BOARD OF WATER
AND SOIL RESOURCES

Assessing Wetland Quality of Depressional Wetlands to Refine Restoration Requirements and Strategies

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Table of Contents

Executive Summary

The Minnesota Board of Water and Soil Resources oversees wetland restorations for conservation and regulatory programs. Restoration guidance and techniques have evolved over time to improve outcomes. We used floristic quality as a measure of wetland condition to compare the results of various vegetation establishment techniques 7-16 years post restoration. Depressional wetlands in the temperate prairie and mixed wood plains regions of Minnesota were selected for study. Three groups of wetlands were selected for comparison as follows: intensively restored (mitigation wetlands, where wetland seed mix was installed and hydrology restored), passively restored (conservation program wetlands with natural regeneration of wetland plants and hydrology restored), and naturally occurring wetlands. Wetland plant communities were mapped and timed meander searches were used to assess floristic quality in each community. Landscape disturbance within a 500 m and 50 m buffer was assessed as well as wetland interspersion.

We found that, when averaging conditions of each community, depressional wetland mitigation wetlands (n=32) constructed between 2000 and 2012 have similar vegetative condition to naturally occurring wetlands (n=46), and better condition than passively restored wetlands (n=46). However, when comparing community type, wet meadow communities tend to be of better quality in mitigation wetlands, while the shallow marsh communities are worse when compared to naturally occurring wetlands. There were no differences in the condition of shallow open water communities among different groups of wetlands.

The results of the study demonstrate that higher quality vegetative communities were achieved when restored sites were actively managed for vegetation in fresh (wet) meadow wetlands. Similar benefits were not observed in shallow marsh or shallow open water communities. Our study also demonstrates no-net-loss in terms of wetland quality. Quality however, was generally in fair or poor condition, consistent with findings from the MPCA's wetland status and trends reports for this region.

State and federal mitigation guidance has been revised since most sites assessed in this study were constructed. These revisions have put greater emphasis on the establishment and management of these sites by requiring more information in the mitigation plan and improved monitoring and documentation of activities during the establishment period. Using the results of this study and with additional long-term monitoring, agency staff can continue to evaluate the effectiveness of restoration strategies to achieve higher quality wetlands in the next generation of mitigation wetlands.

Introduction

Wetlands are a valued resource in Minnesota and are a focus of protection and restoration through conservation and regulatory programs. A main goal of the State's 1991 Wetland Conservation Act is to achieve no net loss in the quantity, quality, and biological diversity of Minnesota's existing wetlands. Statewide efforts are ongoing to monitor status and trends of wetland quantity (Kloiber and Norris 2017) and quality (Bourdaghs et al. 2019, Genet et al. 2019). These statewide assessments provide an overview for the state, but do not specifically report on the quality of wetland mitigation sites. Wetland mitigation sites are wetlands that were restored, established, enhanced, or preserved for the purpose of providing compensation for unavoidable impacts to aquatic resources permitted under federal and state laws. The Minnesota Board of Water and Soil Resources wetland banking program has over 400 sites covering more than 30,000 acres. Over time mitigation guidance and requirements have evolved to improve wetland quality. However, little wetland quality information is collected after the initial 5-year monitoring period to evaluate ecological condition and to show how effective restoration techniques are in the long-term.

Wetlands occur in a variety of landscape positions and community types. For this assessment we targeted depressional wetlands in southern Minnesota because there are many existing and proposed wetland mitigation sites in this area. Mitigation wetlands were compared to wetlands restored via a conservation program and to naturally occurring wetlands. Mitigation wetlands (intensive sites) had hydrology restored and vegetation reestablished through seeding and/or planting. We selected wetlands from the conservation program that also had hydrology restored, but no native seeding of wetland vegetation. Vegetation was left to reestablish naturally (passive sites). Hydrology restoration techniques included tile blocks, ditch plugs and fill, constructed outlets, and earthen embankments. Restored wetlands were 7-16 years old at the time of the assessment.

We evaluated floristic quality on each wetland, as this approach has been shown to be a good indicator of ecological condition (DeBerry et al. 2015) and is used to monitor status and trends of wetlands statewide (Bourdaghs et al. 2019). Floristic quality assessments are based on coefficients of conservatism, which are a range of values (0-10) assigned to each plant species indicating that species' habitat fidelity. High numbers are assigned to species exclusive to undegraded, native habitats, and low numbers are assigned to species with the least fidelity or restriction to specific habitats (Milburn et al. 2007, Spyreas 2019). All non-native species are assigned a value of zero. We assigned condition categories (Table 1) using thresholds developed by the Minnesota Pollution Control Agency (MPCA) (Bourdaghs et al. 2019) and compared condition outcomes for each wetland group.

Table 1. Wetland vegetation condition category descriptions (MPCA 2015)

Condition Category	Description
Exceptional	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.
Good	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.
Fair	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.

Poor	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.

In addition to condition categories, we explored the distributions of floristic quality metrics including the weighted coefficients of conservatism (wC), mean coefficients of conservatism (mean C), floristic quality index (FQI), and native species richness. We also evaluated pre-restoration conditions and restoration practices of wetland mitigation sites to look for relationships with floristic quality outcomes.

Methods

Site Selection

Our study area is within Minnesota's temperate prairie and mixed wood plains ecoregions, further confined by the St. Croix, Upper Mississippi, Lower Mississippi, Minnesota, and Missouri River major basins (Figure 1). We targeted three wetland groups:

1) **Intensively restored wetlands:**
    - Compensatory mitigation sites where hydrology was restored by tile blocks, ditch plugs or fill, and/or earthen embankments;
    - Wetland vegetation was seeded or planted at least to the design pool elevation;
    - Seed mixes had at least 20 native species;
    - At least half of the restored wetland area was completely drained, or lacked wetland hydrology, prior to construction; and
    - Sites were 7-16 years old
2) **Passively restored wetlands:**
    - Wetlands restored through the Reinvest in Minnesota Program, where hydrology was restored by tile blocks, ditch plugs or fill, and/or earthen embankments.
    - Wetland vegetation was not seeded or planted.
    - At least half of the restored wetland area was completely drained, or lacked wetland hydrology, prior to construction; and
    - Sites were 7-16 years old
3) **Naturally occurring wetlands:**
    - These wetlands were not drained, created, or restored. Wetlands that were clearly excavated or recently in row crops were excluded. Some of these wetlands may have been historically altered through additional hydrology, partial drainage, or partial fill from road construction.

The updated National Wetland Inventory (NWI) geospatial layers were used to identify potential study sites by selecting for the landscape position "terrene" (surrounded by upland) as opposed to riverine or lacustrine wetlands. We randomly numbered wetland basins, and in numerical order reviewed wetland basins to determine if selection criteria were met. For restored wetlands, we reviewed administrative records including as-built construction designs, vegetation restoration plans, and pre-construction delineation maps when available. For naturally occurring wetlands, available historical images (1930s-1991) were reviewed to help determine if the wetland had a drainage or restoration history. Landowner permission was required prior to assessing any of the naturally occurring wetlands.

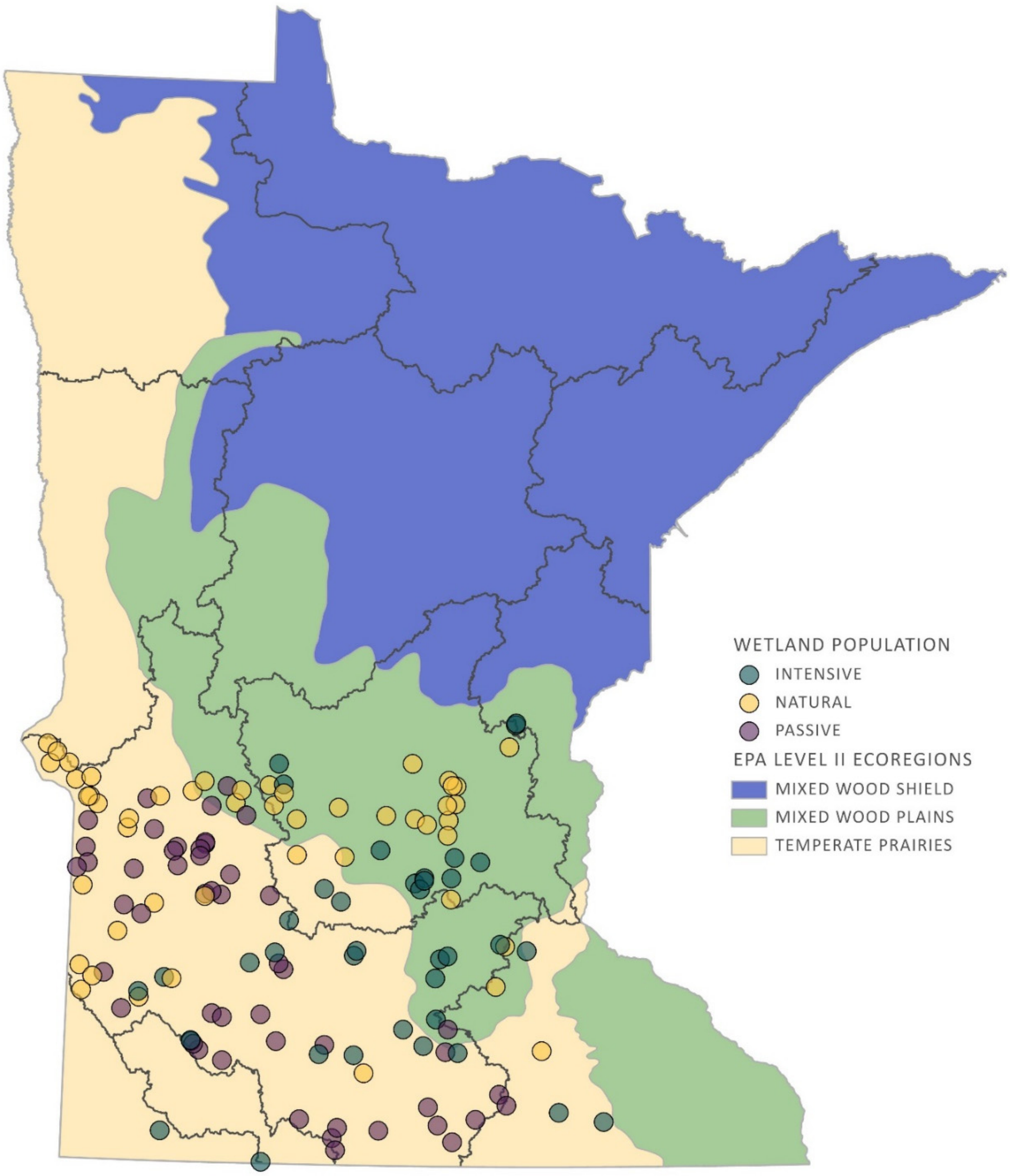

Figure 1. Location of wetlands sampled between 2016-2019. Grey lines depict wetland mitigation bank service areas.

Once a wetland was selected for assessment, wetlands within 1 km of it were eliminated from consideration. This rule was implemented to maintain independent samples, assuring two sites from the same restoration project were not selected as some restoration projects have many depressional basins. Site selection was balanced among three size classes: 1-5 acres, 5-25 acres, and 25-100 acres, with a goal of achieving similar distributions as the intensively restored group. We reported both wetland size class distribution and average area for each community by group. We also reviewed NWI maps to report a wetland interspersion factor as a descriptive factor for each group, describing wetland absence/presence within 2 miles of the assessment area (MnRAM 2010).

Sites were excluded from analyses if they did not meet quality control metrics (Appendix 1) or were found to be outside of the selection parameters after the sample was collected.

