success, all of the surveyed mitigation sites were in compliance with FQI, while only Loudon and Conway (Surveyor 2) were above the 3.5 Mean C compliance threshold. However, caution should be used when interpreting these scores (as well as the FQI scores at these sites) until FQA floristic quality thresholds among different wetland system types have been developed in the Northeast.

<u>Ability to assess condition and identify ecologically significant wetlands</u>
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 the FQA method 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). Caution should be used when interpreting FQA scores until floristic quality thresholds among different wetland system types have been developed in the Northeast.

Mean C scores for the five mitigation sites (ranging from 3.07–3.67; Table 10) were among the lowest of the 32 sites surveyed (Table 8). All five of these sites also had an EIA score below 4 (range 3.30–3.96; Table 10). 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 (Figure 11). 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. 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.

FQA inter-observer variability at the Conway replicate site was notable (Mean C 3.22 vs. 4.11; FQI 28.6 vs. 34.9; Table 12). For the Mean C score of 4.11, 73 wetland species were documented; 78 species were documented for the 3.22 Mean C score. Eleven of the 78 species were recorded by both surveyors but one surveyor considered them to be in upland habitat immediately adjacent to the wetland (so the 11 species were not included in the wetland list for this surveyor). Near the wetland's edge, dry soil conditions created a wide upland–wetland transition zone with a greater number of open, dry site species than expected. Several species on the broad open species-rich upland banking crept into this transition zone. Broad open banks do not naturally occur adjacent to most of the state's wetland types; its occurrence here is a product of wetland creation. Both these factors, dry conditions and upland species from the bank regularly occurring in the upland–wetland transition zone, made determining the exact location of the wetland boundary (and which species to list in the wetland) more difficult. The 11 species documented by one surveyor in the wetland but considered to be in the upland by the other surveyor had a Mean C score of 1.0, notably lowering the overall Mean C score (3.22) measured by the first surveyor. Other reasons for the scoring differences at Conway relate to different Mean C scores for species unique to each surveyor. For the 3.22 Mean C score, the subset of unique species documented by the first surveyor had a Mean C score of 3.4. For the 4.11 Mean C score, the equivalent subset Mean C score was 4.3. Even though determining the wetland boundary at the Conway Mitigation Site was challenging in places, decreasing inter-observer variability is achievable by adding lessons learned from this study to existing sampling protocols. For mitigation sites, additional consideration could be given to selecting well-defined (repeatable) sampling sites and other protocols needing extra attention, since the vegetation composition and structure, hydrology, and physical features of a created wetland may not fit the expectations of surveyors used to studying natural wetlands.

Table 12. FQA and vascular plant species data from the Conway Mitigation Site.

Conway Mitigation Site Data	**Surveyor 1**	**Surveyor 2**
Mean C	3.22	4.11
FQI	28.6	34.9
Total number of species	78	73
Mean C of 11 species documented by the 1st surveyor as barely occurring in the wetland and that were noted by the 2nd surveyor but considered to be in adjacent upland	1.0	--
No. of species only documented by one surveyor	12	18
Mean C for species only documented by single surveyor	3.4	4.3

Unlike FQA, the NHM, USA RAM, and EIA do not require a comprehensive list of vascular plant species as part of the assessment. For one surveyor at Conway Mitigation Site, the wetland condition scores from NHM, USA RAM, and EIA were consistently higher compared to the other surveyor, in an opposite direction relative to condition scores from FQA results. For NHM's Ecological Integrity Function, the two surveyors recorded scores of 7.35 and 6.70 (maximum score for function = 10). The difference in surveyor scores for this function is largely accounted for by responses to Question 7: "Road / driveway / railroad crossings." The first surveyor noted one road that either crossed or was immediately adjacent to the wetland (scoring 5 out of 10) while the second surveyor noted two roads (scoring 1 out of 10).

The first surveyor scored USA RAM 114 out of 144; the second surveyor 102. The metrics with largest scoring difference were Metric 2 (Buffer Mean Width) and 3 (Stressors in the Buffer Area). Out of a maximum score of 12 for each metric, the first surveyor scored these 12 and 9, respectively. The scores from the second surveyor were 6 and 3, respectively (a 12 point difference equal to the difference in overall site score). For Buffer Mean Width, the first surveyor's score of 12 excluded the narrow and infrequently used 4-WD road along the wetlands east side; the second surveyor included this as a dirt road in the buffer. When assessing stressors in the 100 m buffer surrounding the wetland (Metric 3), the first surveyor noted three stressors, each with a low severity code (code ranges from low, moderate, high). The second surveyor documented 11 stressors (9 with a low severity code and two with a moderate code).

