Northern Lakes and Forests Inland Wetland Survey: Relationships between Floristic Quality Assessment and Anthropogenic Stressors – 2012- 2014

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INTRODUCTION

Inland non-forested and forested wetlands in Wisconsin's Northern Lakes and Forests (NLF) are numerous and have critical ecological functions. In 1997, Epstein et al. identified more than 30 coastal and interior basin wetland areas as priorities for protection in the very northern portion of the region, partly based on plant community diversity and the presence of rare plant populations. Some of these wetlands have suffered extensive degradation and loss over the last two centuries and continue to be under threat from human activities (Frayer *et al.* 1983, Dahl 1990, Dahl and Johnson 1991, Dahl 2000). Wetland functions under threat include temporary storage of surface water, stream flow maintenance, nutrient transformation, sediment retention, shoreline stabilization, and provision of fish and wildlife habitat (Tiner 2005).

While there are current large-scale projects underway to monitor the status and trends of coastal wetlands in Wisconsin's Great Lakes basins, there is scarce information and few assessments for inland wetlands of the region (Johnston *et al.* 2007, Johnston *et al.* 2010).

For inland wetlands of southern Wisconsin, where wetland degradation due to human activity has been more extensive, wetland floristic quality is judged using the Wisconsin Floristic Quality Assessment developed by Bernthal (2003). This approach is based on Swink and Wilhelm's (1994) development of Coefficient of Conservatism (C), a numerical score 0-10 assigned to plant species of a region by botanical experts based on species fidelity to specific habitat integrity and to varying degrees of disturbance. With a list of species from a site in-hand, indices of floristic quality are calculated by simple arithmetic methods including mean C and mean C weighted by species richness (Rooney and Rogers 2002, Bourdaghs *et al.* 2006). These measures are known to be sensitive to human disturbance across a wide range of wetland systems in Wisconsin and the Midwest (Hermann 2001, Bernthal *et al.* 2007, Mack 2004, Bourdaghs *et al.* 2006, Bourdaghs *et al.* 2011).

An open question is whether floristic quality approaches can be successfully applied to inland wetlands of the northern third of Wisconsin, where wetlands occur in a generally more forested landscape matrix and are generally less-disturbed. Without information on wetland plant occurrence and benchmarks of overall floristic quality for this region, future vegetation changes in response to human activity or climate change cannot be properly placed in context. The objective of this study is to establish benchmarks of wetland condition for the inland wetlands of the northern third of Wisconsin by evaluating floristic quality indices along a gradient of anthropogenic stress from least-impacted to most-impacted wetlands.

METHODS

Site Selection

Our study was limited to the Northern Lakes and Forests (NLF) Level III Omernik Ecoregion as utilized by the Environmental Protection Agency (Appendix I.) Based on the occurrence and prominence of wetland plant communities in this region, we selected nine wetland plant communities for the development of condition tier benchmarks: Northern Sedge Meadow (NSM), Shallow Water Marsh (SWM), Shrub Carr (SC), Alder Thicket (AT), Open Bog (OB), Black Spruce Swamp (BSS), White Cedar Swamp (CS), Muskeg (MK), and Northern Hardwood Swamp (NHS). A complete description of these nine types is listed in Appendix II.

Many of these community types are most prominent north of the tension zone in Wisconsin and represent rare wetlands over the northern landscape of woods, lakes, and wetlands. Other wetland types not surveyed included aquatic submerged plant communities, deep water marshes, and some lowland hardwood forest types.

Data collected in 2014 from the Northern Lakes and Forests Omernick Ecoregion will supplement the existing Lake Superior Basin FQA data collected in 2012 and 2013 in the creation of a series of condition benchmarks for the nine targeted wetland communities. Lake Superior coastal wetlands in the basin were not considered for this study. (See Appendix III for ordination comparison).

The Wisconsin Wetland Inventory (1986-2014)(WWI) was used in identifying assessment areas(AA) to survey. Mapped wetland units were polygons assigned a code identifier for the type of wetland plant community present. However, some of the plant communities were not easily identified by WWI information. For example, Alder Thicket and Shrub Carr were two communities of interest listed by one community type code; sites of each type were verified with field visits (see below). The communities Shallow Water Marsh and Northern Sedge Meadow had two codes in the WWI database, but the boundaries of mapped polygons were much more clearly defined in GIS than in the field, where they often blended together along a vegetative gradient controlled by water depth.

For the purpose of site selection, we used GIS to characterize human activity in a 300-m buffer around the mapped wetland units in the plant communities. We quantified two anthropogenic variables: 1) road density divided by wetland buffer area including roads and railroads from the TIGER dataset (US Census Bureau 2012), and 2) percent of the wetland buffer in natural land cover types summarized from the 2006 National Land Cover Dataset (NLCD, Fry *et al.* 2011). Wetlands were separated into those likely having high levels and low levels of human disturbance by ranking along these two anthropogenic variables. The goal of sampling was to survey sites at the high and low end of these gradients.

Our site selection process involved selecting an oversample of sites with the goal of approximately 20 wetlands with high and 20 wetlands with low amounts of human disturbance for each of the wetland plant community types. The oversample of wetlands allowed for field rejections of sites due to accessibility or cases when the digital database of the community type did not match the actual plant community in the field.

This project was begun in 2012. During the first year site selection was limited to four plant community types: Alder Thicket, Northern Sedge Meadow, Open Bog, and Shrub Carr. Prior to the 2012 field season, wetland sites in these communities at the high end of the human disturbance gradient were ranked in decreasing order by their density of surrounding roads. Sites having >1.5 km roads per hectare within a 300-m buffer were tentatively classified as having high levels of disturbance. We chose the value 1.5 km per hectare as the cutoff because it represented the 90th percentile of road density values among all wetland buffers. Sites at the upper end of this gradient were primarily located in or near cities of Superior, Ashland, Iron River, and Hurley, Wisconsin. Wetlands were reviewed in decreasing order along this road density gradient for site accessibility and having public ownership or private land ownership that had given permission for sampling. The process continued until a list of about 20 accessible wetland sites was created for each of the four plant community types. Especially for Open Bog, accessible wetlands with high amounts of adjacent road density were not available in the dataset. There are low numbers of heavily disturbed sites in these classes in this Omernik Ecoregion, making it difficult to define the disturbed end of the gradient. In these cases, we purposely selected wetlands with the highest amount of surrounding road density that was available.

A similar process was used for sites at the low end of the human disturbance gradient, whereby wetlands were ranked in decreasing order by their road density. Maps of wetlands were reviewed in decreasing order along this gradient for site accessibility as above, resulting in a pool of 20 accessible wetlands sites for each of the four community types. Sites with low amounts of human disturbance were much more plentiful in the database, and it was therefore easier to get a sufficient number of wetlands minimally affected by human disturbance.

Following the 2012 field season, preliminary data analysis suggested road density was not strongly correlated with floristic quality at our wetland sites in the four plant communities sampled, whereas the amount of natural land cover in a 300-m buffer around the wetland polygon was more tightly linked with floristic quality. Thus, prior to the 2013 and 2014 season, we used land cover instead of road density as the human disturbance variable to rank sites during selection of sites for those years.

For the 2013 field season, sites were selected in Black Spruce Swamp, Muskeg, and White Cedar Swamp by ranking along high- and low-levels of surrounding natural land cover and evaluating for accessibility and ownership as described for road density in 2012 above. To add better coverage at the ends of human disturbance gradients, 19 additional Open Bog sites were added in 2013, as well as 13 Alder Thicket, and 8 Shrub Carr.

For the 2014 field season, the set of wetlands to assess were greatly expanded to include adequate representation across 27 northern Wisconsin counties located in the NLF ecoregion. More than 180 wetlands were assessed with a focus on filling geographic and disturbance gradient gaps in the data. Also, some reference type wetlands conducted by the Natural Heritage Conservation department in 2013 and 2014 were added to the overall data for evaluation. Ten (10) reference sites in the Lake Superior Basin with existing data collected in the late 1990's, were also reviewed. Only Mean C and FQI values were generated in these wetlands, as no cover value were assigned to the species list. A total of 517 (507 AA's) wetlands were assessed over the three year time period (See Appendix IV).

Shrub Carr, Alder Thicket, Northern Hardwood Swamps, and Shallow Water Marsh were four plant communities not easily identified from the WWI digital inventory. Rather than use a site selection process based on GIS analysis of surrounding disturbance, we purposely selected sites in these communities in 2012- 2014 as they were encountered in the field, for example when they were adjacent to surveyed sites with a different plant community. Alder Thicket was well represented at high and low levels of human disturbance, while Shrub Carr was underrepresented at the low-disturbance end of the gradient.

Field Sampling

Five Hundred and seven wetland sites were visited during June-Aug of 2012 -2014. Upon arrival at a site, it was confirmed or rejected for sampling based on being ≥ 0.5 ha, having a homogeneous plant community belonging to one of the nine types of interest, and being accessible within 300 m of a railroad, road, navigable stream, or trail by foot. There were a few occasions that sites were chosen that exceeded the 300 meter access buffer to capture a wetland type at either end of the disturbance gradient. One hundred and sixteen (16%) of 723 site visits resulted in rejections, with the confirmation and survey of 507 wetlands overall.

A timed-meander survey method was used for vegetation sampling at each site (Goff 1982). Although timed-meander surveys do not result in density estimates of vegetation, recent research by Hlina *et al.* (2011), Bourdaghs *et al*. (2011), and Bourdaghs (2012), indicate that they are more cost-effective and yield more complete species lists per wetland than traditional quadrat-based surveys. Floristic quality metrics based on the Coefficient of Conservatism, including the Wisconsin Floristic Quality Assessment (WFQA) approach (Bernthal *et.al* 2007) are known to perform better with complete species lists.

Full details of our timed-meander approach of vegetative sampling are documented in the Standard Operating Procedure (LSRI - FS/27 SOP, Hlina et.al. 2012). Briefly, the timed-meander consisted of two trained botanists searching a wetland site for a minimum of 45 minutes. In cases when human disturbances were not evident, the starting point of the survey was a conveniently chosen location at least 20 m from the border of an adjacent plant community. In cases when human disturbances were evident, the starting point was directly adjacent to a neighboring community (i.e. edge of a roadside). During the timed survey period, the botanists walked through the site and recorded all species present. Plants that were not identified to species in the field were collected and later identified in the laboratory. Special effort was made to record undergrowth species that are easily overlooked. If >3 species were recorded during the last 10 minutes of the 45-minute interval, an additional 15 minutes was added to the survey. If > 3 species were observed during these 15 minutes, an additional 15 minutes were added. This process continued until fewer than three species were added in the final 15-minute interval up to a maximum of 75 minutes.

During the meander survey, hand-held Garmin GPS units were used to record the survey track. At the end of the survey, the botanists estimated to the nearest percent the average total cover of each species along their meander track. Percent cover estimation was calibrated and practiced in sample wetlands prior to surveys. The botanists also completed the Wisconsin Disturbance Factors Field Checklist (Bernthal, *et.al.* 2007) at the end of the survey (Appendix V). This checklist is a rapid method to qualitatively depict hydrological and habitat alterations and percent coverage of invasive plants observed in the wetland. From the checklist, *habitat quality code* is a single index that summarizes the overall level of disturbance and invasive species encroachment on a site, with values of this index ranging from 1-6.

Floristic Quality Metrics

We calculated four metrics of wetland floristic quality using the approach of the Wisconsin Floristic Quality Analysis (Bernthal *et al.* 2007). In all calculations, non-native species were included in the calculations, receiving a C-value of zero. Calculations were made for all surveyed wetlands. The four metrics included:

1) *Mean C* is the arithmetic average of the *C* values across the total number of plant species (*n*) observed in a wetland

$$\bar{C} = (C_1 + C_2 + C_3 + \cdots + C_n) \div n$$

2) *Weighted mean C* is an arithmetic mean where the *C*-value for each species (*i*) is multiplied by its proportional abundance (*p*) and divided by the sum of the proportional abundances:

$$w\bar{C} = \frac{\sum p_i C_i}{\sum p_i}$$

3) *Floristic Quality Index* is calculated by multiplying *mean C* by the square root of the total number of species (*n*).

$$FQI = \bar{C}\sqrt{n}$$

4) *Weighted Floristic Quality Index* is weighted *mean C* divided by the square root of the total number of species (*n*).

$$FQI = w\bar{C}\sqrt{n}$$

Analysis

To evaluate the distinctiveness of the nine wetland plant communities, we ran a non-metric multi-dimensional scaling (NMDS) analysis in PC-ORD (McCune and Mefford 2011). We used 507 sites and 218 species on at least 25 sites (5%).

To verify whether the floristic quality metrics were able to discriminate site quality along a gradient of human disturbance, we created scatter plots and calculated simple linear regressions using the metrics as *y*-variables and site habitat quality code and amount of surrounding natural land cover as two independent *x*-variables. We considered only regressions significant at $\alpha = 0.05$ for condition tier benchmark development. (See Appendix VI).

For the purpose of setting benchmarks, surveyed wetlands were placed into two categories based on field results of the disturbance factor checklist. *Least-disturbed* wetlands were defined as wetlands with habitat quality code scores (from the field disturbance factor checklist) of 1 or 2. *Most-disturbed* wetlands were defined as having habitat quality scores between 4 and 6. In this context, *disturbance* refers to human disturbance and not ecological disturbances including fire or wind that occur naturally in wetland ecosystems. Our goal was to have a minimum of 10 sites in each category, although this was not possible for all of the communities (Table 1)

Table 1. *Number of sites in disturbance classes used for setting condition tier benchmarks.*

Plant Community	*Total Number of Surveyed Wetlands*	*Disturbance Classes Based on Disturbance Factor Field Checklist*		*Disturbance Classes Based on % Natural Surrounding Land Cover*	
		Least Disturbed	Most Disturbed	Least Disturbed	Most Disturbed
Alder Thicket	54	41	13	31	23
Black Spruce Swamp	60	46	14	42	10
Muskeg	53	48	5	34	5
Northern Hardwood Swamp	37	28	9	24	16
Northern Sedge Meadow	57	40	17	35	22
Open Bog	58	51	7	43	7
Shallow Water Marsh	34	24	10	22	10
Shrub Carr	37	18	19	8	26
White Cedar Swamp	40	37	3	31	5

For each of the nine plant community types, a series of condition tier benchmarks (up to 5) were set in the least-disturbed and most-disturbed categories using percentile scores along the mean C and weighted C metrics (Bourdaghs 2012). We did not develop condition tier benchmarks using FQI and weighted FQI based on weak relationships between these metrics and wetland disturbance (see results below). Benchmarks for Condition Tiers 1 and 2 were defined as the 75th and 25th percentiles, respectively, of metric scores in the least disturbed group of wetlands. Thus, future wetland surveys in a particular community type receiving scores at or above these percentiles would be considered in the least-disturbed condition, with Condition Tier 1 reflecting the highest quality wetland. Similarly, in the most-disturbed class, the benchmarks for Condition Tiers 4 and 5 were defined as the 75th and 25th percentiles, respectively, of metric scores among wetlands in this category. Future wetlands that score at or below these values would be considered in the most-disturbed or degraded condition, with Condition Tier 5 representing a very poor quality wetland. Future wetlands receiving scores between the benchmarks for least- and most-disturbed wetlands would be represented in Condition Tier 3 or *intermediate* condition.

