Development of a Rapid Floristic Quality Assessment

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Contents

Introduction

Over the past 20 years a number of wetland Rapid Assessment Methods (RAMs) have been developed and successfully used for a variety of wetland monitoring and assessment purposes. These include functions and values RAMs primarily used for regulatory purposes such as the Minnesota Routine Assessment Method (MnRAM; MN BWSR 2010), and RAMs that focus on assessing wetland condition such as those developed in Ohio (Mack 2001) and California (Collins et al. 2008). Typically RAMs are qualitative in nature, where a series of categorical questions are answered based on simple and easily obtainable field observations. The common thread of all RAMs is the reliance on coarser information in exchange for the ability to provide that information within a reasonable or attainable timeframe. Rapid methods have been defined as those that can be completed with no more than a half day in the field and a half day of office preparation (Fennessy et al. 2004). This degree of on-site/rapid/qualitative based assessment has been described as being Level 2 in the United States Environmental Protection Agency's (EPA) hierarchical monitoring and assessment classification, falling in between landscape scale (Level 1) and on-site/intensive sampling/quantitative based (Level 3) assessment EPA 2006.

The Floristic Quality Assessment (FQA) is a vegetation based ecological condition assessment approach that has been gaining popularity since its original inception in the late 1970s (Wilhelm 1977) and revision in the 1990s (Swink and Wilhelm 1994) to identify areas of high conservation value in the Chicago region of Illinois. FQA is based on the Coefficient of Conservatism (*C*), which is a numerical rating (0-10) of an individual plant species' fidelity to specific habitats and tolerance of disturbance, natural or anthropogenic (Swink and Wilhelm 1994). Species that have narrow habitat requirements and/or little tolerance to disturbance have high *C*-values and vice versa. *C*-values are typically developed and assigned for state or regional floras, including recently assigned values for Minnesota's wetland flora (Milburn et al. 2007). FQA metrics are derived from on-site plant community data and the *C*-values. These include the Mean *C* of the species occurring within the sampling area and the Floristic Quality Index (*FQI*) which is the Mean *C* multiplied by the square root of the native species richness (S_N). The weighted Coefficient of Conservatism (*wC*) incorporates species abundance, where *wC* is the sum of each species' proportional abundance (*p*) times its *C*-value:

$$wC = \sum pC$$

FQA metrics have repeatedly been found to be responsive and reliable wetland condition indicators (Lopez and Fennessey 2002, Cohen et al. 2004, Mack 2004, Bourdaghs et al. 2006, Miller and Wardrop 2006, Rocchio 2007, Milburn et al. 2007) and are one of the most frequently used class of metrics in wetland vegetation based assessment methods (Mack and Kentula 2010).

FQA is generally considered a Level 3 assessment, where intensive vegetation sampling is required to return accurate results. Early proponents have recommended that obtaining a full species list is an ideal approach for FQA, where a site is visited and surveyed several times during the growing season to obtain as complete a species census as possible (Taft et al. 1997, Herman et al. 2001). More recent research has shown, however, that Mean *C* is stable within a small sampling area for individual community types (Rooney and Rogers 2002, Bourdaghs et al. 2006) suggesting that minimal sampling can return an accurate assessment for a site. In other words, a limited sampling effort would likely yield approximately the same Mean *C* (and likewise the resulting condition assessment) as would more intense sampling. Thus, FQA has the potential to be a 'rapid' assessment method if a 'rapid' sampling method is used. Sampling time, however, is only one component of RAM sampling. The other is a focus on simplified observations that are generally qualitative and/or categorical. Gathering high quality vegetation field data typically requires a high level of botanical expertise, and a significant amount of effort is often required to identify less common/more difficult to identify species. One general approach to simplifying a vegetation sampling method would thus be to focus on the more common/easily identified species of a region. Rooney and Rogers (2002) compared Mean *C* values from plant data where *Carex* species were removed from the data set to simulate an inability by the observer to distinguish the species level of this diverse and difficult to identify group and found a small (though statistically significant) difference. This small difference suggests that the metric scores are primarily driven by more common species and (when viewed within a RAM context) a focus on common/easily to identify species may provide an assessment that continues to have a relatively high degree of accuracy while requiring less effort and expertise to accomplish. Consequently, the first project objective was to develop a FQA 'rapid' sampling method that is consistent with existing RAMs in terms of time, complexity, and expertise.

A fully developed assessment approach requires metric values be translated into meaningful assessment outcomes based on criteria derived from quantitative data. In turn, criteria must be based on data from minimally/least impacted reference conditions (Fennessy et al. 2001). To date, most FQA projects have focused on developing *C*-values for local floras as well as evaluating the performance of FQA metrics. There has been little published work, however, on developing assessment criteria that can be used to turn FQA metric values into assessments, which can then be used to make management decisions. One example is from the Chicago district of the United States Army Corps of Engineers, where *FQI* and Mean *C* are used to identify high-quality wetlands and measure mitigation success for Clean Water Act Section 404 permitting (US ACE 2009a). Metric criteria to determine high quality/mitigation compliance are a Mean $C \geq 3.5$ and $FQI \geq 20$. These thresholds were based on typical values achieved at the best ecosystem restorations in the region (Wilhelm and Masters 1995). Therefore, the second project objective was to develop reference based and data driven FQA assessment criteria.

Recognizing the two specific objectives, the overall goal is to develop a Rapid FQA that returns reasonably accurate wetland condition assessments within the accepted RAM spectrum in terms of time and level of expertise required. In other words, a natural resource professional with moderate wetland botanical expertise should be able to consistently complete a Rapid FQA. An additional goal is to develop the Rapid FQA so that it has broad applicability and can meet a variety of wetland condition monitoring and assessment needs.

Methods

Technical committee

To ensure that the Rapid FQA was developed according to project goals and to promote stakeholder support, a technical committee was formed to provide project input and review. Committee members came from a variety of backgrounds including state and federal agencies, tribal and local government; plus private firms (see the Acknowledgements for the Technical Committee roster). The Committee brought a broad spectrum of wetland monitoring and assessment perspectives; as well as, experience with regulatory, probabilistic/ambient, restoration success, local resource planning, rare features, and research monitoring and assessment.

Protocol development-classification

As discussed in Milburn et al. (2007), there are a number of sampling considerations that should be accounted for when using FQA. Chief among these is that the basic sampling and assessment units need to be based on plant communities, because different community types can have different natural and impact response ranges. A number of established wetland community classification systems were evaluated by the technical committee for adoption as the standard classification system for the sampling protocol. These included: 'Circular 39' (Shaw and Fredine 1956) originally developed for wildlife management and specified in several Minnesota statutes; 'Eggers and Reed' (2011) which was refinement of local wetland classes to better enable wetland assessment; and the MDNR Native Plant Communities (NPCs; Minnesota Department of Natural Resources MDNR) 2003, MDNR 2005a, MDNR 2005b) developed by the Minnesota County Biological Survey and Natural Heritage Program. These classification systems represent an increasing degree of complexity, as more ecological knowledge of Minnesota wetlands is gained. The technical committee selected the Eggers and Reed classification for protocol development because it is relatively straight forward, is widely used by natural resource professionals in Minnesota, and has a sufficient number of classes to adequately capture the variability occurring in Minnesota wetland types.

Slight modifications were made to the basic Eggers and Reed classification to more accurately capture wetland variability and one class was excluded due to lack of available data. These changes resulted in a total of 14 wetland plant community classes being used in the sampling protocol (Table 1). The Fresh (Wet) Meadow and Sedge Meadow classes were combined into a single Fresh Meadow class and a new class, Sedge Mat, was added. Sedge Mat is a new class that considers concepts generally equivalent the Open Rich Fen class in the DNR NPCs included in the most recent edition of Eggers and Reed (2011). The Seasonally Flooded Basin class was not considered here due to lack of data.

In addition to community types, biogeography may also affect FQA metrics, where wetland types may have different reference ranges based on different regions in the state (Milburn et al. 2007). Due to the complexities that would have arisen if some of the community classes were regionalized and the splitting of data sets it was decided not to regionalize the classification at this time.

Table 1. Eggers and Reed (2011) plant community classes and brief class descriptions. Two classes have been slightly modified from the original classification. Fresh Meadow combines both the Eggers and Reed Sedge Meadow and Fresh (Wet) Meadow classes into a single class. The Seasonally Flooded Basin class is not being considered at this time.

Community class	Description
Shallow Open Water	Open water aquatic communities with submergent and floating leaved aquatic species
Deep Marsh	Emergent vegetation rooted within the substrate that is typically inundated with > 6" of water. Submergent and floating leaved aquatic species typically a major component of community
Shallow Marsh	Emergent vegetation on saturated soils or inundated with typically < 6" of water. May consist of a floating mat. Submergent and floating leaved aquatic species typically a minor component
Fresh Meadow	Graminoid dominated, soils typically saturated
Wet Prairie	Similar to Fresh Meadow but dominated by prairie grasses
Calcareous Fen	Soils calcareous peat (i.e., organic w/high pH) due to groundwater discharge with high levels of calcium/magnesium bicarbonates. Specialized calcareous indicator species (calciphiles) present-dominant
Sedge Mat	Graminoid dominated communities on circumneutral or slightly acidic peat soils. Often occurs as a floating mat and *Carex lasiocarpa* (wiregrass sedge) is often a dominant
Open Bog	Low shrub or graminoind dominated community on a mat of *Sphagnum* moss/acidic deep peat. Specilized acid tolerant (indicator) species dominant
Coniferous Bog	Forested community dominated by coniferous trees on a mat of Sphagnum moss/acidic deep peat. Specilized acid tolerant (indicator) species dominant
Shrub-Carr	Tall shrub community typically dominated by Willows (*Salix* spp.). Typical understory species composition similar to Fresh Meadow
Alder Thicket	Tall shrub community typically dominated by Alder (*Alnus incana* ssp. *rugosa*)
Hardwood Swamp	Forested community dominated by deciduous hardwood trees on saturated soils
Coniferous Swamp	Forested community dominated by coniferous trees on saturated soils. Soils typically circumneutral or slightly acidic
Floodplain Forest	Forested community dominated by deciduous trees on alluvial soils associated with riverine systems

Protocol development-sampling approach and effort evaluation

One of the goals of the protocol development was to have the basic approach be as flexible as possible so that it can be adapted for a variety of settings and applications yet produce consistent results. Two different general sampling approaches (plot and timed meander based) were evaluated at the same sites. The plot approach was the MDNR releve protocol where a single large plot (20 x 20m plot in forested and 10 x 10m plot in open communities) is established in a representative location within a community type (MDNR 2007). Species are identified to the lowest taxonomic level possible and abundance is estimated using aerial cover classes. Data were collected in nested plots within the releves to assess the effect of sampling area on FQA metrics. Timed meanders were conducted by starting at a representative location within a community type and then walking through the community, recording species as they were observed. Time of observation was recorded for each species to assess meander sampling effort. At 20 minute intervals the percentage of new species added during the most recent 20 minute period was computed. When that percentage reached < 5 percent the meander was stopped as it was assumed that enough sampling effort had been expended to reach the leveling point of the species area curve for the community being sampled. Field work to test the two sampling approaches was carried out in 2008 at three community types: Fresh Meadow, Hardwood Swamp, and Open Bog with three replicate sites for each community for a total of nine sites. All sites sampled in 2008 were judged to be minimally impacted as it was assumed that intact sites would be the most complex and when stable sampling effort was reached this would also be sufficient effort to characterize degraded sites.

An alternative sampling approach was necessary for the Shallow Open Water community as water depth often makes sampling by foot difficult to impossible. A rake tow survey method was developed modeled after lake aquatic vegetation sampling from a boat (Madsen 1999). The basic sampling tool was a handheld garden cultivator with the tines bent backwards tied to a 20 foot length of rope. At a representative location at the Shallow Open Water community boundary (i.e., the shoreline) the cultivator was thrown into the water and retrieved three times: once perpendicular from the shore and both at (+/-) 45°. Floating leaved and submergent aquatic species were then recorded from what was visible from each station and what came back on the rake tows. In 2008, this shoreline sampling was tested at three Shallow Open Water sites with six shoreline sampling stations each. To compare the shoreline station sampling results against a more comprehensive method, kayaks were also used to comprehensively identify the aquatic species at each site.

During the 2008 field season a single site from each of the Fresh Meadow, Hardwood Swamp, Open Bog, and Shallow Open Water community types was sampled at monthly intervals from May-October. This was done to determine the appropriate FQA metric index period. Releve plots were established at each Fresh Meadow, Hardwood Swamp, and Open Bog site and revisited. At the Shallow Open Water site, six aquatic sampling stations were established and revisited.

Table 2. Cover classes, cover class ranges, and percent cover midpoints.

Cover Class	Cover Class Range	Midpoint
7	> 95 - 100%	97.5%
6	> 75 - 95%	85%
5	> 50 - 75%	62.5%
4	> 25 - 50%	37.5%
3	> 5 - 25%	15%
2	> 1 - 5%	3%
1	> 0 - 1%	'0.5%

Following analysis of the 2008 field data, an initial Rapid FQA protocol was developed. Protocol decision rules were largely based on FQA metric stability at a minimum level of sampling (see Results and Discussion section). Field trials of the initial Rapid FQA sampling protocol were undertaken in 2009. These trials included sampling at a variety of community types at varying degrees of condition to test performance under a broad set of conditions. During the field trials it was determined that recording abundance data was necessary due to a weak response of Mean *C* between severe and minimally impacted sites. Estimating aerial cover for each species by cover classes (Table 2) was then added to the protocol. Because cover was not included in the 2008 sampling approach analysis, additional timed meander data were gathered in 2010, where cover classes were estimated at 10 minute intervals to assess *wC* stability against sampling effort. This was done at Fresh Meadow and Shallow Marsh communities in eight depressional wetland sites that ranged from minimally-severely impacted.

Protocol development-rapid species list

Determining a species list that is limited to the more common and easy to identify species to simplify sampling was a central goal of the Rapid FQA protocol development. In general, a significant amount of effort can be spent on difficult to identify species while conducting botanical surveys and a high level of botanical expertise is typically required to accurately identify the majority of species at a site. The target audience for the Rapid FQA is natural resource professionals that have moderate wetland botanical expertise and know many of the common species in wetland types where they work.

A rating system called the Identification (ID) Difficulty Score was developed to systematically rank how difficult it is to identify an individual species based on narrative criteria and best professional judgment. The intention of the ID Difficulty Score was to provide a consistent and repeatable way to determine which species could be considered to be more common and easy to identify in Minnesota wetlands and thus be included in a ‘Rapid Species List’. First, overall species identification difficulty was conceptualized according to three general factors: 1) commonness, 2) distinctness, and 3) whether or not the species is a dominant. General narrative criteria were developed for each factor and assigned a numeric score (Table 3). The Commonness and Distinctness factors each had three ratings ranging from least (1) to most (3) difficult. The base ID Difficulty Score was the sum of the Commonness and Distinctness factors. The Dominance factor was a subtracting factor, where if the species were considered a dominant component of at least one community type, a point was subtracted from the base score. The resulting final ID Difficulty Score is a product of all three factors; where the easiest to identify species (ID Difficulty Score = 1) are very common, distinct looking, and are dominant; and the most difficult (ID Difficulty Score = 6) are those that are rare, not very distinct in appearance, and not dominant (Table 4).

Table 3. Narrative guidance for the Identification (ID) Difficulty Score. Each species is rated according to each of the three scoring factors and factor scores are summed to return an ID Difficulty Score.

Factor	Score	Description
Commonness	1	Very common component in on or more wetland community types and distributed throughout one or more major ecoregions
	2	Occasional component in one or more wetland community types and/or distribution limited to in one major ecoregion totaling <1/3 of the state
	3	“Rare” species that seldom occurs in wetland community types and/or has a very restricted distribution
Distinctness	1	Has unique vegetative features
	2	There are one-several other similar species or has a unique appearance only when in flower/fruit
	3	There are many similar looking species even when in flower/fruit
Dominance	0	Not potentially dominant
	-1	Dominant or potentially dominant in one or more community types

Table 4. Example ID Difficulty Scores.

Scientific Name	Common Name	Commonness	Distinctness	Dominance	ID Difficulty Score
Phragmites australis (Cav.) Trin. Ex Steud.	Common reed	1	1	-1	1
Carex lacustris Willd.	Lake sedge	1	2	-1	2
Iris versicolor L.	Northern blue flag	1	2	0	3
Galium trifidum ssp. *trifidum* L.	Three-cleft bedstraw	1	3	0	4
Carex canescens L.	Silvery sedge	2	3	0	5
Poa paludigena Fern. & Wieg.	Bog bluegrass	3	3	0	6

Two data trials were undertaken to test the effect of limiting data to common/easy to identify species using the ID Difficulty Score on FQA metrics. First, all species from the Minnesota Pollution Control Agency (MPCA) depressional marsh IBI development data set (Gernes and Helgen 2002, Genet and Bourdaghs 2006) which spans a gradient from minimally to severely impacted were assigned initial ID Difficulty Scores. Species were removed from the data set according to the ID Difficulty Score and changes in the FQA metrics were observed. When all species with an ID Difficulty > 3 (i.e., species that were judged as being more difficult to identify) were removed there was a 12.8 percent overall average deviation in species richness and 6.2 percent deviation of Mean *C* determined by linear regression (Figure 1). The second trial consisted of comparing the distributions of Mean *C* from minimally impacted Fresh Meadow sites when all species are included versus when species with ID Difficulty Scores > 3 are removed. MDNR releve data were used in this trial. Box and whisker plots showed an overall downward shift in Mean *C* scores when data were limited by the ID Difficulty Score but little truncation or elongation in the distribution (Figure 2). These results indicated that the more common and easy to identify species were the main drivers of Mean *C* and limiting sampling to these species causes only minor changes in scores and little distortion in distributions

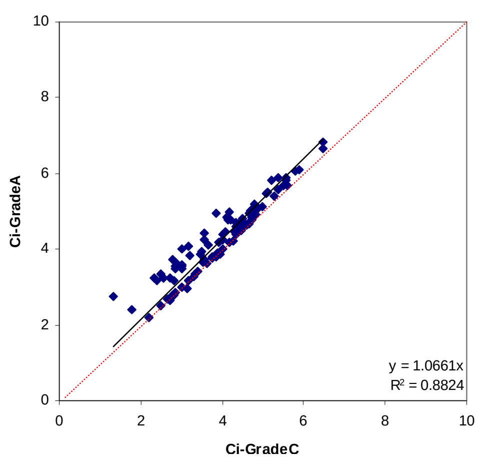

Figure 1. Mean *C* scores when species with ID Difficulty Scores >3 are removed (Ci-Grade C) against Mean *C* scores when all species are included (n=104). The overall deviation percent was determined by slope of the regression line. A one: one line (red) has been added for reference.

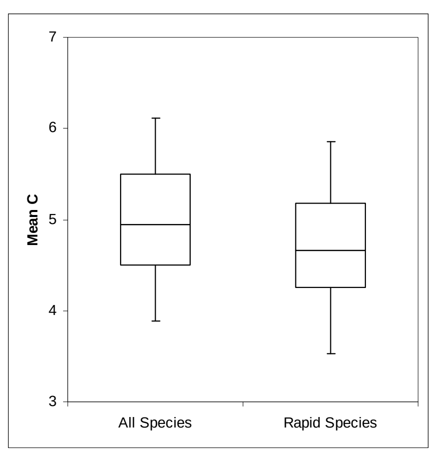

Figure 2. Box and whisker plots of Mean *C* score distributions from minimally impacted Fresh Meadows when all species are included in the data and when species with ID Difficulty Scores > 3 are removed (n=313).

Following these trials, ID difficulty scores were used to determine the Rapid Species List. ID Difficulty Scores were assigned to all 1266 species in the Minnesota wetland flora (Minnesota Wetlist 1.4; Milburn et al. 2007) independently by four botanists according to the narrative criteria in Table 4. Community frequency counts based on the MDNR releve dataset, literature accounts, and best professional judgment were used to make the ratings. If the majority of the four botanists scored a species ≤ 3, that species was included in the Rapid Species List. If there were 2 x 2 ties of ID Difficulty Scores ≤ and > 3 for a species, then the species was reassessed as a group. Possible rating inconsistencies were addressed and the species was then included on the Rapid Species List if the majority of raters had revised scores ≤ 3. If there continued to be a qualitative tie between raters at this stage, ID Difficulty scores were averaged and a species was included in the Rapid Species list if the average score was < 3.5.

Assessment criteria development

A variety of biological assessment criteria development approaches have been developed. The universal feature is the incorporation of a minimally or least anthropogenically impacted 'reference condition', where the assessment criteria are determined based on some observable or measurable deviation from the reference condition (EPA 1990). A common approach to setting biological assessment criteria is to define a reference condition; select data from sites that meet the reference condition definition; compute assessment metrics from the data; and set the metric score thresholds at the 'lowest scoring reference site' or some percentile threshold near the bottom of the reference site distribution (EPA 1990, Genet et al. 2004). If the reference definition is based on regionally 'least impacted' conditions the resulting assessment criteria are relative to those sites that are least impacted. More recently, the Biological Condition Gradient (BCG) has been introduced as a more refined general model of biological response to anthropogenic impacts that describes biological condition according to tiers that range from conditions that are equivalent to those found prior to European settlement to conditions that are found at sites that are severely impacted (EPA 2005, Davies and Jackson 2006). The BCG is essentially an absolute scale that can be used as a framework to calibrate quantitative biological metrics and indices. The technical committee determined that a BCG approach was appropriate as an underlying theoretical framework to develop assessment criteria for the Rapid FQA. The BCG can accommodate broad application as it allows for universal comparisons of BCG tiers across applications; yet provides the flexibility to further place the assessment within an appropriate management context.