For EIA, the overall score was 3.92 for the first surveyor and 3.50 for the second surveyor (score equivalent to an "A" grade = 4.75). Differences in metric scores between the first and second surveyor that accounted for the difference in overall scores were Hydrologic Connectivity (4.75 vs. 4.00), Hydroperiod (4.75 vs. 3.50), Physical Patch Type Diversity (4.40 vs. 3.70), Relative Cover of Native Plant Species (4.75 vs. 4.00), Vegetation Composition (4.75 vs. 3.50), and Vegetation Structure (4.40 vs. 3.70). Overall, the first observer graded these metrics an "A" or "AB" while the second surveyor graded them "B" or "C." The justifications given by the second surveyor for scoring these metrics lower are summarized in Table 13. The variability in these differences can largely be eliminated with 1) standardized protocols associated with features unique to created wetlands (such as form and location of constructed micro-topography), 2) increased surveyor experience applying assessment methods at mitigation sites, and 3) completed evaluation and classification of impacted wetlands prior to their destruction, reducing variability by providing a reference standard when assessing metrics.

Table 13. EIA metrics with significant scoring differences between two surveyors that evaluated the Conway Mitigation Site.

<table>
<tr><th>EIA Metric</th><th>Score of 1st Surveyor</th><th>Score of 2nd Surveyor</th><th>Second Surveyor's Justification for Lower Score</th></tr>
<tr><td>Hydrologic Connectivity</td><td>4.75</td><td>4.00</td><td>Gravel access roads likely alter lateral water movement back to wetland.</td></tr>
<tr><td>Hydroperiod</td><td>4.75</td><td>3.50</td><td>Dominant vegetation and plant zonation somewhat atypical for the inferred water level fluctuations in the wetland. The flood regime appears intermediate between what is typical for this system type and the sand plain basin marsh system (communities and vegetation composition typical of latter system are currently lacking).</td></tr>
<tr><td>Rel. Cover of Native Plant Spp.</td><td>4.75</td><td>4.00</td><td>Cover estimated to be between 97 and 99%.</td></tr>
<tr><td>Physical Patch Type Diversity</td><td>4.40</td><td>3.70</td><td rowspan="3">Created pit and mound micro-topography in alder shrubland not typical of naturally occurring examples of this community type. The hydrology gradient is disrupted and entangled by the created wet hollows supporting emergent marsh species embedded in the alder shrubland. Elsewhere in wetland, dominant vegetation and plant zonation is somewhat atypical for the inferred water level fluctuations. The flood regime appears intermediate between what is typical for this system type and the sand plain basin marsh system (communities and vegetation composition typical of latter system are currently lacking).</td></tr>
<tr><td>Vegetation Composition</td><td>4.75</td><td>3.50</td></tr>
<tr><td>Vegetation Structure</td><td>4.40</td><td>3.70</td></tr>
</table>

EIA's use of system and natural community classifications provide surveyors with a deeper understanding of a wetland's ecology and an increased ability to evaluate its condition. Most of the natural communities in the five wetland mitigation sites are associated with the drainage marsh - shrub swamp system. This system occurs on fine mineral soils containing moderate to high organic content along the borders of streams, rivers, ponds, and lakes. Water levels in drainage marshes are affected by adjacent water bodies. The degree of water level fluctuations at all five mitigation sites appeared somewhat extreme for drainage marsh - shrub swamp systems, based on the observed soil moisture gradient, soil texture, and plant species distributions. These observations suggest the water regime may be somewhat more typical of sand plain basin marsh systems.

Sand plain basin marshes are topogenous and groundwater influenced where vertical fluctuations dominant (Sperduto and Nichols 2011). Productivity and growth are limited by low-nutrient conditions. During drawdown periods, the small amount of organic matter that may be present decomposes rapidly. As a result, organic matter accumulation is minimal. Four of the five mitigation sites were closed basins with no or only intermittent surface water connection (the wetland at Conway was adjacent to and affected hydrologically by a lake). All five wetlands were created on coarse sandy deposits (e.g., sand pits are associated with each site). These porous sandy soils, likely accounting for the degree of seasonal water fluctuations at the mitigation sites, are similar to those normally found in sand plain basin marsh systems (i.e., sand or gravelly sand with shallow muck or sandy muck surface horizons). Gale (2003) states "use of appropriate substrate is critical in ensuring soil conditions and hydrology that emulate those of reference wetlands. Sand, for instance, is often inappropriately used as substrate. Too much sand will cause the wetland to be leakier than a natural system."

From what was originally planted at the mitigation sites, a shift in species composition and/or cover likely is occurring to some degree as species more adaptable to significant seasonal and annual water level fluctuations and low-nutrient conditions persist. Species that are predicted to establish and/or increase in cover, forming more well developed concentric zones, are listed in Table 14 (NH Natural Heritage Bureau, pers. comm. 2013).