For the purpose of comparison and verification, the same process described above to set benchmarks was repeated by using a different variable to define the wetland condition tiers. In this second benchmark analysis, we used the amount of surrounding natural land cover in a 300-m buffer around the wetland meander track for each survey. A similar land use intensity scale has been used by others in establishing and creating condition benchmarks for wetland quality (Bourdaughs 2012, Bernthal *et. al* 2007, Bourdaughs 2006, Wilcox *et.al* 2002, Cohen *et. al*. 2004, Lopez and Fennesey 2002). In our analysis we defined *least-disturbed* wetlands having natural land cover >90%, while *most-disturbed* wetlands were defined as having <75% surrounding natural land cover. The five condition tier benchmarks were defined using the same percentile scores along the four metrics as described above.

RESULTS and DISCUSSION

Site Selection

One hundred and sixteen (16%) of 723 site visits resulted in rejections, with the confirmation and survey of 507 wetlands overall (Figure 1). Most rejections were due to inaccurate map delineations or to site inaccessibility. Among the surveyed sites, 352 (69%) occurred on public lands including city, county, or National Forest, whereas 70 (14%) occurred on private corporate lands representing all of the major cities in the ecoregion. (Superior, Ashland, Rhinelander, Spooner, Marinette, Hayward, etc. etc.). An additional 85 (17%) sites were surveyed on private lands of individual property owners in the region.

Although many wetlands occur on private lands throughout the region, it is difficult to survey these sites because landowners often do not grant permission, plus it takes a large effort to identify and contact landowners. This will likely continue to be a problem with monitoring studies into the future.

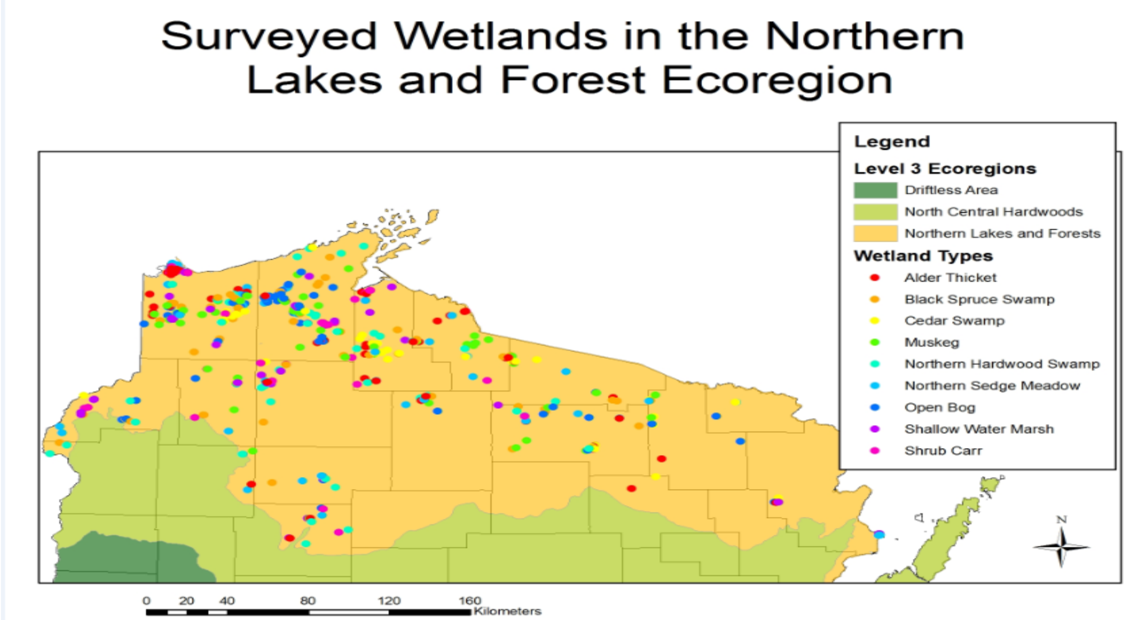
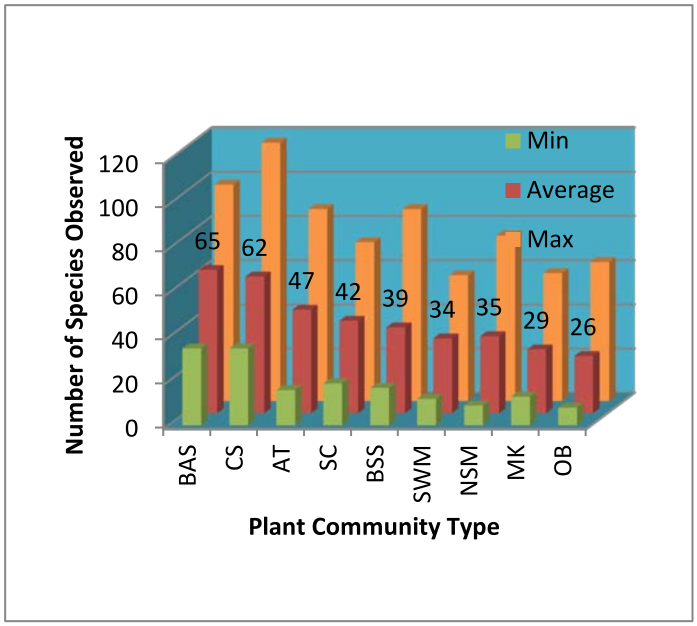


Figure 1: *Wetland Assessment in 507 wetlands 2012-2014*

Some forested swamp and bog communities exhibiting high levels of surrounding human disturbance were difficult to find throughout the NLF ecoregion. Among Muskeg, Open Bog, and White Cedar Swamp, only 8 of 170 surveyed sites had surrounding natural land cover below 60%. Apparently, substantial plant compositional changes occur when these sites are subject to human disturbance, resulting in species replacement towards wetland plant communities not meeting the community type definitions. We hypothesize that when these wetlands are degraded by hydrological or pH changes, these community types may experience declines of *Sphagnum* abundance accompanied by encroachment of *Alnus* and other shrubs, eventually developing not into a degraded coniferous forest or open bog, but instead to an Alder Thicket community. Based on our personal observations, the absence of Open Bog, Muskeg, and White Cedar Swamp with high levels of surrounding human disturbance was due to degradation of these communities into different plant communities entirely, including Alder Thicket, Shrub Carr, Northern Sedge Meadow, and Shallow Water Marsh.

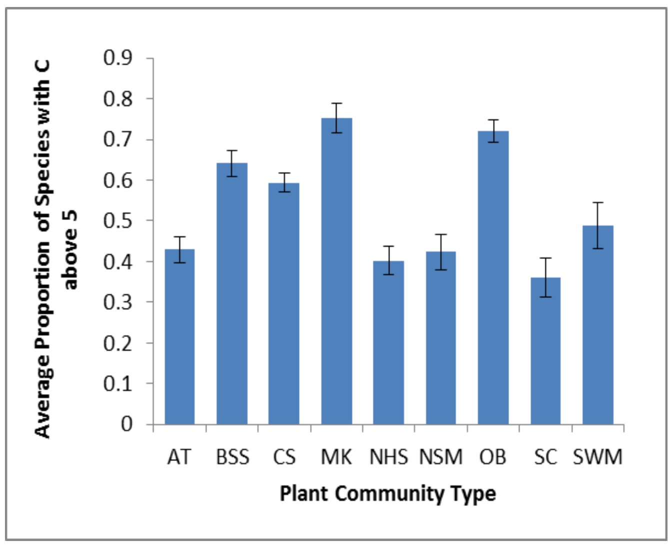
Figure 2. *Minimum, average, and maximum number of species observed per wetland site for nine plant community types.*



Compositional Patterns

Across all 507 wetland site surveys a total of 769 pecies were identified, with 350 species on 10 or more sites. This total represents about10% of the flora of Wisconsin. Minimum, maximum, and average species count for each wetland site by community type are depicted in Figure 2. These values represent native and non-native species combined. Northern Hardwood Swamps (65) and White Cedar Swamp (62) had the greatest average species richness, while Muskeg (29) and Open Bog (27) had the lowest average richness. Muskeg, Open Bog, and White Cedar Swamp had the highest numbers of species with C values ≥5 (Figure 3) indicating these communities tend to harbor a greater proportion of species that are habitat specialists. These species are among the first to disappear from sites following degradation of these swamp and bog communities as they change compositionally into shrub or emergent meadow communities. These latter communities are comprised by a greater proportion of species with C values ≤5, indicating a greater tendency towards habitat generalist and higher tolerance for anthropogenic disturbance.

Figure 3. *Average proportion of species per site with C value above 5. Error bars indicate 95% confidence interval.*



Total species richness values across all sites for each community type were highest for Northern Hardwoop Swamp (479) Alder Thicket (413) and White Cedar Swamp (380) (Figure 4). Northern Sedge meadows had a higher percentage of introduced species (23%) while the Open bogs had the lowest amount (13%). Muskeg (222), Open Bogs (250), and Shallow Water Marsh (306) had the lowest species richness and all had low numbers of introduced species.

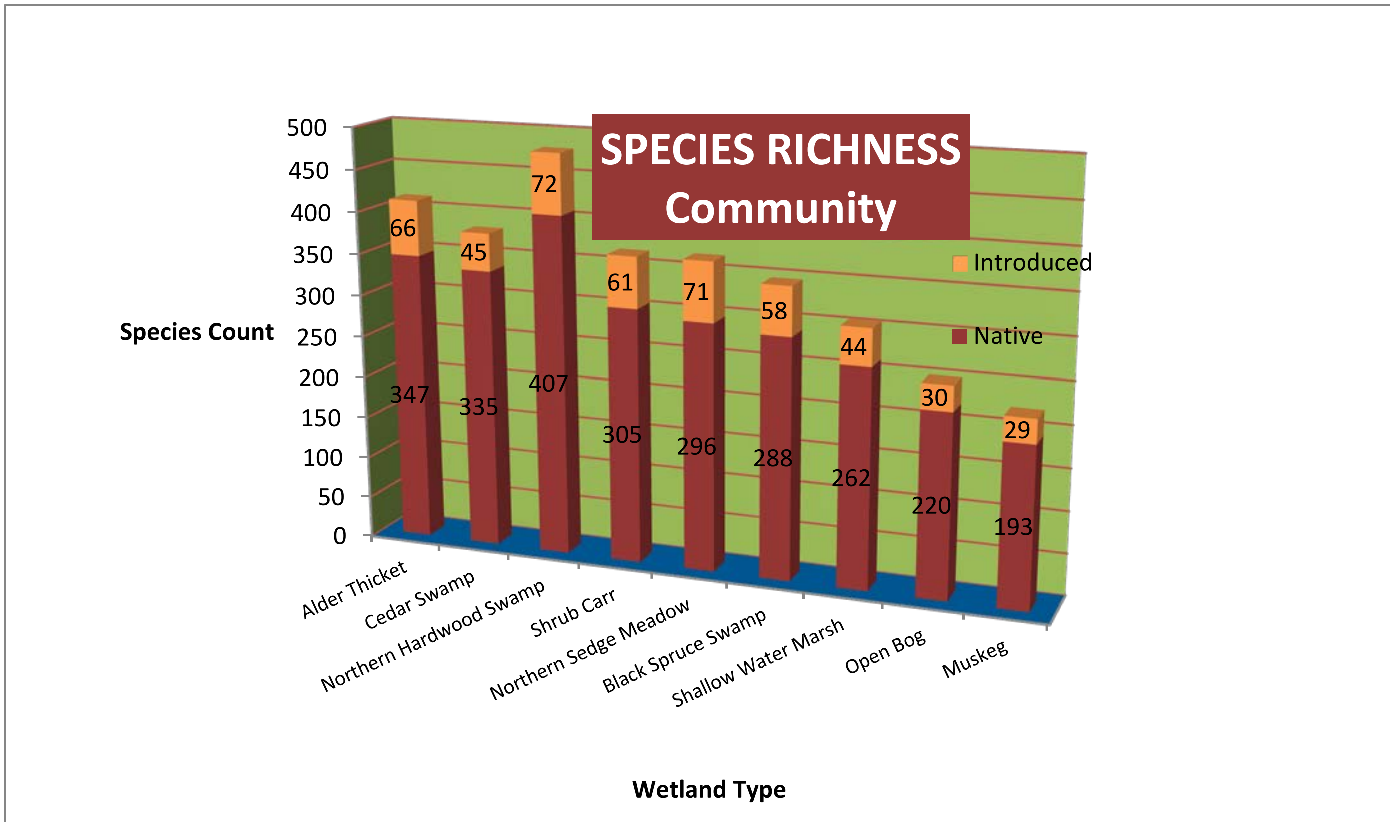


Figure 4. *Total number of native and invasive species recorded across all survey sites for nine plant community types.*

In the NMDS, a 2-dimensional solution was preferred (Figure 5). The first axis was interpreted as primarily a gradient in soil pH and *Sphagnum*-dominated wetlands, whereas the second axis was interpreted as primarily a gradient in tree cover. Some plant communities (i.e. Alder Thicket, Open Bog, Black Spruce Swamp, and White Cedar Swamp) had sharply distinctive