The first step in developing Rapid FQA assessment criteria was to develop a general wetland vegetation BCG model (Table 5). The wetland vegetation BCG was largely adapted from EPA (2005); however, there were a few differences. The EPA (2005) BCG was developed to describe biological conditions in streams based on fish and macroinvertebrate assemblages and included six BCG tiers. The wetland vegetation BCG includes five tiers ranging from pre European settlement conditions (Tier 1) to conditions that can no longer support any vegetation due to ongoing anthropogenic impacts (Tier 5). Rapid FQA assessment thresholds were developed only for tiers 1-4 as tier 5 represents a condition that does not support a sufficient plant community to register meaningful FQA metrics. An example of Tier 5 would be a farmed wetland, where the soil is tilled and planted with crops during dryer years. The BCG tiers are also roughly equivalent to existing wetland assessment methods categories found in the Minnesota Routine Wetland Assessment Method (Exceptional, High, Medium, Low; MN BWSR 2010) and the MDNR County Biological Survey condition ranks for Native Plant Communities (A-D; MDNR 2009).

Table 5. The general wetland vegetation Biological Condition Gradient

BCG Tier	Description
1	Community composition and structure as they exist (or likely existed) in the absence of measurable effects of anthropogenic stressors representing pre-European settlement conditions. Non-native taxa may be present at very low abundance and not causing displacement of native taxa.
2	Community structure similar to natural community. Some additional taxa present and/or there are minor changes in the abundance distribution from the expected natural range. Extent of expected native composition for the community type remains largely intact.
3	Moderate changes in community structure. Sensitive taxa are replaced as the abundance distribution shifts towards more tolerant taxa. Extent of expected native composition for the community type diminished.
4	Large to extreme changes in community structure resulting from large abundance distribution shifts towards more tolerant taxa. Extent of expected native composition for the community type reduced to isolated pockets and/or wholesale changes in composition.
5	Plant life only marginally supported or soil/substrate largely devoid of hydrophytic vegetation due to ongoing severe anthropogenic impacts

To determine quantitative BCG Tier thresholds, development data are typically first assigned to tiers by an expert panel following descriptive attribute models and thresholds are then determined based on separation of metric distributions between tiers (EPA 2005). A simplified, yet similar, approach was used to determine Rapid FQA assessment thresholds. Because biological condition is related to anthropogenic stressors it was decided to use the apparent degree of anthropogenic impacts to assign criteria development data to three analysis groups: Pre Settlement, Minimally Impacted, and Severely Impacted. In terms of anthropogenic impacts, these groups conceptually correspond to BCG tiers 1, 2, and 4, respectively. A general categorical Human Disturbance Assessment (HDA) was developed and used to estimate the exposure of sites to anthropogenic impacts and subsequently to assign sites to the Minimally and Severely Impacted groups (Appendix 1). Minimally Impacted sites were then further reviewed to determine if they could be considered in the Pre Settlement group. If a site was rated as Minimally Impacted according to the HDA; had community composition and structure consistent with the Tier 1 narrative criteria (Table 5); and if it was given a Native Plant Community condition rank of A or AB by the MDNR (the majority of the assessment criteria development data were collected by the MDNR) the site was placed into the Pre Settlement group. The MDNR condition ranks of A or AB are conceptually consistent with tier 1 of the BCG (MDNR 2009).

Once all the assessment criteria development data were assigned to the three analysis groups for each community type, percentile breakpoints of the analysis group distributions were applied to make the numeric thresholds (Figure 3). The 10^{th} percentile of the Minimally Impacted data group became the threshold between Tier 2 and 3. The 10^{th} percentile between the Pre Settlement data group became the initial threshold between Tier 1 and 2. An additional narrative criterion was adopted to separate Tier 1 and 2 due to likely overlap of distributions for most classes. This also allows for the presence of introduced species in very low abundance when they have no apparent affect on the native community at Tier 1 sites. A site is then assessed as Tier 1 if its metric value exceeds the Tier 1 numerical threshold for the community type *and* if the total introduced species cover is < 1percent. This approach was consistent with EPA (2005) where it was decided that a minimal abundance of introduced species was acceptable at a Tier 1 site if there was no apparent displacement of the native community by the introduced species. Finally, the 90^{th} percentile of the Severely Impacted group was used as the threshold between tiers 3 and 4. In other words, the inverse of the 'lowest scoring reference site' approach was used to determine the Tier 3/4 threshold.

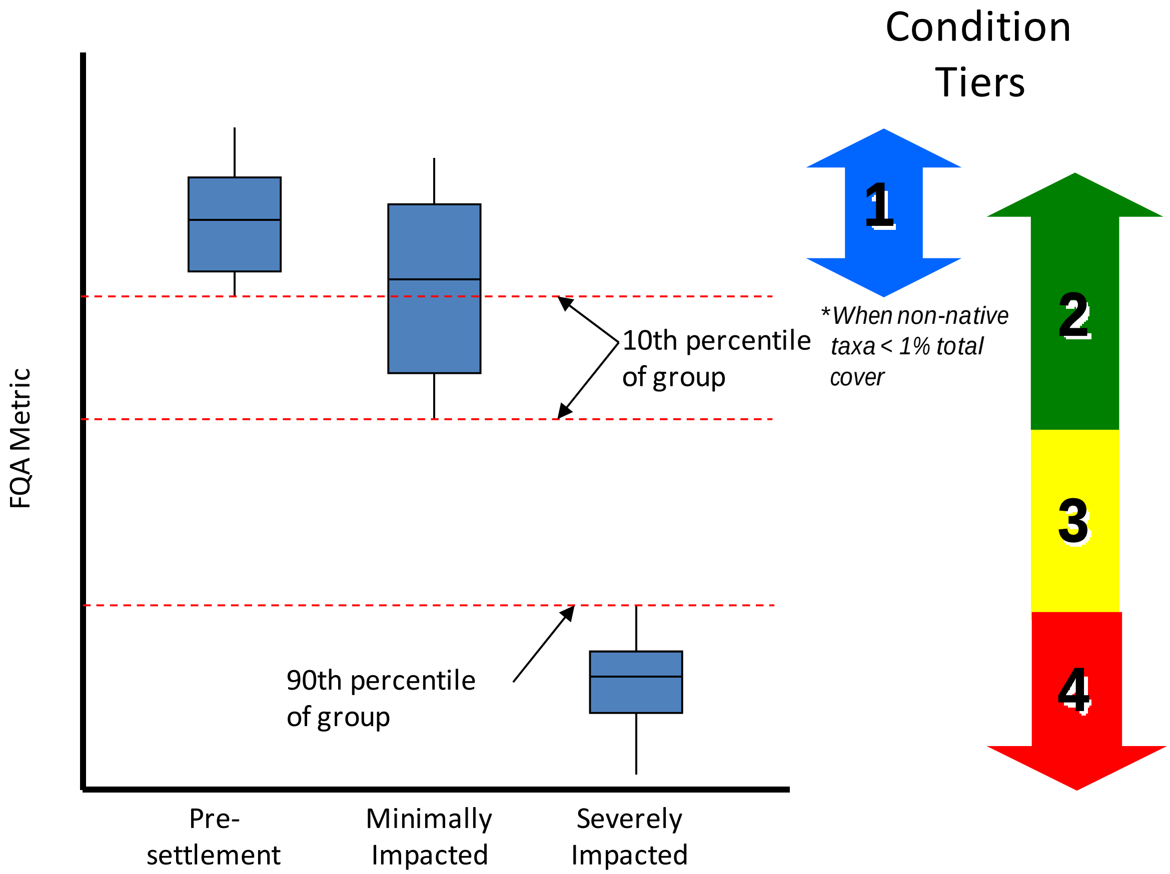

Figure 3. Diagram of Rapid FQA assessment criteria threshold development. Community samples are assigned to data analysis groups (Pre Settlement, Minimally Impacted, or Severely Impacted) and FQA metrics are calculated. Thresholds are determined at designated percentiles of the FQA metric distribution for each data analysis group, which then correspond to the BCG Tiers (Table 5). Separating the Tier 1 and 2 threshold requires an additional narrative criterion to be met.

Assessment criteria development data came from a variety of sources. The majority of the samples were existing data, most of which were releve samples from the MDNR. The basic releve method consists of species and cover class data collected in a single large plot that is located in representative location within a community by the observer (MDNR 2007). The releve method has been used by the MDNR for over two decades to collect plant community data. All releve data that had been assigned a wetland community classification through 2004 was made available to the MPCA for Rapid FQA assessment criteria development. The first step for reviewing releve data was to relate the MDNR Native Plant Communities (NPCs; MDNR 2003, MDNR 2005a, MDNR 2005b) to the Eggers and Reed classification (Table 1) according to class definitions and descriptions (Appendix 2). Many of the NPCs had clear one: one correspondence with Eggers and Reed classes, but not all. For example, communities dominated by *Calamagrostis canadensis* (Michx.) P. Beauv. (bluejoint)/*Carex stricta* (Lam.) (tussock sedge) and communities dominated by *Carex lacustris* Willd. (lake sedge) are both considered in the MDNR classification as the Wet Meadow (WM) System; whereas, in Eggers and Reed these communities would be considered as Fresh Meadow and Shallow Marsh respectively. Releve data were assigned an initial 'primary' Eggers and Reed class according to the community crosswalk and then individual samples were reviewed to determine the final appropriate Eggers and Reed class before inclusion into the assessment criteria development data set. The majority of the Pre Settlement and Minimally Impacted data (except for the Shallow Marsh and Shallow Open Water communities) came from the MDNR releve data set. Existing MPCA data from depressional Index of Biological Integrity (IBI) sampling from Shallow Marsh and Shallow Open Water communities; as well as, some severely impacted Calcareous Fen data from the Army Corps of Engineers was also included in the assessment criteria development data set. The MPCA and Army Corps data were collected using protocols similar to the MDNR releve protocols. To confirm consistency in results from different protocols and validate the use of DNR releve data for Rapid FQA assessment criteria development, a limited Rapid FQA-MDNR releve protocol comparison was undertaken. During the 2010 field season, 4 Fresh Meadow, 4 Hardwood Swamp, and 5 Open Bog communities that had previously been sampled using the releve protocol by MDNR, were sampled with the Rapid FQA protocol. Finally, while the majority of the assessment criteria development data came from existing sources, additional sampling was needed to obtain data for the Severely Impacted analysis groups. Field work during the 2009 and 2010 field seasons focused on finding and sampling severely impacted sites for all of the community types using the Rapid FQA protocol. A site was determined as an example of a severely impacted community if there was strong evidence of both the former type (e.g., dead standing trees, remnant characteristic native species) and severe anthropogenic impacts (i.e., rated as Severely Impacted using the HDA; Appendix 1) present.

All candidate data were reviewed prior to inclusion in the assessment criteria dataset. Review consisted of community class and data analysis group assignment as previously described. Samples that had questionable data or were 'moderately impacted' according to the HDA were excluded. When multiple existing plot samples occurred within the same contiguous community and were sampled at the same time, the data were made into a composite sample as it was assumed that the composite sample would be more consistent with the Rapid FQA protocols. The goal was to have at least 10 and as many as 30 samples for each of the Pre Settlement, Minimally Impacted, and Severely Impacted data groups for each community type. For some community types, > 30 candidate samples were available. When this occurred candidate samples were selected at random during the review process. The selection was stopped, when 30 samples were reached (a few occasions occurred where > 30 samples were selected by mistake and they were retained in the analysis). There were also occasions when < 10 samples were available for an analysis group for a community type. In these cases assessment criteria were still developed, but the resulting threshold was flagged as preliminary. The total number of samples used to develop Rapid FQA assessment criteria was 725 (Table 6).

Table 6. Number of assessment criteria development samples in each data analysis group by community type

Community	Pre-settlement	Minimally impacted	Severely impacted
Shallow Open Water	0	13	12
Deep Marsh	0	16	0
Shallow Marsh	10	29	20
Fresh Meadow	26	31	21
Wet Prairie	18	30	5
Calcareous Fen	3	30	3
Sedge Mat	30	31	5
Open Bog	30	30	2
Coniferous Bog	28	30	5
Shrub-Carr	10	23	11
Alder Thicket	16	21	6
Hardwood Swamp	30	30	10
Coniferous Swamp	30	30	8
Floodplain Forest	3	30	9

Results and Discussion

Protocol development

In 2008, monthly repeated sampling (May-October) was conducted at 4 sites to determine the affect of phenology and the ability of the observer to fully identify species on FQA metric accuracy (S_N, Mean *C*, and *FQI*). The percent deviation of monthly metric values from total composite metric values (i.e., all monthly plot data and timed meander data for a site combined) was calculated for each site and averaged by month. It was assumed that composite metric values would be the most accurate for a site because it includes results from the combined sampling effort throughout the year. Overall, average metric percent deviation (Figure 4) was highest at the earliest (May) and latest months (October) and relatively stable from June-September. This result was consistent with expectations, where fewer species can reliably be identified early and late in the growing season. S_N consistently had the greatest deviation and Mean *C* the least deviation of the three metrics considered, with *FQI* performing in between (Figure 4). For many species, the features required to allow for complete identification are only present during a limited time during the growing season, thus some species may only be identified early and others late in the year. The much lower deviation of Mean *C* throughout the growing season indicates that even though there is turnover in the species pool that can be identified throughout the growing season, that turnover has little affect on Mean *C*. Combined, these results suggest that a single sampling event between June-September will return an accurate assessment when Mean *C* is the primary assessment metric.

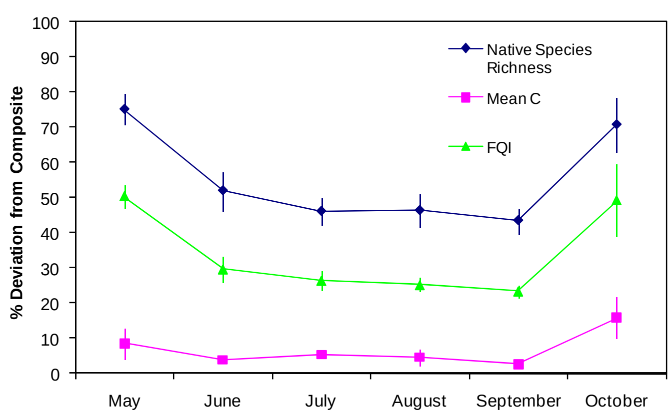

Figure 4. Average monthly metric percent deviation from composite data. Error bars represent the standard error.

The Mean *C* percent deviation for both the plot and timed meander sampling from the composite value (i.e., all data combined) was used to compare the performance of the two sampling approaches from the 2008 data. Overall, the average Mean *C* percent deviation for each sampling approach at the Fresh Meadow, Hardwood Swamp, and Open Bog community types was generally small (Figure 5). All values were < 15 percent deviation, indicating that each approach provides relatively accurate results. Timed meander sampling, however, consistently produced lower average percent deviation from composite values compared to plot based sampling indicating that timed meander sampling may be the more accurate approach, at least when Mean *C* is the primary FQA metric. This intuitively makes sense as timed meander sampling generally covers more sampling area than plot based methods and provides a more complete species census for a site. The shoreline sampling results from the Shallow Open Water community type were similar; where, the average percent Mean *C* deviation produced from shoreline sampling versus the composite of shoreline and kayak sampling was only 5.9 percent. This indicates that the shoreline sampling approach is picking up most of the species in Shallow Open Water habitats and returning an accurate result.

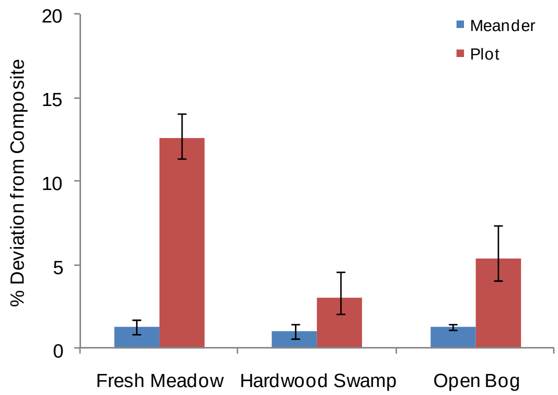

Figure 5. Average Mean C percent deviation of the meander and plot samples compared to the composite samples of the same sites. Error bars represent the standard error.

Sampling effort-FQA metric plots generated from 2008 data confirmed previously observed patterns of the affect of sampling effort on both S_N and Mean *C*. For plot based sampling, S_N increased with sampling area according to the well known species-area relationship (Arrhenius 1921) for all three community types considered (Figure 6A). Likewise, S_N increased with time according to the same relationship during timed meander sampling (Figure 7B). Mean *C*, on the other hand, either had no relationship with sampling effort (Figure 6B, Figure 7B) or a very shallowly sloped negative relationship (Open Bog and Fresh Meadow communities and sampling time; Figure 7B). This indicates that sampling effort has a strong effect on species richness, and subsequently FQA metrics that include species richness as factor (such as *FQI*), but it has no or only a negligible effect on Mean *C*. These results are consistent with pervious findings (Rooney and Rogers 2002, Bourdaghs et al. 2006). The shoreline sampling again returned similar results, where native species richness increased significantly with increased sampling effort (in this case shoreline sampling stations) and Mean *C* was stable (Figure 8).

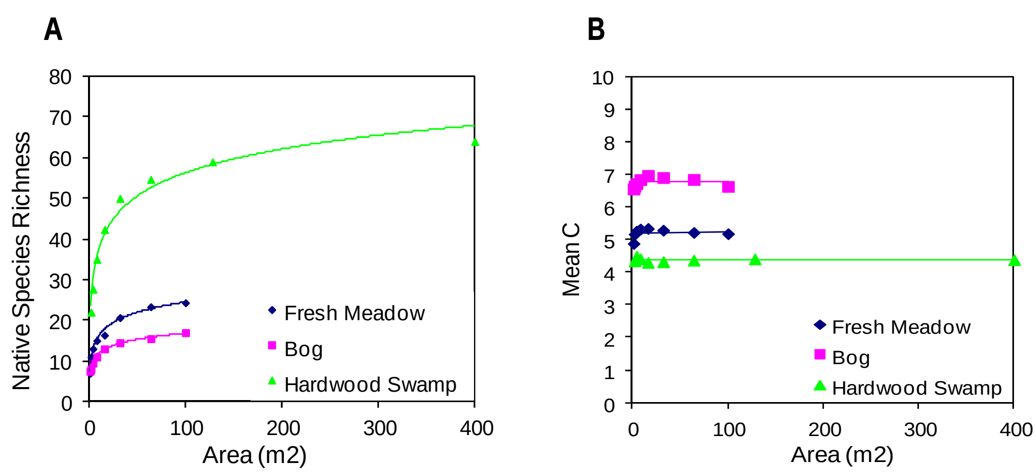

Figure 6. Native species richness (A) and Mean *C* (B) area curves derived from nested plot data for Fresh Meadow, Open Bog, and Hardwood Swamp communities (three replicates for each community, error bars were omitted).

The 2010 meander sampling effort trial produced similar results. In this case, timed meander sampling was conducted with cover classes (Table 2) recorded for each species at 10 minute intervals. The cover data allowed for sampling effort evaluation of *wC*. *wC* was somewhat variable against sampling time at individual sites (Figure 9) where *wC* fluctuated and then became stable over sampling time at some sites while others continued to vary by more than several tenths over the last 2 or 3 time periods. The maximum difference in *wC* for a site between the last two periods was 0.4 in the Fresh Meadow and 0.3 in the Shallow Marsh communities. The average difference, however, for both communities over the last two periods was < 0.1. In addition, when *wC* was averaged over the last four 10-minute time periods for all of the sites (4 time periods equals the site with the least amount of sampling effort, Gleason; Figure 9), there was no significant relationship between *wC* and sampling time (Figure 10). In other words, on average, *wC* is stable by the end of timed meander sampling indicating that timed meander sampling typically returns accurate *wC* values over relatively short periods of time. This is consistent with the performance of Mean *C* (Figure 6B), where sampling effort had more or less no affect on metric values. Based on these results it was decided that 30 minutes of base meander time should be sufficient to return accurate results when aerial cover data are collected in addition to species presence data during timed meanders.