Table 14. Vascular plant species that may establish and/or increase in cover at the five mitigation sites.

Shrubs	**Graminoids**
Chamaedaphne calyculata (L.) Moench	*Carex echinata* Murr.
Myrica gale L.	*Carex stricta* Lam.
Spiraea alba Du Roi var. *latifolia* (Ait.) Dippel	*Cladium mariscoides* (Muhl.) Torr.
Spiraea tomentosa L.	*Cyperus dentatus* Torr.
Vaccinium macrocarpon Ait.	*Dulichium arundinaceum* (L.) Britt.
Forbs	*Eleocharis acicularis* (L.) Roemer & J.A. Schultes
Bidens connata Muhl. *ex* Willd.	*Eleocharis flavescens* (Poir.) Urban
Bidens frondosa L.	*Eleocharis obtusa* (Willd.) J.A. Schultes
Drosera intermedia Hayne	*Eleocharis palustris* (L.) Roemer & J.A. Schultes
Erechtites hieraciifolius (L.) Raf. *ex* DC.	*Eleocharis tenuis* (Willd.) J.A. Schultes
Euthamia graminifolia (L.) Nutt.	*Glyceria borealis* (Nash) Batchelder
Gratiola aurea Pursh	*Glyceria canadensis* (Michx.) Trin.
Hypericum boreale (Britt.) Bickn.	*Juncus canadensis* J. Gay *ex* Laharpe
Lysimachia terrestris (L.) B.S.P.	*Juncus pelocarpus* E. Mey.
Rhexia virginica L.	*Schoenoplectus pungens* (Vahl) Palla
Triadenum virginicum (L.) Raf.	*Schoenoplectus smithii* (Gray) Sojak
Symphyotrichum racemosum (Ell.) Nesom	*Scirpus cyperinus* (L.) Kunth
Viola lanceolata L.	*Panicum virgatum* L.

In planted alder shrublands at Brentwood, Conway, and Peterborough, there exists a created pattern of small, semi-permanently flooded hollows supporting emergent marsh species immediately adjacent to alder hummocks. This "checkered" micro-topography is not typical of what naturally occurs in these wetland types. Normally in marsh systems, up to four separate vegetation zones are distributed along a hydrology gradient, from seasonally saturated (to seasonally flooded) shrublands occurring adjacent to swamps or upland forests, (seasonally saturated to) seasonally flooded meadow marshes, seasonally flooded to semi-permanently flooded emergent marshes, and semi-permanently to permanently flooded aquatic beds. In the alder shrublands at these three sites, the hydrology gradient is disrupted and entangled by the created wet hollows supporting *Sagittaria latifolia* Willd., *Schoenoplectus tabernaemontani* (K.C. Gmel.) Palla, *Sparganium americanum* Nutt., *Typha latifolia* L., and other emergent marsh species.

When applying FQA at mitigation sites, we recommend that both intentionally and unintentionally planted species that are native to the region but seldom to the wetland type (including any rare species listed for the state) be considered introduced with a CoC score of zero. Table 15 lists "introduced" native species at the mitigation sites, their current CoC values, and species status information for New Hampshire.

Table 15. Rare native plant species introduced into the five mitigation sites. See Appendix 5 for an explanation of state rarity status categories.

Mitigation Site	Species	CoC	Status
Brentwood	*Juncus brachycephalus* (Engelm.) Buch.*	6	State Endangered
Conway	*Eutrochium fistulosum* (Barratt) E.E. Lamont* *Hypericum ascyron* L.* *Penstemon digitalis* Nutt. *ex* Sims *Scirpus pendulus* Muhl.*	5 7 2 5	State Endangered State Endangered Indeterminate State Endangered
Hillsboro	---		
Loudon	---		
Peterborough	---		

*Listed in the "Rare Plant List for New Hampshire" by NHB.

Several non-native plant species were introduced into the five mitigation sites as well. Table 16 lists these species and provides their status in New Hampshire. It is recommended more care be given to minimize or prevent the introduction of non-native species into wetland mitigation sites.

Table 16. Non-native plant species introduced into the five mitigation sites.