Floristic Quality Sampling

For each sample wetland, we determined an assessment area defined by the upper edges of the basin where vegetation transitioned to upland species. We used recent aerial imagery and the updated NWI map to estimate assessment areas, digitizing them into a GIS spatial layer. Each assessment area was evaluated in the field to confirm the estimated boundaries and to map wetland communities within the boundary. Communities were classified based on existing conditions using the Eggers and Reed Wetland Classification Key, as modified in Bourdaghs (2012) (Appendix 2). Plant communities were not assessed if they were under 0.1 acre for assessment areas less than 2.5 acres or less than 0.25 acres for assessment areas greater than 2.5 acres. Sites were sampled once between June 13 and September 13 in either 2017, 2018, and 2019.

A timed meander and shoreline sampling were used to record species composition. The timed meander was used in wet meadow, shallow marsh, and some of the shallow open water communities (Sample Type B in Bourdaghs, 2019). This method is effective at acquiring a complete species list, which is advantageous when conducting floristic quality analysis (Goff 1982, Hlina et al. 2011, Bourdaghs et al. 2012). The base meander time was determined by the number of communities: 30 minutes for one community and an additional 20 minutes for each additional community. If an additional 6 species were observed within the last 10 minutes of the timed meander, an additional 10 minutes were added to the meander time. The objective was to traverse through representative areas of the site with a similar sampling effort in each community. The meander path was recorded using GPS positions. Shoreline samples were conducted (Sample Type D in Bourdaghs, 2019) if shallow open water conditions were too deep to safely traverse. This method produced similar results to meander sampling by canoe (Appendix 3). For shoreline sampling, a hand garden cultivator attached to a 20-ft rope was tossed into the shallow open water and retrieved to determine subaquatic vegetation. Three tosses were made at each location: one perpendicular, and two offset 45° from perpendicular, with three locations per site. Both observed and collected aquatic plant species were recorded for shallow open water communities. All plant species were identified to the lowest taxonomic division possible. Percent absolute cover estimates were made using cover classes: >0-1, >1-5, >5-25, >25-50, >50-75, >75-95, and >95-100.

For each community, the wC, mean C, FQI and native species richness were calculated (Table 2).

Table 2. Dependent variables analyzed and their formulas and/or descriptions.

Metric	Formula	Description
Weighted Coefficient of Conservatism (wC)	$wC = \sum_{j=1}^{S} p_j C_j$	The sum of each species (S) Coefficient of Conservatism (C) multiplied by its relative cover or proportion (p), which was derived from the mid-points of the cover classes used.
Mean Coefficient of Conservatism ($\bar{C}$)	$\bar{C} = (\sum_{j=1}^{S} C) \div S$	The average of all Coefficients of Conservatism (C) divided by the total number of species (S).
Floristic Quality Index (FQI)	$FQI = \bar{C}\sqrt{S}$	Product of the calculated mean coefficient of conservatism ($\bar{C}$) multiplied by the square root of the total number of species (S).
Native Species Richness (S_n)		Sum total of all the native species observed and identified to species level.

The wC value was used to determine condition categories, which describe the deviation of a wetland plant species composition and/or abundance distribution from what would be expected in a minimally impacted system (from Appendix B in Bourdaghs et al. 2019 (Table 3)). This metric is not as affected by sampling area and is more responsive to wetland condition than other metrics derived from species richness (Bourdaghs et al. 2006, Bourdaghs 2012). Site level categories were determined by calculating the weighted average condition category based on the relative extent of each community within a site.

Table 3. Weighted coefficients of conservatism condition category criteria for a selection of Eggers and Reed wetland community types (Bourdaghs 2019).

	Community		
Condition Category	**Shallow Open Water**	**Shallow Marsh**	**Wet Meadow**
Exceptional		> 4.9*	> 4.2*
Good	> 5.0	> 4.2	> 4.2
Fair	≤ 5.0	1.9-4.2	1.4-4.2
Poor		< 1.9	< 1.4

* Indicates an additional criteria of less than 1% non-native taxa cover for the exceptional category.

Site-level condition categories were then determined by assigning a number (1-4) to each condition category, and computing a weighted average based on the proportion of each community relative to the site's total area. Count data were used to calculate proportions of each condition category by wetland group. Means and 95% confidence intervals were calculated for all numeric metrics and summarized by community and wetland group.

Species richness was summarized by condition categories for each community. This metric is often included in performance standards assigned to wetland mitigation sites. Understanding what values are associated with a condition class supports selection of target values.

Landscape Condition Assessment

We reviewed and ranked two human disturbance assessment factors used by MPCA in their assessment of wetlands throughout the state: landscape alteration within 500m of the site, and immediate upland alteration within 50m of the site (from Appendix D, Bourdaghs et al. 2019):

- Minimal rankings were assigned if no, or minimal, human land-use alterations were observed (0-19%).
- Low rankings were assigned when the adjacent area was predominantly unaltered (human land use 20-50%) or was recovered land, such as old fields or restored or reconstructed prairie < 10 years old.
- Moderate rankings were assigned when the extent of human land-use alterations within the adjacent area was significant (50-80% rural residential, pasture, hay, turf).
- Severe rankings were assigned when human land-use alterations occupied all or nearly all (>80%) of the adjacent area, with much of the use intensive (industrial/urban/dense residential development, row crops, feed lots, mining).

Results for these two factors were tabulated for each ranking criterion and assessed as a proportion of each group.

We also reviewed the wetland interspersion factor which is the number and type of wetlands within a 0.5-mile radius (MnRAM, 2010). Nearby wetlands may contribute to species richness in created and restored wetlands (Reinartz and Warne 1993). Categories for this factor include:

A. The wetland occurs in a complex of wetlands of various types (at least 3 wetlands within 0.5 miles of assessment wetland, at least one of which has a different dominant plant community than the assessment wetland); or the assessment wetland is the only wetland within a 2-mile radius.
B. Other wetlands of the same plant community as the assessment wetland are present within 0.5 miles.
C. No other wetlands are present within 0.5 miles of the assessment wetland but are present within 2 miles.

Proportions were reported for each wetland group.

Restoration Practices

For wetlands in the intensively restored group, the history of vegetation management for each site was assigned into one of three categories:

- None-sporadic: no management, or every four or more years
- Periodic: management at regular intervals such as every two or three years
- Frequent: management every year or almost every year

We summarized other explanatory factors such as pre-construction condition, restoration method (season planted, number of species installed, construction technique), and age of restoration. Management efforts and other explanatory factors were used to explore potential relationships with native species richness and introduced species cover, two variables that can be directly manipulated through management.

Data Analyses

Prior to analyses, data were reviewed for usability (Appendix 1). Data were analyzed using R Commander (Rcmdr) statistical software (Fox and Bouchet-Valat, 2020).

Categorical data were evaluated as frequency distributions, testing the null hypothesis that there was no difference in distributions among groups ($\alpha < 0.05$). The evaluation of wetland size class was completed using the Pearson's Chi-squared test. Analyses of condition categories by group were completed using a Fisher's Exact Test. This test is applicable when more than 20% of the contingency cells had expected values < 5. When a significant difference was detected, three pairwise comparisons were made using a Bonferroni correction ($\alpha = 0.017$).

Most numerical data were evaluated using a one-way Welch ANOVA (α=0.05), with a Tukey pairwise comparison of means. We tested the null hypotheses, that there was no difference in the means of community size, and no difference in means of floristic quality metrics among the three groups (α=0.05). The Welch form of ANOVA allows for heterogeneity of variance among the sampled groups. The ANOVA test is also robust against departures in normal distributions, as all groups in these tests had sample sizes greater than 15 (Minitab, no date). We calculated 95% confidence intervals for each metric to show variation.

For the analysis of species richness by condition categories we show median values and interquartile ranges of these metrics for each community. The interquartile range was calculated by subtracting the lower quartile value from the upper quartile value.

Limited sample sizes were observed for data related to restoration practices. These data were also described by median values and interquartile ranges (pre-construction condition, restoration methods) or scatterplots (restoration age).

Results

Site Selection

Usable data for wetland basin comparisons were collected and analyzed for 126 sites (Appendix 1). The size class distribution for each group was similar (p-value = 0.826) (Figure 2). Area by community type was also similar overall, with the exception that the passively restored wet meadow communities were on average larger and more variable than the naturally occurring wetlands, but similar in size to intensively restored wetlands (Figure 3).

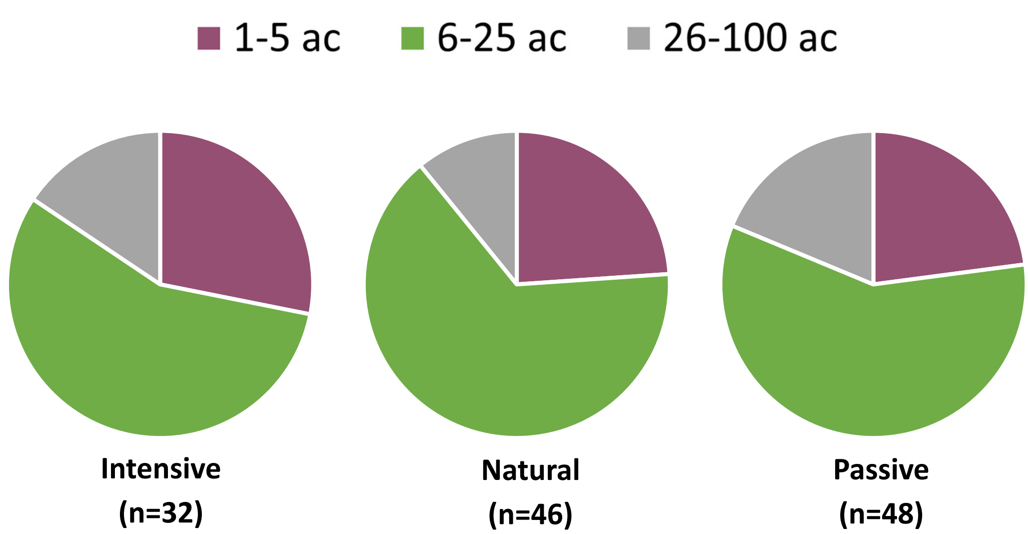

Figure 2. Sample sizes and size class distributions for each wetland group. Proportions were similar among all groups (Pearson's Chi-squared test, p-value = 0.826).

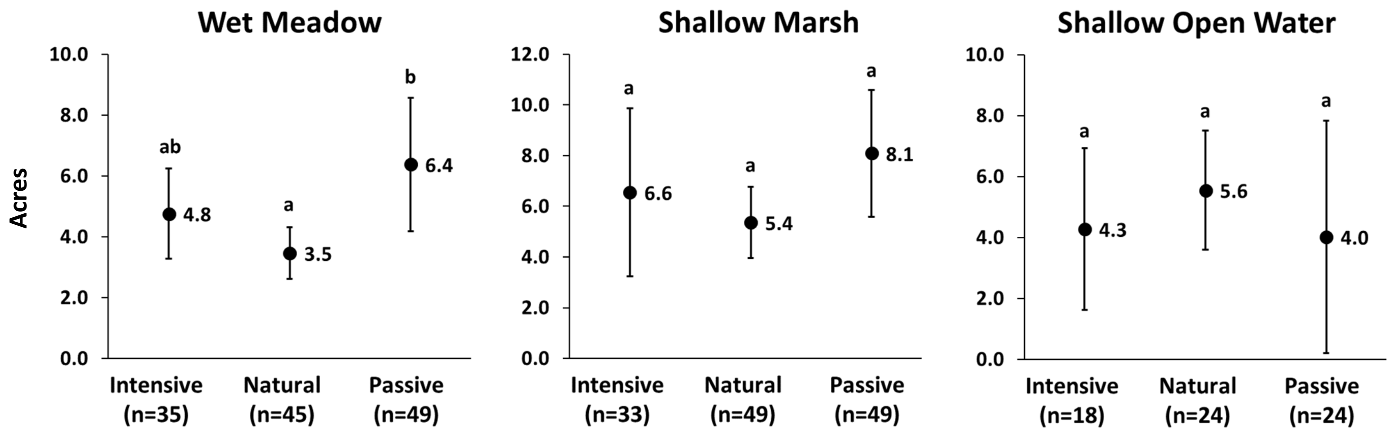

Figure 3. Means and 95% confidence intervals of area in acres observed for the wet meadow, shallow marsh, and shallow open water communities. Results from Welch ANOVA (α < 0.05) and Tukey pairwise comparisons of means where different letters indicate significant differences.