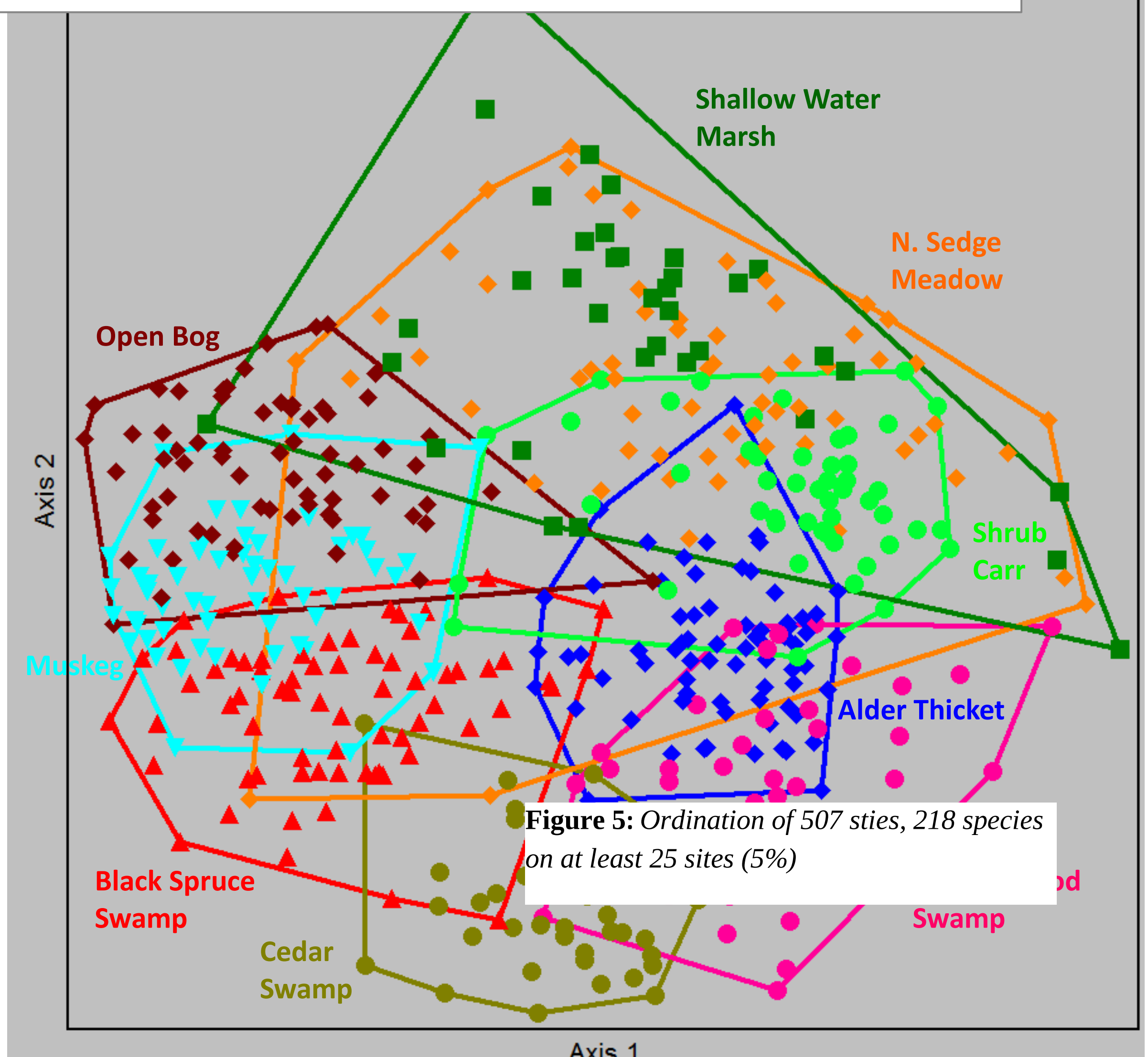


Figure 5: *Ordination of 507 sties, 218 species on at least 25 sites (5%)*

community composition as judged by discrete clouds of points in the ordination. Other communities were less distinct. Muskeg was intermediate between Black Spruce Swamp and Open Bog; this result is perhaps unsurprising because the defining feature of Muskeg is intermediate tree density. Northern Sedge Meadow and Shallow Water Marsh had a fair amount of overlap in community composition, likely due to high shared abundance levels of some open water emergent and floating leaf species (esp. *Sparganium* spp., *Nuphar variegata*, *Brasenia schreberi*, among others) in these communities. Northern Hardwood Swamp and Alder Thicket shared many of the same understory species, resulting in a fair amount of overlap in these communities. We used the generally distinctive patterns of community separation in ordination space as justification for calculating separate benchmarks for each wetland community type. However, there may be justification for combining some of the overlapping communities in future work.

Relationships between Floristic Quality Metrics and Human Disturbances

Metrics based on mean C were more tightly linked to human disturbance than FQI metrics (Appendix VI). In regressions of mean C and weighted mean C versus the habitat quality code score as a measure of human disturbance, 9 of 9 plant communities showed statistically significantly decreasing floristic quality with increasing disturbance. Using FQI and weighted FQI, 6 of 9 plant communities showed significantly decreasing floristic quality. These results indicate the metrics based on C values have more power to discriminate sites along this disturbance gradient.

When the amount of natural land cover in a surrounding 300-m buffer was used as a measure of human disturbance, there were fewer strong relationships with floristic quality (Appendix VI), likely due to the extreme shortness of the disturbance gradient for White Cedar Swamp, Muskeg and Open Bog, where only 8 of a combined 170 sites in these wetlands had natural land cover less than 60% .

Based on the results of the regression analysis with the data collected here, we recommend using mean C and weighted mean C as the most appropriate measures of floristic quality that can discriminate sites along a gradient of human disturbance. For the disturbance gradient, we recommend using the habitat quality code from the disturbance factor checklist. Future refinements of land cover data that better reflect on-the-ground wetland disturbances may make this GIS-based approach more appealing.

Open Bog and Muskeg sites at the low end of the disturbance gradient had the highest mean C values (approximately 7-8), followed by Black Spruce Swamps (approximately 7). There were similar results for weighted mean C, except that White Cedar Swamp sites also had average values in the 7-8 range. Degraded sites with habitat quality code of 5-6 had the lowest mean C scores, typically about 2-3 in Alder Thicket, Northern Sedge Meadow, Shallow Water Marsh and Shrub Carr. These three of these four plant community types also had the best distribution of sites across the entire disturbance gradient. Shrub Carr had the most uniformly low mean C values across this gradient. Across the nine plant community types,, the slope coefficient ranged between -0.18 (Shrub Carr) and -0.68 (Northern Sedge Meadow), indicating that for every increase of 1 in the habitat quality code score, mean C experienced an average drop between -0.18 and -0.68. Using this line of reasoning, we can say floristic quality in Northern Sedge Meadow dropped 4 times more sharply with increasing disturbance gradients than it did for Shrub Carr.

Condition Tier Benchmarks

Benchmarks of mean C and weighted mean C for the condition tiers are presented in Tables 2-5. Here, we provide a brief overview and interpretation of some of the main patterns of benchmark values. The white cedar swamps, muskegs and bogs, representing <15% of the wetlands in the Northern Lakes and Forests Ecoregion are represented in only condition Tiers 1, 2, and 3 at the least-disturbed end of the gradient. Based on our analysis, Open Bog and Muskeg have the highest benchmark values among wetland communities in the region.

Table 2 *Mean C benchmarks for condition tiers defined by values of disturbance factor checklist.*

LSB + NFL	Condition Tiers Defined by 2012-2014 Disturbance Factor Checklist				
Plant community type	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Alder Thicket	>5.8	4.8-5.8	4.0-4.8	3.6-4.0	<3.6
Northern Hardwood Swamp	>5.4	4.6-5.4	4.3-4.6	3.6-4.3	<3.6
Black Spruce Swamp	>7.2	6.5-7.2	5.8-6.5	5.0-5.8	<5.0
Cedar Swamp	>6.4	5.6-6.4	<5.6		
Muskeg	>8.0	6.7-8.0	<6.7		
Northern Sedge Meadow	>6.1	5.1-6.1	3.3-5.1	2.3-3.3	<2.3
Open Bog	>7.9	7.0-7.9	<7.0		
Shallow Water Marsh	>6.1	5.1-6.1	4.3-5.1	3.2-4.3	<3.2
Shrub Carr		>4.9	4.2-4.9	3.4-4.9	<3.4

Conversely, the scrub shrub communities of Alder Thicket and Shrub Carr had representation across most condition tiers, being especially well represented in Tier 3 – Tier 5 along the most-disturbed end of the gradient. These plant communities tended to have lower benchmark scores in the upper condition tiers than bogs and swamps. Alder Thicket, Shrub Carr, Northern Sedge Meadow were commonly found in disturbed areas, while representing the largest percentage (XX%) of wetland areas in the Northern Lakes and Forests Ecoregion . Among all plant communities, Northern Sedge Meadow had the steepest decrease of mean C with increasing human disturbance, which led to the greatest difference in benchmark scores between upper and lower condition tiers. Northern Sedge Meadow communities were commonly degraded with frequent mowing, hydrological alterations, and invasive plant species encroachment; more so than any other community.

Table 3. *Mean C benchmarks for condition tiers defined by values of surrounding natural land cover.*

LSB + NFL	Condition Tiers Defined by 2012-2014 NCLD 2006				
Plant community type	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Alder Thicket	>6.1	5.0-6.1	4.6-5.0	4.0-4.6	<4.0
Northern Hardwood Swamp		>5.5	4.9-5.5	3.8-4.9	<3.8
Black Spruce Swamp	>7.1	6.2-7.1	6.0-6.2	5.3-6.0	<5.3
Cedar Swamp	>6.4	5.8-6.4	<5.8		
Muskeg	>8.5	6.6-8.5	<6.6		
Northern Sedge Meadow	>6.1	4.9-6.1	4.1-4.9	2.6-4.1	<2.6
Open Bog	>8.0	6.9-8.0	<6.9		
Shallow Water Marsh	>6.1	5.2-6.1	4.6-5.2	3.2-4.6	<3.2
Shrub Carr	>4.9	4.6-4.9	4.2-4.6	3.4-4.2	<3.4

There are minor differences of benchmark values in the condition tiers when the least- and most-disturbed wetland classes were defined using surrounding land cover instead of the field disturbance factor checklist. Comparing the values in Table 2 with Table 3 shows that the two methods yielded benchmarks within 0.10 for most wetlands. The largest appreciable difference in benchmark values occurred for Muskeg and Alder Thickets in Condition Tier 1 with differences of 0.5 and 0.3 respectively. Small differences in benchmark values between the two methods suggests that either approach may be valid, although we recommend using the disturbance factor checklist because it yields sites more widely spanning the disturbance gradient, as discussed earlier.

We provided benchmark values of mean C and weighted mean C for comparison within this study and across other earlier studies that have primarily used mean C. In practice, we recommend benchmarks developed with weighted mean C because this approach incorporates proportional abundance. This may be especially important for wetlands that have become dominated by invasive species yet still have a fair number of native species at lower abundances. In these cases, weighted mean C will yield a score that gives greater weight to the proportional abundance of the invasive and will therefore be lower than mean C.

Table 4. *Weighted mean C benchmarks for condition tiers defined by values of disturbance factor checklist.*

LSB + NFL	Condition Tiers Defined by 2012-2014 Disturbance Factor Checklist				
Plant community type	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Alder Thicket	>5.3	4.5-5.3	4.1-4.5	3.8-4.1	<3.8
Northern Hardwood Swamp	>6.2	5.7-6.2	3.9-5.7	2.5-3.9	<2.5
Black Spruce Swamp	>7.9	7.4-7.9	6.7-7.4	5.7-6.7	<5.7
Cedar Swamp	>7.4	6.9-7.4	<6.9		
Muskeg	>8.5	7.9-8.5	<7.9		
Northern Sedge Meadow	>7.1	5.2-7.1	3.5-5.2	<3.5	
Open Bog	>8.9	8.0-8.9	<8.0		
Shallow Water Marsh	>7.1	5.2-7.1	2.8-5.2	<2.8	<.71
Shrub Carr			>5.1	3.9-5.1	<3.9

In practice, using weighted mean C yielded benchmarks within about 0.5 units of benchmarks from mean C. For Condition Tier 1, across all plant community types benchmarks of weighted mean C were higher for 6 of 7 communities (average difference + 0.9). At other condition tiers, the results were more variable, with no consistent upward or downward differences.

The benchmarks developed herein should be used only for the Northern Lakes and Forests Ecoregion in Wisconsin for monitoring and on-going wetland assessment projects. For statewide benchmarks, future efforts and research should include a wider set of wetlands that encompass more urban and agricultural activities for the more southern ecoregions of Wisconsin.

Table 5. *Weighted mean C benchmarks for condition tiers defined b values of surrounding natural land cover*

LSB + NFL	Condition Tiers Defined by 2012-2014 NCLD 2006				
Plant community type	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Alder Thicket	>5.5	4.6-5.5	4.5-4.6	4.0-4.6	<4.0
Northern Hardwood Swamp		>6.2	5.9-6.2	3.6-5.9	<3.6
Black Spruce Swamp	>7.8	7.0-7.8	6.4-7.0	5.5-6.4	<5.5
Cedar Swamp	>7.4	6.9-7.4	<6.9		
Muskeg	>8.5	7.8-8.5	<7.8		
Northern Sedge Meadow	>6.8	5.2-6.8	4.6-5.2	<4.6	
Open Bog	>8.9	8.1-8.9	<8.1		
Shallow Water Marsh	>7.1	5.0-7.1	4.7-5.0	<4.7	
Shrub Carr			>5.1	4.2-5.1	<4.2

LITERATURE CITED

Bernthal, T. W. (2003). *Development of a floristic quality assessment methodology for Wisconsin* (No. #CD975115-01-0). Madison, WI: Wisconsin Department of Natural Resources. http://dnr.wi.gov/wetlands/methods.html Accessed August 8, 2011.