Mitigation Site	Species	Status
Brentwood	*Alnus glutinosa* (L.) Gaertn. *Lythrum salicaria* L.*** *Salix purpurea* L. *Strophostyles helvola* (L.) Ell. *Viburnum opulus* L.	Invasive* Invasive* State Record**
Conway	*Chamaecrista fasciculata* (Michx.) Greene *Larix decidua* P. Mill. *Lotus corniculatus* L. *Lythrum salicaria* L.*** *Monarda fistulosa* L. *Potentilla intermedia L.* *Rhus aromatica* Ait. *Trifolium aureum* Pollich *Vicia cracca* L.	 Invasive* State record**
Hillsboro	*Bidens polylepis* Blake *Helenium autumnale* L. *Lonicera morrowii* Gray*** *Lythrum salicaria* L.*** *Solanum dulcamara* L.***	State record** State record** Invasive* Invasive* Invasive*
Loudon	*Frangula alnus* P. Mill.*** *Lotus corniculatus* L. *Lythrum salicaria* L.***	Invasive* Invasive*
Peterborough	*Lythrum salicaria* L.***	Invasive*

*Listed as invasive in New England by IPANE (2013).
**State record if naturalized.

***May have originated from nearby habitat.

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 9). 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).

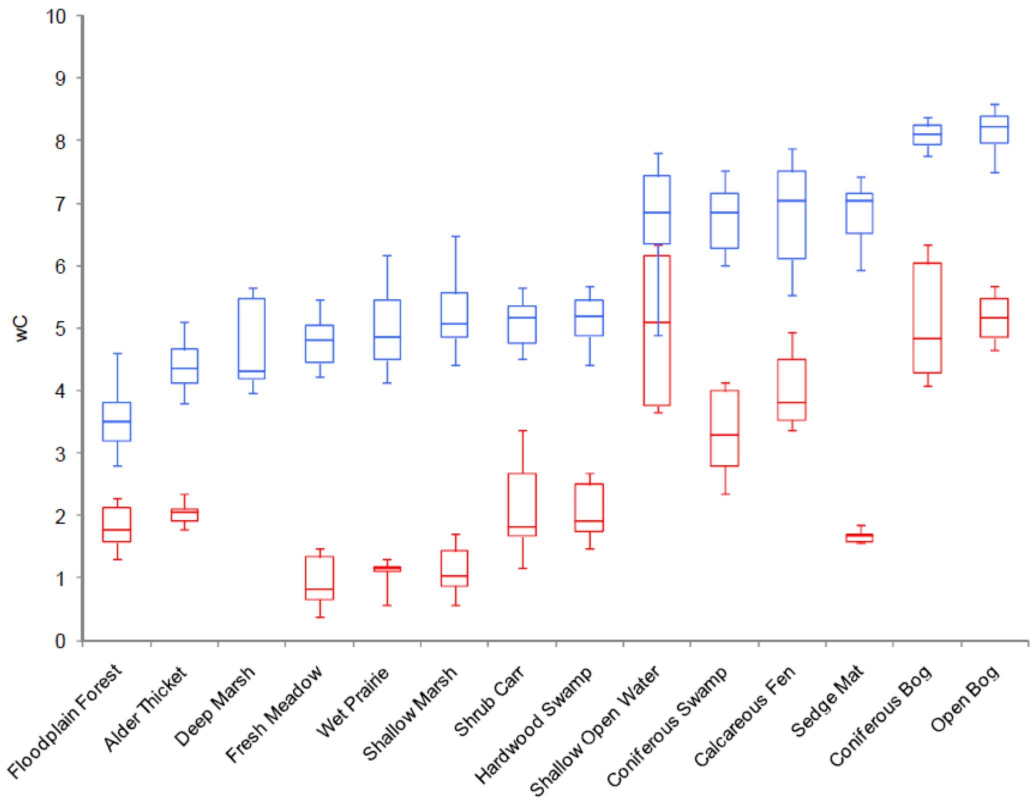


Figure 11. Weighted Mean C (wC) box and whisker distribution plots from all system types in Minnesota. Blue plots = pre-settlement and minimally impacted examples; red plots = severely impacted examples. Arranged from left to right according to increasing median wC scores for the pre-settlement/minimally 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 17; Figure 12) as seen in Minnesota (Figure 11).