Results of the wetland interspersion factor (MnRAM, 2010) showed similar results by category for each group, with most assessment areas occurring in a complex of wetlands of various types within a 0.5 mile radius, and occasionally the only wetland within a 2 mile radius (Figure 4).

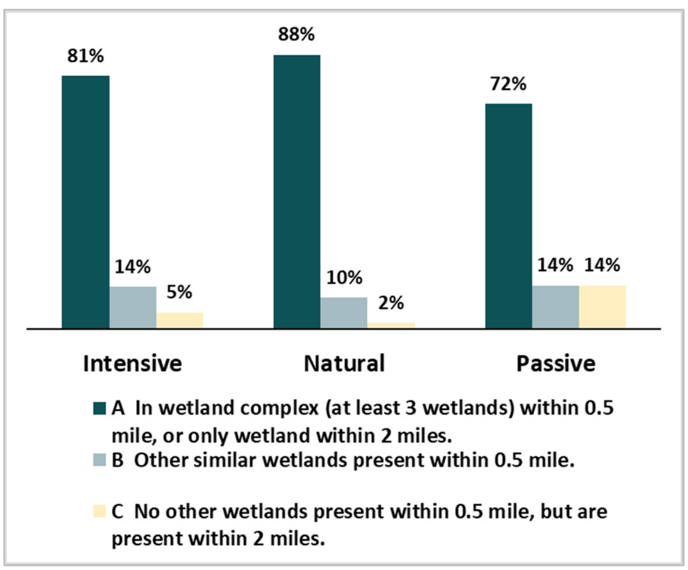

Figure 4. Percent of sites in three categories (A-C) of wetland interspersion (MnRAM 2010)

Floristic Quality

Condition Categories by Group

The distribution of condition categories varied by wetland group type (p-value = 0.002). Pairwise comparisons indicate that the intensively restored group has a higher proportion of sites in the fair category than the passively restored group (p-value = 0.003), but a similar distribution when compared to the naturally occurring wetlands (p-value = 0.122) (Figure 5). The “good” category wetlands observed in the naturally occurring wetlands were in the northern range of our study area (Figure 6). Nearly all passively restored sites occur in the temperate prairie region of the state.

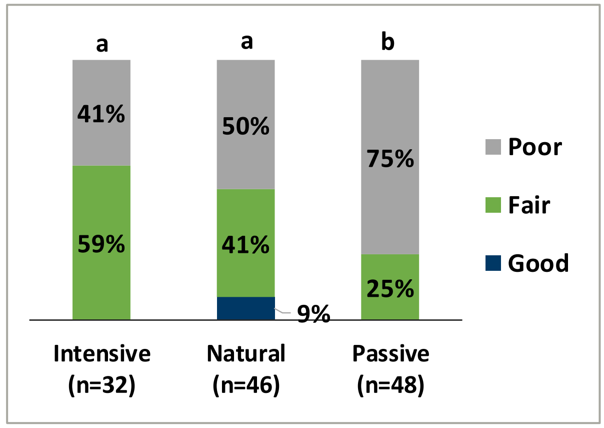

Figure 5. Proportions of sites in good, fair, and poor condition categories for each population. Different letters indicate significant differences (p-value < 0.017) among populations.

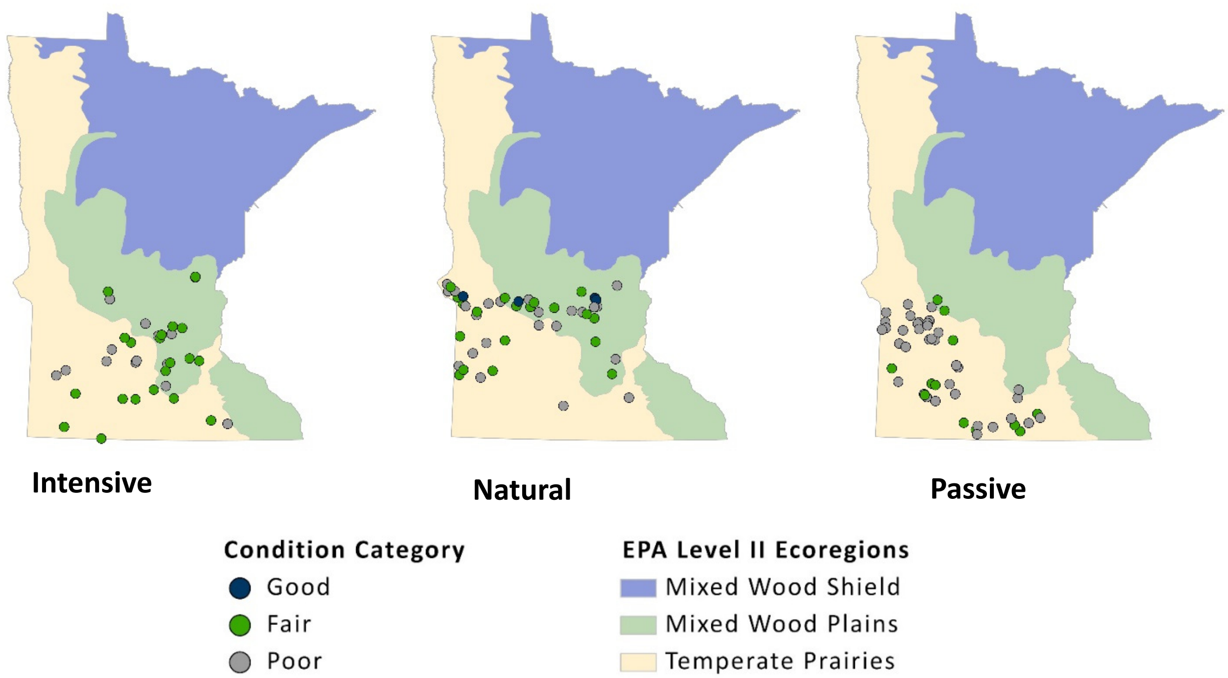

Figure 6. Location of wetlands sampled and their condition categories, by group.

When summarizing condition categories by community type, we observed slight changes in sample sizes than those observed at the wetland basin level. This is related to completeness criteria summarized in Appendix 1. We detected significant differences among groups for the wet meadow and shallow marsh communities ($p < 0.000$ and $p = 0.013$ respectively), and no difference among groups for the shallow open water community ($p = 0.422$, Figure 7). Intensively restored wetlands had a higher proportion of fair quality wet meadow communities than either the naturally occurring wetlands (p-value < 0.000) or the passively restored wetlands (p-value < 0.000) (Figure 7A). Proportionally more of the naturally occurring wetlands had higher quality shallow marsh vegetation than the intensively restored wetlands (p-value = 0.008) and the passive group of shallow marsh communities is similar to both the intensive group (p-value = 0.143) and the natural group (p-value = 0.094) (Figure 7B).

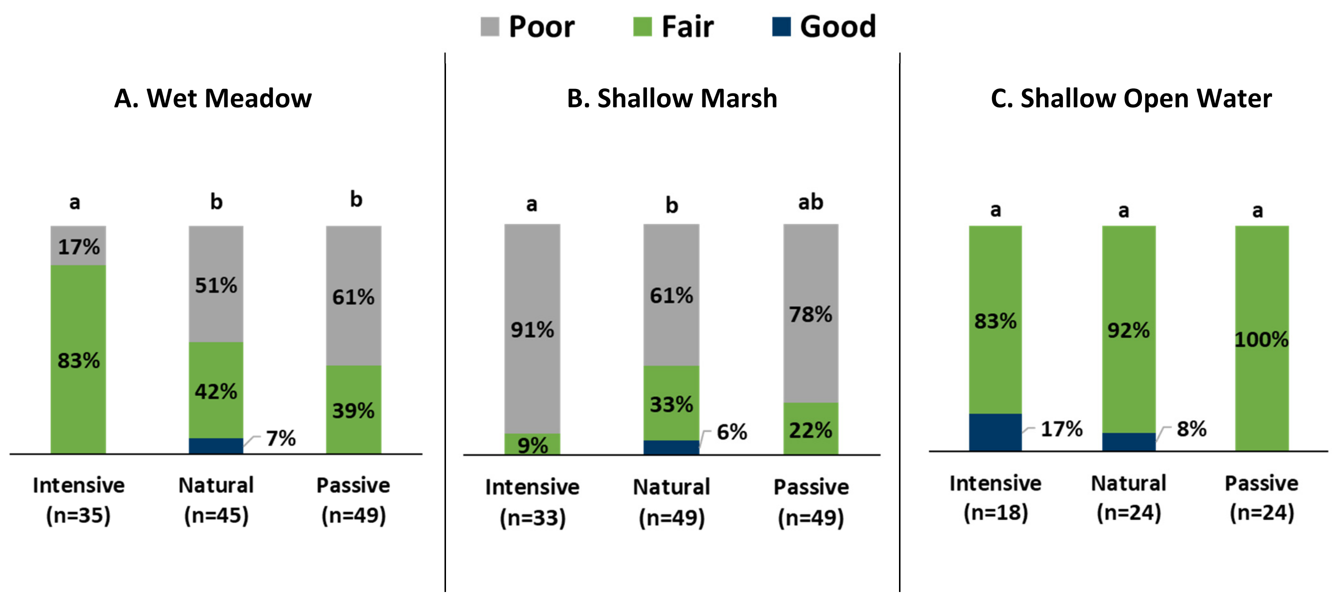

Figure 7. Proportions of (A) wet meadow, (B) shallow marsh, and (C) shallow open water communities in good, fair, and poor condition among the populations (intensive, natural, and passive). Different letters indicate significant differences among populations.

Metrics by Group

For each community, we compared the means and 95% confidence intervals of the wC, mean C, FQI, and native species richness (Figure 8).

The metrics for the wet meadow community (Figure 8) closely followed the pattern observed in condition categories. The intensively restored wetlands had the highest average values for wC (2.4), mean C (3.1), FQI (16.1), and native species richness (27.5), and statistically significant differences for all variables except the mean C value - where the naturally occurring wetlands had a similar outcome. All other metrics for the wet meadow community showed the naturally occurring and passive wetlands having similar mean values. As introduced (non-native) cover contributes to the calculation of wC values, we summarized common introduced species observed during the surveys. Introduced cover for all groups was typically reed canarygrass (*Phalaris arundinacea*) and non-native cattail (*Typha angustifolia or T. x glauca*). These two species together contributed to greater than 90% cover of the introduced category in most (70%) of the wet meadow communities. Other common introduced species in the wet meadow communities with greater than 5% cover included Canada thistle (*Cirsium arvense*), Kentucky bluegrass

(*Poa pratensis*), and timothy grass (*Phleum pratense*). When introduced cover was estimated to be less than 20% cover, we observed Canada bluejoint (*Calamagrostis canadensis*), prairie cordgrass (*Spartina pectinata*), sedges (*Carex* spp.), manna grasses (*Glyceria* spp.), and bulrushes (*Scirpus* spp.) were often dominant native species.