Bernthal, T.W., J. Kline and A. Reis (2007). *Floristic quality assessment benchmarks for wetlands in southeast Wisconsin.* (No. #CD96511801). Madison, WI: Wisconsin Department of Natural Resources.

Bourdaghs, M. (2012). *Development of a rapid floristic quality assessment*, St. Paul, MN, USA Minnesota Pollution Control Agency.

Bourdaghs, M., C. A. Johnston and R. R. Regal (2006). Properties and performance of the floristic quality index in Great Lakes coastal wetlands. *Wetlands* 26(3):718-735.

Cohen, M.J. , S. Carsteen and C.R. Lane (2004). Floristic quality indices for biotic assessment of depressional marsh condition in Florida *Ecological Applications*, 14(3): 784-794.

Dahl, T. E. (1990). *Wetland losses in the United States 1780's to 1980's*. Washington, DC, USA U.S. Fish and Wildlife Service.

Dahl, T. E. (2000). *Status and trends of wetlands in the conterminous United States 1986 to 1997*. Washington, DC, USA U.S. Fish and Wildlife Service.

Dahl, T. E. and C. E. Johnson (1991). *Status and trends of wetlands in the conterminous United States, mid-1970's to mid-1980's.* Washington, DC, USA U.S. Fish and Wildlife Service.

Danz, N.P., G.J. Niemi, R.R. Regal, T. Hollenhorst, L.B. Johnson, J.M. Hanowski, R.P. Axler, J. H. Ciborowski, T. Hrabik, V.J. Brady, J.R. Kelly, J.A. Morrice, J.C. Brazner, R.W. Howe, C.A. Johnston and G.E. Host (2007). Integrated measures of anthropogenic stress in the U.S. Great Lakes Basin. *Environmental Management* (2007)39:631–647.

Danz, N.P., R.R. Regal, G.J. Niemi, V.J. Brady, T. Hollenhorst, L.B. Johnson, G.E. Host, J.M. Hanowki, C.A. Johnston, T. Brown, J. Kingston and J.R. Kelly (2005). Environmentally stratified sampling design for the development of great lakes environmental indicators. *Environmental Monitoring and Assessment* 102:41–65.

Epstein, E.J., E.J. Judziewicz and W.A Smith (1997). *Priority wetland sites of Wisconsin's Lake Superior Basin.* (PUB ER-096 99). Madison, WI: Wisconsin Department of Natural Resources.

Frayer, W. E., T. J. Monahan, D. C. Bowden and F. A. Graybill (1983). *Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's.* Fort Collins, CO, USA Colorado State University.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.

Goff, F.G., G. Dawson and J. Rochow (1982). Site examination for threatened and endangered plant species. *Environmental Management* 6(4):307-316.

Herman, K.D., L.A. Masters, M.R. Penskar, A.A. Reznicek, G.S. Wilhelm, W.W. Brodovich and K.P. Gardiner (2001). *Floristic quality assessment with wetland categories and examples of computer applications for the State of Michigan.* Lansing, MI, Michigan Department of Natural Resources.

Hlina, P.S. and D.S. Anderson (2011). Wetland assessment and inventory of the Pokegama Carnegie Wetland state natural area, Douglas County, Wisconsin. *Michigan Botanist* 50(1):2-25.

Hlina, P.S., D.S. Anderson and K. Nummi (2011). *Comparing wetland sampling methods for floristic quality assessment in Superior, Wisconsin.* Publication filed with Wisconsin Department of Natural Resources, Grant #QMJ00000814.

Hlina, P.S. N.P. Danz and K. Prihoda, (2012) *Standard Operating Procedure – Timed-meander sampling protocol for forested and non-forested wetland floristic quality assessment* - Lake Superior Research Institute, SOP-FS/27.

Host, G.E., T.N. Brown, T.P. Hollenhorst, L.B. Johnson, J.J.H. Ciborowski (2011). High-resolution assessment and visualization of environmental stressors in the Lake Superior basin.

Johnston, C.A., B.L. Bedford, M. Bourdaghs, T. Brown, C. Frieswyk, M. Tulbure, L. Vaccaro and J.B. Zedler (2007). Plant species indicators of physical environment in Great Lakes coastal wetlands. *Journal of Great Lakes Research* 33(sp3):106-124.

Johnston, C.A., J.B. Zedler and M.G. Tulbure (2010). Latitudinal gradient of floristic condition among Great Lakes coastal wetlands. *Journal of Great Lakes Research* 36(4), 772-779.

Lopez, R.D. and M.S. Fennessy (2002). Testing the floristic quality assessment index as an indicator of wetland condition *Ecological Applications, 12(2). 487-497.*

Mack, J. J. (2004). *Integrated wetland assessment program. Part 4: Vegetation index of biotic integrity (vibi) and tiered aquatic life uses (talus) for Ohio wetlands.* Ohio EPA Technical Report WET/2004-4. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

McCune, B. and M. J. Mefford. 2011. PC-ORD. Multivariate Analysis of Ecological Data. Version 6.0 MjM Software, Gleneden Beach, Oregon, U.S.A.

Rooney, T.P. and D.A. Rogers (2002). The modified floristic quality index. *Natural Areas Journal 22:340-344.*

Swink, F.A. and G.S. Wilhelm (1994). *Plants of the Chicago Region, fourth edition*. Morton Arboretuem, Lisle, IL.

Tiner, R.W. (2005). Assessing cumulative loss of wetland functions in the Nanticoke River watershed using enhanced national wetlands inventory data. *Wetlands* 25(2):405-419.

U.S. Census Bureau. 2012. TIGER/Line Shapfiles [machine-readabe data files]/ prepared by the U.S. Census Bureau, 2012. [http://www.census.gov/geo/maps-data/data/tiger-line.html]

United States Environmental Protection Agency, Office of Environmental Information. 2002. Guidance for Quality Assurance Project Plans, EPA QA/G-5. EPA/240/R-02/009, December 2002, 111 pgs.

United States Environmental Protection Agency. 2005. DRAFT: Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards: Tiered Aquatic Life Uses.

Voss, E.G. and A.A. Reznicek (2012). Field Manual of Michigan Flora. University of Michigan Press, Ann Arbor, pp. 1008.

Wilcox, J.C., T. Bernthal, P. Trochlell and J. Kline. Improving Wisconsin's Wetland Compensatory Mitigation Program: Factors Influencing Floristic Quality and Methods for Monitoring Wildlife. *Final Report to USEPA, Region V Wetland Grant No. CD 00E9901.* Wisconsin Department of Natural Resources.

Wisconsin Department of Natural Resources, (1984 -2013). Wisconsin Wetland Inventory,, http://dnrmaps.wi.gov/sl/?Viewer=SWDV

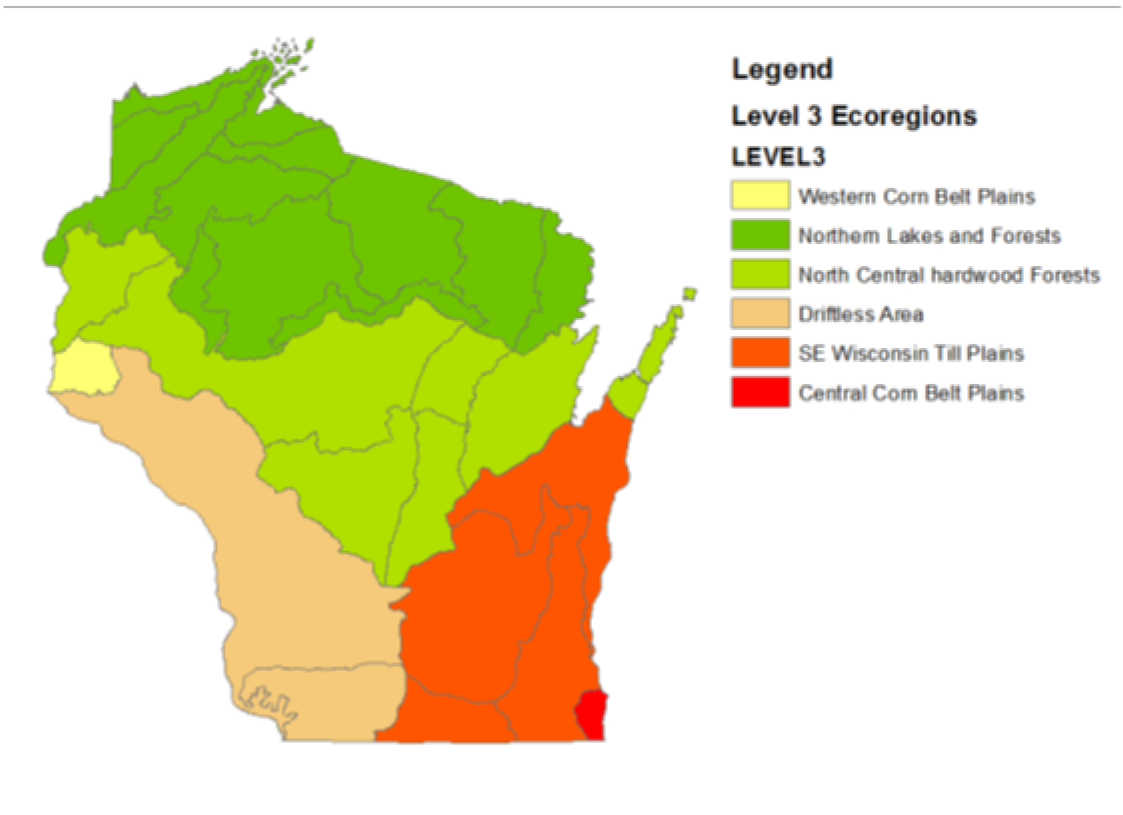
Wisconsin Department of Natural Resources (updated 2012). Ecological Landscapes of Wisconsin Handbook. Available on WDNR website http://dnr.wi.gov/topic/landscapes/Handbook.html.

Appendix I. Omernik Level III and IV Region Description

Northern Lakes and Forests

The Northern Lakes and Forests (50) is an ecoregion of relatively nutrient poor glacial soils, coniferous and northern hardwoods forests, undulating till plains, morainal hills, broad lacustrine basins, and areas of extensive sandy outwash plains. Soils are formed primarily from sandy and loamy glacial drift material and generally lack the arability of those in adjacent ecoregions to the south. Ecoregion 50 also has lower annual temperatures and a frost-free period that is
considerably shorter than other ecoregions in Wisconsin. These conditions generally hinder agriculture; therefore, woodland and forest are the predominant land use/land cover. The numerous lakes that dot the landscape are clearer, at a lower trophic state (mostly oligotrophic to mesotrophic with few eutrophic lakes), and less productive than those in ecoregions to the south. Streams of ecoregion 50 are mostly perennial, originating in lakes and wetlands; however, stream density is relatively low compared to ecoregions to the south. The Northern Lakes and Forests region is the only ecoregion in Wisconsin where acid sensitive lakes are found. Portions of the southern boundary of ecoregion 50 roughly correspond to the southernmost extent of lakes with alkalinity values less than 400 meq/l (Omernik and Griffith 1986).

OMERNIK LEVEL III ECOREGIONS FOR WISCONSIN



Appendix II. Nine wetland plant communities for which benchmarks were developed.

Forested wetland communities

Black Spruce Swamp (BSS): An acidic conifer swamp forest characterized by a relatively closed canopy (i.e., larger than 20' tall and greater than 30% cover) of black spruce (*Picea mariana*) and tamarack (*Larix larcina)* with an understory in which Labrador-tea (*Ledum groenlandicum*) and sphagnum mosses (*Sphagnum spp*.) are often prominent, along with three-leaved false Solomon's-seal (*Maianthemum trifolia*), creeping snowberry (*Gaultheria hispudula*), and three-seeded sedge (*Carex trisperma*). The herbaceous understory is otherwise relatively depauperate. This community is closely related to Open Bogs and Muskegs, and sometimes referred to as Forested Bogs outside of Wisconsin.

Northern Hardwood Swamps: These are northern deciduous forested wetlands that occur along lakes or streams, or in insular basins in poorly drained morainal landscapes. The dominant tree species is black ash (*Fraxinus nigra*), but in some stands red maple (*Acer rubrum*), yellow birch (*Betula allegheniensis*) (and formerly) American elm (*Ulmus americana*) are also important. The tall shrub speckled alder (*Alnus incana*) may be locally common. The herbaceous flora is often diverse and may include many of the sample species found in alder thickets. Typical species are marsh-marigold (*Caltha palustris*), swamp raspberry (*Rubus pubescens*), skull cap *(Scutellaria galericulata*), orange jewelweed (*Impatiens capensis*) and the greatest diversity of sedges (*Carex spp.*) of all wetland types. Soils may be mucks or mucky sands.

White Cedar Swamp (CS): This forested minerotrophic wetland is dominated by white cedar (*Thuja occidentalis*) and occurs on rich, neutral to alkaline substrates. Balsam fir (*Abies balsamea*), black ash (*Fraxinus nigra*), and spruces (*Picea glauca* and *P. mariana*) are among the many potential canopy associates. The understory is rich in sedges (i.e., *Carex disperma* and *C. trisperma*), orchids (e.g., *Platanthera obtusata* and *Listera cordata*), and wildflowers such as gold thread (*Coptis trifolia*), fringed polygala (*Polygala pauciflora*), and naked miterwort (*Mitella nuda*), and trailing sub-shrubs such as twinflower (*Linnaea borealis*) and creeping snowberry (*Gaultheria hispidula*). A number of rare plants occur more frequently in the cedar swamps than in any other habitat.

Wetland plant communities dominated by woody shrubs

Scrub Shrub: **Alder Thicket (AT)**: Deciduous shrub community excluding bog birch; sphagnum moss mat layer absent. *Alnus incana* is dominant (greater than 50% shrub canopy layer). **Shrub Carr (SC)**: Deciduous shrub community excluding bog birch; sphagnum moss mat layer absent. Willow species dominant (i.e., *Salix petiolaris*, *S. discolor*, *S. pyrifoila*), with *Cornus stolonifera* and *Spiraea alba* often present. The forb layer is very similar to the northern sedge meadow.