Table 17. 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

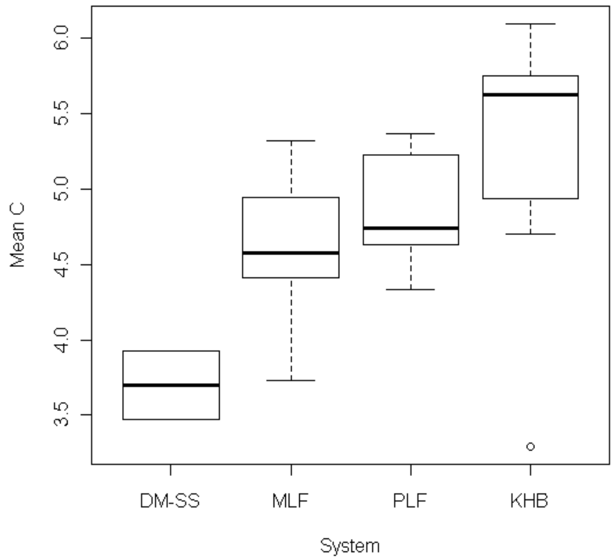


Figure 12. Boxplot of Mean C scores by system type for relatively undisturbed examples (EIA rank of A or B) in our study. Depicts median, quartiles, minimum, and maximum. DM-SS = drainage marsh - shrub swamp system (n = 2); MLF = medium level fen system (n = 7); PLF = poor level fen/bog system (n = 9); 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 18). These results can be used to assist users in selecting an appropriate method given their particular goals and constraints.

Table 18. 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. Questionnaires for Surveyors.

Each surveyor will complete the following:

1. Method assessment after each survey (specific to combination of observer-method-date-site).
2. Comparison of the methods after field season.

1. 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:

2. 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. Successful Mitigation.

The following is from Gale (2003):

Measures of Success
Scientists agree that successful mitigation is determined by the ability of a created or restored wetland to provide the biological, hydrological, and biogeochemical functions of the original wetland or a natural reference wetland (Erwin 1990a; Erwin 1990b; Kusler and Kentula 1990; Mitsch and Gosselink 2000; Institute for Water Resources 1994). The following characteristics can be used to judge success based on comparison to the emulated system:

- Landscape position and contour design emulating that of the affected wetland or a chosen reference system. Successful wetland creation or restoration is often determined by such basic structural considerations (Erwin 1990a).
- A self-perpetuating hydroperiod similar to that of the emulated wetland. The major determinant of success is the presence of a self-perpetuating oscillating hydrologic regime in the created or restored wetland (Niering 1990).Achieving a self-perpetuating hydroperiod in a created system requires an understanding of the geohydrology which causes the reduced conditions in which wetland species thrive (D'Avanzo 1990).An appropriate regime should generate conditions such as those described in the 1987 Corps Delineation Manual (US ACOE 1987). Colonization by wetland plants and use of the system by wetland fauna are gross indicators of an appropriate hydroperiod.
- Successful colonization and dominance of wetland plant species similar to the emulated wetland. Vegetation characteristics that can be measured include below- and above-ground biomass, plant density, and number of reproductive stalks. Metrics of success can vary. The Corps requires that 80 percent of a created marsh area be covered with grasses after three years (Erwin 1990b). The state of Massachusetts requires that a created wetland have a 75% cover of indigenous hydrophytes within two growing seasons (Jarman et al. 1991). Out-competition by upland species, decreasing diversity, invasion of exotic species, or lack of vegetative colonization may be indicators of the need to alter the design of the system or perform selective maintenance, or of system failure.
- Chemical and physical properties characteristic of wetlands soils and similar to the emulated wetland. The 1987 Corps Delineation Manual (US ACOE 1987) can be used as a guideline to determine whether the soils in the constructed or restored area display wetland characteristics. Nitrogen, phosphorus, and organic matter levels and primary productivity should increase with the age of the created site. Nitrogen and phosphorus should reach reference wetland concentrations in 15 - 30 years (D'Avanzo 1990; Craft et al. 1988).
- Diversity, density, and biomass of animal species similar to the emulated wetland. Monitoring for certain indicator species is a common method used to evaluate this characteristic (Weller 1990; Croonquist and Brooks 1991). Use of a wetland habitat value model, habitat assessment procedure, or diversity index is a method recommended by the Corps to determine similarities between the created or restored system and a natural wetland (Institute for Water Resources 1994). An assessment of how biotic communities develop and interact both within the created/restored wetland and between it and the surrounding landscape is more indicative of success than is an assessment of individual indicator species.

All of the above criteria for success are interdependent; a failure in one, particularly hydroperiod, can lead to a failure in others over time. It can be seen from the bullets above that the essential, requisite conditions used to identify a natural wetland (appropriate hydrology, hydrophytes, and hydric soils) can also be used to determine whether the created/restored area functions as a wetland. External forces other than hydrologic factors can bear on the success of a mitigation project. If water quality upstream is poor or incoming runoff or ground water movement is polluted, particularly with toxic compounds, pre-treatment of these sources may be necessary for successful establishment of a mitigation wetland. Upland buffers (see “Improving the Likelihood of Successful Mitigation” below) and protective measures such as structural and management best management practices (BMPs), in the contributing watershed protect the wetland and facilitate its establishment. Many wetland-dependent animal species require upland habitat adjacent to wetlands for part of their life cycle as well. Upland buffers can thus facilitate development of a more diverse wetland ecosystem.