For shallow marsh communities, naturally occurring wetlands had the highest values for wC (1.8), mean C (3.4), FQI (13.3), and native species richness (15). We observed overlapping distributions of mean C, FQI, and native species richness between the naturally occurring and intensively restored wetlands (Figure 8). Introduced cover in the shallow marsh was predominantly non-native cattail (*Typha angustifolia or T. x glauca*) or reed canarygrass (*Phalaris arundinacea*). These two species together contributed to greater than 90% cover of the introduced category in nearly all (98%) of the shallow marsh communities. The sites that had relatively low introduced cover (<40%) tended to have higher proportions of river bulrush (*Bolboschoenus fluviatilis*) and sedges (*Carex* spp.). One site also had a dominance of giant bur-reed (*Sparganium eurycarpum*) (63%) and another broad-leaf arrowhead (*Sagittaria latifolia*) (38%).

Of the shallow open water communities, we observed similar averages of the mean C (3.4-3.8), FQI (7.7-7.9), and native species richness (4.5-5) among all three groups. The wC values were higher for the naturally occurring wetlands (3.5) compared to the passively restored wetlands (2.6), and were similar to intensively restored wetlands (3.2) (Figure 8).

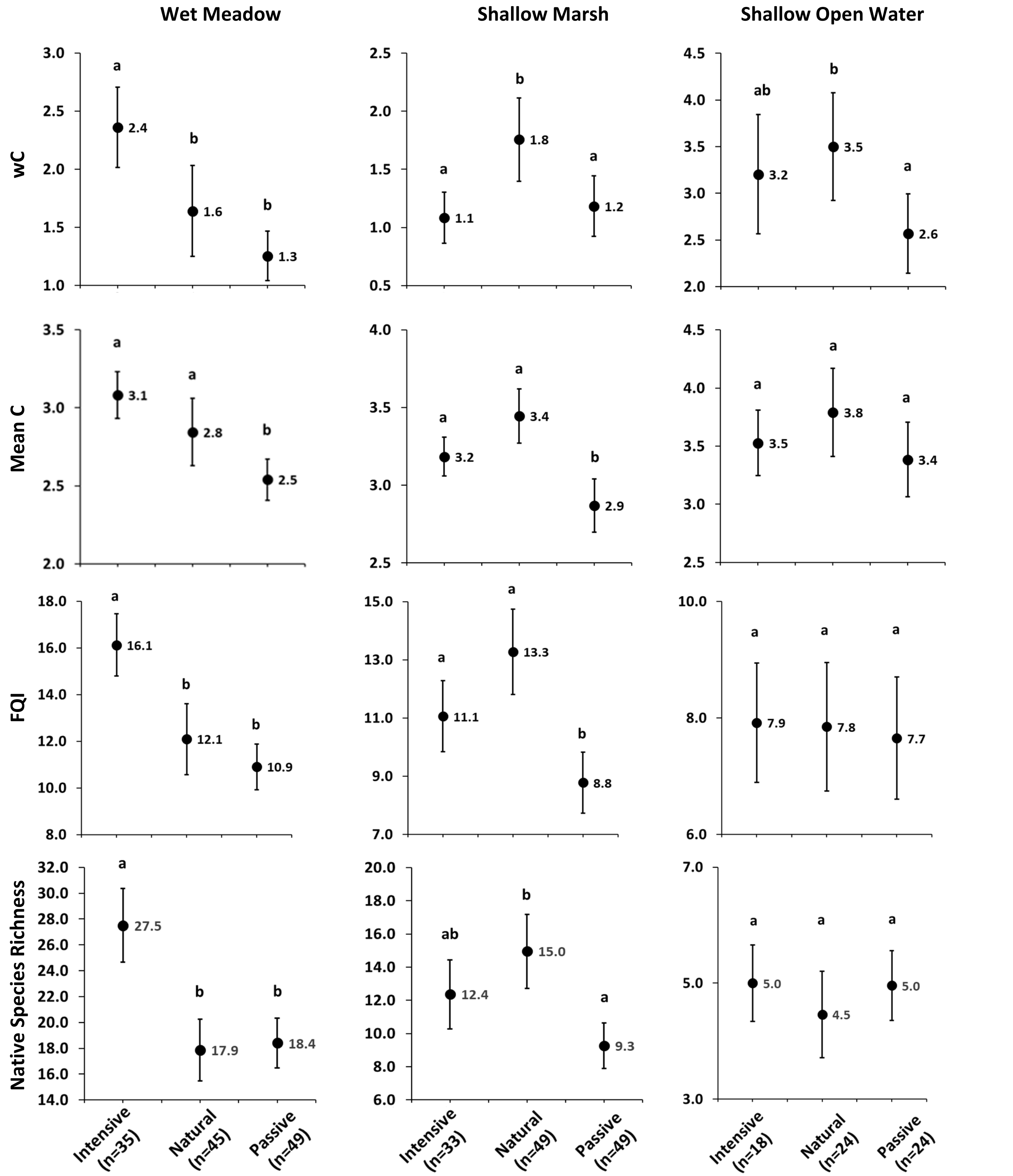

Figure 8. Means and 95% confidence intervals observed for the weight coefficient of conservatism (wC), mean coefficient of conservatism (mean C), and floristic quality index (FQI). Sample sizes varied by community. Results from Welch ANOVA and Tukey pairwise comparisons of means where different letters indicate significant differences.

Native Species Richness by Condition Category

We reviewed native species richness by 'good, fair, and poor' condition categories, regardless of wetland group (Table 4). For all three communities, sample size was limited for the good category.

For the wet meadow, median values of native species richness were higher and similar (27 and 25) for the good and fair condition categories, and lower for the poor condition category (15). Native richness values of the shallow marsh communities were highest for the good condition category (27) and lowest for the fair and poor condition categories (12 and 10). Native species richness results were similar for the shallow open water condition categories.

Table 4. Sample size (n), median, and interquartile range (IQR) of native richness observed in wetland communities by condition category (good, fair, poor).

Community, metric	Statistic	Good	Fair	Poor
Wet Meadow	n	3	67	59
	Median (IQR)	27 (9)	25 (10)	15 (10)
Shallow Marsh	n	3	30	98
	Median (IQR)	27 (13)	12 (8)	10 (6)
Shallow Open Water	n	5	61	-
	Median (IQR)	6 (3)	5 (2)	-

Landscape Condition Assessment

Proportions of landscape alteration rankings were similar among intensively restored, naturally occurring, and passively restored sites – with the exception of naturally occurring sites having a small portion with 'minimal' human land-use alterations in the 500 m radius (Figure 9 – top row). Categories for immediate upland alteration within 50 m was more variable, with naturally occurring wetlands divided among the four disturbance levels, while the restored wetlands were mostly in the low-moderate categories (Figure 9 – bottom row). This outcome is likely related to upland buffer requirements of both restoration programs.

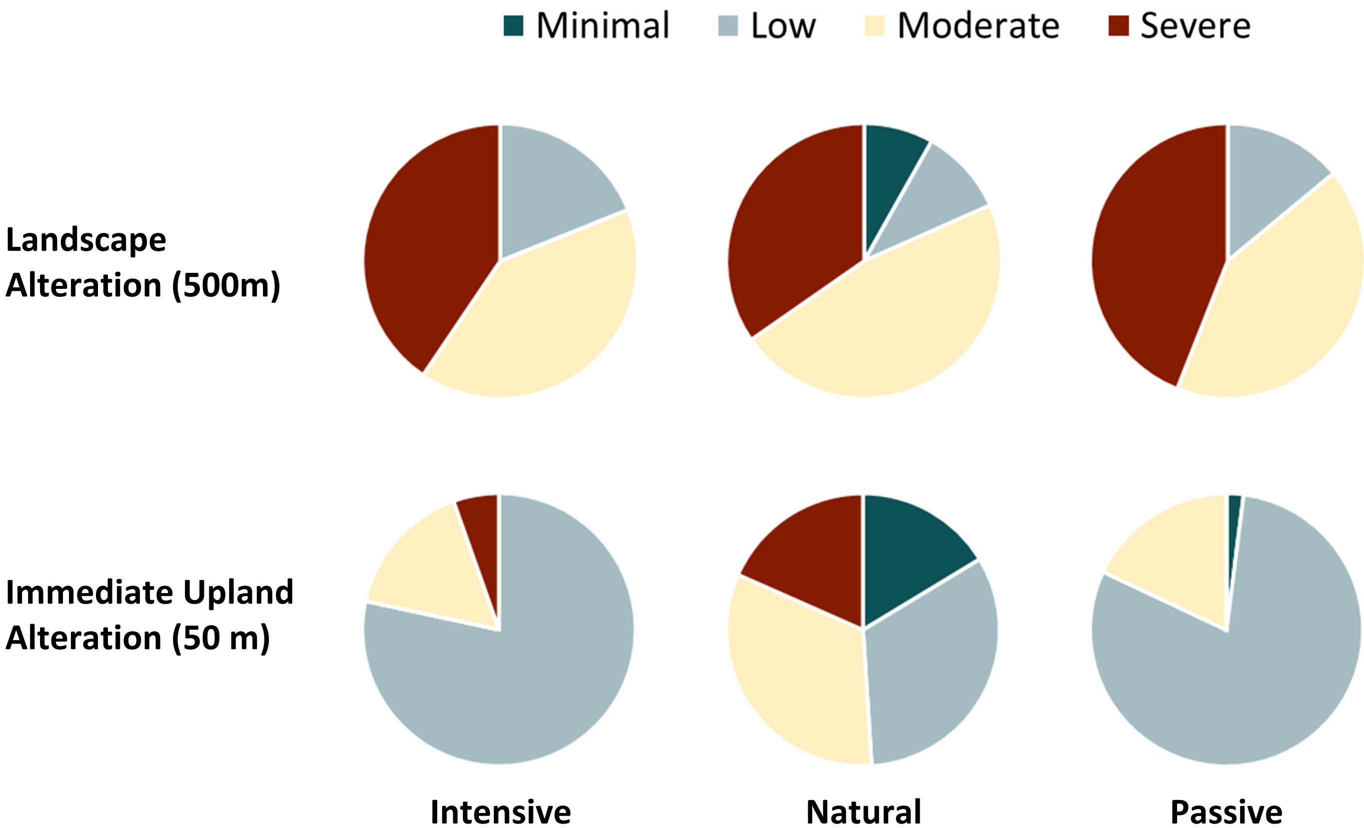

Figure 9. Proportions of sites in four disturbance categories of landscape and immediate upland alterations.

Restoration Practices

Pre-construction condition

Most intensive sites had similar pre-construction conditions (Table 5) resulting in an inadequate sample size to statistically compare this factor against native species richness and wC values. Median species richness and wC values were similar between pre-construction site conditions of row-cropped, the most common category, and the category of hay, fallowed, and partially row-cropped combined. We also compared four pre-construction drainage categories specific to each mapped community observed. The categories are for how much of the wetland community was completely drained prior to restoration, based on pre-construction wetland delineations. Similar native species richness and wC values were observed among drainage categories for shallow marsh and shallow open water communities. Wet meadow communities had a higher native species richness (40, n=4) in 50-74% drained areas than 75-100 percent drained areas, although this did not correspond to change in wC values (=2.3).

Table 5. Median and interquartile range (IQR) and sample size (n) reported for native species richness and wC values by community type for various pre-construction conditions.