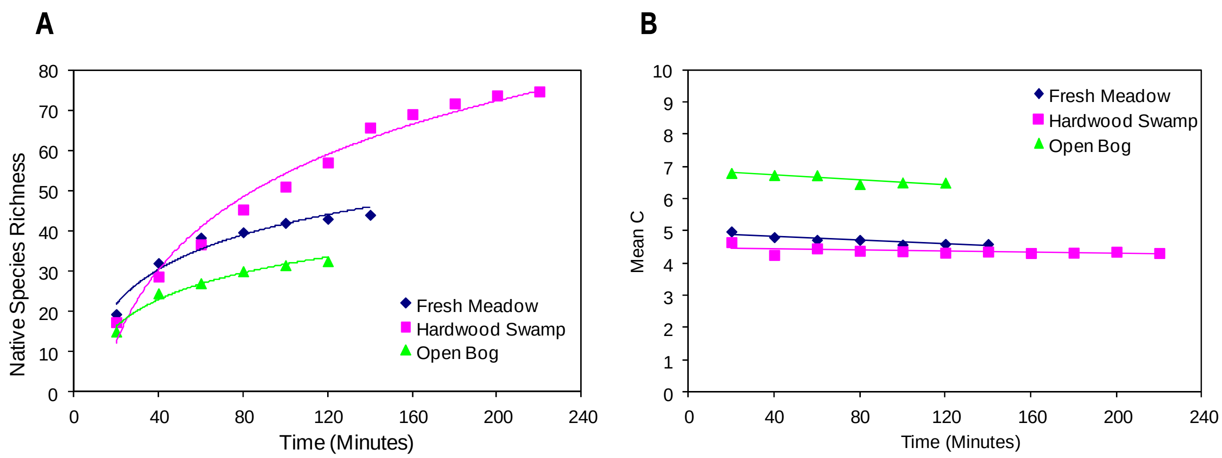

Figure 7. Native species richness (A) and Mean *C* (B) sampling time curves derived from timed meander data for Fresh Meadow, Open Bog, and Hardwood Swamp communities (three replicates for each community, error bars were omitted).

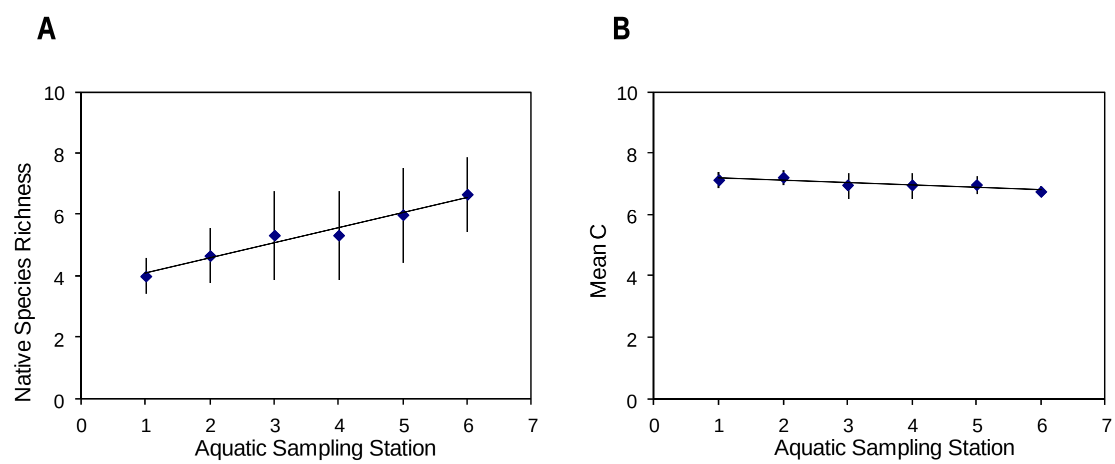

Figure 8. Native species richness (A) and Mean *C* (B) sampling time relationships derived from shoreline sampling data at Shallow Open Water communities (three replicates, error bars represent the standard error).

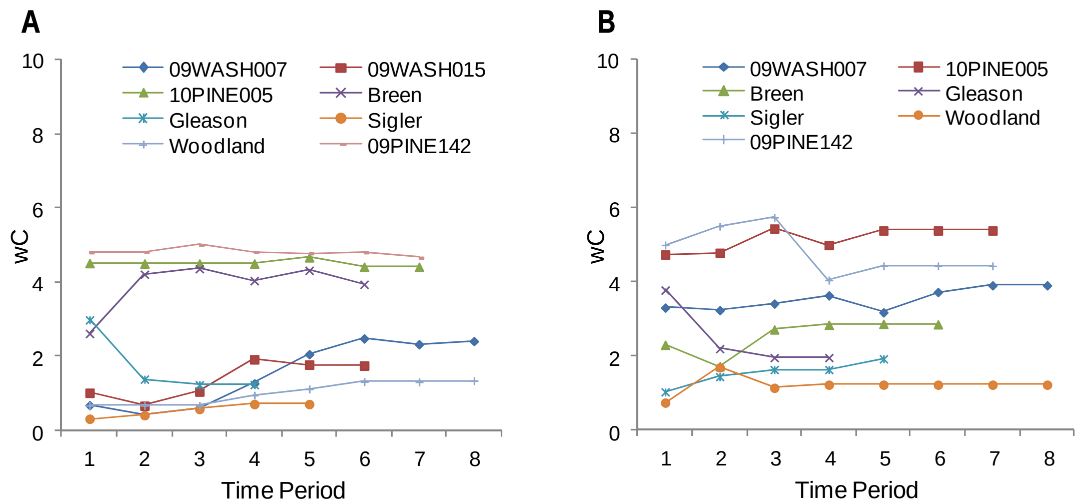

Figure 9. *wC* plotted against 10-minute time periods for eight individual Fresh Meadow (A) and seven individual Shallow Marsh (B) sites.

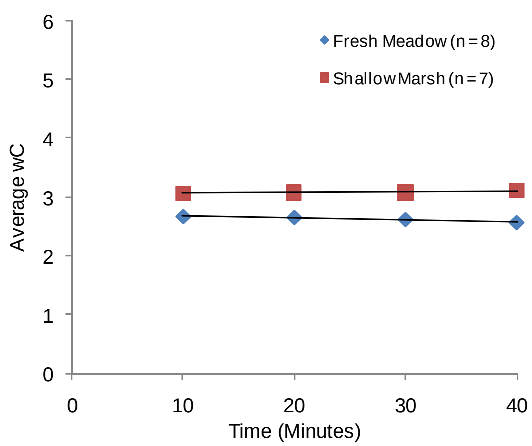

Figure 10. Average *wC* for the final four 10-minute time periods for the Fresh Meadow and Shallow Marsh communities (error bars omitted).

The Rapid Species List development effort produced a list of 290 of the more common and relatively easier to identify species occurring in Minnesota wetlands (Appendix 3). Again, the goal of the Rapid Species List was to limit the Rapid FQA protocol to observing only the common/easy to identify species, thereby simplifying the protocol and making it consistent with 'rapid' assessment methods and feasible for natural resource professionals with moderate botanical expertise to do. The Rapid Species List includes many of the native species that are dominants and define Minnesota wetland community types; as well as, a number of introduced/invasive species that indicate degradation. Some species are common in many different community types such as *Calamagrostis canadensis* (bluejoint). On the other hand, some species are not very common overall but may be common or an indicator of a specific community type. *Parnasia glauca* Raf. (American grass-of-Parnassus) and *Parnassia palustris* L. (Northern grass-of-Parnassus) are very common species in Calcareous Fens. Calcareous Fens, however, are a less common community type in Minnesota. The Rapid Species List is the primary component of the field data sheet (Appendix 4), where it serves as a species checklist organized by growth form. These growth forms are consistent with the growth forms described in the US Army Corps of Engineers regional delineation manual supplements (US ACE 2010).

Throughout the development of the Rapid FQA protocol, performance of the various FQA metrics was assessed. This was done to either eliminate metrics if various protocol decisions were reached that make the metrics inherently inaccurate and/or to ultimately focus on metrics that consistently outperform others. A primary goal of the Rapid FQA protocol is for it to be flexible in a variety of circumstances. In other words, it should be able to return accurate results from sites that range in size and complexity. It also has to have the flexibility to be used at different scales for different purposes, such as an entire wetland complex or a portion of wetland that may be under consideration for a partial impact. A progressive timed meander approach, where meander time can be added to accommodate larger and more complex sites better provides this flexibility for a 'rapid' method. In addition to being conceptually appealing, results also indicate that timed meanders return accurate results within a relatively rapid time frame when considering *C*-value based metrics (Figure 5, Figure 7, and Figure 10). To use species richness or *FQI* as an assessment metric, sampling area/effort must be standardized in the protocol due to the species-area relationship (Figure 6, Figure 7, Figure 8, Bourdaghs et al. 2006). A progressive timed meander sampling approach must therefore rely on *C*-value based metrics as sampling effort is not standardized. Early on during the 2009 field trials of the initial Rapid FQA protocol (which was a progressive timed meander that recorded only species presence), it was observed that Mean *C* was not responsive between minimally and severely impacted sites. This was not expected and was due to the increased likelihood that the observer would find small remnant pockets of native species in severely impacted sites during meander sampling. In other words, sites where almost all of the native composition had been replaced by invasive species had Mean *C* scores relatively similar to sites composed almost entirely of the expected native composition because small remnant patches were found that harbored many characteristic native species. Estimating cover according to cover classes was then added to the protocol so that *wC* could be calculated. Assessment criteria development data confirmed this initial observation, where *wC* was a much more responsive metric than Mean *C* (Figure 11). Due to superior performance, it was decided that *wC* would be the primary Rapid FQA metric.

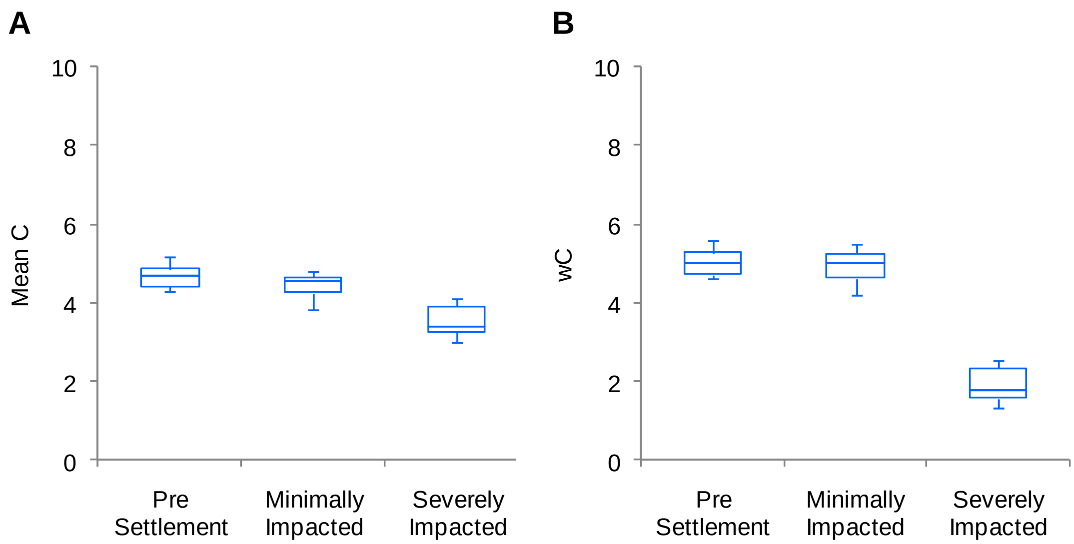

Figure 11. Box whisker plots for (A) Mean C and (B) wC distributions according to pre-settlement, minimally impacted, and severely impacted assessment criteria data groups for the Hardwood Swamp community type.

Rapid FQA sampling protocol

Results from the protocol development work were synthesized into the following general Rapid FQA sampling protocol:

1) **Map/sketch the approximate boundaries of the assessment area (AA) and plant communities**

   The Assessment Area (AA) is the targeted wetland area that is being represented in the assessment. This may be an entire wetland basin or complex, or a portion of a wetland. Individual plant communities are the basic assessment unit of the Rapid FQA. It will be necessary to determine the relative proportions of the different community types within the AA to complete a Rapid FQA. It will be beneficial to define the AA and determine the communities as best as possible prior to field sampling. The preferred method is to map AA and community polygons in a GIS, using aerial photography, topographic maps, and National Wetlands Inventory

(NWI) maps to guide interpretations. An acceptable method is to sketch AA and community boundaries on printed aerial photos/maps or create a rough AA/community sketch. Communities should follow Eggers and Reed types (Table 1).

2) Confirm and correct AA and community types/boundaries on-site

When first arriving at the AA effort should be spent doing an initial confirmation and (if necessary) correction of the AA boundaries and community types. Record any differences with the community mapping done in Step 1 on a printed aerial photo or AA sketch. Following field sampling this information should be used to update GIS polygons. Record the community types in the numbered spaces provided on the data sheet (Appendix 4). Each data sheet has capacity to record data for three community types for a single AA. If the AA has more than three community types, use an additional data sheet. Final confirmation and correction of the AA and communities can be done while doing meander sampling to avoid the need to walk the AA multiple times.

3) Determine the base meander time

The primary Rapid FQA sampling approach is a progressive timed meander that provides flexibility to sample AA's of varying size and complexity. There is a 'base' meander time that varies according to the number of different communities (Table 1) present in the AA and then time is added to the meander if new species are encountered greater than a certain rate as the meander progresses. All community types within the AA are sampled in a single composite meander. The base meander time is the minimum amount of sampling time for an AA and is determined as follows: 30 minutes for the first community type and add 20 minutes for each additional community type in the AA. For example, an AA with Fresh Meadow, Shrub-Carr, and Shallow Marsh communities would have a meander base time of 30 + 20 + 20 = 70 minutes.

4) Conduct the composite timed meander

Once the AA and communities have generally been identified and confirmed (Step 2) and the base meander time has been determined (Step 3), timed meander sampling can begin. All communities within the AA (except Shallow Open Water) are sampled in a single composite meander; however, data are recorded separately by community type. Begin the meander in a representative area of community #1 and record the meander start time on the data sheet. Record the presence of plant species on the Species Checklist (i.e., Rapid Species List) provided on the data sheet (Appendix 4) by circling the space in front of a species name that corresponds with the correct designated community number. Only record species that can be confidently identified during the time of sampling and are on the checklist. The same species can occur in multiple community types. Leave enough room within the circle to record a cover class (Step 6). Meander through community #1 recording species on the checklist as they are encountered. The meander path should move from community to community so that approximately equal amounts of time are spent in each community present in the AA. Mentally keep track of the approximate aerial cover of each species per community type as the meander proceeds. During the final 10 minutes of the base meander time begin keeping track of any new species encountered. If < 3 new species are encountered during these 10 minutes, stop the meander at the end of the base meander time. If ≥ 3 new species are encountered during the last 10 minutes of the base meander time, continue the meander for an additional 10 minute time period. Continue adding 10 minute periods to the meander until < 3 new species are encountered in a time period. Once this occurs, the meander can be stopped. Record the meander stop time and determine the total meander time. At small AAs the composite meander may be stopped before the base time expires if the entire AA has been observed. A composite meander may also be 'paused' to walk to different areas of the AA without recording observations, and then started again at the discretion of the observer.

5) Conduct shallow open water sampling (if present)

The Shallow Open Water community is sampled using a 'shoreline' sampling approach due to the general difficulty of sampling in this community type. In general, three shoreline sampling stations are established in representative locations along the emergent/aquatic interface of the AA and aquatic vegetation is sampled using a handheld garden cultivator with the tines bent backwards tied to a 20' length of rope. The cultivator is thrown into the water and retrieved three times, once perpendicular from the shore and both (+/-) 45° from perpendicular. Aquatic species on the Species Checklist are recorded as they are observed from both within eyesight of the sampling station and by examining the aquatic vegetation retrieved from the garden cultivator. Shallow Open Water sampling can be done concurrently with the composite timed meander (Step 4) so that walking the AA multiple times can be avoided. The timed meander is paused when shoreline sampling is being conducted. Species encountered during the shoreline sampling do not count towards the species tally used to add time to the composite meander.

6) Make cover estimations

Estimate the aerial cover of each species observed by community type (including Shallow Open Water species) according to the cover classes provided on the data sheet. Record the cover class of each species within the circle by the corresponding community type. Field sampling is now complete.

Assessment criteria

Data gathered using both the DNR releve method and Rapid FQA protocol at the same sites typically produced similar results. The average absolute difference in *wC* scores from both sampling approaches was 0.4 from Fresh Meadow, 0.4 from Hardwood Swamp, and 0.5 from Open Bog community types. These average differences were considered small given the overall theoretical range (0-10) and typical response range (approximately 4.5 between the highest and lowest scoring sites for a community) of *wC*. This suggests that *wC* scores generated from either method are typically close to each other and that either method would likely return the same assessment for the same AA. Therefore, the DNR releve data should be a compatible source of data to calibrate Rapid FQA assessment criteria with. Based on these results, it was similarly assumed that data gathered using existing Minnesota Pollution Control Agency (MPCA) and United States Army Corps methods (that rely on representatively placed plots) would also be compatible to use for Rapid FQA assessment criteria development. It should be noted, however, that there were two cases (of 13) in the sampling methodology trial that had relatively large *wC* differences (≥ 1.0). In these cases, substantial cover of invasive species was observed at the community during the Rapid FQA sampling event that was not recorded in the DNR releve. It was likely that the large difference in scores was due either to the DNR releve being established as to avoid the invasive (which would then mean it was an unrepresentative sample of the community) or that the abundance of invasive had increased between the two sampling events. In any case, while the overall difference was small, it was possible that occasional larger *wC* differences could occur. To minimize this possibility, candidate assessment criteria development sites that had obvious changes and/or signs of increased invasive species abundance on recent aerial photos were omitted from the assessment criteria data set during the data review.

There was a strong response in *wC* scores across almost all community types, validating its effectiveness as an indicator of wetland condition. Twelve of the 14 community types had clear separation of *wC* distributions between reference data (Pre Settlement and Minimally Impacted data combined) and Severely Impacted data (Figure 12) and *wC* consistently provided greater separation between these data groups than Mean *C* (Figure 11). The exceptions were the Shallow Open Water (which had some distribution overlap) and Deep Marsh (where there was no severely impacted data available to test the response) communities. Non-wooded community types (Shallow Marsh, Fresh Meadow, Wet Prairie, and Sedge Mat) tended to have different *wC* response patterns than wooded communities. The non-wooded communities tended to have larger separation between the reference and Severely Impacted data and overall lower Severely Impacted data distributions. Often these open communities tend to become dominated by invasive species such as *Phalaris arundinacea* L. (reed canary grass), *Typha angustifolia* L. (narrow leaved cattail), and/or *Typha* x *glauca* Godr. (pro sp.) (hybrid cattail) when they are exposed to high degrees of anthropogenic stressors. The wooded communities, on the other hand, tend to retain at least some abundance of native trees and/or shrubs when exposed to anthropogenic stressors, resulting in relatively higher *wC* scores. The exception to this pattern was the Open Bog community, where very conservative acid bog species tended to be replaced by native Fresh Meadow and Shrub-Carr species (as opposed to invasive species) when Severely Impacted, resulting in a range roughly equivalent to reference data from those two types. These Severely Impacted Open Bog observations were generated from only two samples, so additional data will be necessary to better determine Open Bog response ranges. The different *wC* ranges and response patterns by community type was also consistent with previous observations (Milburn et al. 2007) reinforcing the need to use plant communities as a basic assessment unit with FQA.

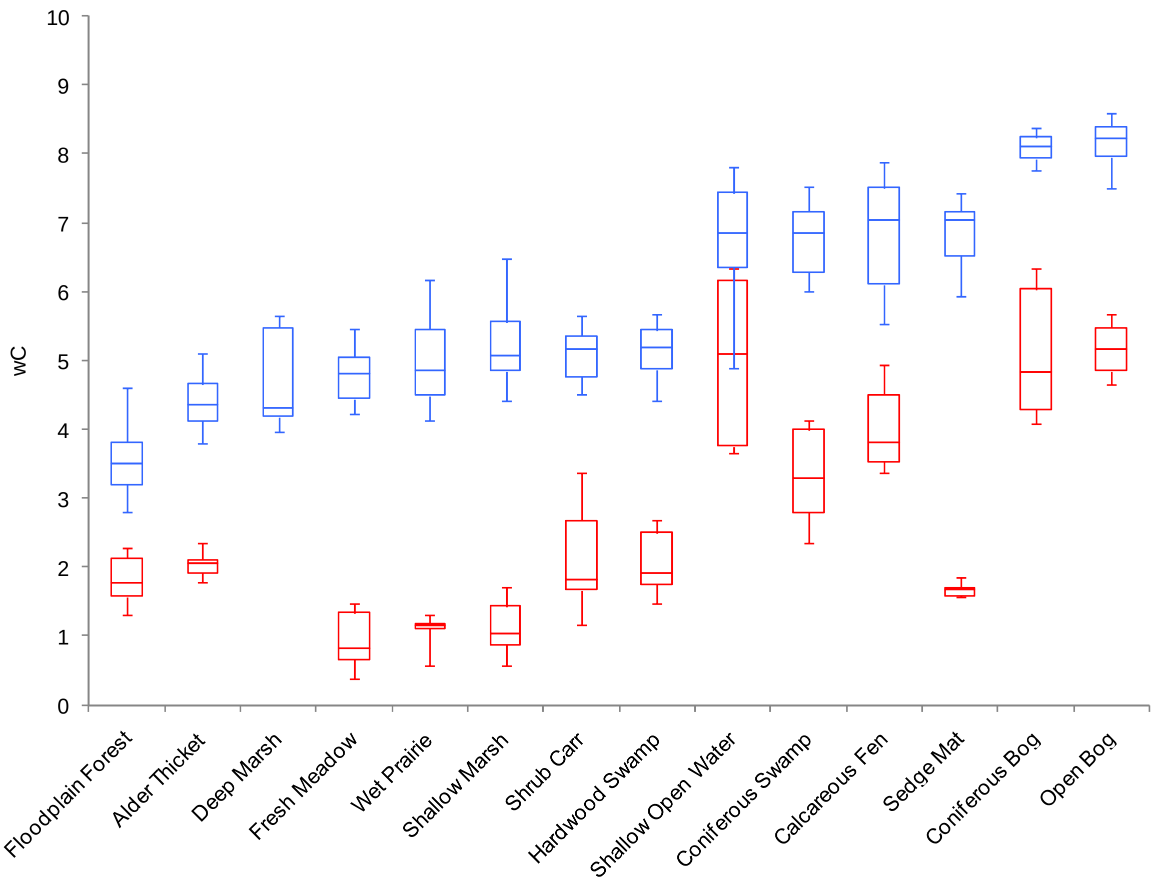

Figure 12. wc box and whisker distribution plots for all community types. Blue plots display the distribution on pre-settlement and minimally impacted data combined and red plots display the distribution of severly impacted data for each types are arranged from left to right according to increasing median *wC* scores for the pre-settlement/minimally impacted plots.