Muskeg (MK): These weakly minerotrophic conifer swamps are dominated by black spruce (*Picea mariana)* and tamarack (*Larix larcina)* representing more than 30% of the cover and less than 20' tall. Jack pine (*Pinus banksiana*) may be a significant canopy component in certain parts of the range of this community complex. Understories are composed mostly of sphagnum mosses (*Sphagnum spp.*) and ericaceous shrubs such as leatherleaf (*Chamaedaphne calyculata*), Labrador-tea (*Ledum groenlandicum*), and small cranberry (*Vaccinium oxycoccos*) and sedges such as (*Carex trisperma* and *C. magellanica*).

Appendix II. cont... Nine wetland plant communities for which benchmarks were developed.

Open Bog (OB): Low ericaceous shrubs leatherleaf (*Chamaedaphne calyculata*), bog rosemary (*Andromeda glaucophylla),* bog laurel (*Kalmia polifolia)* or graminoid dominated community on a mat of Sphagnum moss/acidic deep peat. Specialized acid tolerant (indicator) species dominant (i.e., *Carex lasiocarpa*, *C.*

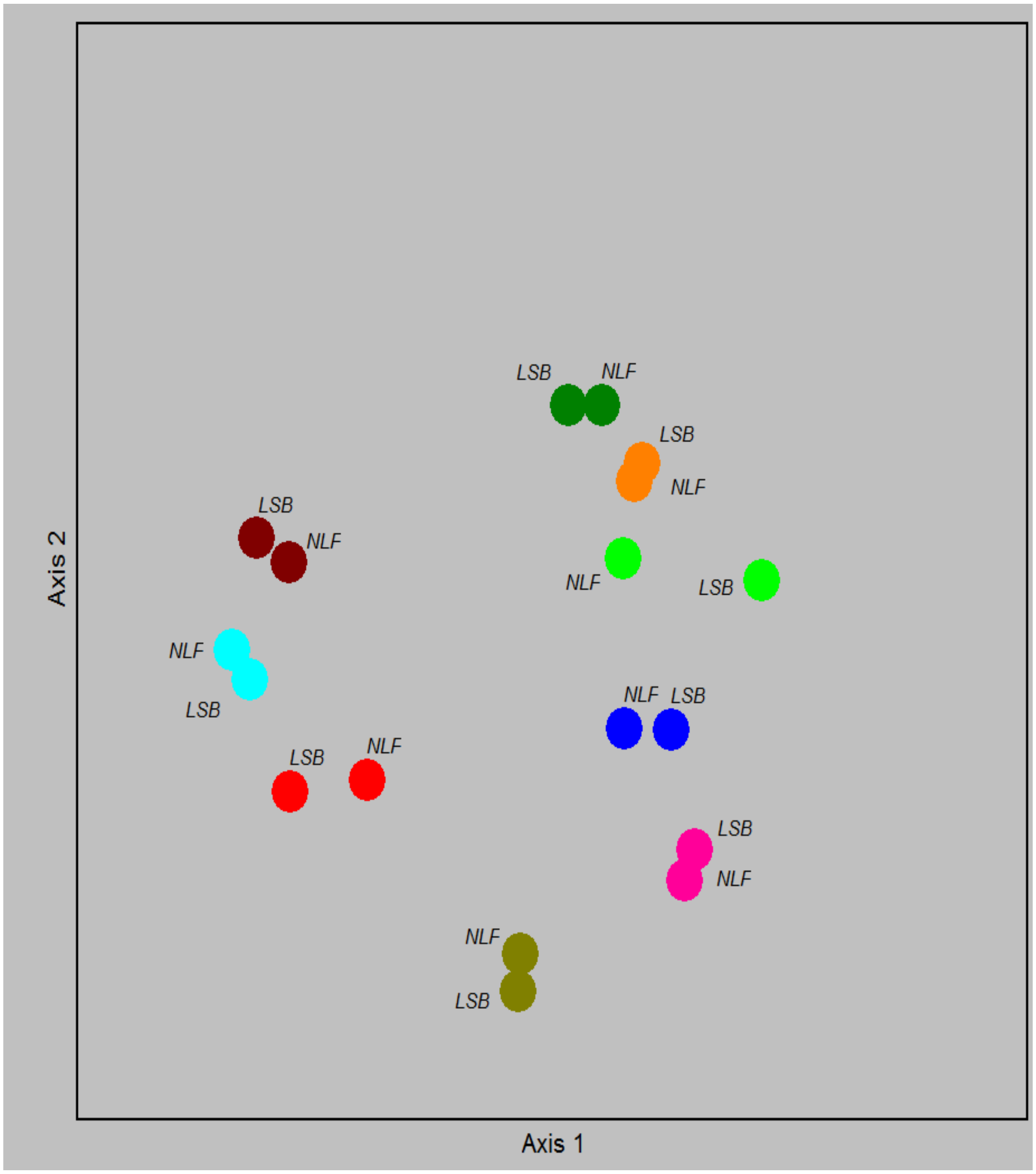
oligosperma, *C. magellanica*). We lumped the open bog and northern poor fen as one type as species compostion closely corresponds to one another. **Northern Poor Fen**: This acidic, weakly minerotrophic peatland type is similar to the Open Bog, but can be differentiated by higher Ph, nutrient availability, and floristics. Sphagnum (Sphagnum spp.) mosses are common but don't typically occur in deep layers with pronounced hummocks. Floristic diversity is higher than in the Open Bog and may include white beak-rush(*Rhynchospora alba*), pitcher-plant (*Sarracenia purpurea)*, sundews (*Drosera spp.*), pod grass *(Scheuchzeria palustris*), and the pink-flowered orchids (*Calopogon tuberosus*, *Pogonia ophioglossoides* and *Arethusa bulbosa*). Common sedges are *(Carex oligosperma*, *C. limosa*, *C. lasiocarpa*, *C. chordorrhiza)*, and cotton-grasses (*Eriophorum spp.*)

Wetland plant communities dominated by herbaceous plants

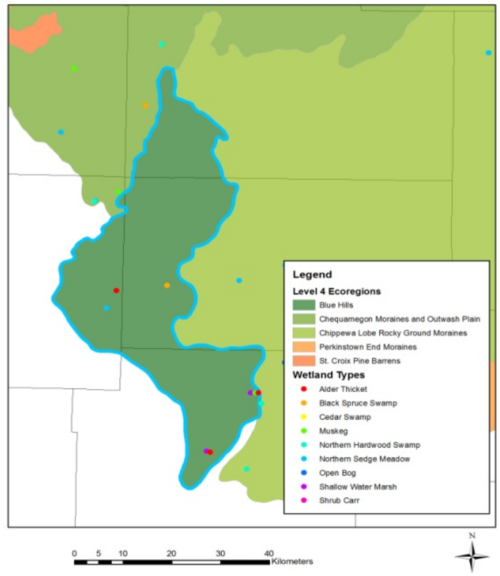
Northern Sedge Meadow (NSM): Sphagnum moss mat absent; dominant vegetation consists of graminoids. Soils are usually neutral to alkaline, poorly-drained mineral soils and mucks. Over 50% of the cover dominance contributed by sedges or grasses, especially *Carex lacustris*, *Carex stricta* and/or *Calamagrostis canadensis*. Emergent plants growing on saturated soils to areas inundated by standing water up to 6 inches in depth throughout most of the growing season. Characteristic forbs include *Eupatorium maculatum*, *Aster umbellatus*, *Solidago gigantea*, *Impatiens capensis*, etc.

Shallow Water Marsh (SWM): These open, marsh, lake, riverine and estuarine communities with permanent standing water are dominated by robust emergent macrophytes, in pure stands of single species or in various mixtures. Dominants include cattails *(Typha spp.)*, bulrushes (particularly *Schoenoplectus tabermontani S. acutus*, and *Bolboschoenus fluviatilis*), bur-reeds (*Sparganium spp.*), giant reed (*Phragmites australis* subsp. *americanus*), pickerel-weed (*Pontederia cordata*), water-plantains *(Alisma spp.)*, arrowheads (*Sagittaria spp.*), and the larger species of spikerush such as *(Eleocharis palustris)*

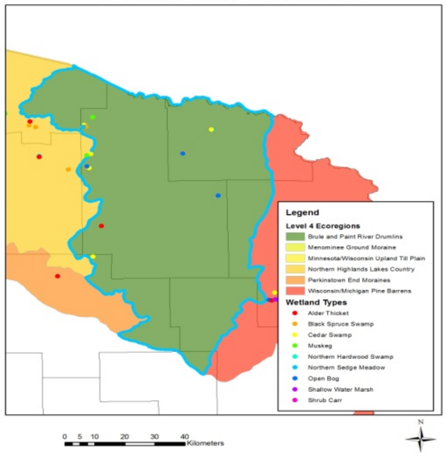
Appendix III. NMDS Ordination, 507 sites and 218 species on at least 25 sites (5%). This plot has centroids for each community type for each region (LSB = Lake Superior Basin, NLF = Northern Lakes and Forests).



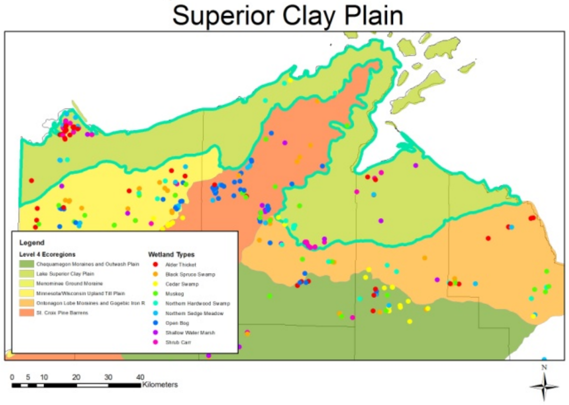
Surveyed Wetlands of the Blue Hills



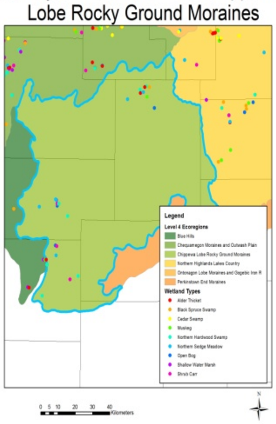
Surveyed Wetlands in the Brule and Paint River Drumlins



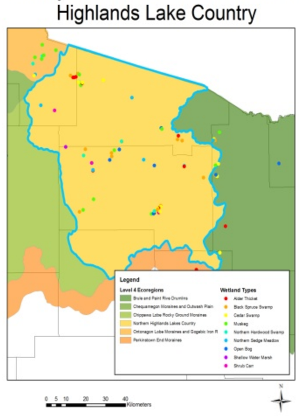
Surveyed Wetlands in the Lake Superior Clay Plain



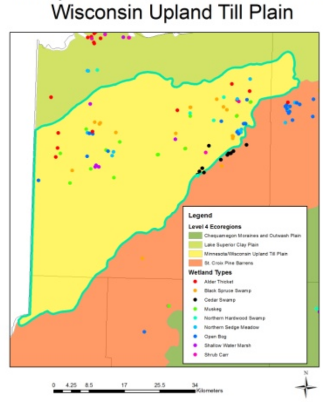
Surveyed Wetlands in the Chippewa Lobe Rocky Ground Moraines



Surveyed Wetlands in the Northern Highlands Lake Country

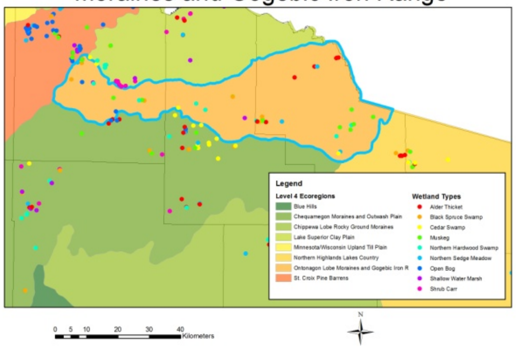


Surveyed Wetlands in the Minnesota/ Wisconsin Upland Till Plain

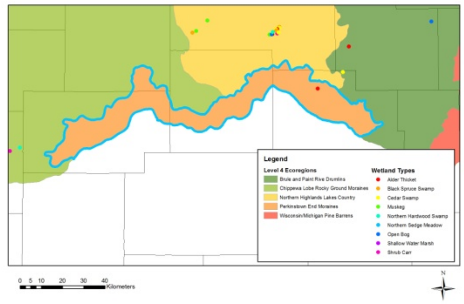


Appendix IV cont: Omernik Level IV – Northern Lakes and Forests

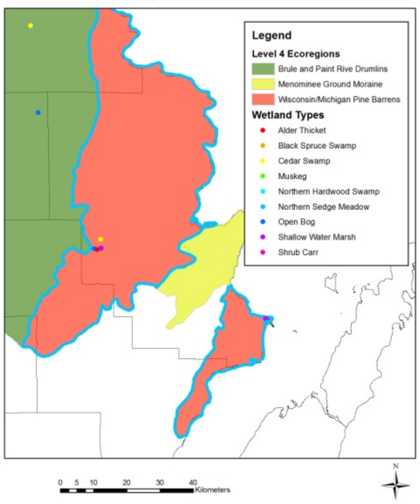
Surveyed Wetlands in the Ontonagon Lobe Moraines and Gogebic Iron Range



Surveyed Wetlands in the Perkinstown End Moraines



Surveyed Wetlands in the Wisconsin/ Michigan Pine Barrens



Appendix V. Disturbance Factors Field Checklist (page 1).