	Native Species Richness			wC		
	Wet Meadow	Shallow Marsh	Shallow Open Water	Wet Meadow	Shallow Marsh	Shallow Open Water
Pre-Construction Crop Condition						
Row-Cropped:	27 (9), n=32	11 (6), n=30	5 (2), n=13	2.5 (1.3), n=32	0.9 (1.1), n=30	2.7 (1.6), n=13
Hay, Fallow, or Partially Row-cropped:	27 (16), n=3	13 (2), n=3	5 (2), n=5	1.9 (0.3), n=3	1.2 (0.3), n=3	2.9 (0.6), n=5
Pre-Construction % completely drained						
0-24%	-	11 (4), n=3	7 (0), n=1	-	0.8 (0.7), n=3	2.0 (0), n=1
25-49%	-	11 (0), n=1	5 (0), n=1	-	0.4 (0), n=1	4.1 (0), n=1
50-74%	40 (15), n=4	14 (6), n=4	6 (2), n=4	2.3(1.3), n=4	0.7 (0.4), n=4	4.2 (2.6), n=4
75-100%	27 (9), n=31	11 (5), n=25	5 (2), n=12	2.3 (1.3), n=31	1.2 (1.1), n=25	2.7 (0.6), n=12

Restoration Methods

Native plant species richness and wC values were summarized by several restoration attributes (Table 6).

Median values for season planted and number of species seeded within each community were similar. Although construction techniques were similar among sites (28 with embankments, 27 with tile blocks), data were summarized and compared for sites with scrapes versus without scrapes. Scrapes were more common for the shallow marsh and shallow open water communities (n=7), but little variation in median values was observed for richness or wC values. Also, no pattern was detected for different levels of management effort noted for sites.

Management actions for mitigation sites are often driven by the need to meet performance criteria or standards for regulatory requirements. Fourteen of 35 mitigation sites lacked performance criteria, all of which were constructed prior to 2006. Of 21 sites with performance criteria, criteria were reported to be met at 15 sites, not met in one site, and no information was available for five sites. Management effort typically consists of activities such as mowing and herbicide applications to reduce non-native invasive species cover. Upland buffer management (e.g. prescribed burns or thistle management) was not tabulated because it could not be directly related to wetland plant community management.

Our goal was to summarize management effort during establishment (typically 5 years after construction) and post establishment. Management effort categories were noted for all but eight mitigation sites 'during establishment', and for only four sites 'post establishment'. Uncategorized sites tended to be older and were lacking enough information for reviewers to confidently assign a category. Over 60 percent of the categorized sites had periodic management (every 2-3 years) and only two had frequent management (annual). Post establishment monitoring effort was voluntarily reported by landowners, with information for only four of the 35 wetlands.

Table 6. Median and interquartile range (IQR) and sample size (n) reported for native species richness and relative introduced cover by community type for various restoration attributes.

	Native Species Richness			wC		
Restoration Attribute	Wet Meadow	Shallow Marsh	Shallow Open Water	Wet Meadow	Shallow Marsh	Shallow Open Water
Season Planted						
Fall	27 (8), n=21	12 (5), n=20	-	2.6 (1.0), n=21	1.3 (1.1), n=20	-
Spring	27 (9), n=10	10 (4), n=9	-	2.3 (1.2), n=10	0.9 (0.7), n=9	-
Unknown	31 (17), n=4	11 (5), n=4	-	1.4 (1.2), n=4	0.6 (0.2), n=4	-
# species seeded						
0	-	14 (3), n=4	5 (2), n=18	-	0.6 (0.1), n=4	2.8(1.0), n=18
3-15	-	17 (7), n=4	-	-	1.5 (0.7), n=4	-
16-30	26 (7), n=11	11 (5), n=20	-	2.1 (0.7), n=11	0.9 (1.0), n=20	-
31-42	28 (9), n=24	11 (3), n=5	-	2.5 (1.5), n=24	1.4 (1.2), n=5	-
Scrapes						
Without Scrape	27 (13), n=33	11 (5), n=26	5 (2), n=11	2.3 (1.4), n=33	0.9 (1.1), n=26	2.5 (1.5), n=11
With Scrape	37 (12), n=2	12 (4), n=7	5 (2), n=7	2.3 (0.5), n=2	0.9 (0.7), n=7	3.0 (0.4), n=7
Management Effort[1]						
Unknown	27 (13), n=8	10 (5), n=7	5 (2), n=6	1.9 (1.7), n=8	0.8 (0.5), n=7	2.8 (0.4), n=6
None-Sporadic	23 (12), n=8	12 (4), n=7	6 (1), n=4	2.5 (0.8), n=8	1.3 (1.2), n=7	3.6 (1.6), n=4
Periodic	28 (7), n=17	11 (6), n=18	4 (1), n=7	2.5 (1.1), n=17	0.9 (1.1), n=18	2.7 (2.0), n=7
Frequent	31 (5), n=2	16 (0), n=1	5 (0), n=1	1.4 (0.4), n=2	0.6 (0), n=1	2.4 (0), n=1

[1]Assigned at the wetland level, extrapolated to each community

Restoration Age

We observed considerable variation in native species richness and wC values relative to restoration age (Figure 10) for each community. Despite the variations it appears that younger wet meadow and shallow open water communities are in better condition than older sites (Figure 10).

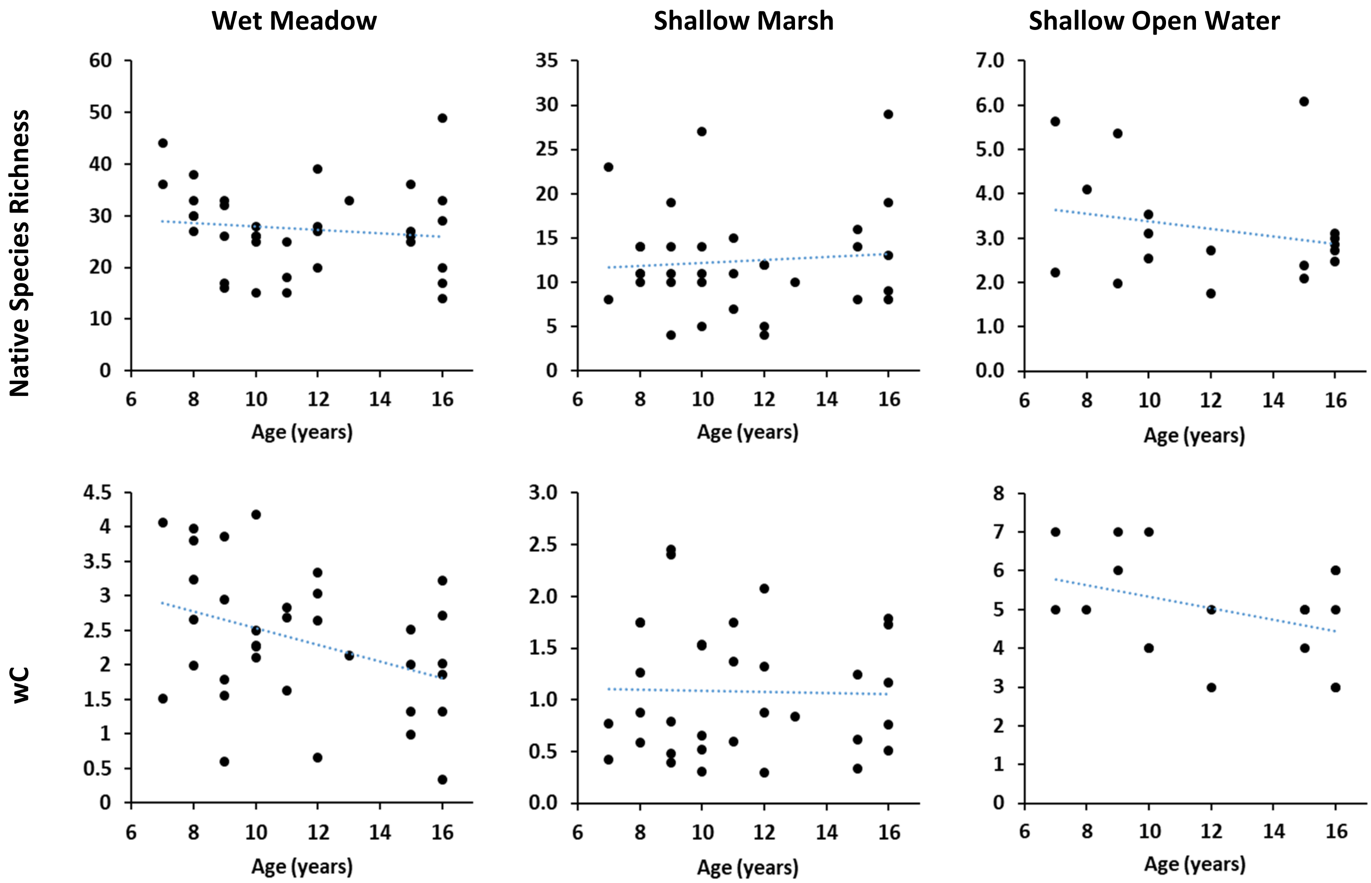

Figure 10. Scatterplots of values observed for native species richness and wC values for mitigation sites, based on the age of the site during the assessment. Dotted lines indicate linear trendlines.

Discussion

This study provides insight into the condition of wetland mitigation sites after initial establishment and management actions and some of the factors that may influence condition. We were able to achieve adequate sample sizes to compare wetlands of similar size classes, community types, and geomorphic setting (depressional). We found that landscape and immediate upland alteration differed by group type, with naturally occurring wetlands having a small proportion of sites with minimal alteration - a category essentially not observed for restored wetlands (Figure 9). This is expected because greater than 50% of the wetland area had to be completely drained prior to restoration for a restored basin to be included in the study, thereby selecting highly modified landscapes. For the immediate upland buffer parameter (within 50 meters of the site), restored wetlands had a higher proportion of low to moderate rankings than naturally occurring wetlands which is likely related to programmatic buffer requirements, whereas naturally occurring wetlands had a balanced distribution among the four categories. Given the agricultural setting of most sites, we anticipated that the vegetation communities would be influenced by a disturbance history and that most sites would be in fair to poor condition.

Condition

The condition of mitigation sites (intensively restored wetlands) was similar to naturally occurring wetlands (Figure 5). Passively restored wetlands were in poorer condition (75% of sites) likely due to reliance on natural revegetation rather than seeding native wetland species. Geographic location may have a role in condition outcomes as our passively restored wetlands were mostly limited to the temperate prairies, while intensive and natural sites are also represented in the mixed wood plains where a few good condition scores were observed (Figure 6). To better understand these results, we compared condition among different plant communities using floristic quality metrics (wC, Mean C, FQI, and native species richness).

For the wet meadow community, intensively restored wetlands had higher scores for all metrics we reviewed (Figure 8), yet we did not observe a condition category above fair (Figure 7). Most (83%) of intensively restored wet meadows were in fair condition (Figure 7). Among all wet meadow communities the median value for species richness was 25 for fair condition sites, and 15 for poor condition sites with high variability in both categories (Table 4). There were only three wet meadows with a good condition score, and their median value of native species was 27, similar to the fair condition category.

The shallow marsh communities of intensively restored wetlands were in poorer condition than those of naturally occurring wetlands, but similar to passively restored sites (Figure 7). A review of the individual metrics shows that median values for all metrics were higher in naturally occurring wetlands, with overlapping confidence intervals with intensively restored wetlands for all metrics except the wC value. As the wC value is in part calculated by percent cover estimates, we can assume that naturally occurring wetlands likely have a higher native percent cover than restored wetlands. Among all sites regardless of group, the median value for species richness was similar for fair (median = 12) and poor (median = 10) condition categories (Table 4). There were only three shallow marshes with a good condition score, and the median native richness was 27.