When the *wC* distributions were examined for all three assessment criteria development data groups for determining assessment criteria thresholds, there was consistent strong separation between the Minimally and Severely Impacted data groups, but overlapping *wC* distributions between the Pre-Settlement and Minimally Impacted groups in 12 of the 14 community types (Figure 13). In these cases, the breaks between the Minimally and Severely Impacted data groups allowed for establishing clear numerical thresholds between BCG tiers 2/3 and 3/4 for most community types according to the adopted approach for determining cutoffs (Figure 3). The overlapping distributions for the Pre Settlement and Minimally Impacted groups were expected as both tier 1 and 2 combined were conceived of as being the overall ‘reference condition’. Tier 1 is essentially a fine conceptual distinction at the upper end of the BCG that acknowledges a wetland condition in the absence of measurable effects of anthropogenic stressors; whereas, tier 2 represents conditions that are largely similar to Tier 1 but allow for some minor changes to the community due to anthropogenic impacts (Table 5). The overlapping *wC* distributions of these groups (with the Pre Settlement data group typically having slightly higher distributions) indicate that *wC* has limited capacity to indicate Tier 1 condition alone. Thus, there was the need to add the < 1 percent total introduced species cover narrative criteria to distinguish between tiers one 1and 2 for overlapping *wC* scores (Figure 3, Figure 13). In other words, for a community to be considered in a tier 1 condition, it must have a *wC* score > the 10th percentile of the Pre Settlement data group for that community *and* have < 1 percent total introduced species cover present.

The assessment criteria thresholds based on percentile breakpoints are provided in Table 7. Thresholds were considered robust if the data analysis group (i.e., Pre-Settlement, Minimally Impacted, or Severely Impacted) had ≥ 10 samples (Table 6). If the number of samples was < 10 for a group, the threshold was considered preliminary. There were robust thresholds between tiers 2 and 3 for all but one of the community types (Shallow Open Water). Four of the 14 communities (Shallow Marsh, Fresh Meadow, Shrub-Carr, and Hardwood Swamp) had robust thresholds for all tiers. Six of the communities (Wet Prairie, Sedge Mat, Open Bog, Coniferous Bog, Alder Thicket, and Coniferous Swamp), had robust Tier 1/2 and 2/3 thresholds, but preliminary tier 3/4 thresholds. Only the tier 2/3 threshold was robust for the Calcareous Fen and Floodplain Forest community types with tier 1/2 and 3/4 preliminary. Finally, just the tier 2/3 threshold was developed for the Shallow Open Water and Deep Marsh communities, with tiers 1 and 4 being undefined. In the case for Deep Marsh, only Minimally Impacted data were available for assessment criteria development. For Shallow Open Water, on the other hand, there was more data available but there was not clear separation in *wC* distributions between data analysis groups (Figure 12). This may be due to the lower number of aquatic species on the Rapid Species List (Appendix 3) so that there are not enough species to generate a reliable signal; the shoreline sampling approach is insufficient; or that *wC* is not as a responsive condition indicator in this community type. More research will be required to determine if the shoreline sampling approach is appropriate or if *wC* can ultimately be a strong indicator of vegetation condition in the Shallow Open Water community. Given that there was some evidence of *wC* response in the Shallow Open Water community, it was decided to set a general preliminary *wC* tier 2/3 threshold at 5.0 based on the median of the Severely Impacted distribution which was the first major percentile occurring above the 10th percentile of the Minimally Impacted data (Figure 12).

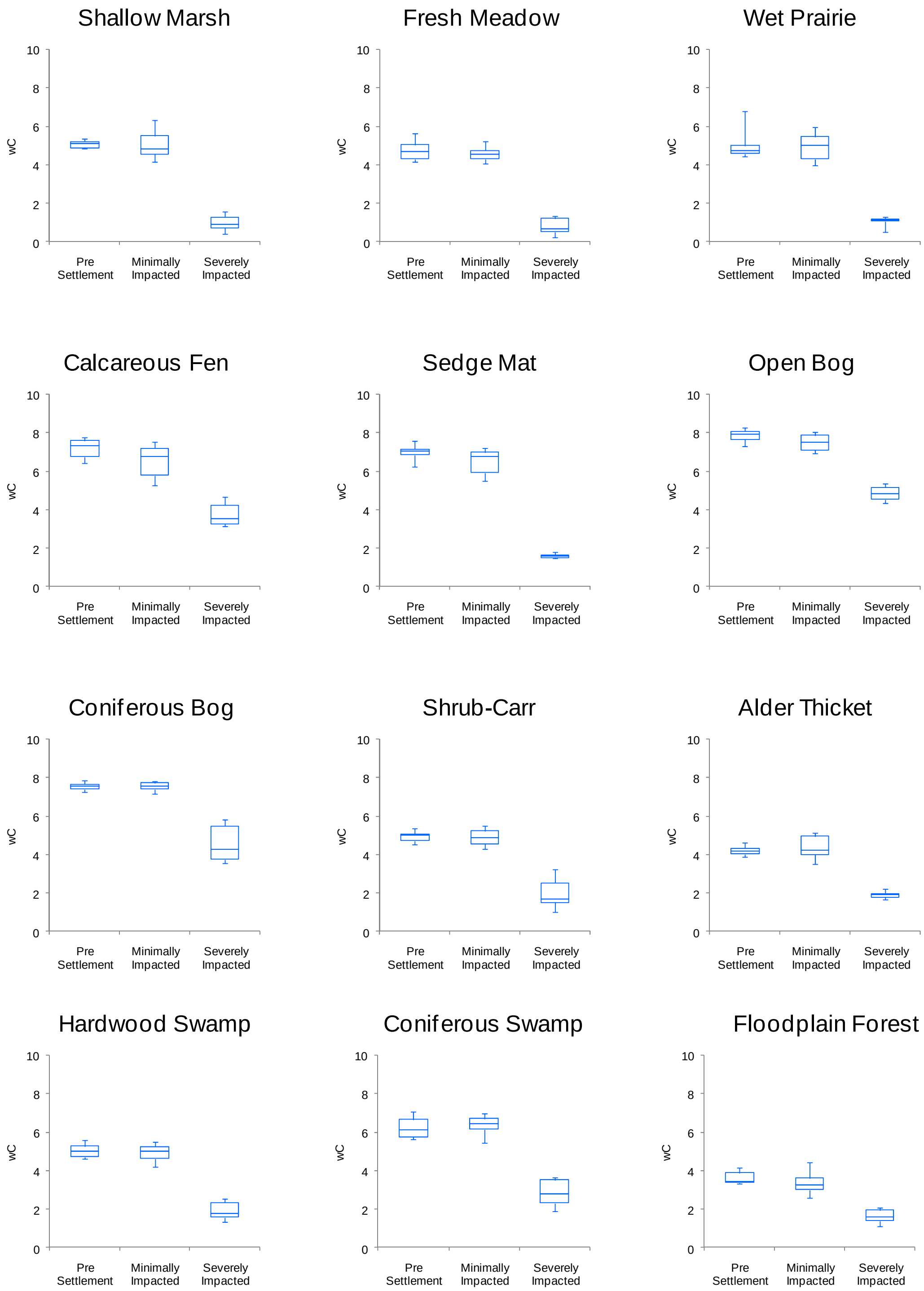

Figure 13. *wC* box and whisker distribution plots for all community types (except Shallow Open Water and Deep Marsh) according to the three assessment development data groups: Pre Settlement, Minimally Impacted, and Severely Impacted.

Table 7. BCG tier assessment criteria for all community types based on wC. Red type indicates that the threshold is preliminary due to <10 samples available to determine the threshold. An additional narrative criteria (*) is required to meet Tier 1: Total introduced species cover <1 percent (i.e., an AA must score above the numeric threshold and meet the narrative requirement to meet Tier 1).

	Community						
Tier	Shallow Open Water	Deep Marsh	Shallow Marsh	Fresh Meadow	Wet Prairie	Calcareous Fen	Sedge Mat
1			> 4.9*	> 4.2*	> 4.4*	> 6.4*	> 6.2*
2	> 5.0	> 4.0	> 4.2	> 4.1	> 3.9	> 5.2	> 5.5
3			1.6 - 4.2	1.3 - 4.1	1.3 - 3.9	4.7 - 5.2	1.8 - 5.5
4			< 1.6	< 1.3	< 1.3	< 4.7	< 1.8

	Community						
Tier	Open Bog	Coniferous Bog	Shrub-Carr	Alder Thicket	Hardwood Swamp	Coniferous Swamp	Floodplain Forest
1	> 7.3*	> 7.3*	> 4.5*	> 3.9*	> 4.6*	> 5.6*	> 3.3*
2	> 7.1	> 7.2	> 4.3	> 3.5	> 4.2	> 5.5	> 2.7
3	5.4 - 7.1	5.8 - 7.2	3.2 - 4.3	2.2 - 3.5	2.5 - 4.2	5.5 - 3.6	2.1 - 2.7
4	< 5.4	< 5.8	< 3.2	< 2.2	< 2.5	< 3.6	< 2.1

* Total introduced species cover < 1 percent

Rapid FQA data and assessment protocol

The general assessment approach is to first determine the BCG Tier for each community type within an AA based on the calculated *wC* scores derived from Rapid FQA sampling and compared to the assessment thresholds (Table 7). Finally, the overall weighted average BCG Tier for the AA can be determined based on the proportional area of the communities multiplied by the respective community BCG Tier. This will be the most representative assessment for an AA as it takes into account the extent of the plant communities present. While an overall assessment is the primary Rapid FQA output, the individual community assessments will also be informative by providing more specific information on which communities may be intact versus degraded in mixed condition situations. The general protocol to calculate *wC* and complete a Rapid FQA for an AA is as follows:

1) Calculate wC

The primary metric of the Rapid FQA is the abundance weighted Coefficient of Conservatism (*wC*). *wC* is the sum of each species' proportional abundance (*p*) multiplied by its *C*-value for a community and requires several steps to calculate. First, the community data needs to be arranged in a table with the species names in the rows and the following columns: the cover classes recorded for each species in the field; the midpoint percent cover that corresponds to each cover class (Table 2); and the corresponding *C*-value for each species (Appendix 3). Next, sum all of the midpoint percent cover values for the community to get a total cover estimate. Create a new column in the table and compute the proportional abundance (*p*) of each species by dividing the individual species midpoint percent cover by the total percent cover. Create another column in the table and multiply the *C*-value by the proportional abundance of each species. Finally, sum all of these values for the community to get *wC*. Calculate *wC* for each community type in the AA.

2) **Determine community assessments**

Determine the BCG Tier of each community within the AA by comparing *wC* scores to the Tier thresholds (Table 7). The thresholds are specific for each community. If a *wC* score meets the Tier 1 numerical criteria for a community, re-examine the data and sum the total midpoint percent cover of all introduced species. A community must also have < 1 percent total introduced species cover to be considered Tier 1. If the community has > 1 percent introduced species cover (even though it has a *wC* score that meets the Tier 1 numerical criteria) it is considered Tier 2.

3) **Determine the AA assessment**

Once the tiers for the individual communities have been determined, the overall AA assessment is made by taking the weighted average of the community tiers. First, determine the proportion of the AA that is occupied by each community. If the AA and community polygons were mapped in GIS this can be calculated by dividing the area of the community by the total AA area. If a site sketch was made, estimate the proportion of each community based on the sketch. Next multiply each community BCG Tier by its proportional extent and sum the values. Rounding to the nearest whole number will return the weighted average BCG tier for the AA. A complete Rapid FQA example describing each step of the sampling and assessment protocols and includes an AA and community map is provided in Appendix 5.

A complete Rapid FQA example that includes an AA and community map; as well as *wC* calculation and an AA assessment is provided in Appendix 6.

Conclusions

The Rapid FQA is presented as a valid and improved approach to wetland condition rapid assessment. Once trained, users should be able to complete a Rapid FQA within the half day in the field/half day in the office rapid assessment guideline (Fennessy et al. 2004). The sampling protocol has the flexibility to be used in AAs of different sizes and complexity, returning consistent and accurate results. Limiting the species that need to be observed to those that are more common and easier to identify simplifies sampling and reduces the level of botanical expertise required. Natural resource professionals with moderate wetland botanical expertise should be able to successfully use the Rapid FQA in the community types that they frequently work in. The assessment criteria are quantitative, data driven, and available for the majority of the wetland community types that occur in Minnesota (Table 1, Table 7). This is an improvement over other wetland vegetation assessment methods currently used in Minnesota such as the vegetation integrity component in MnRAM which relies on a much more limited set of vegetation observations and assessments based on best professional judgment (MN BWSR 2010) or the vegetation IBIs which have only been developed for depressional marshes with semi permanent-permanent open water and have more limited assessment criteria (Gernes and Helgen 2002, Genet and Bourdaghs 2006, Genet and Bourdaghs 2007). Depressional wetland IBI assessment criteria are based on regional reference conditions and are only able to differentiate two or three categories of condition; as opposed to the assessment criteria developed here, which can differentiate up to four categories of condition and are based on a more absolute scale of condition (the BCG; Table 5).

In addition to being applied as a stand-alone approach, the Rapid FQA has the potential to be integrated with common existing wetland sampling and assessment approaches. Vegetation data collected by other methods may be suitable for use in the Rapid FQA as long as a few general conditions are met. First, the data must be collected by community types that can be related to the Eggers and Reed (2011) community types (Table 1) and sampling should be of sufficient effort to be representative. Second, aerial cover must be estimated for each species by community type. This will be necessary to calculate *wC*. Third, the data should be limited to only those species that occur on the Rapid Species List

(Appendix 3). The Rapid FQA assessment criteria were developed using only the species on the Rapid Species List, so including additional or too few species may cause inaccurate results. An example sampling protocol that may be adapted to produce a Rapid FQA is the US Army Corps of Engineers vegetation sampling guidance for wetland determinations (US ACE 2010); where vegetation plots are established in representative areas by community type and aerial cover is estimated. As long as the species occurring in the plot(s) are identified to at least the level of the Rapid Species List, this sampling approach has the potential to return reasonable Rapid FQA results. The Rapid FQA also has the potential to be used as the vegetation component in more comprehensive types of assessment methods, where vegetation is one of multiple assessment components. For example, the Rapid FQA could be substituted as a quantitative vegetation component in the MnRAM, where the BCG Tier assessment categories are generally equivalent to the four MnRAM vegetation quality ratings (MN BWSR 2010).

A limitation of the Rapid FQA sampling protocol is the reliance on observer interpretations of wetland plant community types and the potential affect of interpretation inconsistencies on assessment outcomes. When wetland plant communities are in transition from one type to another or there are broad transition zones between types in the same wetland, consistently determining types and boundaries can become difficult for even experienced wetland professionals. A limited examination of method precision and repeatability was undertaken during the 2009-10 field trials where the same AA's were sampled using the Rapid FQA field protocol multiple times by multiple observers (Appendix 6). In most cases, the different observers had consistent community interpretations. In one AA, however, there were multiple community type interpretations that led to different assessments. Another level of complexity is added when trying to interpret types that have changed due to natural or anthropogenic disturbance. In general, community types should be assessed as they currently exist. Depending on the context, however, it may be appropriate to assess a community as a former type, as wholesale changes in type can result from severe anthropogenic impacts. This degree of impact is consistent with BCG Tier 4 (Table 5). Changes in community type also occur due to natural disturbance. In general, for an AA to be assessed as a former type, even though the AA would no longer meet the definition of that type, evidence of the former type and clear anthropogenic impacts should both be present. For example, if an AA is currently dominated by Shallow Marsh vegetation yet dead *Larix laricina* (Du Roi) K. Koch (tamarack) trees are present in great abundance and there is clear evidence of flooding of the site due to an anthropogenic impact, the AA could be assessed as a severely impacted Coniferous Swamp. If the field conditions were more or less the same (i.e., Shallow Marsh vegetation with dead trees) but the alteration was due to a beaver impoundment, the alteration of the AA would be due to a natural process and the AA would be more properly assessed as a Shallow Marsh. The reliance of the Rapid FQA on community type interpretation has the potential to be a large source of error and needs to be addressed more thoroughly in future Rapid FQA development efforts (Appendix 6). It should be noted that this is not an issue that is unique to the Rapid FQA. Other observer interpretation driven sampling approaches would likely have similar issues where differences in interpretation could lead to sampling error.

Finally, the Rapid FQA should have broad applicability to meet a variety of wetland monitoring and assessment needs. It can be used for wetland regulatory monitoring and assessment purposes. The U.S. Army Corps of Engineers St. Paul District has listed FQA as an appropriate assessment method to help determine compensatory mitigation requirements (US ACE 2009b). The Rapid FQA can also be used to identify high quality wetlands that may warrant increased protection. It also has potential to be used for wetland planning or ambient monitoring purposes. Beginning with a watershed based pilot project (Genet and Olsen 2008) and continuing as part of a Minnesota monitoring and assessment strategy (MPCA 2006), the MPCA has been conducting ambient monitoring to determine the status and trends of wetland quality in the state. A statewide probabilistic survey using macroinvertebrate and vegetation IBIs has been completed to establish baseline conditions for depressional marshes (MPCA 2007; 2012a). Currently, the MPCA is expanding ambient monitoring beyond depressional marshes to all community types by relying on elements from the Rapid FQA in a second statewide probabilistic wetland condition survey being done in conjunction with EPA's National Wetland Condition Assessment (EPA 2008) The FQA will be the primary assessment tool for the statewide survey, with community based meander sampling and results expressed as BCG tiers similar to those developed for the Rapid FQA. Applicability of the Rapid FQA will continue to be explored as training materials are developed and it begins to be used. Currently, a Rapid FQA manual is available that provides step by step instruction and includes practical guidance on how to use it in conjunction with other methods (MPCA 2012b).

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Appendix 1-Human Disturbance Assessment

Description

The Human Disturbance Assessment (HDA) was adapted from the MPCA Human Disturbance Score (HDS) used to develop depressional wetland Indices of Biological Integrity (Gernes and Helgen 2002) The HDA is generally the same in that key anthropogenic stressor/impact categories are assessed individually and assigned a qualitative/categorical rating. Several modifications, however, have been made. The purpose of the HDA is to assign a site to one of three general stressor/impact categories (minimally, moderately, or severely impacted) according to a consistent and repeatable process. Unlike the HDS, which assigns scores to qualitative ratings and sums over the categories, the output of the HDA is categorical. The stressor/impact categories are similar to HDS categories but have been modified in some cases to increase consistency. All rating narratives are expressed in terms of stressor/impact exposure.

Overall site ratings have also been refined in the HDA. Severe impacts to wetlands can occur either cumulatively or they can occur when a single type of stressor is extremely prevalent. The HDS expresses cumulative impacts in that it is a sum of all the factors but no single factor can trigger an overall severely impacted rating. In the HDA, "Severe" ratings in what are considered direct stressor/impact categories can trigger an overall "Severely Impacted" site rating. In this way the HDA can account for an actual severe impact caused by a single local factor which would otherwise not be accounted for in the HDS. The following factors are considered to be direct stressors/impacts: #3 Within Wetland Physical Alteration; #4 Hydrologic Alteration; #5 Chemical Pollution; #6 Invasive Species. Factors #1 Landscape Alteration and #2 Immediate Upland Alteration are surrogate measures of human stress and are factored into an overall HDA site rating when accounting for cumulative impacts.

General HDA Procedure

Rate each of the anthropogenic stressor/impact factor (Landscape Alteration, Immediate Upland Alteration, Within Wetland Physical Alteration, Hydrologic Alteration, Chemical Pollution, and Invasive Species) according to the narrative guidelines provided. Make the overall site HDA rating according to the following guidelines:

- *Minimally Impacted:* No more than four factors rated as ‘Low’ with no single factor rated greater than ‘Low’ and at least one of factors #3-#6 rated as ‘Minimal’
- *Moderately Impacted:* Any combination of factor ratings that indicate impacts between the ‘Minimally and ‘Severely Impacted’ criteria
- *Severely Impacted:* four or more factors rated greater than or equal to ‘Moderate’ or any of factors #3-#6 rated ‘Severe’

HDA Factors & Rating Guidance

1) Landscape Alteration (500m buffer)

   Human land use in surrounding uplands is a general indicator of exposure to anthropogenic stress, not a direct measure of stress. The purpose of the Landscape Alteration Factor is to capture potential stressors/impacts originating from the broader landscape that may not be accounted for in the other factors. Assess the human land use within a 500 m buffer of the site according to the narrative guidelines below taking into account both extent and intensity.