Wisconsin Floristic Quality Assessment for Wetlands
Bureau of Integrated Science Services
Northwest Region, Lake Superior Basin

Disturbance Factors Field Checklist Form – WFQAF06

Site Location Information			
Site Name:	**County:**		**PLSS: T___N R___E/W Sec___, ___1/4___1/4**
Date: **Observer:**	**X, Y Coordinates:**		**Coordinate System:**
Hydro & Habitat Alteration:	**Feature**	**Presence**	**Alteration Intensity**
Is there hydrological or habitat alteration present at the site? Check the box if present. Circle low, medium or high to indicate the intensity of alteration. Circle only one.	Ditch	□Present □ None	Low Medium High
	Tile	□Present □ None	Low Medium High
	Dike	□Present □ None	Low Medium High
	Weir	□Present □ None	Low Medium High
	StormH20 input	□Present □ None	Low Medium High
	Filling/grading	□Present □ None	Low Medium High
	Road/RR	□Present □ None	Low Medium High
	Dredging	□Present □ None	Low Medium High
	Mowing/Grazing	□Present □ None	Low Medium High
	Clear cut	□Present □ None	Low Medium High
	Selective cut	□Present □ None	Low Medium High
	Herb removal	□Present □ None	Low Medium High
	Sedimentation	□Present □ None	Low Medium High
	Plowing/Other Ag.	□Present □ None	Low Medium High
	Eutrophication	□Present □ None	Low Medium High
	Motor vehicle use	□Present □ None	Low Medium High
	Other:		
Overall Disturbance: *Based on above selections, what is the overall disturbance level at the site? Select only one.*	□ (1) Non-disturbed □ (2) Minimal □ (3) Moderate □ (4) Major □ (5) Severe		
Tree Age Class: *What is the average age of the trees based on diameter at breast height? Select only one.*	□ Not applicable □ (1) Seedlings: < 2.5 cm □ (2) Saplings: 2.5-10cm □ (3) Middle-Age: 10-25 cm □ (4) Mature: >25 cm		

Appendix V. Disturbance Factors Field Checklist (page 2).

Wisconsin Floristic Quality Assessment for Wetlands
Bureau of Integrated Science Services
Northwest Region, Lake Superior Basin

Disturbance Factors Field Checklist Form – WFQAF06

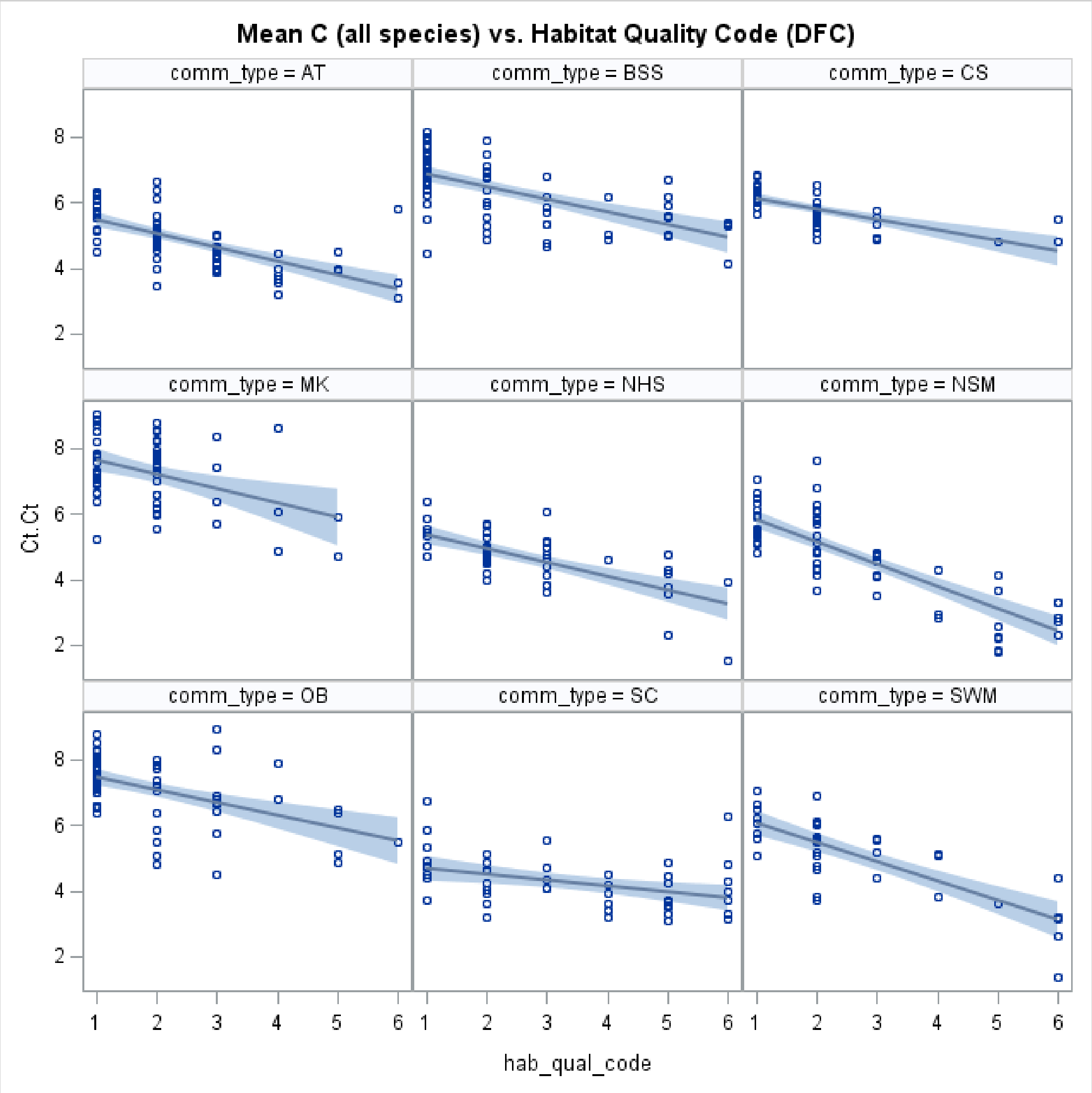
% Coverage Invasive Plants[1]: *Consider the entire site. List the invasive plants present at the site. What percent of the site is covered with invasive plants? Select only one coverage class for each plant listed.*	Invasive Plant 1:	□ (1) Absent: 0% aerial cover of invasive plants. □ (2) Present: 1-5% aerial cover of invasive plants. □ (3) Sparse: 5-25% aerial cover of invasive plants. □ (4) Medium: 25-50% aerial cover of invasive plants. □ (5) Extensive: >50% aerial cover of invasive plants.
	Invasive Plant 2:	□ (1) Absent: 0% aerial cover of invasive plants. □ (2) Present: 1-5% aerial cover of invasive plants. □ (3) Sparse: 5-25% aerial cover of invasive plants. □ (4) Medium: 25-50% aerial cover of invasive plants. □ (5) Extensive: >50% aerial cover of invasive plants.
	Invasive Plant 3:	□ (1) Absent: 0% aerial cover of invasive plants. □ (2) Present: 1-5% aerial cover of invasive plants. □ (3) Sparse: 5-25% aerial cover of invasive plants. □ (4) Medium: 25-50% aerial cover of invasive plants. □ (5) Extensive: >50% aerial cover of invasive plants.

[1]See the Wisconsin State Herbarium website for detailed information on invasive species: http://www.botany.wisc.edu/wisflora/

Habitat Quality Assessment: *Based on all the above selections, what is your Best Professional Judgment of site quality? Select only one.*	□ (1) Natural structure & function of biotic community maintained. □ (2) Minimal changes in structure & function. □ (3) Evident changes in structure & minimal changes in function. □ (4) Moderate changes in structure & minimal changes in function. □ (5) Major changes in structure & moderate changes in function. □ (6) Severe changes in structure & function.

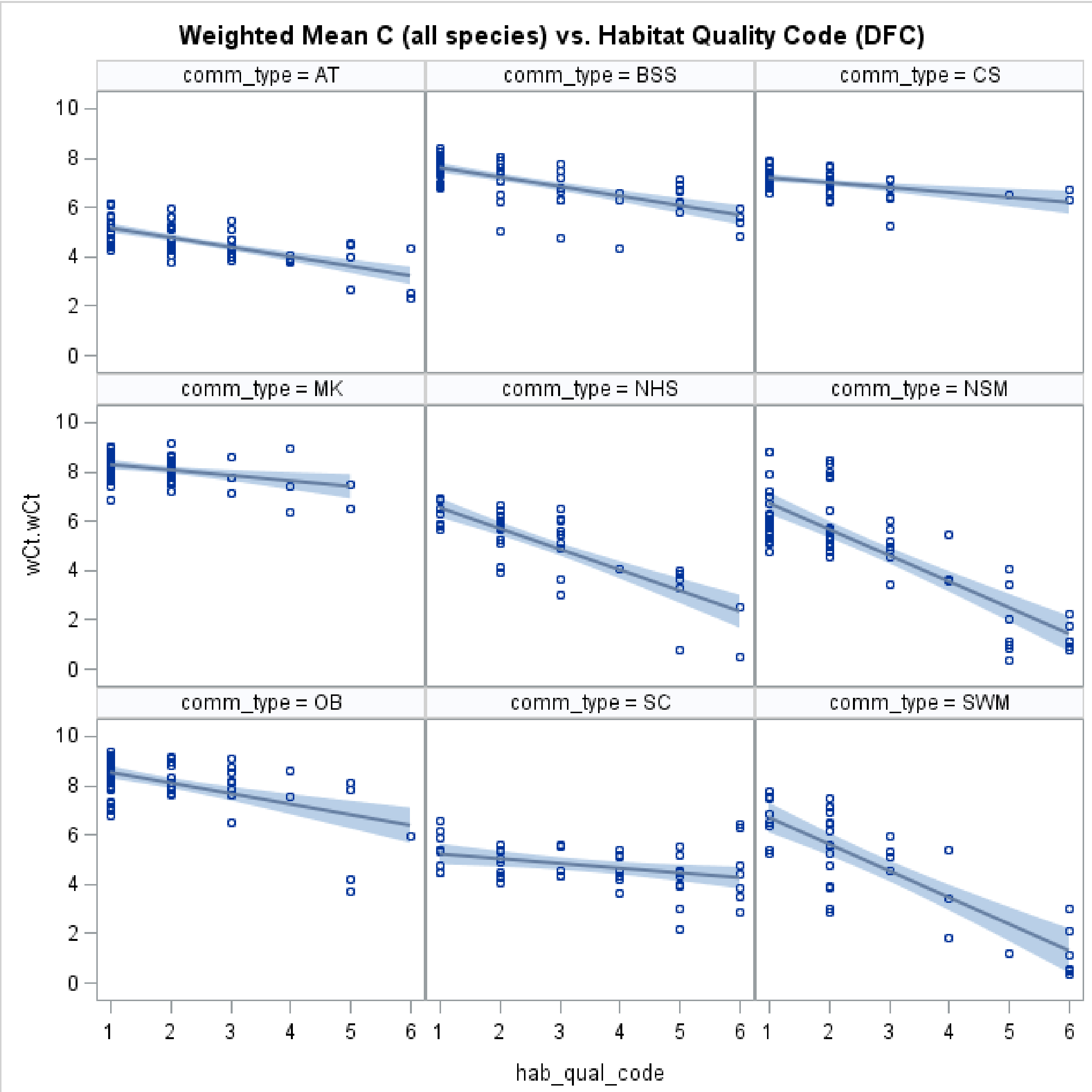
General Comments:

Appendix VI. Scatter plots of *mean C* versus habitat quality code for sites in nine wetland plant communities. The trend line is a simple linear regression, while the shading indicates the 95% confidence interval for the line. Regression statistics are included in the accompanying table. $\bar{C}$



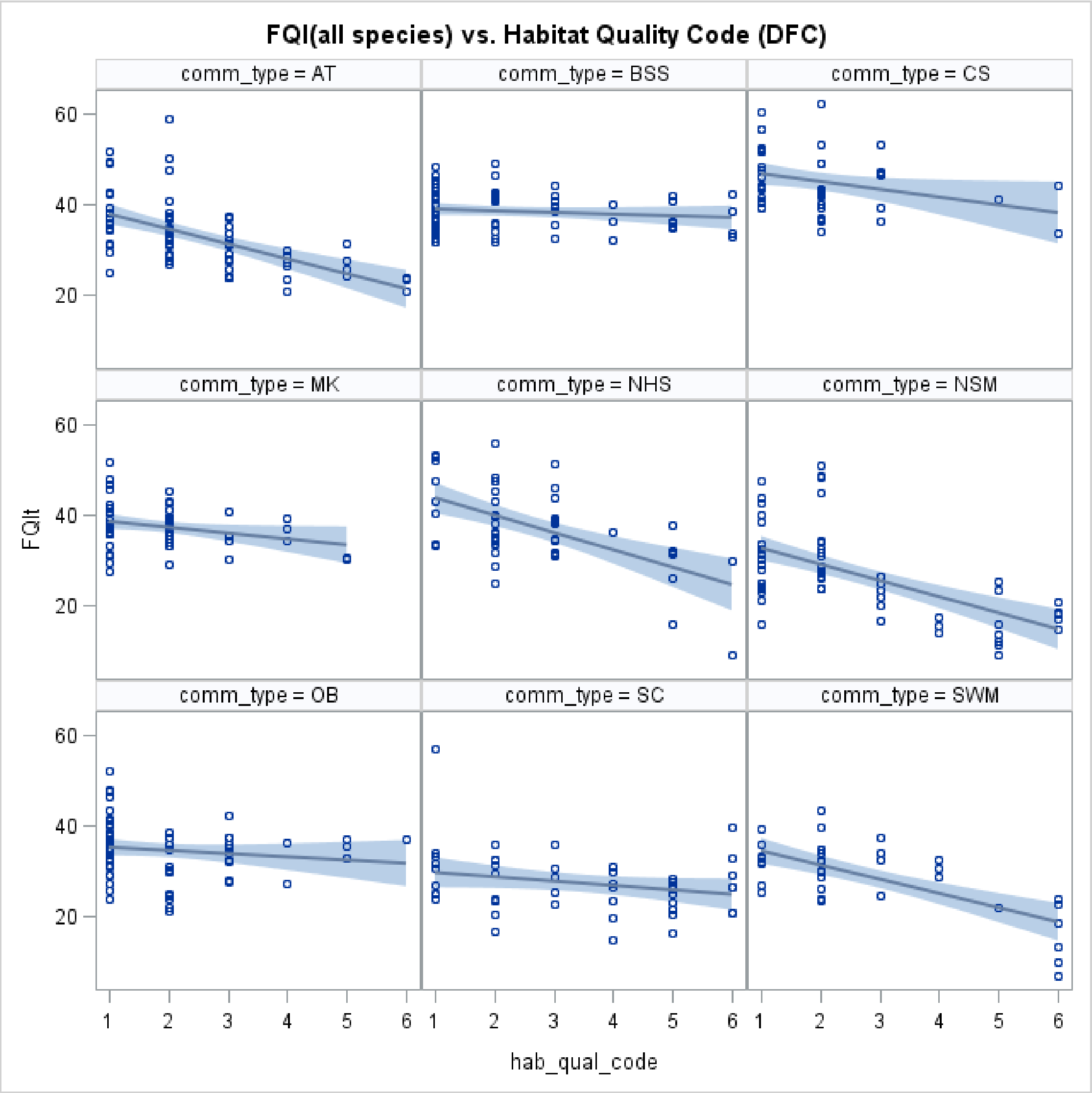
Floristic Quality Metric	Plant Community Type	Slope	r^2	*p*-value
$\bar{C}$	Alder Thicket (AT)	-0.42	0.44	**0.0000**
$\bar{C}$	North Hardwood Swamp (NHS)	0.42	0.45	**0.0000**
$\bar{C}$	Black Spruce Swamp (BSS)	-0.39	0.39	**0.0000**
$\bar{C}$	Muskeg (MK)	-0.44	0.16	**0.0018**
$\bar{C}$	Northern Sedge Meadow (NSM)	-0.68	0.68	**0.0000**
$\bar{C}$	Open Bog (OB)	-0.39	0.25	**0.0000**
$\bar{C}$	Shallow Water Marsh (SWM)	-0.59	0.64	**0.0000**
$\bar{C}$	Shrub Carr (SC)	-0.18	0.15	**0.0062**
$\bar{C}$	White Cedar Swamp (CS)	-0.32	0.45	**0.0000**

Appendix VI. cont… Scatter plots of *weighted mean C* versus habitat quality code for sites in nine wetland plant communities. The trend line is a simple linear regression, while the shading indicates the 95% confidence interval for the line. Regression statistics are included in the accompanying table.