The shallow open water community had a potential of two condition categories as outcomes: good or fair (Table 3). Each group had a similar distribution of these condition scores, with the majority (>80%) in the fair category (Figure 7). The measured values for wC, Mean C, FQI, and native species richness were similar among group types as well (Figure 8). Among all sites regardless of group, median values of native species richness were similar between the good and fair categories (6 and 5, respectively) (Table 4).

Our condition category results are similar to MPCA's statewide ambient and trend monitoring for the southern part of the state. Their survey results based on 88 wetlands estimated that over 80% of wetland extent in the temperate prairie and mixed wood plains ecoregions are categorized as poor or fair condition based on vegetation (Bourdaghs et al. 2019). An additional assessment of depressional wetlands completed by the MPCA found 58% of basins in fair condition and 24.7% in poor condition (Genet et al. 2019). Their survey focused on sites that had open water and shallow marsh communities, typically excluding non-emergent zones such as the wet meadow fringe from the sampled area. By community, 70.3% of shallow open water acres are in fair condition and 20.7% in good condition, and 71.4% of shallow marsh acres are in poor condition and 18.6% in fair condition. Although MPCA results are reported by wetland area and our results are by basin, we have similar outcomes in that the predominant condition of shallow marshes in this part of the state is poor, and fair for shallow open water communities.

Condition categories have been shown to be consistently assigned among different observers (Bourdaghs 2012), whereas other floristic quality metrics may be more variable among observers and assessment area size. Although sampling by meander may introduce bias through subjectivity within the sample area, it is thought to be the better approach over random sampling to detect uncommon species and; therefore, determine floristic quality metrics more efficiently and effectively. Repeatability of these later measures was not reviewed and should be interpreted with caution.

Restoration Practices

In general, of the 35 compensatory mitigation sites reviewed, administrative files had variable completeness levels, but newer projects tended to have more complete files than older projects with information on management effort and performance standards. This is likely an outcome of policy changes related to state (2002) and federal (2008) level rule changes for compensatory mitigation. We did not detect any distinct patterns in condition or native species richness related to constructed features, time of year planted, or number of species in the seed mix (varied from 16-42 in wet meadow), nor were relationships detected for levels of management effort (Table 7). Restoration practices were not well documented for older mitigation sites used in the study.

Most plant communities for compensatory mitigation sites had similar pre-restoration hydrologic conditions with 75-100% of the wetland drained and in row crop production (Table 5). Of these restorations, 80% of sites included embankments, 77% had tile blocks, and most did not have a sediment removal or scraping component as part of the restoration (Table 6). Of the two wet meadow communities that included a scrape, native species richness was slightly higher, but no trend was observed for the shallow marsh (n=7) or shallow open water (n=7) communities with scrapes. A recent review of depressional wetland restorations with scrapes showed higher plant diversity and lower probabilities of invasive lants initially, but invasive plants had expanded 3-6 years after restoration (Larson et al. 2020). Because our assessment took place 7-16 years after restoration, and most sites had periodic to sporadic management levels during establishment, we suspect any positive effects from scraping would have been negated by invasive species expansion.

Other studies of depressional wetlands have shown invasive species are not self-correcting and will spread unless managed (Aronson and Galatowitsch 2008, Larson et al. 2020). Status and trends reports for Minnesota wetlands found invasive plants appear to be the primary drivers of vegetation community change, with reed canarygrass (*Phalaris arundinacea*) and non-native cattails (*Typha angustifolia and T.* x *glauca*) the most widespread (Bourdaghs et al. 2019). We observed a declining trend in condition related to older wet meadow communities (Figure 10). Although this may be related to non-native species invasion over time, we suspect that improvements to establishment practices (more frequent management actions, higher performance standards) have some role in higher condition scores observed for younger sites. Repeat sampling is needed to determine if these sites maintain their higher condition over time.

It appears that seed mix composition may be a primary driver of condition in wet meadow communities. The common seed mix used in mitigation restorations (32 native species) is successful at competing with non-native species during establishment – a main objective in its design. However, due to expense and availability, species with a higher C value are not as represented in the mix. Future seed mixes could be improved to more closely correspond with natural plant communities within constraints of species availability and cost. For the shallow marsh communities, only a 10-15 foot band around the edge of the marsh community was typically seeded during establishment. This seed mix did well in that zone, but failed to spread to deeper water areas where non-native cattail typically dominated. Most of the intensively restored shallow marsh communities were estimated to be 75-

100% completely drained and in row crop production prior to restoration, reducing the likelihood of a viable native seed bank establishing according to research by Wienhold and van der Valk (1989). Current practices (as of 2018) for restoring this community include installation of a 6 species seed mix in combination with non-native cattail control - the effectiveness of which has not been evaluated yet. More regular management during establishment may improve the long-term trajectory of native cover and condition (Larson et al. 2020).

Conclusion

The Minnesota Wetland Program Plan identifies long-term monitoring and assessment of wetland restoration sites as an activity of high importance (Gernes et al. 2012). Without monitoring, we are unable to evaluate one of the goals of the Wetland Conservation Act: to maintain biological diversity of Minnesota's wetlands. No-net-loss of wetland quality is a policy at both the state and federal levels. This effort focused on evaluating depressional wetlands, comparing mitigation wetlands to other restored wetlands and naturally occurring ones to better understand condition and effective restoration strategies. Our conclusions:

- Most wetlands observed were categorized as fair or poor condition. This was not an unexpected result given the high degree of landscape disturbance related to agriculture and other development in our study area. MPCA vegetation condition monitoring has also documented widespread degradation, with invasive plant cover being primary driver of vegetative community change (Bourdaghs et al. 2019). Presence of non-native invasive species result in a lower condition score. Restored wetlands in the study had a history of drainage and cropping prior to restoration. Although we frequently observed poor and fair vegetative condition categories, restored wetlands are achieving many functional gains as land transitioned from row crops to wetland habitat. Some of these functions, such as trapping sediment and processing of excess nutrients may impede vegetative condition by creating conditions well-tolerated by invasive species (Galatowitsch et al. 1998).
- We documented no-net-loss in terms of wetland quality for depressional wetlands, as vegetative condition of 7-16 year-old mitigation wetlands was similar to naturally occurring wetlands. This result is driven by the wet meadow community which was in better condition than naturally occurring and passively restored wetlands. In these mitigation wetlands, installation of native seed was part of the restoration plan, likely resulting in higher condition scores. Relying on seedbank and natural recruitment does not result in conditions similar to naturally occurring wet meadows and shallow marshes, but is sufficient for shallow open water communities. We suspect management activities targeting invasive control also contribute to better vegetative condition but lack sufficient documentation on establishment and post-establishment management to verify this conclusion.
- Results of this study support current practices, such as installing native wetland seed and adopting management plans to limit invasive establishment. State seed mixes, a recommended component of restoration plans, continue to be amended to improve options and outcomes. The next revision of mixes will include the addition of a marsh mix intended to improve outcomes of shallowly inundated areas by providing competition with cattails, which has been a pilot mix since 2018. Policy and guidance continue to develop, with the Minnesota Wetland Restoration Guide, Federal Mitigation Rule (2008), and revisions to the Wetland Conservation Act (2009 and current) all aiming to increase consistency and efficacy of wetland mitigation throughout the state.

The Minnesota Board of Water and Soil Resources is continuing this monitoring effort by collecting baseline vegetative condition data on mitigation wetlands statewide from all hydrogeomorphic classes. We anticipate that after establishing baseline condition data, a subset of sites will be selected for trend monitoring to provide more information on the influence of establishment techniques or age. These data will continue to inform our mitigation guidance and determine the extent of long-term management needs to maintain native wetland communities in approved wetland mitigation sites.

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Appendix 1 – Quality Assurance Process Outcomes for Data Usability

Quality control activities for this project were developed to ensure that we had suitable data to use for our final analyses. Our goal was to have replicable data that adequately characterized wetland communities in order to make floristic quality conclusions. Data quality measures included precision, completeness, and representativeness. To estimate precision, repeated measurements were done to determine agreement for plant identification (voucher verification) and condition score assignment (field data verification). Completeness was first reviewed by determining the proportions of species identified at each site. To further review data completeness, we included an additional criterion of relative cover that was reviewed at the community level for each site. Representativeness was validated by reviewing the wetland indicator status of species listed for each community. Any data that did not meet criteria identified for these measures were further reviewed to determine if they were adequate for our intended use. Seasonal or climatic conditions accounted for some of the deviations observed in the data, and these data were determined to be useable. In other cases limitations were identified in representativeness or completeness, and those samples were excluded from analyses.

Precision

Voucher verification

For each sample site, at the end of the survey, two plant species listed on the field data sheet were randomly selected: one which was identified in the field and the other which would be later identified in the laboratory. These randomly chosen specimens were collected and preserved as vouchers. A member of the voucher verification team then identified each specimen to the lowest taxonomic level possible without seeing the original identification. The voucher verification team was comprised of Dan Shaw (Board of Water and Soil Resources Vegetation Specialist), Carol Strojny (Board of Water and Soil Resources Monitoring Specialist), Steve Eggers (US Army Corps of Engineers Senior Ecologist), and Barbara Walther (US Army Corps of Engineers Senior Ecologist). Welby Smith (Minnesota Department of Natural Resources Botanist) also assisted with voucher verification at the end of the season. Voucher identification sessions were held monthly or more frequently as needed.

We sampled 137 sites over the three field seasons, and 14 sites were resampled for quality control, resulting in 306 specimens to verify. For field identified species, our goal was at least 90% agreement on identification. Our agreement rate was 96% (147 of 153). For lab identified species, our goal was at least 80% agreement which we met with an agreement rate of 84% (128 of 153). When agreement was not met, the identification of the verification team was used in the data.

Field data verification

This study's sampling methodology includes classifying communities and conducting a meandered survey to describe vegetative composition within each community. To assess variability of community classification and scores, a field team with members that were not involved in the primary samples conducted repeat sampling of 10% of the sites surveyed.

Of the 137 sites sampled, 14 were randomly selected and resampled within three weeks of the primary sample. Resampling was performed by either Dan Shaw (Board of Water and Soil Resources Vegetation Specialist) or Carol Strojny (Board of water and Soil Resources Monitoring Coordinator). Our quality assurance criteria were to have a match rate of 75% in both community classification and condition classes.

For the sites resampled, *community classifications* (n=34) matched 100% (Table 1). *Community condition* categories matched (79%) (Table 1). Also, no bias was detected in the repeat sampling. The condition classes that did not match were evenly dispersed between better and worse categories. *Site condition categories* (weighted by area of each community) matched 93% (Table 2). Criteria were met, resulting in the primary samples being used unless review of further quality control criteria were not met for completeness and representativeness.

Table 1. Community classification and condition category results for the primary and replicate field data, including scores for the weighted coefficient of conservatism (wC). Lack of agreement shown in red.