   - Minimal: No or minimal amount of human land-use
     - Examples: mature (> 20 year) forest/prairie; other wetlands; extent of human land-use < 20 percent
   - Low: Predominantly unaltered or recovered land with some human land-use
     - Examples: Old field; Conservation planting; restored prairie (< 10 year); young forest (< 20 year); extent of human land-use 20-50 percent

- Moderate: Extent of human land use within buffer significant, some of which is intensive
    - o Examples: Rural residential; pasture; hay/alfalfa; turf park; extent of human land-use 50-80 percent
- Severe: Human land use occupies all or nearly all of the buffer area, much of the land use is intensive
    - o Examples: Industrial/urban/dense residential development; intensive/row crop agriculture; feedlots; mining/gravel pits; extent of human land-use > 80 percent

2) Immediate Upland Alteration (50m buffer)

The Immediate Upland Alteration Factor captures potential stressors/impacts originating from human land use and alterations in the immediate upland area. Assess the human land use and physical alterations within a 50 m buffer of the site according to the narrative guidelines below taking into account both extent and intensity.

- Minimal: No or minimal amount of human land-use
    - o Examples: mature (> 20 year) forest/prairie; other wetlands; extent of human land-use < 20 percent
- Low: Predominantly unaltered or recovered land with some human land-use
    - o Examples: Old field; Conservation planting; restored prairie (< 10 year); young forest (< 20 year); extent of human land-use 20-50 percent
- Moderate: Extent of human land use within buffer significant, some of which is intensive
    - o Examples: Rural residential; pasture; hay/alfalfa; turf park; extent of human land-use 50-80 percent
- Severe: Human land-use occupies all or nearly all of the buffer area, much of the land use is intensive
    - o Examples: Industrial/urban/dense residential development; intensive/row crop agriculture; feedlots; mining/gravel pits; extent of human land-use > 80 percent

3) Within Wetland Physical Alteration

This factor is specifically focused on physical alterations of soil and vegetation within the wetland (or former wetland) boundary. Any subsequent hydrologic impact from a physical alteration is assessed separately in Factor #4 (Hydrologic Alterations). Rate the relative extent, severity, and frequency of physical alterations for a site according to the narrative guidelines below.

- Minimal: No human physical alteration within wetland
- Low: Small extent/historical/low intensity human physical alteration
- Moderate: Significant human physical alteration
- Severe: Extensive/high intensity/high frequency human physical alteration
    - o Examples: Grazing; hoof compaction; vegetation removal; grading; bulldozing; plowing; vehicle use; dredging; filling; sedimentation

4) Hydrologic Alteration

The Hydrologic Alteration factor deals specifically with the human alteration of a wetland's natural hydrologic regime. Hydrologic alterations are not uni-directional, meaning that depending on the wetland increasing or decreasing water volume/flow/intensity/frequency/duration/source may represent an alteration to the natural hydrologic regime. Rate the relative human hydrologic alterations below.

- Minimal: No evidence of human hydrologic alterations, natural hydrologic regime present

- Low: Low intensity alteration of the hydrologic regime or historical alteration that is not currently affecting the wetland
- Moderate: Significant and ongoing alteration of the hydrologic regime
- Severe: Severe alteration of hydrologic regime, may result in extensive plant community type changes
    - o Examples: Ditch/tile/stormwater input; point source; controlled/artificial outlet; within site ditching/dredging; road/railroad/berm constricting flow; unnatural connection to other waters; dewatering in or near wetland; source water changes; and drainage

5) Chemical Pollution

The intention of the Chemical Pollution Factor is to assess the broad spectrum of potential human sources of chemical pollution that could impact a wetland including: nutrients, salts, herbicides, etc. A key component for rating this factor is evidence that the chemical pollution is coming from a human source as opposed to concentrations naturally occurring within the expected natural range for the site type. Rate the Chemical Pollution according to the narrative guidelines below. In cases where chemical data is not available omit rating this factor and continue to rate site according to same guidelines.

- Minimal: Chemistry within natural range and no evidence of human sources
- Low: Some deviation of chemistry from natural range and some evidence of human sources
- Moderate: Significant and deviation of chemistry from natural range and clear evidence of human sources
- Severe: Severe chemical pollution from human sources with clear evidence of harm to the biota
    - o Examples: High chemical concentrations; point source present; high input potential; herbicide treated area

6) Invasive Species

In many cases the presence and/or increase of abundance of invasive species in a wetland is a response to human impacts. There are, however, cases where invasive species can become established and increase in abundance in the absence of any other human impacts. Thus, invasive species can be considered stressors as well as a response to stress. Rate the relative impact of invasive species according to the narrative guidelines below.

- Minimal: No invasive species present or non-native taxa occurring at a very low abundance (< one percent of aerial cover) and not causing displacement of the native community
- Low: Invasive species are established at a low abundance and expansion appears to be limited
- Moderate: Invasive species are established and expanding
- Severe: Invasive species are dominant and there is evidence of significant replacement of the native community
    - o Examples: Phalaris arundinacea (reed canary grass); Typha angustifolia and x glauca (invasive cattail); Lythrum salicaria (purple loosestrife); Frangula alnus (glossy buckthorn); Carp; fathead minnow.

Appendix 2-Plant Community Crosswalk

Eggers and Reed - MDNR Native Plant Community (NPC) crosswalk based on class definitions/descriptions. In cases where the there is not a clear one: one correspondence between the NPC and the Eggers and Reed class, an alternate Eggers and Reed class that the NPC may correspond to is provided.

Primary E&R Type	Alternate E&R Type	DNR NPC	NPC Name	Type Name
Alder Thicket		FPn73a	Northern Rich Alder Swamp	Alder-(Maple-Loosestrife) Swamp
Calcareous Fen		OPn93a	Northern Extremely Rich Fen	Spring Fen
Calcareous Fen		OPp93a	Prairie Extremely Rich Fen	Calcareous Fen (Northwestern)
Calcareous Fen		OPp93b	Prairie Extremely Rich Fen	Calcareous Fen (Southwestern)
Calcareous Fen		OPp93c	Prairie Extremely Rich Fen	Calcareous Fen (Southeastern)
Coniferous Bog		APn80a	Northern Spruce Bog	Black Spruce Bog
Coniferous Bog		APn81a	Northern Poor Conifer Swamp	Poor Black Spruce Swamp
Coniferous Bog		APn81b	Northern Poor Conifer Swamp	Poor Tamarack-Black Spruce Swamp
Coniferous Swamp		FPn62a	Northern Rich Spruce Swamp (Basin)	Rich Black Spruce Swamp (Basin)
Coniferous Swamp		FPn63a	Northern Cedar Swamp	White Cedar Swamp (Northeastern)
Coniferous Swamp		FPn63b	Northern Cedar Swamp	White Cedar Swamp (Northcentral)
Coniferous Swamp		FPn63c	Northern Cedar Swamp	White Cedar Swamp (Northwestern)
Coniferous Swamp		FPn71a	Northern Rich Spruce Swamp (Water Track)	Rich Black Spruce Swamp (Water Track)
Coniferous Swamp		FPn72a	Northern Rich Tamarack Swamp (Eastern Basin)	Rich Tamarack Swamp (Eastcentral)
Coniferous Swamp		FPn81a	Northern Rich Tamarack Swamp (Water Track)	
Coniferous Swamp		FPn82a	Northern Rich Tamarack Swamp (Western Basin)	Rich Tamarack-(Alder) Swamp
Coniferous Swamp		FPn82b	Northern Rich Tamarack Swamp (Western Basin)	Extremely Rich Tamarack Swamp
Coniferous Swamp		FPs63a	Southern Rich Conifer Swamp	Tamarack Swamp (Southern)
Coniferous Swamp		FPw63a	Northwestern Rich Conifer Swamp	Tamarack-Black Spruce Swamp (Aspen Parkland)
Coniferous Swamp		FPw63b	Northwestern Rich Conifer Swamp	Tamarack Seepage Swamp (Aspen Parkland)
Coniferous Swamp		WFn53a	Northern Wet Cedar Forest	Lowland White Cedar Forest (North Shore)
Coniferous Swamp		WFn53b	Northern Wet Cedar Forest	Lowland White Cedar Forest (Northern)
Deep Marsh	Shallow Marsh	MRn93a	Northern Bulrush-Spikerush Marsh	Bulrush Marsh (Northern)

Deep Marsh	Shallow Marsh	MRn93b	Northern Bulrush-Spikerush Marsh	Spikerush-Bur Reed Marsh (Northern)
Deep Marsh	Shallow Marsh	MRp93a	Prairie Bulrush-Arrowhead Marsh	Bulrush Marsh (Prairie)
Deep Marsh	Shallow Marsh	MRp93b	Prairie Bulrush-Arrowhead Marsh	Spikerush-Bur Reed Marsh (Prairie)
Deep Marsh	Shallow Marsh	MRp93c	Prairie Bulrush-Arrowhead Marsh	Arrowhead Marsh (Prairie)
Deep Marsh		MRu94a	Lake Superior Coastal Marsh	Estuary Marsh (Lake Superior)
Floodplain Forest		FFn57a	Northern Terrace Forest	Black Ash-Silver Maple Terrace Forest
Floodplain Forest		FFn67a	Northern Floodplain Forest	Silver Maple-(Sensitive Fern) Floodplain Forest
Floodplain Forest		FFs59a	Southern Terrace Forest	Silver Maple-Green Ash-Cottonwood Terrace Forest
Floodplain Forest		FFs59b	Southern Terrace Forest	Swamp White Oak Terrace Forest
Floodplain Forest		FFs59c	Southern Terrace Forest	Elm-Ash-Basswood Terrace Forest
Floodplain Forest		FFs68a	Southern Floodplain Forest	Silver Maple-(Virginia Creeper) Floodplain Forest
Fresh Meadow	Shallow Marsh	WMn82b	Northern Wet Meadow/Carr	Sedge Meadow
Fresh Meadow		WMp73a	Prairie Wet Meadow/Carr	Prairie Meadow/Carr
Fresh Meadow		WMs83a	Southern Seepage Meadow/Carr	Seepage Meadow/Carr
Fresh Meadow		WMs92a	Southern Basin Wet Meadow/Carr	Basin Meadow/Carr
Hardwood Swamp		WFn55a	Northern Wet Ash Swamp	Black Ash-Aspen-Balsam Poplar Swamp (Northeastern)
Hardwood Swamp		WFn55b	Northern Wet Ash Swamp	Black Ash-Yellow Birch-Red Maple-Basswood Swamp (East-Central)
Hardwood Swamp		WFn55c	Northern Wet Ash Swamp	Black Ash-Mountain Maple Swamp (Northern)
Hardwood Swamp		WFn64a	Northern Very Wet Ash Swamp	Black Ash-Conifer Swamp (Northeastern)
Hardwood Swamp		WFn64b	Northern Very Wet Ash Swamp	Black Ash-Yellow Birch-Red Maple-Alder Swamp (Eastcentral)
Hardwood Swamp		WFn64c	Northern Very Wet Ash Swamp	Black Ash-Alder Swamp (Northern)
Hardwood Swamp		WFs55a	Southern Wet Aspen Forest	Lowland Aspen Forest
Hardwood Swamp		WFs57a	Southern Wet Ash Swamp	Black Ash-(Red Maple) Seepage Swamp
Hardwood Swamp		WFs57b	Southern Wet Ash Swamp	Black Ash-Sugar Maple-Basswood-(Blue Beech) Seepage Swamp
Hardwood Swamp		WFw54a	Northwestern Wet Aspen Forest	Lowland Black Ash-Aspen-Balsam Poplar Forest
Open Bog		APn90a	Northern Open Bog	Low Shrub Bog
Open Bog		APn90b	Northern Open Bog	Graminoid Bog
Open Bog		APn91a	Northern Poor Fen	Low Shrub Poor Fen
Open Bog		APn91b	Northern Poor Fen	Graminoid Poor Fen (Basin)
Open Bog		APn91c	Northern Poor Fen	Graminoid Poor Fen (Water Track)
Sedge Mat	Alder Thicket	OPn81a	Northern Shrub Shore Fen	Bog Birch-Alder Shore Fen
Sedge Mat	Open Bog	OPn81b	Northern Shrub Shore Fen	Leatherleaf-Sweet Gale Shore Fen
Sedge Mat		OPn91a	Northern Rich Fen (Water Track)	Shrub Rich Fen (Water Track)
Sedge Mat	Open Bog	OPn91b	Northern Rich Fen (Water Track)	Graminoid Rich Fen (Water Track)
Sedge Mat		OPn92a	Northern Rich Fen (Basin)	Graminoid Rich Fen (Basin)

Sedge Mat	Open Bog	OPn92b	Northern Rich Fen (Basin)	Graminoid-Sphagnum Rich Fen (Basin)
Sedge Mat	Fresh Meadow	OPp91a	Prairie Rich Fen	Rich Fen (Mineral Soil)
Sedge Mat	Fresh Meadow	OPp91b	Prairie Rich Fen	Rich Fen (Peatland)
Sedge Mat	Fresh Meadow	OPp91c	Prairie Rich Fen	Rich Fen (Prairie Seepage)
Shallow Marsh		MRn83a	Northern Mixed Cattail Marsh	Cattail-Sedge Marsh (Northern)
Shallow Marsh		MRn83b	Northern Mixed Cattail Marsh	Cattail Marsh
Shallow Marsh		MRp83a	Prairie Mixed Cattail Marsh	Cattail-Sedge Marsh (Prairie)
Shallow Marsh		MRp83b	Prairie Mixed Cattail Marsh	Cattail Marsh (Prairie)
Shrub-Carr	Fresh Meadow	WMn82a	Northern Wet Meadow/Carr	Willow-Dogwood Shrub Swamp
Wet Prairie		WPn53a	Northern Wet Prairie	Wet Seepage Prairie (Northern)
Wet Prairie		WPn53b	Northern Wet Prairie	Wet Brush-Prairie (Northern)
Wet Prairie		WPn53c	Northern Wet Prairie	Wet Prairie (Northern)
Wet Prairie		WPn53d	Northern Wet Prairie	Wet Saline Prairie (Northern)
Wet Prairie		WPs54a	Southern Wet Prairie	Wet Seepage Prairie (Southern)
Wet Prairie		WPs54b	Southern Wet Prairie	Wet Prairie (Southern)
Wet Prairie		WPs54c	Southern Wet Prairie	Wet Saline Prairie (Southern)

Appendix 3-Rapid Species List

The rapid species list with select attributes from Wetlist 1.4 (Milburn et al. 2007) included.

Scientific Name	Common Name	MN Native Status	*C*	MNWI	Growth Habit	tsn
Abies balsamea	balsam fir	Native	4	FACW	Tree	18032
Acer negundo	boxelder	Native	1	FACW-	Tree	28749
Acer rubrum var. *rubrum*	red maple	Native	3	[FAC]	Tree	28729
Acer saccharinum	silver maple	Native	3	FACW	Tree	28757
Acer spicatum	mountain maple	Native	5	FACU	Tree, Shrub	28758
Achillea millefolium	common yarrow	Native	1	FACU	Forb/herb	35423
Acorus americanus	sweetflag	Native	7	[OBL]	Forb/herb	182561
Adiantum pedatum	northern maidenhair	Native	7	FAC-	Forb/herb	17311
Agrostis gigantea	redtop	Introduced	0	[FACW]	Graminoid	40414
Alisma subcordatum	American water plantain	Native	4	OBL	Forb/herb	38895
Alisma triviale	northern water plantain	Native	4	[OBL]	Forb/herb	182441
Alliaria petiolata	garlic mustard	Introduced	0	FAC	Forb/herb	184481
Alnus incana ssp. *rugosa*	speckled alder	Native	3	[OBL]	Tree, Shrub	181888
Ambrosia artemisiifolia	annual ragweed	Native	0	FACU	Forb/herb	36496
Ambrosia trifida var. *trifida*	great ragweed	Native	0	[FAC+]	Forb/herb	182422
Amorpha fruticosa	desert false indigo	Native	4	FACW+	Shrub	25368
Amphicarpaea bracteata	American hogpeanut	Native	2	FAC	Forb/herb	182067
Andromeda polifolia var. *glaucophylla*	bog rosemary	Native	9	[OBL]	Shrub	526876
Andropogon gerardii	big bluestem	Native	4	FAC-	Graminoid	40462
Anemone canadensis	Canadian anemone	Native	3	FACW	Forb/herb	18436
Anemone quinquefolia var. *bifolia*	twoleaf anemone	Native	5	[FAC]	Forb/herb	531161
Angelica atropurpurea	purplestem angelica	Native	6	OBL	Forb/herb	29436
Apocynum cannabinum	Indianhemp	Native	3	FAC	Forb/herb	30157
Aralia nudicaulis	wild sarsaparilla	Native	4	FACU	Forb/herb	29376
Argentina anserina	silverweed cinquefoil	Native	4	[FACW+]	Forb/herb	184598
Arisaema triphyllum	Jack in the pulpit	Native	4	FACW-	Forb/herb	42525
Asclepias incarnata ssp. *incarnata*	swamp milkweed	Native	4	[OBL]	Forb/herb	184805
Athyrium filix-femina ssp. *angustum*	subarctic ladyfern	Native	4	[FAC]	Forb/herb	17414
Beckmannia syzigachne	American sloughgrass	Native	4	OBL	Graminoid	41325

Betula alleghaniensis var. *alleghaniensis*	yellow birch	Native	7	[FAC]	Tree	183520
Betula papyrifera var. *papyrifera*	paper birch	Native	3	[FACU+]	Tree	19490
Betula pumila var. *glandulifera*	bog birch	Native	7	[OBL]	Shrub	183527
Bidens cernua	nodding beggartick	Native	3	OBL	Forb/herb	35710
Boehmeria cylindrica	smallspike false nettle	Native	5	OBL	Forb/herb	19121
Botrychium virginianum	rattlesnake fern	Native	6	FACU	Forb/herb	17173
Brasenia schreberi	watershield	Native	7	OBL	Forb/herb	18370
Bromus ciliatus var. *ciliatus*	fringed brome	Native	6	[FACW]	Graminoid	566208
Bromus inermis	smooth brome	Introduced	0	[FACU]	Graminoid	40502
Calamagrostis canadensis	bluejoint	Native	4	OBL	Graminoid	40544
Calamagrostis stricta ssp. *stricta*	slimstem reedgrass	Native	7	[FACW+]	Graminoid	523718
Calla palustris	water arum	Native	8	OBL	Forb/herb	42546
Caltha palustris var. *palustris*	yellow marsh marigold	Native	6	[OBL]	Forb/herb	527037
Calystegia sepium	hedge false bindweed	Native	1	FAC	Vine	30650
Campanula aparinoides	marsh bellflower	Native	5	OBL	Forb/herb	34476
Carex aquatilis var. *aquatilis*	water sedge	Native	7	[OBL]	Graminoid	527072
Carex atherodes	wheat sedge	Native	5	OBL	Graminoid	39449
Carex comosa	longhair sedge	Native	4	OBL	Graminoid	39384
Carex interior	inland sedge	Native	7	OBL	Graminoid	39652
Carex intumescens	greater bladder sedge	Native	5	FACW+	Graminoid	39403
Carex lacustris	hairy sedge	Native	5	OBL	Graminoid	39409
Carex lasiocarpa var. *americana*	American woollyfruit sedge	Native	7	[OBL]	Graminoid	527107
Carex oligosperma	fewseed sedge	Native	8	OBL	Graminoid	39729
Carex pellita	woolly sedge	Native	4	[OBL]	Graminoid	507767
Carex stipata var. *stipata*	owlfruit sedge	Native	3	[OBL]	Graminoid	527159
Carex stricta	upright sedge	Native	5	OBL	Graminoid	39435
Carex utriculata	Northwest Territory sedge	Native	7	[OBL]	Graminoid	501288
Carex vulpinoidea	fox sedge	Native	3	OBL	Graminoid	39442
Celtis occidentalis var. *occidentalis*	common hackberry	Native	3	[FAC-]	Tree, Shrub	527229
Ceratophyllum demersum	coon's tail	Native	2	OBL	Forb/herb	18403
Chamaedaphne calyculata var. *angustifolia*	leatherleaf	Native	8	[OBL]	Shrub	527274
Chamerion angustifolium ssp. *circumvagum*	fireweed	Native	3	[FAC]	Forb/herb	566020
Chelone glabra	white turtlehead	Native	7	OBL	Forb/herb	33182
Cicuta bulbifera	bulblet-bearing water hemlock	Native	7	OBL	Forb/herb	29459
Cicuta maculata	spotted water hemlock	Native	5	OBL	Forb/herb	29456