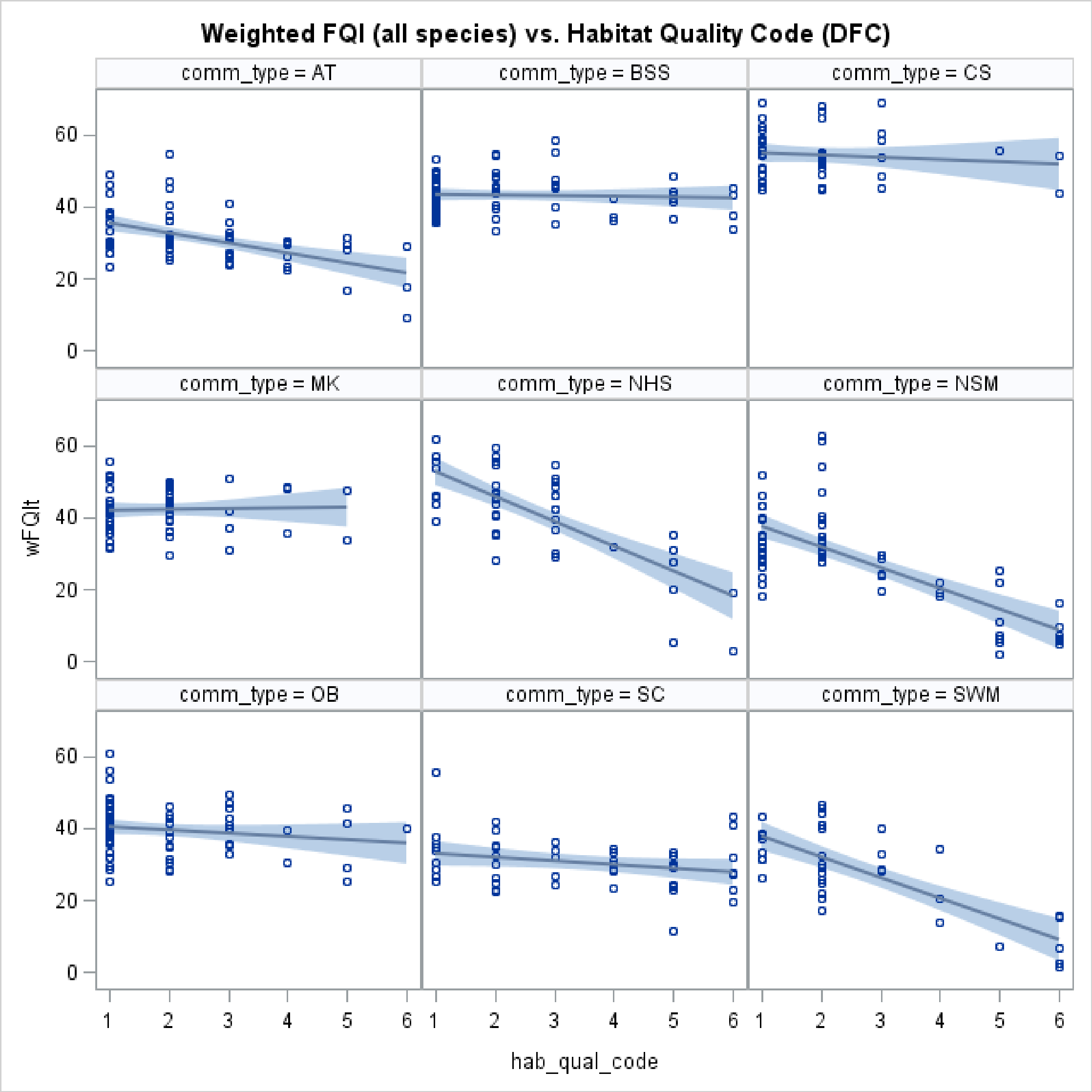
Floristic Quality Metric	Plant Community Type	Slope	r^2	*p*-value
$w\bar{C}$	Alder Thicket (AT)	-0.39	0.48	**0.0000**
$w\bar{C}$	North Hardwood Swamp (NHS)	-0.84	0.64	**0.0000**
$w\bar{C}$	Black Spruce Swamp (BSS)	0.39	0.48	**0.0000**
$w\bar{C}$	Muskeg (MK)	-0.22	0.14	**0.0048**
$w\bar{C}$	Northern Sedge Meadow (NSM)	-1.06	0.67	**0.0000**
$w\bar{C}$	Open Bog (OB)	-0.43	0.29	**0.0000**
$w\bar{C}$	Shallow Water Marsh (SWM)	-1.08	0.69	**0.0000**
$w\bar{C}$	Shrub Carr (SC)	-0.19	0.14	**0.0091**
$w\bar{C}$	White Cedar Swamp (CS)	-0.20	0.24	**0.0006**

Appendix VI. cont… Scatter plots of *FQI* versus habitat quality code for sites in nine wetland plant communities. The trend line is a simple linear regression, while the shading indicates the 95% confidence interval for the line. Regression statistics are included in the accompanying table.



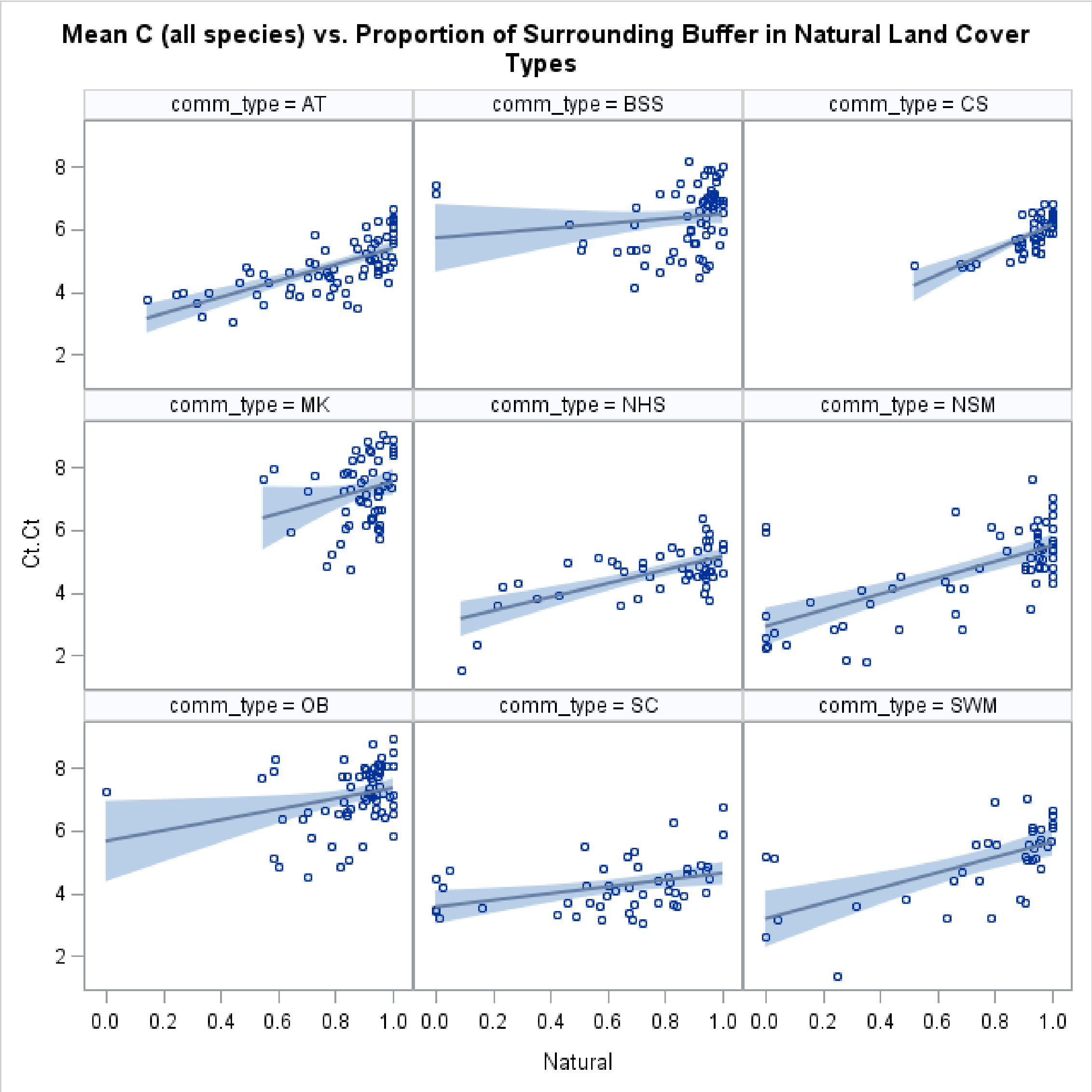
Floristic Quality Metric	Plant Community Type	Slope	r^2	*p*-value
FQI	Alder Thicket (AT)	-3.31	0.33	**0.0000**
FQI	North Hardwood Swamp (NHS)	-3.85	0.33	**0.7533**
FQI	Black Spruce Swamp (BSS)	-0.37	0.02	**0.2644**
FQI	Muskeg (MK)	-1.29	0.07	**0.0436**
FQI	Northern Sedge Meadow (NSM)	-3.59	0.38	**0.0000**
FQI	Open Bog (OB)	-0.71	0.02	**0.2443**
FQI	Shallow Water Marsh (SWM)	-3.15	0.48	**0.4679**
FQI	Shrub Carr (SC)	0.97	0.06	**0.0864**
FQI	White Cedar Swamp (CS)	1.72	0.10	**0.0372**

Appendix VI. cont… Scatter plots of *weighted FQI* versus habitat quality code for sites in nine wetland plant communities. The trend line is a simple linear regression, while the shading indicates the 95% confidence interval for the line. Regression statistics are included in the accompanying table.



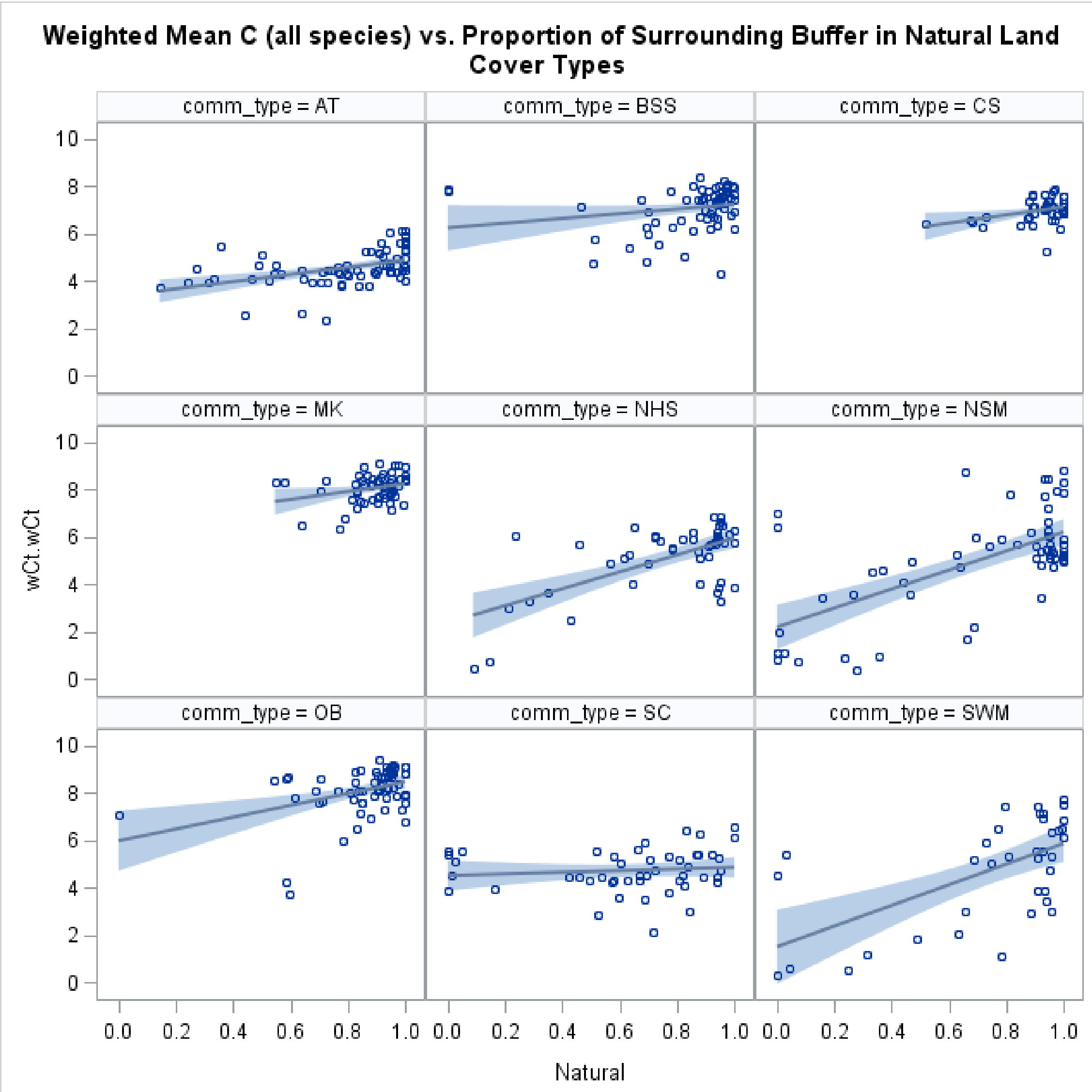
Floristic Quality Metric	Plant Community Type	Regression Slope	r^2	*p*-value
wFQI	Alder Thicket (AT)	-2.79	0.26	**0.0000**
wFQI	North Hardwood Swamp (NHS)	-6.93	0.56	**0.0000**
wFQI	Black Spruce Swamp (BSS)	-0.19	0.00	**0.6481**
wFQI	Muskeg (MK)	0.21	0.00	**0.7985**
wFQI	Northern Sedge Meadow (NSM)	-5.78	0.52	**0.0000**
wFQI	Open Bog (OB)	-0.90	0.03	**0.1860**
wFQI	Shallow Water Marsh (SWM)	-5.75	0.59	**0.0000**
wFQI	Shrub Carr (SC)	-1.03	0.07	**0.0789**
wFQI	White Cedar Swamp (CS)	-0.62	0.01	**0.4694**