Group	Assessment Area (Site)	Primary Sample			Replicate Sample		
		Community	wC	Condition	Community	wC	Condition
Natural	NAT RN011	Fresh Meadow	0.5	Poor	Fresh Meadow	0.8	Poor
	NAT RN011	Shallow Marsh	1.8	Poor	Shallow Marsh	3.0	Fair
	NAT RN2423	Fresh Meadow	2.6	Fair	Fresh Meadow	1.1	Poor
	NAT RN2423	Shallow Marsh	0.5	Poor	Shallow Marsh	1.7	Poor
	NAT RN2995	Fresh Meadow	1.0	Poor	Fresh Meadow	1.1	Poor
	NAT RN2995	Shallow Marsh	1.7	Poor	Shallow Marsh	0.6	Poor
	NAT RN4392	Fresh Meadow	4.0	Fair	Fresh Meadow	3.3	Fair
	NAT RN4392	Shallow Marsh	1.0	Poor	Shallow Marsh	0.6	Poor
Passive	RIM 12.05.02.01-1	Fresh Meadow	0.5	Poor	Fresh Meadow	0.3	Poor
	RIM 12.05.02.01-1	Shallow Marsh	0.5	Poor	Shallow Marsh	0.8	Poor
	RIM 12.05.02.01-1	Shallow Open Water	2.3	Fair	Shallow Open Water	2.0	Fair
	RIM 12.13&14.01.01-1	Fresh Meadow	1.9	Fair	Fresh Meadow	0.5	Poor
	RIM 12.13&14.01.01-1	Shallow Marsh	1.0	Poor	Shallow Marsh	1.6	Poor
	RIM 12.13&14.01.01-1	Shallow Open Water	3.5	Fair	Shallow Open Water	3.5	Fair
	RIM 24.06.01.01-1	Fresh Meadow	0.7	Poor	Fresh Meadow	1.7	Fair
	RIM 24.06.01.01-1	Shallow Marsh	1.4	Poor	Shallow Marsh	1.1	Poor

	RIM 24.06.01.01-1	Shallow Open Water	2.6	Fair	Shallow Open Water	3.0	Fair
	RIM 37.50.01.01-8	Fresh Meadow	2.7	Fair	Fresh Meadow	3.3	Fair
	RIM 37.50.01.01-8	Shallow Marsh	0.8	Poor	Shallow Marsh	1.6	Poor
	RIM 64.02.00.01-8	Fresh Meadow	0.4	Poor	Fresh Meadow	0.8	Poor
	RIM 64.02.00.01-8	Shallow Marsh	0.8	Poor	Shallow Marsh	1.0	Poor
	RIM 64.02.00.01-8	Shallow Open Water	2.5	Fair	Shallow Open Water	4.3	Fair
Intensive	WB 3737 - 2	Fresh Meadow	2.8	Fair	Fresh Meadow	2.6	Fair
	WB 3737 - 2	Shallow Marsh	1.7	Poor	Shallow Marsh	1.0	Poor
	WB 3864 - 1	Fresh Meadow	1.6	Fair	Fresh Meadow	2.6	Fair
	WB 3864 - 1	Shallow Marsh	1.4	Poor	Shallow Marsh	2.3	Fair
	WB 4285 - E	Fresh Meadow	3.0	Fair	Fresh Meadow	2.7	Fair
	WB 4285 - E	Shallow Marsh	2.4	Fair	Shallow Marsh	1.7	Poor
	WB 4285 - E	Shallow Open Water	5.4	Good	Shallow Open Water	5.0	Fair
	WB 4423 - 1	Fresh Meadow	4.0	Fair	Fresh Meadow	4.2	Fair
	WB 4423 - 1	Shallow Marsh	1.1	Poor	Shallow Marsh	0.7	Poor
	WB 4423 - 1	Shallow Open Water	3.2	Fair	Shallow Open Water	3.5	Fair
	WB 4625 - 1	Fresh Meadow	2.3	Fair	Fresh Meadow	3.2	Fair
	WB 4625 - 1	Shallow Marsh	0.5	Poor	Shallow Marsh	1.0	Poor

Table 2. Site condition categories and date sampled for the primary and replicate field data. Lack of agreement shown in red.

		Primary Sample		Replicate Sample	
Group	**Assessment Area (Site)**	**Date**	**Condition**	**Date**	**Condition**
Natural	NAT RN011	June 14, 2017	Poor	June 26, 2017	Poor
Intensive	WB 4423 - 1	July 11, 2017	Fair	July 28, 2017	Fair
Passive	RIM 37.50.01.01-8	August 2, 2017	Poor	August 23, 2017	Poor
Passive	RIM 64.02.00.01-8	August 22, 2017	Poor	September 7, 2017	Poor
Intensive	WB 4625 - 1	June 20, 2018	Fair	June 27, 2018	Fair
Natural	NAT RN2995	July 10, 2018	Poor	July 26, 2018	Poor

Passive	RIM 12.13&14.01.01-1	July 25, 2018	Poor	August 14, 2018	Poor
Natural	NAT RN2423	August 2, 2018	Poor	August 14, 2018	Poor
Intensive	WB 3864 - 1	August 22, 2018	Fair	August 29, 2018	Fair
Passive	RIM 24.06.01.01-1	August 30, 2018	Fair	September 10, 2018	Poor
Intensive	WB 3737 - 2	September 7, 2018	Poor	September 10, 2018	Poor
Intensive	WB 4285 - E	June 18, 2019	Fair	July 1, 2019	Fair
Passive	RIM 12.05.02.01-1	July 23, 2019	Poor	August 13, 2019	Poor
Natural	NAT RN4392	July 26, 2019	Poor	August 13, 2019	Poor
Intensive	WB 3737 - 2	September 7, 2018	Poor	September 10, 2018	Poor
Intensive	WB 4285 - E	June 18, 2019	Fair	July 1, 2019	Fair
Passive	RIM 12.05.02.01-1	July 23, 2019	Poor	August 13, 2019	Poor
Natural	NAT RN4392	July 26, 2019	Poor	August 13, 2019	Poor

Completeness

Data sheet review

A completeness review was done to ensure the plant lists were sufficient for estimating floristic quality metrics. In order to be included in the calculations of a condition score, each vascular plant species needed to have a cover class listed and be identified to species level. Through periodic reviews we confirmed that all vascular species listed had a percent cover category. As plants only known to genus, family, or a higher classification are excluded from condition score calculations, our project plan set a performance goal of at least 90% of vascular plants listed to be identified to the species level. Among the 151 samples (includes replicate samples), the range of plants identified to a species level was 79-100% at the site level. The 22 sample sites (two replicate and 20 primary) that did not meet the criteria were further reviewed to determine why the data did not meet the objective.

Unknown specimens were typically members of genera or families that are difficult to identify without flowering parts or when the plant is immature (*Bidens*, *Carex*, *Eleocharis*, *Juncus*, *Rubus*, *Rumex*, *Salix*, *Symphyotrichum*, Brassicaceae, Poaceae, Potamogetonaceae). The cover classes for unknowns was often <1%, signifying that they would not likely have a strong effect on the calculated wC value. However, we will also be evaluating other metrics including native species richness and non-native cover. Therefore, we determined an additional criterion was needed as an indicator of completeness. We required 80% of the relative cover to be known to the species level for each community. After reviewing this threshold, eight sites were identified that did not meet this criterion. One site's data was replaced with the replicate data set (WB 4423-1), and 7 other sites were removed from site-level analyses and community level analyses where deficient (Table 3). For example, if the fresh meadow and shallow marsh data were usable, and the shallow open water data was not, the data would be included only for analyses specific to fresh meadows and shallow marshes.

Table 3. Sample sites having a community with <80% relative cover of known plants (identified to species)

Assessment Area (Site)	Community Not Meeting Completeness Criterion	Relative Cover of Knowns
RIM 8.22&23.00.01-1	Shallow Open Water	14%
WB 4552 - 1	Shallow Open Water	27%
WB 4536 - 1	Shallow Open Water	45%
NAT RN1853	Shallow Open Water	67%
WB 4226 - 1	Shallow Open Water	69%
NAT RN354	Fresh Meadow	71%
NAT RN090	Shallow Open Water	73%

Representativeness

Data sheet review

Representativeness was reviewed to determine if the species listed were characteristic of the community identified. Our goal was for 75% of species listed to be typical of the community type. If this goal was not met, the data were further reviewed to determine if climate conditions may explain the observations, or if an error was made.

- For shallow open water communities, we expected at least 75% composition of wetland obligate species. Of 81 shallow open water communities, one site did not meet this criterion. However, it was surveyed during a natural draw down period, and the non-obligate species were annuals typical of mudflats. Data from this site were not considered to be an error.
- For shallow marsh communities, we expected at least 75% composition of wetland obligate and facultative wetland species. Of 148 shallow marsh communities, we observed two sites that did not meet this criterium. One site had 5 of 9 species that were obligate or facultative wetland. The relative cover of those five species was 98% indicating the list was sufficiently representative. The other site (RIM 46.01&03.01.01-1) had 5 of 7 species that were obligate or facultative wetland, but these species only had 69% relative cover. The other cover consisted of *Salix x rubens* (facultative) and *Populus deltoides* (facultative). Both these species are commonly found in wetlands. The willow (*Salix x rubens*) had a cover class of 5-15% and appeared to be colonizing the shallow marsh area. These data were not considered to be an error.
- For fresh meadow communities, we expected at least 75% composition of hydrophytic (facultative or wetter) wetland species. Of 148 fresh meadow communities, 23 samples were below this threshold with 54-74% of listed species as hydrophytic. The facultative upland or upland plants typically had <1%

cover, and were weedy agricultural plants such as *Abutilon theophrasti*, *Ambrosia artemisiifolia*, *Sonchus arvensis*, or invasive perennial plants such as *Bromus inermis*, *Cirsium arvense*, and *Elymus repens.* Native upland species (*Achillea millefolium*, *Asclepia syriaca*, and *Solidago canadensis)* were often observed in the upper edges of the fresh meadow community as well. For the 24 samples not meeting the threshold, we also looked at hydrophytic cover. Two sites had less than 80% relative hydrophytic cover. One site (NAT RN243) was the only grazed site and had 56% relative hydrophytic cover. We determined that data from this site would not be representative, and it was excluded from analyses. The other site had 22% facultative upland cover, which included *Solidago canadensis*, *Bromus inermis*, and *Cirsium arvense* observed in the drier edge of the wetland's transition zone. These data were not considered to be an error because those species were commonly observed among other sites in the data set, and this sample was included in site level analyses. The fresh meadow community likely had a higher rate of sites below the threshold because we encouraged our observers to include the edge of the wetland in every survey. Wetland area may have been overestimated to include upland areas in some cases. This is a minor concern because only wetland species are used to calculate the metrics of interest.

Appendix 2 – Eggers and Reed Community Classification

[1]Adapted from Eggers and Reed (2015) plant communities of Minnesota and Wisconsin. Several classes have been modified from the original classification. Modifications are as follows:

- The Fresh Meadow class here combines the original Eggers & Reed classes: Sedge Meadow, Fresh (Wet) Meadow (Native Subtype), and Fresh (Wet) Meadow (Disturbed Subtype) into a single class.
    - Rationale for the change is that the soil conditions and the species composition/abundance distributions are not significantly different between the Sedge Meadow and Fresh (Wet) Meadow (Native Subtype) and that the Fresh (Wet) Meadow (Disturbed Subtype) represents a degradation of the former classes (i.e., a Fresh Meadow in fair or poor condition as indicated by the FQA).
- The Hardwood Swamp class here includes the Eggers & Reed Hardwood Swamp (Vernal Pool Subtype). The MPCA lacks the data on Hardwood Swamps that can be interpreted as the Vernal Pool Subtype and cannot confirm whether it should be treated as a distinct subtype.
- The Sedge Mat class here, which is now named Sedge Meadow (Sedge Mat Subtype) in Eggers & Reed is more consistent with what are described as Open Rich Peatlands in the MN DNR Native Plant Community classification. Our data supports that the species composition/abundance distribution of the Sedge Mat type is distinct from Sedge Meadow; thereby it is better treated as a distinct type, not merely a subtype. Also, communities where bog wiregrass sedge (*Carex oligosperma*) and a mat of *Sphagnum* are present are more appropriately grouped as an Open Bog as opposed to the Sedge Meadow (Sedge Mat Subtype) as is currently described in Eggers and Reed.
- The Seasonally Flooded class here is inclusive of a broader range of habitat settings than the Eggers & Reed Seasonally Flooded Basin. The Seasonally Flooded class includes habitats associated with lakes, streams, and open water wetlands where the water level has dropped, exposing a mudflat, that is quickly dominated by annual species. These are ephemeral habitats that are very similar to the Seasonally Flooded Basin described in Eggers & Reed. If the water level is permanently lower, perennials will begin to take over and if water levels return it will revert back to open water habitats.