Circaea alpina ssp. *alpina*	small enchanter's nightshade	Native	6	[FACW]	Forb/herb	27564
Circaea lutetiana ssp. *canadensis*	broadleaf enchanter's nightshade	Native	2	[FACU]	Forb/herb	27569
Cirsium arvense	Canada thistle	Introduced	0	FACU	Forb/herb	36335
Cirsium muticum	swamp thistle	Native	6	OBL	Forb/herb	36387
Clematis virginiana	devil's darning needles	Native	4	FAC	Vine	18716
Clintonia borealis	bluebead	Native	7	FAC+	Forb/herb	42903
Comarum palustre	purple marshlocks	Native	7	[OBL]	Forb/herb	501615
Conyza canadensis var. *canadensis*	Canadian horseweed	Native	0	[FAC-]	Forb/herb	527476
Coptis trifolia	threeleaf goldthread	Native	7	FACW	Forb/herb	18767
Cornus canadensis	bunchberry dogwood	Native	6	FAC	Forb/herb	27816
Cornus racemosa	gray dogwood	Native	2	[FACW-]	Shrub	501635
Cornus sericea ssp. *sericea*	redosier dogwood	Native	3	[FACW]	Tree, Shrub	523904
Cryptotaenia canadensis	Canadian honewort	Native	3	FAC	Forb/herb	29475
Cyperus esculentus var. *leptostachyus*	chufa flatsedge	Introduced	0	[FACW]	Graminoid	534184
Cypripedium reginae	showy lady's slipper	Native	8	FACW+	Forb/herb	43538
Dasiphora floribunda	shrubby cinquefoil	Native	7	[FACW]	Shrub	565123
Dioscorea villosa	wild yam	Native	4	FAC-	Forb/herb	43367
Doellingeria umbellata	parasol whitetop	Native	5	[FACW]	Forb/herb	508093
Drosera rotundifolia var. *rotundifolia*	roundleaf sundew	Native	8	[OBL]	Forb/herb	527791
Dryopteris carthusiana	spinulose woodfern	Native	6	[FACW-]	Forb/herb	502157
Dryopteris cristata	crested woodfern	Native	7	OBL	Forb/herb	17531
Dulichium arundinaceum	threeway sedge	Native	8	OBL	Graminoid	40009
Echinochloa crus-galli	barnyardgrass	Introduced	0	FACW	Graminoid	502210
Echinocystis lobata	wild cucumber	Native	2	FACW-	Vine	22378
Eleocharis obtusa	blunt spikerush	Native	3	OBL	Graminoid	40017
Eleocharis palustris	common spikerush	Native	5	OBL	Graminoid	40019
Elodea canadensis	Canadian waterweed	Native	4	OBL	Forb/herb	38937
Elymus virginicus	Virginia wildrye	Native	4	FACW-	Graminoid	40681
Epilobium leptophyllum	bog willowherb	Native	7	OBL	Forb/herb	27311
Equisetum arvense	field horsetail	Native	1	FAC	Forb/herb	17152
Equisetum fluviatile	water horsetail	Native	7	OBL	Forb/herb	17150
Eupatorium maculatum	spotted joepyeweed	Native	4	[OBL]	Forb/herb	502517
Eupatorium perfoliatum var. *perfoliatum*	common boneset	Native	4	[FACW+]	Forb/herb	528117
Euthamia graminifolia	flat-top goldentop	Native	4	FACW-	Forb/herb	37352
Fragaria virginiana	Virginia strawberry	Native	2	FAC-	Forb/herb	24639

Frangula alnus	glossy buckthorn	Introduced	0	[FAC+]	Tree, Shrub	504744
Fraxinus nigra	black ash	Native	6	FACW+	Tree	32945
Fraxinus pennsylvanica	green ash	Native	2	FACW	Tree	32929
Galium aparine	stickywilly	Native	1	FACU	Forb/herb	34797
Gaultheria hispidula	creeping snowberry	Native	8	FACW	Subshrub	23653
Gentiana andrewsii	closed bottle gentian	Native	6	FACW	Forb/herb	29967
Geranium maculatum	spotted geranium	Native	4	FACU	Forb/herb	29107
Glyceria borealis	small floating mannagrass	Native	8	OBL	Graminoid	40841
Glyceria canadensis	rattlesnake mannagrass	Native	7	OBL	Graminoid	40842
Glyceria grandis var. *grandis*	American mannagrass	Native	6	[OBL]	Graminoid	528256
Glyceria striata	fowl mannagrass	Native	4	OBL	Graminoid	40833
Gymnocarpium dryopteris	western oakfern	Native	6	FAC	Forb/herb	17579
Hackelia virginiana	beggarslice	Native	1	FAC-	Forb/herb	31921
Helenium autumnale var. *autumnale*	common sneezeweed	Native	4	[FACW+]	Forb/herb	528347
Helianthus giganteus	giant sunflower	Native	4	FACW	Forb/herb	36612
Helianthus grosseserratus	sawtooth sunflower	Native	3	FACW-	Forb/herb	36644
Heracleum maximum	common cowparsnip	Native	4	[FACW]	Forb/herb	502953
Heuchera richardsonii	Richardson's alumroot	Native	7	FAC-	Forb/herb	24372
Hordeum jubatum ssp. *jubatum*	foxtail barley	Native	0	[FAC+]	Graminoid	524156
Hydrophyllum virginianum	Shawnee salad	Native	3	FACW-	Forb/herb	31396
Hypoxis hirsuta	common goldstar	Native	8	FAC	Forb/herb	503146
Ilex verticillata	common winterberry	Native	6	FACW+	Tree, Shrub	27985
Impatiens capensis	jewelweed	Native	2	FACW	Forb/herb	29182
Iris versicolor	harlequin blueflag	Native	4	OBL	Forb/herb	43196
Kalmia polifolia	bog laurel	Native	9	OBL	Shrub	23679
Lactuca serriola	prickly lettuce	Introduced	0	FAC	Forb/herb	36608
Laportea canadensis	Canadian woodnettle	Native	3	FACW	Forb/herb	19127
Larix laricina	tamarack	Native	7	FACW	Tree	183412
Lathyrus palustris	marsh pea	Native	6	FACW	Forb/herb	25866
Lathyrus venosus	veiny pea	Native	6	FAC	Forb/herb	25886
Ledum groenlandicum	bog Labrador tea	Native	8	OBL	Shrub	23546
Leersia oryzoides	rice cutgrass	Native	3	OBL	Graminoid	40886
Lemna minor	common duckweed	Native	5	OBL	Forb/herb	42590
Lemna trisulca	star duckweed	Native	5	OBL	Forb/herb	42595
Liatris pycnostachya var. *pycnostachya*	prairie blazing star	Native	7	[FAC-]	Forb/herb	528786

Linnaea borealis ssp. *americana*	twinflower	Native	7	[FAC]	Forb/herb	525179
Lobelia kalmii	Ontario lobelia	Native	9	OBL	Forb/herb	34525
Lobelia siphilitica var. *ludoviciana*	great blue lobelia	Native	5	[FACW+]	Forb/herb	528853
Lobelia spicata	palespike lobelia	Native	7	FAC	Forb/herb	34532
Lycopus americanus	American water horehound	Native	4	OBL	Forb/herb	32254
Lycopus uniflorus	northern bugleweed	Native	5	OBL	Forb/herb	32257
Lysimachia ciliata	fringed loosestrife	Native	5	FACW	Forb/herb	23984
Lysimachia thyrsiflora	tufted loosestrife	Native	6	OBL	Forb/herb	24000
Lythrum salicaria	purple loosestrife	Introduced	0	OBL	Forb/herb	27079
Maianthemum canadense	Canada mayflower	Native	5	FAC	Forb/herb	503653
Maianthemum stellatum	starry false lily of the vally	Native	5	[FAC-]	Forb/herb	503656
Maianthemum trifolium	threeleaf false lily of the vally	Native	9	[OBL]	Forb/herb	503657
Matteuccia struthiopteris	ostrich fern	Native	5	FACW	Forb/herb	17596
Menispermum canadense	common moonseed	Native	4	FAC	Vine	18871
Mentha arvensis	wild mint	Native	3	FACW	Forb/herb	565302
Menyanthes trifoliata	buckbean	Native	9	OBL	Forb/herb	30102
Mertensia virginica	Virginia bluebells	Native	6	FACW	Forb/herb	31673
Mimulus ringens var. *ringens*	Allegheny monkeyflower	Native	5	[OBL]	Forb/herb	529204
Mitella nuda	naked miterwort	Native	7	FACW	Forb/herb	24410
Monotropa uniflora	Indianpipe	Native	6	FACU	Forb/herb	23778
Muhlenbergia richardsonis	mat muhly	Native	8	FAC+	Graminoid	41938
Myrica gale	sweetgale	Native	8	OBL	Shrub	19265
Najas flexilis	nodding waternymph	Native	5	OBL	Forb/herb	38996
Nelumbo lutea	American lotus	Native	8	OBL	Forb/herb	18398
Nuphar lutea ssp. *variegata*	varigated yellow pond-lily	Native	6	[OBL]	Forb/herb	524345
Nymphaea odorata	American white waterlily	Native	6	OBL	Forb/herb	18384
Oligoneuron riddellii	Riddell's goldenrod	Native	8	[OBL]	Forb/herb	507638
Onoclea sensibilis	sensitive fern	Native	4	FACW	Forb/herb	17637
Orthilia secunda	sidebells wintergreen	Native	7	[FAC+]	Shrub	504066
Osmorhiza claytonii	Clayton's sweetroot	Native	3	FACU-	Forb/herb	29789
Osmunda cinnamomea var. *cinnamomea*	cinnamon fern	Native	7	[FACW]	Forb/herb	529311
Osmunda regalis var. *spectabilis*	royal fern	Native	7	[OBL]	Forb/herb	529314
Ostrya virginiana var. *virginiana*	hophornbeam	Native	4	[FACU-]	Tree, Shrub	195247
Panicum virgatum var. *virgatum*	switchgrass	Native	2	[FAC+]	Graminoid	529371
Parnassia glauca	fen grass of Parnassus	Native	9	OBL	Forb/herb	24210

Parnassia palustris	marsh grass of Parnassus	Native	8	OBL	Forb/herb	24206
Parthenocissus vitacea	woodbine	Native	2	FACU	Vine	28605
Pedicularis lanceolata	swamp lousewort	Native	8	FACW+	Forb/herb	33365
Penthorum sedoides	ditch stonecrop	Native	3	OBL	Forb/herb	504241
Petasites frigidus var. *palmatus*	arctic sweet coltsfoot	Native	6	[FACW]	Forb/herb	529540
Phalaris arundinacea	reed canarygrass	Introduced	0	FACW+	Graminoid	41335
Phragmites australis	common reed	Native	1	FACW+	Graminoid	41072
Physocarpus opulifolius	common ninebark	Native	5	FACW-	Shrub	25282
Physostegia virginiana ssp. *virginiana*	obedient plant	Native	6	[FACW]	Forb/herb	196102
Picea glauca	white spruce	Native	5	FACU	Tree	183295
Picea mariana	black spruce	Native	7	FACW	Tree	183302
Pilea pumila var. *pumila*	Canadian clearweed	Native	3	[FACW]	Forb/herb	529663
Pinus strobus	eastern white pine	Native	5	FACU	Tree	183385
Poa palustris	fowl bluegrass	Native	5	FACW+	Graminoid	41151
Poa pratensis ssp. *pratensis*	Kentucky bluegrass	Introduced	0	[FAC-]	Graminoid	566071
Polygonum amphibium	water knotweed	Native	4	OBL	Forb/herb	20865
Polygonum lapathifolium	curlytop knotweed	Native	2	FACW+	Forb/herb	20860
Polygonum pensylvanicum	Pennsylvania smartweed	Native	1	FACW+	Forb/herb	20861
Polygonum sagittatum	arrowleaf tearthumb	Native	4	OBL	Forb/herb	20863
Pontederia cordata	pickerelweed	Native	8	OBL	Forb/herb	42620
Populus balsamifera ssp. *balsamifera*	balsam poplar	Native	4	[FACW]	Tree	22454
Populus deltoides ssp. *monilifera*	plains cottonwood	Native	1	[FAC+]	Tree	22447
Populus tremuloides	quaking aspen	Native	2	[FAC]	Tree	195773
Potamogeton amplifolius	largeleaf pondweed	Native	7	OBL	Forb/herb	39021
Potamogeton crispus	curly pondweed	Introduced	0	OBL	Forb/herb	39007
Potamogeton natans	floating pondweed	Native	5	OBL	Forb/herb	39008
Potamogeton zosteriformis	flatstem pondweed	Native	6	OBL	Forb/herb	39055
Potentilla norvegica ssp. *monspeliensis*	Norwegian cinquefoil	Native	1	[FAC]	Forb/herb	524586
Prenanthes racemosa	purple rattlesnakeroot	Native	9	FACW	Forb/herb	38281
Pycnanthemum virginianum	Virginia mountainmint	Native	6	FACW+	Forb/herb	32670
Quercus macrocarpa var. *macrocarpa*	bur oak	Native	5	[FAC-]	Tree, Shrub	531113
Quercus rubra	northern red oak	Native	5	FACU	Tree	19408
Ranunculus flabellaris	yellow water buttercup	Native	6	OBL	Forb/herb	18563
Ranunculus longirostris	longbeak buttercup	Native	7	OBL	Forb/herb	18623
Ranunculus trichophyllus var. *trichophyllus*	threadleaf crowfoot	Native	7	[OBL]	Forb/herb	529983

Rhamnus alnifolia	alderleaf buckthorn	Native	7	OBL	Shrub	28562
Rhamnus cathartica	common buckthorn	Introduced	0	FACU	Tree, Shrub	28573
Ribes americanum	American black currant	Native	4	FACW	Shrub	24451
Rubus idaeus ssp. strigosus	grayleaf red raspberry	Native	3	[FACU+]	Shrub	524636
Rubus pubescens var. *pubescens*	dwarf red blackberry	Native	6	[FACW+]	Forb/herb	530148
Rudbeckia hirta var. *pulcherrima*	blackeyed Susan	Native	3	[FACU]	Forb/herb	530172
Rudbeckia laciniata var. *laciniata*	cutleaf coneflower	Native	4	[FACW+]	Forb/herb	530178
Rumex crispus ssp. *crispus*	curly dock	Introduced	0	[FAC+]	Forb/herb	566082
Rumex orbiculatus	greater water dock	Native	6	OBL	Forb/herb	20967
Sagittaria latifolia	broadleaf arrowhead	Native	3	OBL	Forb/herb	38908
Sagittaria rigida	sessilefruit arrowhead	Native	7	OBL	Forb/herb	38928
Salix amygdaloides	peachleaf willow	Native	5	FACW	Tree, Shrub	22499
Salix bebbiana	Bebb willow	Native	6	FACW+	Tree, Shrub	22507
Salix candida	sageleaf willow	Native	9	OBL	Shrub	22514
Salix discolor	pussy willow	Native	3	FACW	Tree, Shrub	22524
Salix interior	sandbar willow	Native	2	[OBL]	Shrub, Tree	520829
Salix nigra	black willow	Native	4	OBL	Tree	22484
Salix petiolaris	meadow willow	Native	5	FACW+	Tree, Shrub	22567
Salix X rubens	hybrid crack willow	Introduced	0		Tree	22579
Sambucus nigra ssp. *canadensis*	common elderberry	Native	3	[FACW-]	Tree, Shrub	525079
Sanguinaria canadensis	bloodroot	Native	6	FACU-	Forb/herb	18990
Sarracenia purpurea ssp. *purpurea*	purple pitcherplant	Native	9	[OBL]	Forb/herb	195652
Saxifraga pensylvanica	eastern swamp saxifrage	Native	7	OBL	Forb/herb	24234
Scheuchzeria palustris ssp. *americana*	rannoch-rush	Native	9	[OBL]	Forb/herb	38985
Schoenoplectus acutus var. *acutus*	hardstem bulrush	Native	6	[OBL]	Graminoid	531332
Schoenoplectus fluviatilis	river bulrush	Native	4	[OBL]	Graminoid	521092
Schoenoplectus pungens	common threesquare	Native	6	[OBL]	Graminoid	508146
Schoenoplectus tabernaemontani	softstem bulrush	Native	4	[OBL]	Graminoid	507797
Scirpus cyperinus	woolgrass	Native	3	OBL	Graminoid	40228
Scolochloa festucacea	common rivergrass	Native	7	OBL	Graminoid	41349
Scutellaria galericulata	marsh skullcap	Native	5	OBL	Forb/herb	32798
Scutellaria lateriflora	blue skullcap	Native	5	OBL	Forb/herb	32765
Sicyos angulatus	oneseed burr cucumber	Native	2	FACW-	Vine	22402
Sium suave	hemlock waterparsnip	Native	5	OBL	Forb/herb	29558
Solanum dulcamara var. *dulcamara*	climbing nightshade	Introduced	0	[FAC]	Vine	530416

Solidago canadensis	Canada goldenrod	Native	1	FACU	Forb/herb	36224
Solidago gigantea	giant goldenrod	Native	3	FACW	Forb/herb	36259
Solidago uliginosa var. *uliginosa*	bog goldenrod	Native	9	[OBL]	Forb/herb	530486
Sonchus arvensis	field sowthistle	Introduced	0	FAC-	Forb/herb	38421
Sorbus americana	American mountain ash	Native	5	FAC+	Tree, Shrub	25319
Sorghastrum nutans	Indiangrass	Native	5	FACU+	Graminoid	42102
Sparganium eurycarpum	broadfruit bur-reed	Native	5	OBL	Forb/herb	42316
Spartina pectinata	prairie cordgrass	Native	5	FACW+	Graminoid	41272
Spiraea alba	white meadowsweet	Native	5	FACW+	Shrub	25329
Spiraea tomentosa var. *rosea*	steeplebush	Native	7	[FACW]	Shrub	530522
Spirodela polyrrhiza	common duckmeat	Native	5	[OBL]	Forb/herb	505347
Stachys palustris	marsh hedgenettle	Native	4	OBL	Forb/herb	32344
Staphylea trifolia	American bladdernut	Native	6	FAC	Tree, Shrub	28646
Stellaria longifolia	longleaf starwort	Native	6	FACW+	Forb/herb	20185
Streptopus lanceolatus var. *longipes*	twistedstalk	Native	7	[FAC]	Forb/herb	531400
Stuckenia pectinatus	sago pondweed	Native	3	[OBL]	Forb/herb	565547
Symphyotrichum lanceolatum	white panicle aster	Native	5	[FACW]	Forb/herb	522219
Symphyotrichum lateriflorum	calico aster	Native	4	[FACW-]	Forb/herb	522220
Symphyotrichum novae-angliae	New England aster	Native	3	[FACW]	Forb/herb	522226
Symphyotrichum puniceum	purplestem aster	Native	6	[OBL]	Forb/herb	522241
Symplocarpus foetidus	skunk cabbage	Native	8	OBL	Forb/herb	42538
Taraxacum officinale	common dandelion	Introduced	0	FACU	Forb/herb	36213
Thalictrum dasycarpum	purple meadow-rue	Native	4	FACW-	Forb/herb	18667
Thelypteris palustris var. *pubescens*	eastern marsh fern	Native	7	[FACW+]	Forb/herb	530656
Thuja occidentalis	arborvitae	Native	7	FACW	Tree	505490
Tilia americana var. *americana*	American basswood	Native	5	[FACU]	Tree	530690
Toxicodendron rydbergii	western poison ivy	Native	1	FAC	Shrub	28822
Toxicodendron vernix	poison sumac	Native	7	OBL	Tree, Shrub	28823
Triadenum fraseri	Fraser's marsh St. Johnswort	Native	6	OBL	Forb/herb	21473
Trientalis borealis ssp. *borealis*	starflower	Native	6	[FAC+]	Forb/herb	524769
Trillium cernuum	whip-poor-will flower	Native	7	FAC	Forb/herb	43065
Typha angustifolia	narrowleaf cattail	Introduced	0	OBL	Forb/herb	42325
Typha latifolia	broadleaf cattail	Native	2	OBL	Forb/herb	42326
Typha X glauca	hybrid cattail	Introduced	0	OBL	Forb/herb	42328
Ulmus americana	American elm	Native	3	FACW-	Tree	19049

Urtica dioica ssp. *gracilis*	California nettle	Native	1	[FAC+]	Forb/herb	19154
Utricularia macrorhiza	common bladderwort	Native	5	OBL	Forb/herb	34456
Vaccinium angustifolium	lowbush blueberry	Native	5	FACU	Shrub	23579
Vaccinium macrocarpon	cranberry	Native	9	OBL	Shrub	23599
Vaccinium oxycoccos	small cranberry	Native	8	OBL	Shrub	505635
Vallisneria americana	American eelgrass	Native	6	OBL	Forb/herb	38951
Verbena hastata	swamp verbena	Native	6	FACW+	Forb/herb	32071
Vernonia fasciculata	prairie ironweed	Native	5	FACW	Forb/herb	38629
Veronicastrum virginicum	Culver's root	Native	6	FAC	Forb/herb	34073
Viburnum lentago	nannyberry	Native	4	FAC+	Tree, Shrub	35266
Viburnum opulus var. *americanum*	American cranberrybush	Native	5	[FACW]	Tree, Shrub	530811
Vitis riparia	riverbank grape	Native	2	FACW-	Vine	28624
Wolffia columbiana	Columbian watermeal	Native	5	OBL	Forb/herb	42602
Xanthium strumarium	rough cockleburr	Native	0	FAC	Forb/herb	38692
Zizania palustris	northern wildrice	Native	8	[OBL]	Graminoid	505807
Zizia aurea	golden zizia	Native	6	FAC+	Forb/herb	29906

Appendix 4-Rapid FQA Data Form

Continued on next page.