Appendix VI. cont… Scatter plots of *mean C* versus proportion of 300-m buffer in natural land cover types for sites in nine wetland plant communities. The trend line is a simple linear regression, while the shading indicates the 95% confidence interval for the line. Regression statistics are included in the accompanying table.



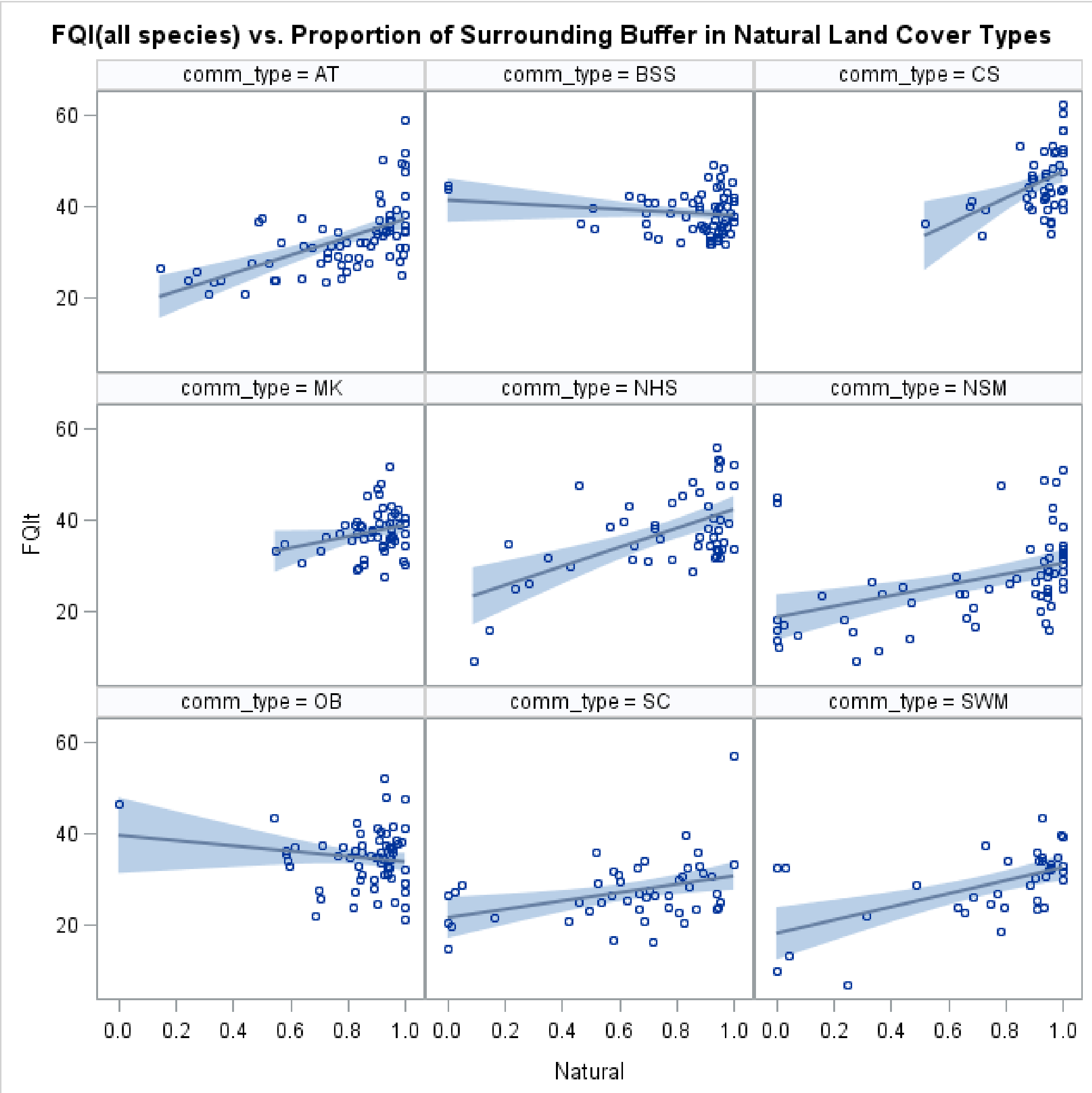
Floristic Quality Metric	Plant Community Type	Slope	r^2	*p*-value
$\bar{C}$	Alder Thicket (AT)	2.61	0.46	**0.0000**
$\bar{C}$	North Hardwood Swamp (NHS)	2.18	0.41	**0.0000**
$\bar{C}$	Black Spruce Swamp (BSS)	0.76	0.02	**0.2220**
$\bar{C}$	Muskeg (MK)	2.54	0.06	**0.0780**
$\bar{C}$	Northern Sedge Meadow (NSM)	2.59	0.43	**0.0000**
$\bar{C}$	Open Bog (OB)	1.70	0.08	**0.0242**
$\bar{C}$	Shallow Water Marsh (SWM)	2.45	0.37	**0.0000**
$\bar{C}$	Shrub Carr (SC)	1.08	0.15	**0.0069**
$\bar{C}$	White Cedar Swamp (CS)	4.03	0.51	**0.0000**

Appendix VI. cont… Scatter plots of *weighted mean C* versus proportion of 300-m buffer in natural land cover types for sites in nine wetland plant communities. The trend line is a simple linear regression, while the shading indicates the 95% confidence interval for the line. Regression statistics are included in the accompanying table.



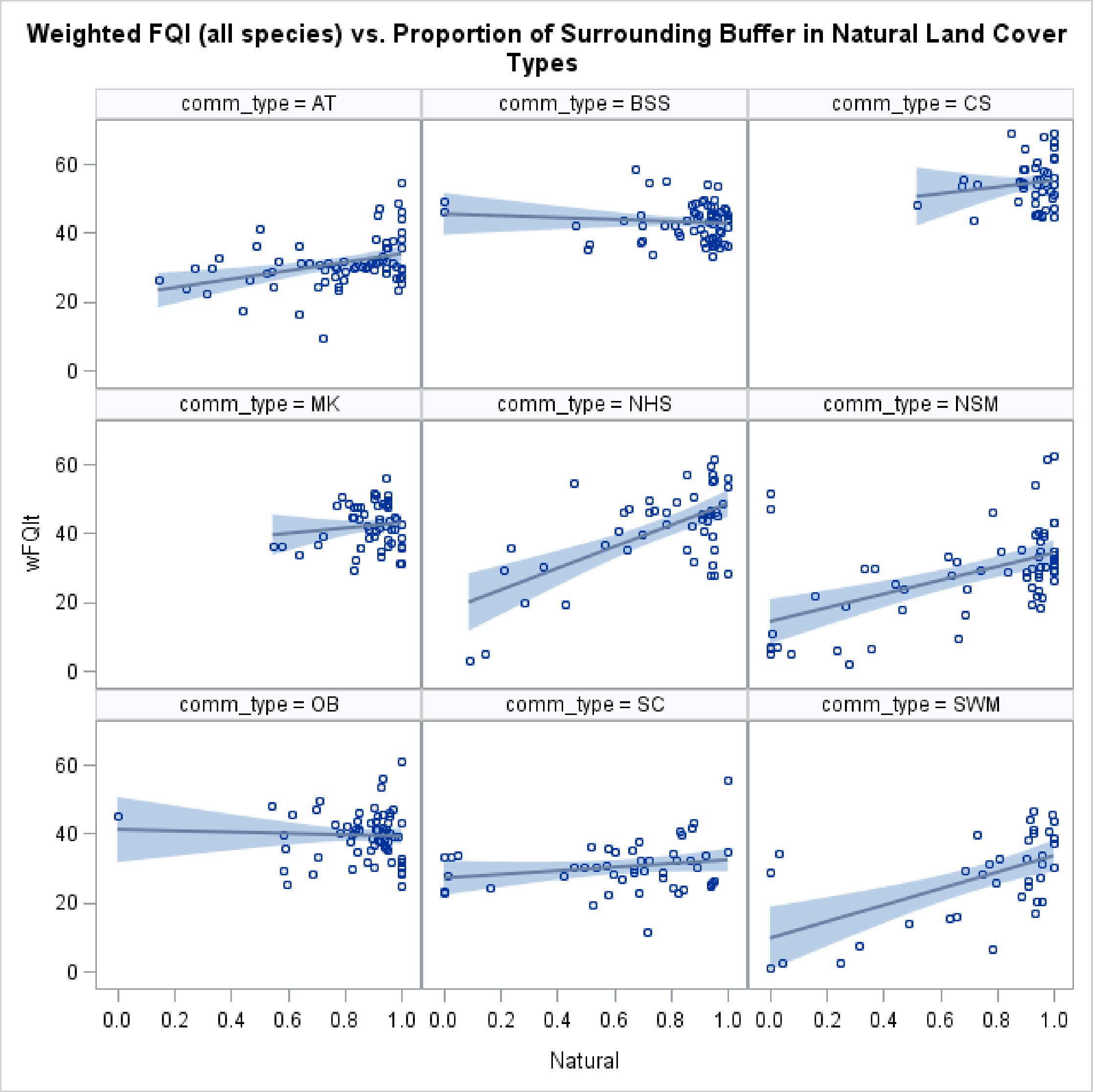
Floristic Quality Metric	Plant Community Type	Slope	r^2	*p*-value
$w\bar{C}$	Alder Thicket (AT)	1.51	0.20	**0.0000**
$w\bar{C}$	North Hardwood Swamp (NHS)	3.57	0.39	**0.0000**
$w\bar{C}$	Black Spruce Swamp (BSS)	0.99	0.05	**0.0745**
$w\bar{C}$	Muskeg (MK)	1.65	0.08	**0.0377**
$w\bar{C}$	Northern Sedge Meadow (NSM)	4.00	0.42	**0.0000**
$w\bar{C}$	Open Bog (OB)	2.49	0.15	**0.0011**
$w\bar{C}$	Shallow Water Marsh (SWM)	4.36	0.37	**0.0001**
$w\bar{C}$	Shrub Carr (SC)	0.34	.01	**0.4578**
$w\bar{C}$	White Cedar Swamp (CS)	1.71	0.12	**0.0177**

AppendixVI. cont… Scatter plots of *FQI* versus proportion of 300-m buffer in natural land cover types for sites in nine wetland plant communities. The trend line is a simple linear regression, while the shading indicates the 95% confidence interval for the line. Regression statistics are included in the accompanying table.



Floristic Quality Metric	Plant Community Type	Slope	r^2	*p*-value
FQI	Alder Thicket (AT)	19.83	0.32	**0.0000**
FQI	North Hardwood Swamp (NHS)	20.83	0.33	**0.0000**
FQI	Black Spruce Swamp (BSS)	-3.36	0.02	**0.2213**
FQI	Muskeg (MK)	12.58	0.07	**0.0513**
FQI	Northern Sedge Meadow (NSM)	11.84	0.18	**0.0005**
FQI	Open Bog (OB)	-5.80	0.02	**0.2284**
FQI	Shallow Water Marsh (SWM)	14.47	0.33	**0.0002**
FQI	Shrub Carr (SC)	9.15	0.15	**0.0068**
FQI	White Cedar Swamp (CS)	29.14	0.19	**0.0025**

Appendix VI.cont… Scatter plots of *weighted FQI* versus proportion of 300-m buffer in natural land cover types for sites in nine wetland plant communities. The trend line is a simple linear regression, while the shading indicates the 95% confidence interval for the line. Regression statistics are included in the accompanying table.



Floristic Quality Metric	Plant Community Type	Regression Slope	r^2	*p*-value
wFQI	Alder Thicket (AT)	12.34	0.14	**0.0014**
wFQI	North Hardwood Swamp (NHS)	31.39	0.39	**0.0000**
wFQI	Black Spruce Swamp (BSS)	-2.71	0.00	**0.4356**
wFQI	Muskeg (MK)	7.67	0.02	**0.3591**
wFQI	Northern Sedge Meadow (NSM)	19.85	0.27	**0.0000**
wFQI	Open Bog (OB)	-1.90	0.00	**0.7283**
wFQI	Shallow Water Marsh (SWM)	23.98	0.34	**0.0001**
wFQI	Shrub Carr (SC)	5.23	0.05	**0.1456**
wFQI	White Cedar Swamp (CS)	9.62	0.02	**0.3496**