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[1] From Bourdaghs, M. and M. Gernes. Wetland monitoring standard operating procedures: Vegetation sampling procedures for wetland biological monitoring sites. Minnesota Pollution Control Agency wq-bwm3-01

1A) Mature trees (dbh > 6”) are present and form closed stands (> 17 trees/acre; > 50% canopy cover……….…… **2**

2A) Hardwood trees are dominant (> 50% areal cover); alluvial, peaty/mucky, or poorly-drained mineral soils……….…… **3**

3A) Silver maple, American elm, green ash, black willow, peach-leaved willow, box elder, cottonwood, and/or whitecrack willow (*Salix x rubens*) are dominant; growing on floodplains that are temporarily inundated during flood events, but may be well-drained for much of the growing season……………………………… **FLOODPLAIN FOREST**

3B) Black ash, red maple, yellow birch, balsam poplar, and/or quaking aspen are dominant; green ash, tamarack, balsam fir, and/or northern white cedar may be subdominant; growing on poorly-drained peat/muck or mineral soils…………………………………………………………………….…………. **HARDWOOD SWAMP**

2B) Coniferous trees are dominant (> 50% areal cover); soils usually peat/muck…………………………..…………. **4**

4A) Tamarack and/or black spruce are dominant; growing on a nearly continuous mat of *Sphagnum* moss and acidic peat soils; ericaceous (acid tolerant) shrubs dominate the understory ………………………………..………………………………………………………………………………….**CONIFEROUS BOG**

4B) Tamarack, black spruce, and/or northern white cedar are dominant; a continuous mat of mosses may be present but dominated by minerotrophic mosses; soils neutral-acidic; minerotrophic plant species present-abundant in the understory………………….…………………………… **CONIFEROUS SWAMP**

1B) Mature trees are absent or (if present) form open sparse stands; other woody plants (if present) are tall or low shrubs……………………..………………………………………………………………………………..………………… **5**

5A) Community dominated (> 50% areal cover) by woody shrubs……………..………………………………………… **6**

6A) Low, woody shrubs (usually < 3’ in height)…………………………………..……………………………………… **7**

7A) Shrubs are ericaceous and evergreen growing on a mat of *Sphagnum* moss; soils are acidic peat ……………………………………………..……………………………………………………………………… **OPEN BOG**

7B) Shrubs are deciduous, typically dominated by shrubby cinquefoil and/or bog birch as a sub-dominant; often growing on sloping wetlands or extensive flats located in northwestern MN that receive mineral rich groundwater discharge and alkaline peat soils; calcium-tolerant plants (calciphiles) are present; *Sphagnum* moss typically absent…………….…………… **CALCAREOUS FEN**

6B) Tall, deciduous shrubs (usually > 3’ in height)…………………………………………………………………………. **8**

8A) Speckled alder is dominant (comprising >50% areal cover of the tall shrub canopy); tamarack, black spruce, black ash, and/or northern white cedar may be present but do not form a canopy; typically growing on muck/peat soils………………………..……………..…………… **ALDER THICKET**

8B) Willows, red-osier dogwood, and/or bog birch are dominant; soils mineral or muck/peat ranging from alkaline-neutral-moderately acidic…………………………………..………………….. **SHRUB-CARR**

5B) Community dominated by emergent graminoids and/or forbs; or open water wetland……………………… **9**

9A) Open water wetland; emergent vegetation layer absent; vegetation consisting of floating, floating-leaved, and/or submergent aquatic species……………………………………………… **SHALLOW OPEN WATER**

9B) Emergent vegetation layer present; standing water may or may not be present………………………… **10**

10A) Seasonally to permanently inundated by water with depths up to 3' or more during most growing seasons; aquatic species often present to abundant in the understory………………… **11**

11A) Typically inundated by water of depths of 6" to 3' or more throughout the growing season in most years; community a mixture emergent and aquatic vegetation; emergent plants rooted in the sediment; common dominant emergent species include: soft stem bulrush, hardstem bulrush, river bulrush, wild rice, sessile fruited arrowhead ………… **DEEP MARSH**

11B) Inundated by water typically up to 6"; often drying to down to saturated soils during the latter half of most growing seasons; dominated by emergent species such as: narrowleaf cattail, hybrid cattail, lake sedge, slough sedge, whitetop, beaked sedge, aquatic species typically a minor component; emergent dominants can form a floating mat ………………………………………………………………………………………………………. **SHALLOW MARSH**

10B) Saturated soils or only temporarily inundated during most growing seasons; aquatic species typically absent or (if present) a very minor component of the community…………………………. **12**

12A) Temporarily inundated for a few weeks in spring giving way to mudflats and then typically dry for the remainder of the growing season; annuals (e.g., smartweeds, beggars ticks, wild millet) typically dominate; can occur as small shallow wetland basins or along lake shores and streams or semi-permanent open water wetlands that have dried up ……………………………………………………………………………………………….. **SEASONALLY FLOODED**

12B) Saturated soils, at or below the surface during the latter half of the growing season, at most briefly inundated; typically 75-100% areal cover by perennial grasses, sedges, and/or forbs..……. **13**

13A) Nearly continuous mat of *Sphagnum* moss present, acid peat soils, acid tolerant graminoids (bog wiregrass sedge, cotton grasses) are dominant………………… **OPEN BOG**

13B) *Sphagnum* moss mat absent, soils alkaline-neutral –moderately acidic, communities more productive……………………………………………………………………………………………… **14**

14A) Spring-fed supply of calcareous groundwater and calcareous peat present; calciphiles are abundant including: prairie sedge, sterile sedge, beaked spikerush, needle beakrush, low nutrush, and/or marsh arrow-grass………. **CALCAREOUS FEN**

14B) Calciphiles absent or (if present) are moderate-weak calcareous fen indicators and generally low in abundance………………………………………………………..……………… **15**

15A) Prairie graminoids and forbs are dominant including: big bluestem, prairie cordgrass, indian grass, sunflowers; soils typically mineral/saturated below the surface……………… ……………………………..……………………………………… **WET PRAIRIE**

15B) Prairie graminoids and forbs absent or (if present) are at moderate-low abundance…………………………………………………………………………………………………. **16**

16A) Bluejoint, tussock sedge, woolly sedge, woolgrass, narrow reedgrass, and/or reed canary grass are dominant; soils mucky/saturated at the surface or mineral/saturated below the surface……………… **FRESH MEADOW**

16B) Often occurs as a floating mat of circumneutral-slightly acidic peat; fen wiregrass sedge typically dominant, occasionally occurs as a floating mat of minerotrophic *Sphagnum* with marsh fern and/or arrowhead as dominants; impacted sites may be dominated by invasive cattail………….. ………………………………………………………………………………………….. **SEDGE MAT**

Appendix 3 – Shoreline vs Meander Sampling in Shallow Open Water Communities

We did meander sampling by canoe and shoreline sampling (three per shoreline) at eight sites. Sites ranged in size from 0.4 to 11.4 acres, with most (seven) being less than 3 acres. Samples were collected at separate times by independent observers between August 27th and September 13th, 2019. Samples included lists of all species observed in the shallow open water community, and an estimate of their percent cover. Unvegetated cover was also estimated. From the species lists we determined the weighted coefficient of conservatism (wC), total native species richness, total cover, and total unvegetated cover for each wetland. We compared the means of the sampling techniques using a paired t-test (α = 0.05) (Figure 1).

Figure 2. Shoreline and meander sampling method used on the same shallow open water community.

All measurements had similar outcomes except for total cover, where the meander method detected higher values for total cover. Unvegetated cover was similar, however, indicating layering of vegetation was observed by meander. The data supports this, with floating leaved plants (*Lemna* spp., *Wolffia* spp., *Spirodela polyrrhiza*) observed with submergent plants (*Ceratophyllum demersum*, *Elodea* spp., *Potamogeton* spp., *Stuckenia pectinata*).

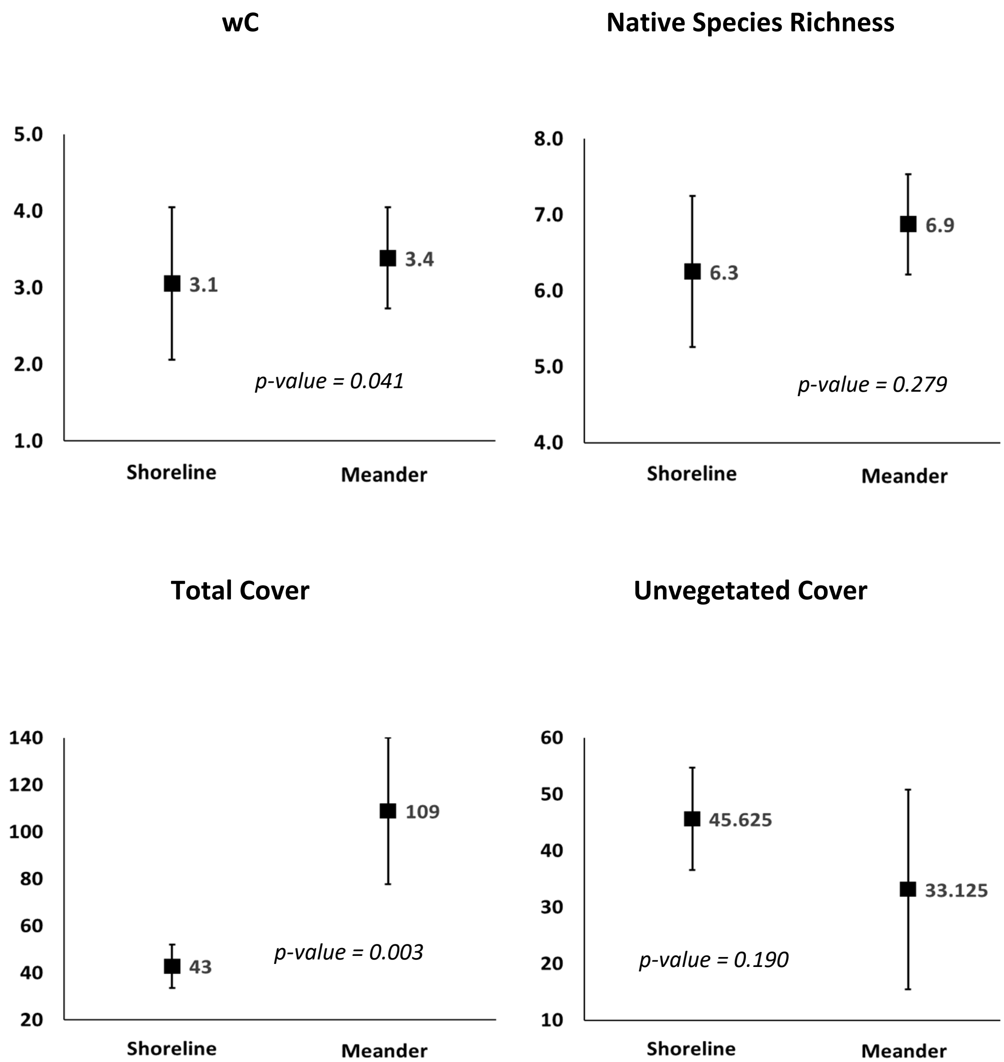

Figure 1. Mean values and 95% confidence intervals observed for shoreline and meander sampling of shallow open water communities (n=8). Results of paired t-test (α = 0.05) shown in italics.