RAPID FQA DATA FORM

Version 0.5 11/2010

General Information

Site/AA Name:	Date:	Surveyors Name:

Remarks:

Community Information

Eggers & Reed Plant Community Type — **% of AA**

#1) ______________________ ______

#2) ______________________ ______

#3) ______________________ ______

Start Time	End Time	Total Time

Species Tally (# of spp. observed during final 10 min)

Base	Add 1	Add 2	Add 3

Cover Classes

7	>95 - 100%
6	>75 - 95%
5	>50 - 75%
4	>25 - 50%
3	>5 - 25%
2	>1 - 5%
1	>0 - 1%

Species Checklist (circle community space when species is present in community, record cover class in circle following meander)

Aquatic Stratum (true aquatic plants that are submergent or have floating leaves)

Community # 1 2 3

_ _ _ Brasenia schreberi
_ _ _ Ceratophyllum demersum
_ _ _ Elodea canadensis
_ _ _ Lemna minor
_ _ _ Lemna trisulca
_ _ _ Najas flexilis
_ _ _ Nelumbo lutea
_ _ _ Nuphar lutea ssp. variegata
_ _ _ Nymphaea odorata
_ _ _ Polygonum amphibium
_ _ _ Potamogeton amplifolius
_ _ _ Potamogeton crispus
_ _ _ Potamogeton natans
_ _ _ Potamogeton zosteriformis
_ _ _ Ranunculus flabellaris
_ _ _ Ranunculus longirostris
_ _ _ Ranunculus trichophyllus var. trichophyllus
_ _ _ Spirodela polyrrhiza
_ _ _ Stuckenia pectinatus
_ _ _ Utricularia macrorhiza
_ _ _ Vallisneria americana
_ _ _ Wolfia columbiana

Tree Stratum (woody plants with typical max growth ≥ 3" DBH)

Community # 1 2 3

_ _ _ Abies balsamea
_ _ _ Acer negundo
_ _ _ Acer rubrum var. rubrum
_ _ _ Acer saccharinum
_ _ _ Betula alleghaniensis var. alleghaniensis
_ _ _ Betula papyrifera var. papyrifera
_ _ _ Celtis occidentalis var. occidentalis
_ _ _ Fraxinus nigra
_ _ _ Fraxinus pennsylvanica
_ _ _ Larix laricina
_ _ _ Ostrya virginiana var. virginiana
_ _ _ Picea glauca
_ _ _ Picea mariana
_ _ _ Pinus strobus
_ _ _ Populus balsamifera ssp. balsamifera
_ _ _ Populus deltoides ssp. monilifera
_ _ _ Populus tremuloides
_ _ _ Quercus macrocarpa var. macrocarpa
_ _ _ Quercus rubra
_ _ _ Salix amygdaloides
_ _ _ Salix nigra
_ _ _ Salix X rubens
_ _ _ Sorbus americana
_ _ _ Thuja occidentalis
_ _ _ Tilia americana var. americana
_ _ _ Ulmus americana

Shrub Stratum (woody plants with typical max growth < 3" DBH and > 1m tall)

Community # 1 2 3

_ _ _ Acer spicatum
_ _ _ Alnus incana ssp. rugosa
_ _ _ Amorpha fruticosa
_ _ _ Betula pumila var. glandulifera
_ _ _ Cornus racemosa
_ _ _ Cornus sericea ssp. sericea
_ _ _ Dasiphora floribunda
_ _ _ Frangula alnus
_ _ _ Ilex verticillata
_ _ _ Myrica gale
_ _ _ Physocarpus opulifolius
_ _ _ Rhamnus alnifolia
_ _ _ Rhamnus cathartica
_ _ _ Ribes americanum
_ _ _ Rubus idaeus ssp. strigosus
_ _ _ Salix bebbiana
_ _ _ Salix candida
_ _ _ Salix discolor
_ _ _ Salix interior
_ _ _ Salix petiolaris
_ _ _ Sambucus nigra ssp. canadensis
_ _ _ Spiraea alba
_ _ _ Spiraea tomentosa var. rosea
_ _ _ Staphylea trifolia
_ _ _ Toxicodendron vernix
_ _ _ Viburnum lentago
_ _ _ Viburnum opulus var. americanum

Woody Vine Stratum (all woody vines)

Community # 1 2 3

_ _ _ Clematis virginiana
_ _ _ Menispermum canadense
_ _ _ Parthenocissus vitacea
_ _ _ Solanum dulcamara var. dulcamara
_ _ _ Vitis riparia

Herb Stratum (all non-aquatic herbaceous plants and woody plants with typical max growth < 1m tall)

Community # 1 2 3

_ _ _ Achillea millefolium
_ _ _ Acorus americanus
_ _ _ Adiantum pedatum
_ _ _ Agrostis gigantea
_ _ _ Alisma subcordatum
_ _ _ Alisma triviale
_ _ _ Alliaria petiolata
_ _ _ Ambrosia artemisiifolia
_ _ _ Ambrosia trifida var. trifida
_ _ _ Amphicarpaea bracteata
_ _ _ Andromeda polifolia var. glaucophylla
_ _ _ Andropogon gerardii
_ _ _ Anemone canadensis
_ _ _ Anemone quinquefolia var. bifolia
_ _ _ Angelica atropurpurea
_ _ _ Apocynum cannabinum
_ _ _ Aralia nudicaulis
_ _ _ Argentina anserina
_ _ _ Arisaema triphyllum
_ _ _ Asclepias incarnata ssp. incarnata
_ _ _ Athyrium filix-femina ssp. angustum
_ _ _ Beckmannia syzigachne
_ _ _ Bidens cernua
_ _ _ Boehmeria cylindrica

Herb Stratum *Continued* (all non-aquatic herbaceous plants and woody plants < 1m tall)

Community #
1 2 3

_ _ _ Botrychium virginianum
_ _ _ Bromus ciliatus var. ciliatus
_ _ _ Bromus inermis
_ _ _ Calamagrostis canadensis
_ _ _ Calamagrostis stricta ssp. st
_ _ _ Calla palustris
_ _ _ Caltha palustris var. palustris
_ _ _ Calystegia sepium
_ _ _ Campanula aparinoides
_ _ _ Carex aquatilis var. aquatilis
_ _ _ Carex atherodes
_ _ _ Carex comosa
_ _ _ Carex interior
_ _ _ Carex intumescens
_ _ _ Carex lacustris
_ _ _ Carex lasiocarpa var. americ
_ _ _ Carex oligosperma
_ _ _ Carex pellita
_ _ _ Carex stipata var. stipata
_ _ _ Carex stricta
_ _ _ Carex utriculata
_ _ _ Carex vulpinoidea
_ _ _ Chamaedaphne calyculata var. a
_ _ _ Chamerion angustifolium ssp. cir
_ _ _ Chelone glabra
_ _ _ Cicuta bulbifera
_ _ _ Cicuta maculata
_ _ _ Circaea alpina ssp. alpina
_ _ _ Circaea lutetiana ssp. canad
_ _ _ Cirsium arvense
_ _ _ Cirsium muticum
_ _ _ Clintonia borealis
_ _ _ Comarum palustre
_ _ _ Conyza canadensis var. can
_ _ _ Coptis trifolia
_ _ _ Cornus canadensis
_ _ _ Cryptotaenia canadensis
_ _ _ Cyperus esculentus var. lept
_ _ _ Cypripedium reginae
_ _ _ Dioscorea villosa
_ _ _ Doellingeria umbellata
_ _ _ Drosera rotundifolia var. rotu
_ _ _ Dryopteris carthusiana
_ _ _ Dryopteris cristata
_ _ _ Dulichium arundinaceum
_ _ _ Echinochloa crus-galli
_ _ _ Echinocystis lobata
_ _ _ Eleocharis obtusa
_ _ _ Eleocharis palustris
_ _ _ Elymus virginicus
_ _ _ Epilobium leptophyllum
_ _ _ Equisetum arvense
_ _ _ Equisetum fluviatile
_ _ _ Eupatorium maculatum
_ _ _ Eupatorium perfoliatum var. p
_ _ _ Euthamia graminifolia
_ _ _ Fragaria virginiana
_ _ _ Galium aparine
_ _ _ Gaultheria hispidula
_ _ _ Gentiana andrewsii
_ _ _ Geranium maculatum
_ _ _ Glyceria borealis
_ _ _ Glyceria canadensis

Community #
1 2 3

_ _ _ Glyceria grandis var. grandis
_ _ _ Glyceria striata
_ _ _ Gymnocarpium dryopteris
_ _ _ Hackelia virginiana
_ _ _ Helenium autumnale var. autumnale
_ _ _ Helianthus giganteus
_ _ _ Helianthus grosseserratus
_ _ _ Heracleum maximum
_ _ _ Heuchera richardsonii
_ _ _ Hordeum jubatum ssp. jubatum
_ _ _ Hydrophyllum virginianum
_ _ _ Hypoxis hirsuta
_ _ _ Impatiens capensis
_ _ _ Iris versicolor
_ _ _ Kalmia polifolia
_ _ _ Lactuca serriola
_ _ _ Laportea canadensis
_ _ _ Lathyrus palustris
_ _ _ Lathyrus venosus
_ _ _ Ledum groenlandicum
_ _ _ Leersia oryzoides
_ _ _ Liatris pycnostachya var. pycnostachya
_ _ _ Linnaea borealis ssp. americana
_ _ _ Lobelia kalmii
_ _ _ Lobelia siphilitica var. ludoviciana
_ _ _ Lobelia spicata
_ _ _ Lycopus americanus
_ _ _ Lycopus uniflorus
_ _ _ Lysimachia ciliata
_ _ _ Lysimachia thyrsiflora
_ _ _ Lythrum salicaria
_ _ _ Maianthemum canadense
_ _ _ Maianthemum stellatum
_ _ _ Maianthemum trifolium
_ _ _ Matteuccia struthiopteris
_ _ _ Mentha arvensis
_ _ _ Menyanthes trifoliata
_ _ _ Mertensia virginica
_ _ _ Mimulus ringens var. ringens
_ _ _ Mitella nuda
_ _ _ Monotropa uniflora
_ _ _ Muhlenbergia richardsonis
_ _ _ Oligoneuron riddellii
_ _ _ Onoclea sensibilis
_ _ _ Orthilia secunda
_ _ _ Osmorhiza claytonii
_ _ _ Osmunda cinnamomea var. cinnamomea
_ _ _ Osmunda regalis var. spectabilis
_ _ _ Panicum virgatum var. virgatum
_ _ _ Parnassia glauca
_ _ _ Parnassia palustris
_ _ _ Pedicularis lanceolata
_ _ _ Penthorum sedoides
_ _ _ Petasites frigidus var. palmatus
_ _ _ Phalaris arundinacea
_ _ _ Phragmites australis
_ _ _ Physostegia virginiana ssp. virginiana
_ _ _ Pilea pumila var. pumila
_ _ _ Poa palustris
_ _ _ Poa pratensis ssp. pratensis
_ _ _ Polygonum amphibium
_ _ _ Polygonum lapathifolium

Community #
1 2 3

_ _ _ Polygonum pensylvanicum
_ _ _ Polygonum sagittatum
_ _ _ Pontederia cordata
_ _ _ Potentilla norvegica ssp. monspeliensis
_ _ _ Prenanthes racemosa
_ _ _ Pycnanthemum virginianum
_ _ _ Rubus pubescens var. pubescens
_ _ _ Rudbeckia hirta var. pulcherrima
_ _ _ Rudbeckia laciniata var. laciniata
_ _ _ Rumex crispus ssp. crispus
_ _ _ Rumex orbiculatus
_ _ _ Sagittaria latifolia
_ _ _ Sagittaria rigida
_ _ _ Sanguinaria canadensis
_ _ _ Sarracenia purpurea ssp. purpurea
_ _ _ Saxifraga pensylvanica
_ _ _ Scheuchzeria palustris ssp. americana
_ _ _ Schoenoplectus acutus var. acutus
_ _ _ Schoenoplectus fluviatilis
_ _ _ Schoenoplectus pungens
_ _ _ Schoenoplectus tabernaemontani
_ _ _ Scirpus cyperinus
_ _ _ Scolochloa festucacea
_ _ _ Scutellaria galericulata
_ _ _ Scutellaria lateriflora
_ _ _ Sicyos angulatus
_ _ _ Sium suave
_ _ _ Solidago canadensis
_ _ _ Solidago gigantea
_ _ _ Solidago uliginosa var. uliginosa
_ _ _ Sonchus arvensis
_ _ _ Sorghastrum nutans
_ _ _ Sparganium eurycarpum
_ _ _ Spartina pectinata
_ _ _ Stachys palustris
_ _ _ Stellaria longifolia
_ _ _ Streptopus lanceolatus var. longipes
_ _ _ Symphyotrichum lanceolatum
_ _ _ Symphyotrichum lateriflorum
_ _ _ Symphyotrichum novae-angliae
_ _ _ Symphyotrichum puniceum
_ _ _ Symplocarpus foetidus
_ _ _ Taraxacum officinale
_ _ _ Thalictrum dasycarpum
_ _ _ Thelypteris palustris var. pubescens
_ _ _ Toxicodendron rydbergii
_ _ _ Triadenum fraseri
_ _ _ Trientalis borealis ssp. borealis
_ _ _ Trillium cernuum
_ _ _ Typha angustifolia
_ _ _ Typha latifolia
_ _ _ Typha X glauca
_ _ _ Urtica dioica ssp. gracilis
_ _ _ Vaccinium angustifolium
_ _ _ Vaccinium macrocarpon
_ _ _ Vaccinium oxycoccos
_ _ _ Verbena hastata
_ _ _ Vernonia fasciculata
_ _ _ Veronicastrum virginicum
_ _ _ Xanthium strumarium
_ _ _ Zizania palustris
_ _ _ Zizia aurea

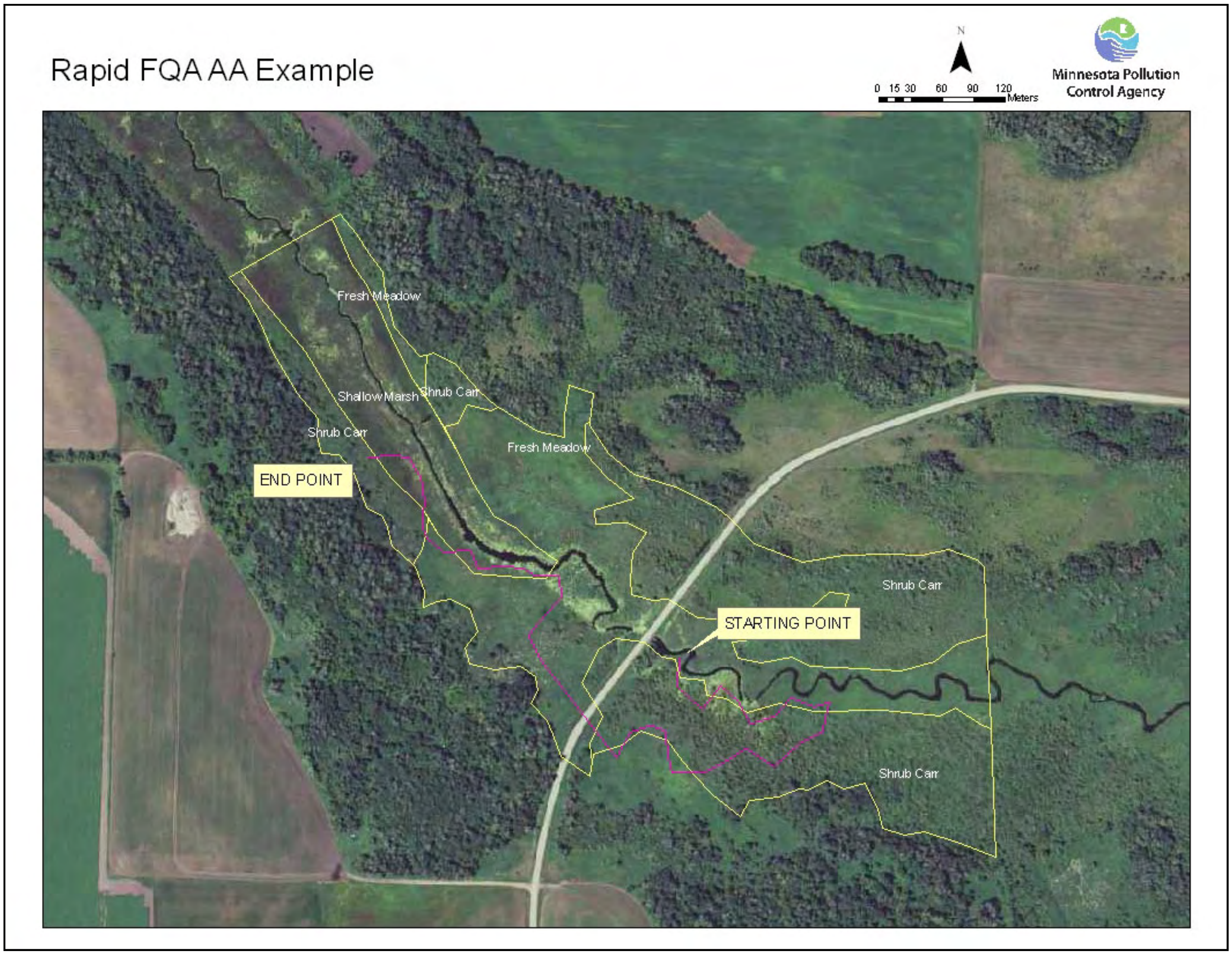
Appendix 5-Worked Example

A Rapid FQA example according to the numbered steps provided in the Results and Discussion section.

FIELD SAMPLING

Steps 1 and 2

Below is the final site map for the example. Prior to sampling, AA and community polygons were drawn in GIS based on aerial photos, topographic maps, and NWI interpretation (yellow line work). The base photography is 2010 1m resolution FSA. The community types follow those described in Table 1. After field sampling, the polygons were revised based on the observations made during Step 2. Once the GIS project was setup (which can be dedicated to Rapid FQA mapping), total mapping time was about 30 minutes.



Step 3

There are three community types within this AA: Shrub-Carr, Fresh Meadow, and Shallow Marsh. The base meander time is then: 30 minutes + 20 minutes + 20 minutes = 70 minutes.

Step 4

The meander path is provided in the AA map (magenta). Species listed on the data sheet (i.e., the rapid species; Appendix 4) were recorded as the meander proceeded. The meander started in the Fresh Meadow and preceded east crossing into the Srub-Carr. The path then crossed through the Shrub-Carr heading west and the upland boundary of the AA was confirmed. The meander was then paused for a few minutes as the observer headed northwest across the road into a different area of the AA. The meander finished by working through the Fresh Meadow and Shallow Marsh in the northwestern portion of the AA. Five rapid species were observed during the final 10 minutes of the base meander time, so an additional 10 minute meander time period was added. During this period, only 2 more rapid species were observed so the meander was stopped. The meander covered all three communities in the AA with approximately equal time in each type.

Step 5

During Step 2, it was determined that the stream channel was deep water habitat, not a Shallow Open Water wetland community. Step 5 was not necessary.

Step 6

Cover was estimated for each rapid species occurring in each community type according to the cover classes in Table 2. Field sampling was now complete with a total field time at the AA of about 120 minutes.

Data and assessment

Step 1

Field data (scientific names and cover classes/CC) were entered into an excel spreadsheet by community type to calculate wC (see below). The CC ranges and Midpoint percent Cover came from Table 2. Species attributes (Minnesota Native Status, Minnesota NWI, and C) came from the Rapid Species List (Appendix 3). The Total Midpoint percent Cover, and Total Introduced Spp. Cover was then calculated for each community. Next the proportional cover (p) for each species was calculated by dividing the species' midpoint percent cover by the total cover. Each species C-value was then multiplied by its proportional abundance (pC). Finally, these values were summed to produce wC for each community type.