Common Mitigation Pitfalls

Some of the most common immediate reasons for mitigation/restoration efforts to fall short of success or to be set back include:

- Inability to accurately estimate or lack of awareness of the following site features during planning:
    - hydroperiod
    - water depth
    - water supply
    - substrate
    - nutrient levels
    - toxic compounds
- Technical aspects of design are unsound
- The project is not constructed as planned
- Contingencies not adequately dealt with:
    - exotic species invasion
    - grazing of plantings
    - catastrophic events (floods, storms, droughts)
    - human impacts (mowing, ditching, off-road vehicles etc.)
- Insufficient follow-through:
    - inadequate monitoring
    - maintenance is ignored

(Kusler and Kentula 1990; Mitsch and Gosselink 2000; McKinstry and Anderson 1994)

Improving the Likelihood of Successful Mitigation

Permit-related failure of mitigation projects can be reduced by incorporating the following requirements into a regulatory program (Josselyn et al. 1990):

- Permit applicants should provide a sufficiently thorough habitat evaluation of the impact site prior to destruction to allow useful subsequent comparison of the mitigation wetland. Evaluation level of detail should be flexible and predicated on system complexity and difficulty of replacement as determined by initial site surveillance. Evaluations should address the following:
    - landscape position and landscape-related functions
    - topographic information
    - soils assessment
    - surficial geology
    - vegetation
    - fixed point panoramic photographs
    - rainfall and water level data
    - wildlife utilization
    - fish and macroinvertebrate data (Erwin 1990b)

The permit application must include design objectives, detailed design drawings, and targeted functions and values.

Use of appropriate substrate is critical in ensuring soil conditions and hydrology that emulate those of reference wetlands. Sand, for instance, is often inappropriately used as substrate. Too much sand will cause the wetland to be leakier than a natural system. Lower organic matter, and as a result, lower soil nitrogen and phosphorus levels, than in a natural system are common (D'Avanzo 1990). Applicants should be encouraged or required to transfer organic or other surface substrate from affected wetlands to mitigation sites. If organic material from a site other than the wetland affected by the permitted activity is to be used for substrate, the applicant should be required to identify the source of material and apparent floristic composition. Adequate soil rooting volume above hardpan is important for successful restoration of forested wetlands (Clewell 1990).

Applicants should be required to provide a management program and long-term maintenance provisions for created wetlands, including a maintenance schedule for eradication of undesirable species; a schedule for and content of reporting; identification of a monitoring and maintenance contractor; identification of the responsible entity for mitigation areas; contingency plans should mitigation fail; demonstration of responsible entity's financial capability; details on performance bonds or other financial instruments if appropriate; an instrument establishing homeowners associations' or other responsible entity's obligations; and necessary zoning protection steps. Permits should in turn formalize all such information.

The mitigation site should be constructed prior to or concurrently with the permitted project to reduce non-compliance and to facilitate use in the created wetland of materials from the wetland affected by the permitted development activity.

Maintenance activity, largely removal of undesirable vegetation, on a frequent basis following construction, and less often as desirable species become established, is essential for achieving the desired ecological communities within a reasonable time frame.

The developer should conduct post-creation monitoring assessments once construction is completed, on a more frequent basis initially, then at larger regular intervals (at least annually) for a number of years (typically 5 to 15), depending on the system type, to document progress or the need for remedial action. Mitigation sites frequently require buffering from adjacent human activities and sometimes from herbivores (Clewell 1990). Mitigation design should include buffering elements suited to adjacent land use activities. Such elements include a simple setback distance of vegetated area; a buffer of shrub/tree plantings on the perimeter of the wetland or setback area; informational signs at intervals around wetland perimeter; and fencing. Issued permits should include, as applicable, conditions to inform future lot owners of restrictions, such as requirements for deed restrictions on adjacent development lots or lots extending into mitigation areas; full notification to potential purchasers; and transfer of responsibilities to subsequent owners.

Successful establishment of a wetland takes time. Thus, compliance with permit conditions typically requires long-term monitoring. Natural wetlands have evolved over tens, hundreds, or thousands of years. While long-term trends in the structural establishment of herbaceous wetlands may become apparent within as little as two to three years, it may take 15 years for a carefully created forested wetland to begin to achieve canopy closure, and to begin to look and function like a natural forested system, and decades before it approximates the structure and function of the habitat that it was intended to duplicate (Craft et al. 1988; D'Avanzo 1990).

Appendix 3. Ecological Performance Standards and Ecological Integrity.