Shrub Carr

SciName	Cover Class	CC Range	Midpoint CC	MN Native Status	MN NWI	C	p	pC
Salix petiolaris	5	>50 - 75%	62.5	Native	FACW+	5	0.3655	1.82749
Phalaris arundinacea	4	>25 - 50%	37.5	Introduced	FACW+	0	0.2193	0
Calamagrostis canadensis	3	>5 - 25%	15	Native	OBL	4	0.0877	0.35088
Cornus sericea ssp. sericea	3	>5 - 25%	15	Native	[FACW]	3	0.0877	0.26316
Salix discolor	3	>5 - 25%	15	Native	FACW	3	0.0877	0.26316
Carex stricta	2	>1 - 5%	3	Native	OBL	5	0.0175	0.08772
Eupatorium maculatum	2	>1 - 5%	3	Native	[OBL]	4	0.0175	0.07018
Impatiens capensis	2	>1 - 5%	3	Native	FACW	2	0.0175	0.03509
Polygonum amphibium	2	>1 - 5%	3	Native	OBL	4	0.0175	0.07018
Salix bebbiana	2	>1 - 5%	3	Native	FACW+	6	0.0175	0.10526
Salix interior	2	>1 - 5%	3	Native	[OBL]	2	0.0175	0.03509
Ambrosia trifida var. trifida	1	>0 - 1%	0.5	Native	[FAC+]	0	0.0029	0
Bidens cernua	1	>0 - 1%	0.5	Native	OBL	3	0.0029	0.00877
Caltha palustris var. palustris	1	>0 - 1%	0.5	Native	[OBL]	6	0.0029	0.01754
Cirsium arvense	1	>0 - 1%	0.5	Introduced	FACU	0	0.0029	0
Echinocystis lobata	1	>0 - 1%	0.5	Native	FACW-	2	0.0029	0.00585
Lemna minor	1	>0 - 1%	0.5	Native	OBL	5	0.0029	0.01462
Lycopus uniflorus	1	>0 - 1%	0.5	Native	OBL	5	0.0029	0.01462
Pilea pumila var. pumila	1	>0 - 1%	0.5	Native	[FACW]	3	0.0029	0.00877
Poa palustris	1	>0 - 1%	0.5	Native	FACW+	5	0.0029	0.01462
Rhamnus cathartica	1	>0 - 1%	0.5	Introduced	FACU	0	0.0029	0
Rumex orbiculatus	1	>0 - 1%	0.5	Native	OBL	6	0.0029	0.01754
Solidago gigantea	1	>0 - 1%	0.5	Native	FACW	3	0.0029	0.00877
Symphyotrichum puniceum	1	>0 - 1%	0.5	Native	[OBL]	6	0.0029	0.01754
Thalictrum dasycarpum	1	>0 - 1%	0.5	Native	FACW-	4	0.0029	0.0117
Urtica dioica ssp. gracilis	1	>0 - 1%	0.5	Native	[FAC+]	1	0.0029	0.00292
Vitis riparia	1	>0 - 1%	0.5	Native	FACW-	2	0.0029	0.00585

Total Midpoint % Cover	171	**wC**	3.3
Total Introduced Spp. Cover	38.5		

Fresh Meadow

SciName	Cover Class	CC Range	Midpoint CC	MN Native Status	MN NWI	C	p	pC
Phalaris arundinacea	5	>50 - 75%	62.5	Introduced	FACW+	0	0.2778	0
Calamagrostis canadensis	4	>25 - 50%	37.5	Native	OBL	4	0.1667	0.66667
Ambrosia trifida var. trifida	3	>5 - 25%	15	Native	[FAC+]	0	0.0667	0
Carex lacustris	3	>5 - 25%	15	Native	OBL	5	0.0667	0.33333
Carex stricta	3	>5 - 25%	15	Native	OBL	5	0.0667	0.33333
Eupatorium maculatum	3	>5 - 25%	15	Native	[OBL]	4	0.0667	0.26667
Typha angustifolia	3	>5 - 25%	15	Introduced	OBL	0	0.0667	0
Apocynum cannabinum	2	>1 - 5%	3	Native	FAC	3	0.0133	0.04
Cirsium arvense	2	>1 - 5%	3	Introduced	FACU	0	0.0133	0
Cornus sericea ssp. sericea	2	>1 - 5%	3	Native	[FACW]	3	0.0133	0.04
Impatiens capensis	2	>1 - 5%	3	Native	FACW	2	0.0133	0.02667
Phragmites australis	2	>1 - 5%	3	Native	FACW+	1	0.0133	0.01333
Polygonum amphibium	2	>1 - 5%	3	Native	OBL	4	0.0133	0.05333
Populus tremuloides	2	>1 - 5%	3	Native	[FAC]	2	0.0133	0.02667
Rumex orbiculatus	2	>1 - 5%	3	Native	OBL	6	0.0133	0.08
Salix discolor	2	>1 - 5%	3	Native	FACW	3	0.0133	0.04
Salix interior	2	>1 - 5%	3	Native	[OBL]	2	0.0133	0.02667
Salix petiolaris	2	>1 - 5%	3	Native	FACW+	5	0.0133	0.06667
Solidago gigantea	2	>1 - 5%	3	Native	FACW	3	0.0133	0.04
Symphyotrichum puniceum	2	>1 - 5%	3	Native	[OBL]	6	0.0133	0.08
Thalictrum dasycarpum	2	>1 - 5%	3	Native	FACW-	4	0.0133	0.05333
Urtica dioica ssp. gracilis	2	>1 - 5%	3	Native	[FAC+]	1	0.0133	0.01333
Acer negundo	1	>0 - 1%	0.5	Native	FACW-	1	0.0022	0.00222
Echinocystis lobata	1	>0 - 1%	0.5	Native	FACW-	2	0.0022	0.00444
Helianthus giganteus	1	>0 - 1%	0.5	Native	FACW	4	0.0022	0.00889
Helianthus grosseserratus	1	>0 - 1%	0.5	Native	FACW-	3	0.0022	0.00667
Lycopus uniflorus	1	>0 - 1%	0.5	Native	OBL	5	0.0022	0.01111
Mentha arvensis	1	>0 - 1%	0.5	Native	FACW	3	0.0022	0.00667
Parthenocissus vitacea	1	>0 - 1%	0.5	Native	FACU	2	0.0022	0.00444
Rubus idaeus ssp. strigosus	1	>0 - 1%	0.5	Native	[FACU+]	3	0.0022	0.00667
Thelypteris palustris var. pubescens	1	>0 - 1%	0.5	Native	[FACW+]	7	0.0022	0.01556
Typha latifolia	1	>0 - 1%	0.5	Native	OBL	2	0.0022	0.00444

Total Midpoint % Cover	225	**wC**	2.3
Total Introduced Spp. Cover	80.5		

Shallow Marsh

SciName	Cover Class	CC Range	Midpoint CC	MN Native Status	MN NWI	C	p	pC
Typha angustifolia	6	>75 - 95%	85	Introduced	OBL	0	0.6719	0
Calamagrostis canadensis	3	>5 - 25%	15	Native	OBL	4	0.1186	0.47431
Carex lacustris	3	>5 - 25%	15	Native	OBL	5	0.1186	0.59289
Lemna minor	2	>1 - 5%	3	Native	OBL	5	0.0237	0.11858
Acorus americanus	1	>0 - 1%	0.5	Native	[OBL]	7	0.004	0.02767
Bidens cernua	1	>0 - 1%	0.5	Native	OBL	3	0.004	0.01186
Carex stricta	1	>0 - 1%	0.5	Native	OBL	5	0.004	0.01976
Cicuta bulbifera	1	>0 - 1%	0.5	Native	OBL	7	0.004	0.02767
Cirsium arvense	1	>0 - 1%	0.5	Introduced	FACU	0	0.004	0
Cornus sericea ssp. sericea	1	>0 - 1%	0.5	Native	[FACW]	3	0.004	0.01186
Impatiens capensis	1	>0 - 1%	0.5	Native	FACW	2	0.004	0.00791
Leersia oryzoides	1	>0 - 1%	0.5	Native	OBL	3	0.004	0.01186
Mentha arvensis	1	>0 - 1%	0.5	Native	FACW	3	0.004	0.01186
Phalaris arundinacea	1	>0 - 1%	0.5	Introduced	FACW+	0	0.004	0
Pilea pumila var. pumila	1	>0 - 1%	0.5	Native	[FACW]	3	0.004	0.01186
Polygonum amphibium	1	>0 - 1%	0.5	Native	OBL	4	0.004	0.01581
Polygonum lapathifolium	1	>0 - 1%	0.5	Native	FACW+	2	0.004	0.00791
Rubus idaeus ssp. strigosus	1	>0 - 1%	0.5	Native	[FACU+]	3	0.004	0.01186
Rumex orbiculatus	1	>0 - 1%	0.5	Native	OBL	6	0.004	0.02372
Salix petiolaris	1	>0 - 1%	0.5	Native	FACW+	5	0.004	0.01976
Spirodela polyrrhiza	1	>0 - 1%	0.5	Native	[OBL]	5	0.004	0.01976

Total Midpoint % Cover	126.5	**wC**	1.4
Total Introduced Spp. Cover	86		

Step 2

The *wC* values were then compared to the BCG Tier thresholds in Table 7 to determine the assessment Tier for each community

Community Type	wC	BCG Tier
Shrub Carr	3.3	3
Fresh Meadow	2.3	3
Shallow Marsh	1.4	4

Step 3

The area of each community and the total AA area were calculated using GIS. Next, the proportion of each community was calculated by dividing the community area by the total. Finally, the proportion was multiplied by the BCG Tier for each community, summed, and rounded to the nearest whole number to produce the weighted average Tier for the AA.

Community Type	wC	BCG Tier	Area in AA (M^2)	Proportion of AA	Proportion x Tier
Shrub Carr	3.3	3	81287	0.4823668	1.4471003
Fresh Meadow	2.3	3	59526	0.3532344	1.0597032
Shallow Marsh	1.4	4	27704	0.1643988	0.6575954

Total AA Area (M^2) 168517

Weighted Average Tier 3

Appendix 6-Repeatability and Precision

Introduction

Sampling repeatability and indicator precision are important concepts in monitoring and assessment. A high degree of consistency is a goal when developing sampling methods. Assessment approaches that have high variability due to sampling errors and/or natural variability may not be able to detect actual changes in wetland condition.

A number of sources of variation exist that can affect the Rapid FQA including:

- Natural variability of vegetation and AA size
- Plant community type and extent interpretation
- Meander starting point and path (i.e., sampling location)
- Sampling error (e.g., species identification and cover estimate errors)

During the Rapid FQA field trials, a small number studie AAs were sampled multiple times in order to begin to assess precision/repeatability.

Methods

In 2009, four study AAs were sampled three individual times each in August and September. The same observer conducted 2 of the samples and a second observer conducted the final sample. Each sampling event had different meander starting points and followed different meander paths through the AAs.

During 2010, four more repeat AAs were added to the trial to increase the total number of AAs to eight. Each of the AAs was sampled in June and again in September. Sampling occurred at least three times at all of the AAs. There was a greater variety of independent observer combinations in 2010, though. Each AA was sampled by a minimum of two different observers. At three of the AAs, a total of four observers conducted a Rapid FQA. In addition, at a subset of the AAs (five) pairs of independent observers conducted the meander sampling in parallel, where the observers had the same starting point and followed the path simultaneously.

The target AAs were depressional wetlands that included areas of Fresh Meadow, Shallow Marsh, and Shallow Open Water plant community types. Including multiple communities provided results for a modest range of types as well as repeat trials to assess overall patterns. AAs were selected along a range of sizes from: 0.6– 215 ha to assess if AA size affects the Rapid FQA. AAs were also selected along a gradient of anthropogenic impacts according to the Human Disturbance Assessment (HDA; Appendix 1), with two Minimally Impacted; three Moderately Impacted; and three Severely Impacted AAs. This was done to examine if the degree of human impacts/condition of the AA is associated with Rapid FQA precision/repeatability. In general, none of the four major factors that affect precision/repeatability (i.e., natural variability, community interpretation, sampling location, and sampling error) were strictly isolated in the experimental design. The goal of the experimental design was to provide some control of individual factors over a variety of conditions (e.g., several community types, range of AA sizes, and range impacts/condition) to explore potential major factors of variation, as opposed to a comprehensive study of precision/repeatability where each component can be analyzed individually.

Rapid FQA precision/repeatability results were quantitatively analyzed based on the measured variation of the primary assessment metric *wC* over a variety of scenarios that the experimental design permitted. The overall standard deviation of *wC* for each of the three community types was computed using ANOVA. ANOVA variance estimates were also used to compute signal: noise ratios which (in general terms) is the between site variance of sites along a gradient of anthropogenic impacts (signal) divided by the within site variance (noise). Signal: noise ratios measure the ability of a metric to detect changes in condition and are a common approach to assess metric precision (Kauffman et al. 1999, Fore 2003). In addition, community type and extent interpretation error was examined qualitatively for a single AA. Finally, the rate of agreement of assessment outcomes (percent BCG Tier Agreement = number of number of samples equal to the median BCG Tier for the AA/total number of samples) was computed for each of the community types to assess the overall consistency of the Rapid FQA.

Results and discussion

Of the eight AA's included in the Rapid FQA precision/repeatability trial, the plant communities of seven were interpreted consistently, where all observers agreed on what community types were present with only slight variations in community extent. The AA where there was some disagreement (09WASH015) was interpreted in three different ways by five different observers. 09WASH015 was a depressional basin that was naturally isolated from surface water inputs/outputs (there was a small man made ditch that served as an overflow for a smaller adjacent wetland basin) and had concentric rings of plant communities based on the basin water level. A Shallow Open Water community type occupied the center. Basin sides were relatively steep so that emergent vegetation zones were generally narrow moving from the Shallow Open Water to the upland margin. The emergent vegetation zones consisted of a Deep Marsh zone (emergent vegetation in standing water, intermixed with the aquatic vegetation), a mudflat zone dominated by annual species late in the season (best described as the Seasonally Flooded Basin community type in Eggers and Reed (2011)), and a Fresh Meadow zone (dominated by perennial grasses and sedges). These emergent vegetation zones move, expand, and contract according to water level fluctuations. During dryer years, the water level recedes exposing the mudflats. If the water level remains low for successive years, this zone becomes dominated by perennials, converting the area to Fresh Meadow. If the water level rises, the mudflat/wet meadow is quickly replaced by the Shallow Open Water and/or the Deep Marsh community. In 2009-10, the region was predominantly experiencing drought conditions, causing the AA to be in a low water period and exposing the mudflat annual zone. The presence of this mudflat/annual zone caused the different community interpretations at the AA. Two observers lumped the mudflat/annual zone with the Deep Marsh and called it a Shallow Marsh. Another observer lumped the mudflat/annual zone the Fresh Meadow community and did not recognize any marsh community. Two other observers identified the 4 distinct community types described above.

All of the observers at 09WASH015 were experienced wetland professionals that had worked with the Eggers and Reed classification for years and had received basic Rapid FQA training. Yet, in this case there were different interpretations of the community types present which led towards very different data sets that were ultimately incomparable. This case illustrates how community type interpretation has the potential to be a large source of error in the Rapid FQA. The basic sampling and assessment unit is the plant community which must be interpreted by the observer. Large discrepancies in community interpretation can lead to large discrepancies in results. The overall interpretation results from the trial (where there was consistent interpretation at seven of eight AA's) indicate that experienced professionals will make the same community interpretations most of the time. The site where there was a problem had active plant community changes due to dropping water levels. This suggests that the Rapid FQA results will be most consistent at AAs with stable plant communities. AAs that have communities in transition or have broad transition zones from one type to another will have a greater likelihood of Rapid FQA variability due to interpretation errors.

In the AAs that did have consistent community type interpretations, the overall standard deviation (i.e., when all of the variance components are considered) of *wC* in the 3 community types was between 0.40 and 0.66 (Table 1). This represents approximately four – seven percent of the overall range of *wC* (0 -10) or eight – 14 percent of the effective *wC* range (approximately 0 – 5) for these community types. Signal:

noise ratios for the three types were ≥ 4.5 (Table 1). In other words, the range (signal) of *wC* from minimally to severely impacted sites was at least 4.5 times greater than the variability due to sampling error (noise). Signal: Noise ratios ranging from two-six are generally considered a good/acceptable level of precision/repeatability for biological condition indicators (Kaufman et al. 1999, Fore 2003). These results are consistent with similar trials of precision/repeatability for the depressional marsh IBIs (Genet and Bourdaghs 2006, Genet and Bourdaghs 2007).

Table1. wCand BCG tier precision statistics by community type

Community type	Overall Standard Deviation wC	Signal Noise wC	Average Paired Abs Diff wC	% BCG tier agreement
Fresh Meadow	0.62	5.2	0.20	79
Shallow Marsh	0.66	4.5	0.47	79
Shallow Open Water	0.40	23.8	0.12	94

While the experimental design did not strictly control all factors, it did allow for some analysis of the individual sources of variation. The standard deviation of *wC* at individual AAs was not correlated with AA size for each of the communities (Figure 1), indicating that AA size alone does not affect Rapid FQA precision/repeatability. This result is consistent with the sampling effort trial where *wC* tends to become stable at the end of meander sampling no matter how large an AA is.

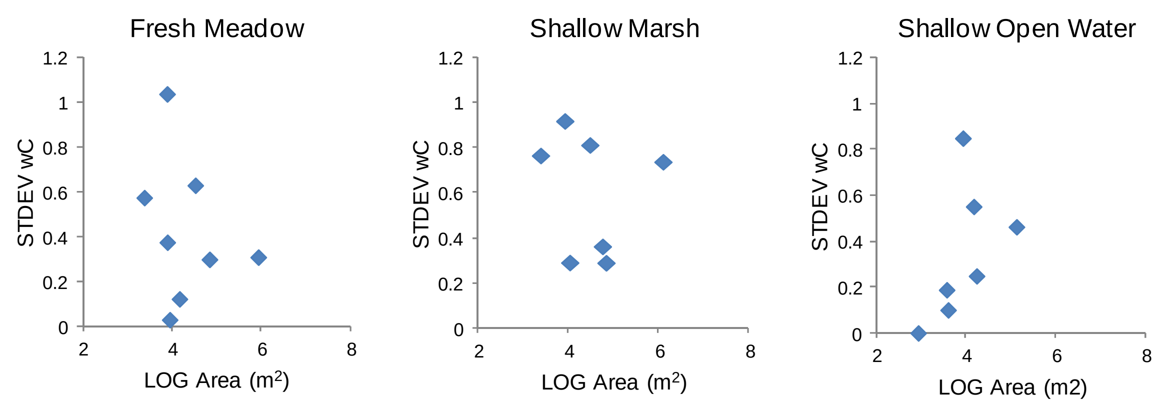


Figure 1. Standard deviation of *wC* plotted against area (m^2) for the Fresh Meadow, Shallow Marsh, and Shallow Open Water plant community types. Area has been Log transformed.

Conversely, the average absolute differences in *wC* scores produced by paired sampling trials (where two observers sampled the same AA simultaneously following the same meander path) were less than the overall *wC* standard deviation (Table 1). Paired sampling essentially eliminated sampling location and time as a factor of variability, isolating sampling error between two observers. The results indicate that there is observer error associated with different observers. They also suggest that sampling location is perhaps also a substantial contributor to the overall variation in *wC*. What most likely is happening is that when observers (the same or different) have different starting points and meander paths they have a greater likelihood of making different cover estimations of the most abundant species leading to different *wC* scores.

In addition, the standard deviation of *wC* varied at different levels of anthropogenic impacts. The Fresh Meadow and Shallow Marsh communities had the greatest standard deviation at moderately impacted AAs (0.73 and 0.88 respectively) compared too minimally (0.09 and 0.29) or severely impacted (0.56 and 0.43) AAs. The standard deviations at moderately impacted AAs exceeded the overall standard deviations for those types; while the standard deviation at the minimally and severely impacted AAs was lower than the overall estimates (Table 1). This suggests that the vegetation of moderately impacted AAs (and consequently, AAs in moderate condition) is more complex or varied. Moderately impacted AAs tend to have a mixture of native and non-native invasive vegetation; whereas minimally and severely impacted AAs typically have a predominance of either native or non-native invasive vegetation.

Observers should be able to make more consistent observations in the less variable AAs. To examine this further, the standard deviation of *wC* at individual sites was plotted against the standard deviation of introduced species cover estimation (Figure 2). Variability of *wC* was positively correlated with the variability of introduced species cover in both the Fresh Meadow (r = 0.68, p < 0.10) and the Shallow Marsh (r = 0.79, p < 0.05) communities, suggesting that as the 'patchiness' of invasive species increases the variability of the Rapid FQA increases. Introduced species have a large effect on *wC* scores because they have a *C* = 0. An increase in introduced species variability is therefore clearly expressed in wC scores.

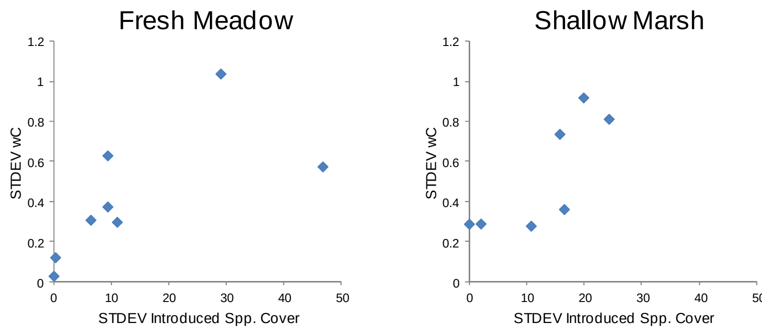


Figure 2. Standard deviation of *wC* plotted against the standard deviation of the introduced species cover for the Fresh Meadow and Shallow Marsh community types.

The Rapid FQA, as with any monitoring and assessment approach, is susceptible to some sources of variability which can affect assessment outcomes. The largest source of variation appears to be community type and extent interpretation errors; where, observers make inconsistent community interpretations. To minimize this, potential users should have experience with the Eggers and Reed (2011) plant community types and training materials should stress the importance of community interpretation. It should be noted that this is not an issue that is unique to the Rapid FQA. Other methods that rely on the observer choosing 'representative' sampling locations within a community type that was interpreted by the observer would likely have the same issues.

Another apparent source of error is the sampling location (i.e., meander starting point and path), particularly in AAs that have moderate and/or patchy cover of introduced invasive species. Again, training materials should highlight the importance of the meander being a 'representative' sample of the AA. While the *wC* has a moderate degree of variability, it is within generally accepted levels and is consistent with previous IBI development efforts (Genet and Bourdaghs 2006, Genet and Bourdaghs 2007). Considering that the Rapid FQA is a level 2 assessment method (EPA 2006) where some precision is sacrificed for greater applicability in terms of time and expertise the level of precision/repeatability in the trial is conceptually on target. When *wC* results are translated into assessment outcomes (i.e., BCG tiers), the percent BCG Tier Agreement (i.e., number of samples equal to the median BCG Tier for the AA/total number of samples) was ≥ 79 percent for each of the community type (Table 1). In other words, any given sample that followed the protocol, no matter the observer, the time in the growing season, or which meander path was chosen returned the same results ≥ 79 percent of the time. This level of consistent assessment outcomes is encouraging, further supporting that the Rapid FQA can be an effective wetland condition monitoring and assessment approach.

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