The following is slightly modified from Faber-Langendoen et al. (2008):

There is a growing consensus on the performance requirements needed for mitigated wetlands (National Research Council 2001; Environmental Law Institute 2004). Our suggested performance standards build on the following recommendations (adapted from National Research Council 2001):

1. Mitigation goals are set in the context of a watershed approach. See "Methods for a Watershed Approach," where this topic is addressed.
2. Impacted sites and mitigated sites are evaluated using the same ecological assessment tools. Ecological Integrity Assessment methods provide a general framework for addressing the range of conditions of ecosystems. The same metrics that are used to address condition for mitigation sites are part of general assessments of the condition of ecosystems elsewhere. For example, there are many rapid assessment methods that rely on the same kinds of metrics needed for mitigation (e.g., Mack et al. 2004; Sutula et al. 2006). NatureServe's methodology for evaluating wetlands of all types, as described in this report, is also based on similar metrics. Thus measures of ecological performance are becoming more widely available for a variety of ecological systems
3. Mitigation projects evaluate the full range of ecological integrity and ecological attributes relevant to functions. Ecological integrity assessments (EIAs) address the major attributes relevant to assessing ecological functions of ecological systems, including vegetation, hydrology, soils (physicochemistry), landscape context and size. The EIA approach does not make explicit statements about "functions" that a wetland performs; however, it does implicitly assume that a wetland with high ecological integrity is performing all the expected functions for the HGM class in which it is found (Figure 13).
4. Mitigation goals are clearly stated so that the desired range of ecological integrity and function are specified. Structure, composition and function are all relevant to the goals. Ecological integrity assessments are based on clearly stated metrics and ratings that assess the full range of ecological integrity and function. In so far as mitigation goals require clarity on these aspects of mitigation, they can be addressed by using EIAs.
5. Assessing wetland function is based on a science-based, rapid assessment procedure that incorporates at least the following characteristics:
   a. Effectively assess goals of wetland mitigation projects.
   b. Assess all recognized functions.
   c. Incorporate effects of the position in the landscape.
   d. Reliably indicate important wetland processes or scientifically established structural surrogates of these processes.
   e. Scale the assessment to results from reference sites.
   f. Sensitivity to changes in performance over a dynamic range (i.e., the metric is sensitive enough to show a range of responses to a stressor, not just a pass/fail).
   g. Integrate over space and time (i.e., the metric should be useful across the spatial range of a type and be useful for monitoring over time).
   h. Generate parametric and dimensioned units, rather than nonparametric ranks, in order to allow for greater rigor in statistical testing.

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

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

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

Third, we assess wetland composition, structure and function using an ecological integrity assessment approach based on reference conditions and natural and historic ranges of variation. Measures of ecological integrity provide the needed tools to address wetland functions identified in #5 above, coupled with recommendations #2–#4. Identifying criteria (metrics) that describe the major ecological attributes will ensure that the basic components of wetland pattern and process are covered (Figure 13).

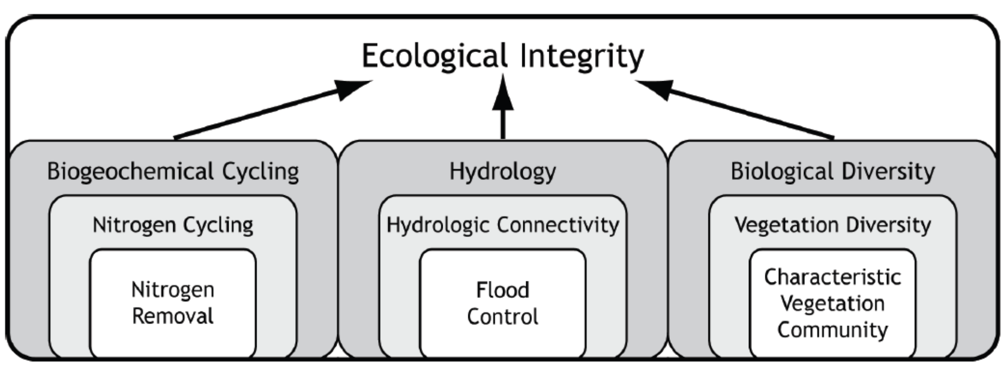

Figure 13. A schematic illustration of ecological integrity as the integrating function of wetlands, encompassing both ecosystem structure and processes. Integrity includes processes such as hydrology and hydrologic connectivity that address functions such as flood control (from Fennessey et al. 2007; based on Smith et al. 1995).

Wetland Classification and Performance Standards

The success of developing indicators of wetland ecological integrity depends on an understanding of the structure, composition and processes that govern the wide variety of wetland systems. Ecological classifications can be helpful tools in categorizing this variety. These classifications help wetland managers to better cope with natural variability within and among types so that differences between occurrences with good integrity and poor integrity can be more clearly recognized. Classifications are also important in establishing "ecological equivalency;" for example, an impacted salt marsh should be replaced with a mitigated salt marsh with equivalent or better integrity.

Outline of the Mitigation Application

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

Table 19 summarizes a series of performance standards for wetland mitigation developed for Ohio (Mack et al. 2004). It also includes a list of Level 2 (rapid field-based) and Level 3 (intensive field-based) metrics from the EIA approach developed in this study that are relevant to measuring progress on those performance standards. Thus the metrics developed for this EIA methodology cover many of the performance standards needed for mitigation. It may not be necessary to measure all metrics, but metrics should be chosen that span the range of major ecological attributes.

Table 20 illustrates how field values and thresholds for these EIA metrics can be used to track the progress of a mitigated site. The table is incomplete and provides a few examples only. There can be substantial challenges in achieving benchmarks for certain metrics in certain wetlands. Figure 14 shows how mitigation of vegetation structure for swamp forests in Ohio may require a 10- to 100-year monitoring window (see Mack et al. 2004; Klimas et al. 2006). However, many forested (bottomland hardwood) wetlands in Arkansas and across the Lower Mississippi Valley may develop structural features more quickly than in Ohio. Thus, where studies from Ohio show that 15 cm (6") trees require 30 years to develop, 10" trees, 60 years, etc., such development may be twice as rapid in the Lower Mississippi Valley. Restoration of forested swamps in mitigation projects appears very practical there over short (decadal) time frames. Many hundreds of thousands of acres have been mitigated or restored, often with good success, and there is a broad understanding of the requirements for mitigation (T. Foti pers. comm. 2008). Thus performance standards will need to be adjusted to specific Ecological Systems.
These examples provide a sense of direction for how EIAs can be applied to mitigation. Case studies are now needed to apply the method.

Table 19. Performance Standards for Wetland Mitigation (based primarily on standards developed for Ohio mitigation projects by Mack et al. (2004), and corresponding metrics that provide data to assess performance.

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

Table 20. Conceptual schedule for required monitoring and reporting activities, with benchmark variables. XR= the reference site or impacted site value that is chosen as the basis for assessing performance. X1= the measure of a metric in Year 1, etc. At Year 5, the X value can be compared against the reference value and a decision made on the progress of the mitigation project. Examples of possible benchmark values are shown for various metrics and performance standards. Metrics in shaded rows were not chosen as part of the monitoring project.

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

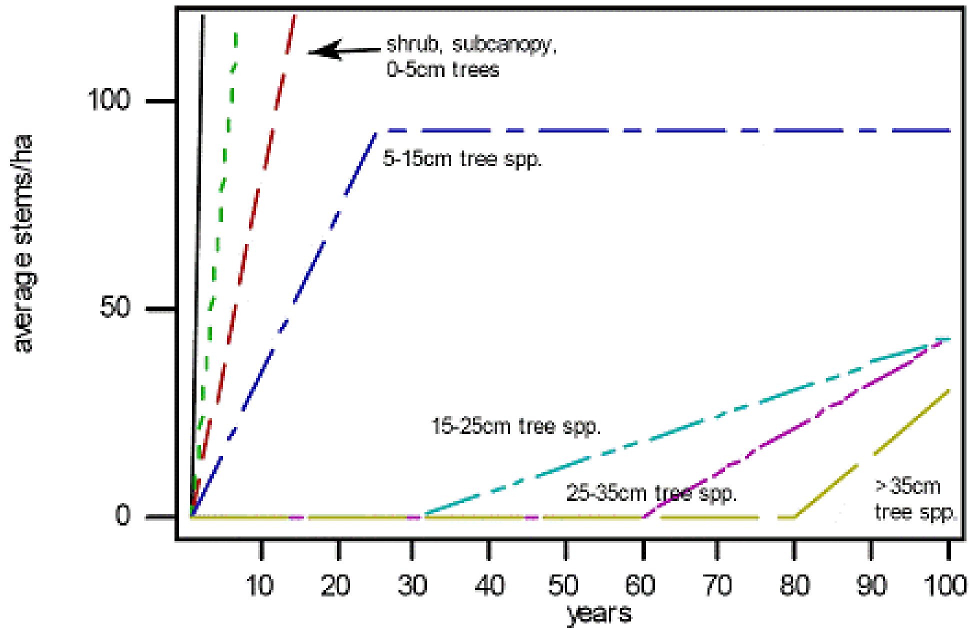

Figure 14. Hypothetical performance curves for tree and shrub establishment. Graph shows expected performance at 10 and 100 years derived from reference wetland data for depressional wetland forests (from Mack et al. 2004, Figure 16).

Appendix 4. Explanation of Global and State Rank Codes.

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 5. 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.