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Performance of rapid floristic quality assessment indices for increasing cost-effectiveness of wetland condition evaluation

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ABSTRACT

This project tested whether rapid floristic quality indices can be used in North Carolina's diverse wetland types, given the many cost-saving benefits that can be realized from using such indices. Vegetation plot data from 2030 North Carolina wetland plots were analyzed to test how well two floristic quality assessment indices, based on cover-dominant species and based on non-graminoid species, were correlated with full index values based on a comprehensive species list.

Dominance based indices (Mean C and FQI) significantly correlated with Mean C and FQI using all species, but Mean C was more strongly correlated than FQI. Mean C of cover-dominant species correlated with the Ohio Rapid Assessment Method, but could only distinguish the lowest and highest North Carolina Wetland Assessment Method ratings. Removal of graminoids as a group, which are difficult to identify, did not appear to affect Mean C, even in herbaceous wetlands, though some wetlands were comprised of only graminoids; a dominance based index would still be useful in graminoid marshes. The availability of this cost-saving assessment tool will benefit researchers and practitioners looking for more expedient ways of assessing wetland quality or validating rapid assessments with direct measurements.

1. Introduction

Tremendous population growth in North Carolina and many other areas in the Southeast has put increasing pressure on wetland and stream resources from increased urbanization, nutrient loading, and coverage by invasive and exotic plants. Wetland monitoring is imperative for helping states and tribes better manage and protect wetland resources.

The US Environmental Protection Agency describes a three-tiered framework for wetlands monitoring and assessment. Level 1, or landscape scale assessment, exclusively uses GIS data to produce landscape metrics describing wetland condition. Level 2, or rapid assessment, utilizes simple metrics based on readily observable characteristics or stressors on location, to place a wetland on a gradient of disturbance and ecological integrity. Level 3, or intensive site assessment, requires directly gathering detailed measurements of biological taxa and/or hydrogeomorphic function. Level 3 assessment often includes vegetation data collection, soil analysis, and/or faunal surveys, which then can be valuable for validating and refining Level 2 and Level 1 assessment methods.

Floristic quality assessment is a Level 3 measure of vegetation composition which has proven to be an excellent indicator of wetland quality and condition (Lopez and Fennessy, 2002, Bourdaghs et al., 2006, Miller and Wardrop, 2006, Rocchio, 2007; Taft et al., 1997). Floristic quality assessment has been shown to be robust to successional changes, natural variability, and turnover in taxonomic composition (Spyreas et al., 2012, Bried et al., 2013, Deimeke et al., 2013). Two floristic quality assessment metrics, the Floristic Quality Index (FQI) and Mean C (part of the FQI) are being used throughout the Southeast in Florida (Cohen et al., 2004), Georgia (Zomlefer et al., 2013), Kentucky (Shea et al., unknown date), Mississippi (Ervin et al., 2006), North Carolina (Yepsen, 2012), and Tennessee (Elam, 2015), as well as in many states outside of the Southeast (Wilhelm and Mazur, 2016). Floristic quality indices make use of species-specific Coefficients of Conservatism (C values), numbers from 0 to 10 which are based on plant species' habitat requirements. High C values are associated with species restricted to high quality, undegraded habitats; low C values represent species found in a broad range of habitats, usually with a strong tolerance for anthropogenic disturbance. C values are assigned by expert botanists, and, although they are subjective, have been shown to carry a great deal of ecological information, especially when considered collectively for species assemblages (Matthews et al., 2015).

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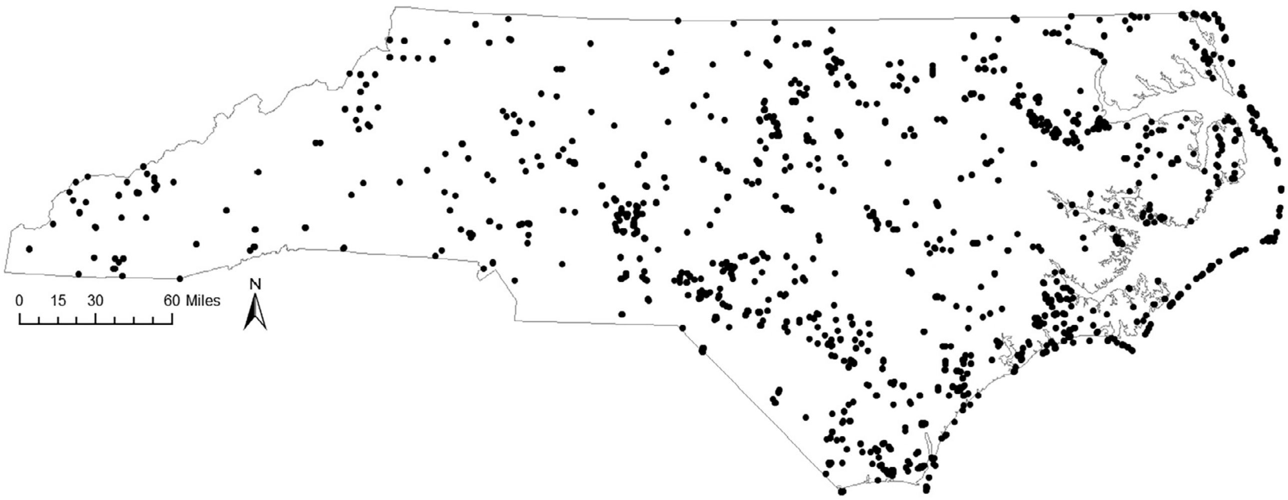

Fig. 1. Map of wetland vegetation plot locations in North Carolina (n = 2030).

Table 1
Data sources used for testing the rapid floristic indices.

Data Source	Years Collected	Number of Wetland Plots
NC Division of Water Resources Projects (NC DWR)	2005–2016	92
National Wetland Condition Assessment (NWCA) North Carolina Plots	2011–2016	92
Carolina Vegetation Survey (CVS)	1981–2015	1818
National Park Service (NPS)	1997–2010	28

Although it is an excellent way to evaluate wetland condition, one drawback to floristic quality assessment has been the typical requirement that every plant within a sampling area be identified to species-level. This often requires significant time commitment and sampling personnel with a high level of expertise. Often states, especially in the southeastern United States, do not monitor their wetlands regularly, or at all, due to time and cost constraints. Rapid methods will allow more sustainable and efficient monitoring of natural wetlands, assessing of impact areas and restoration success, and location of priority conservation areas.

Currently, only a few rapid floristic quality indices have been tested. In Minnesota, Bourdaghs (2012) has successfully developed a timed meandering sampling method as a way of reducing the time required. His team created a species checklist for the most common and easiest to identify species for inclusion in their rapid FQI. Testing showed no

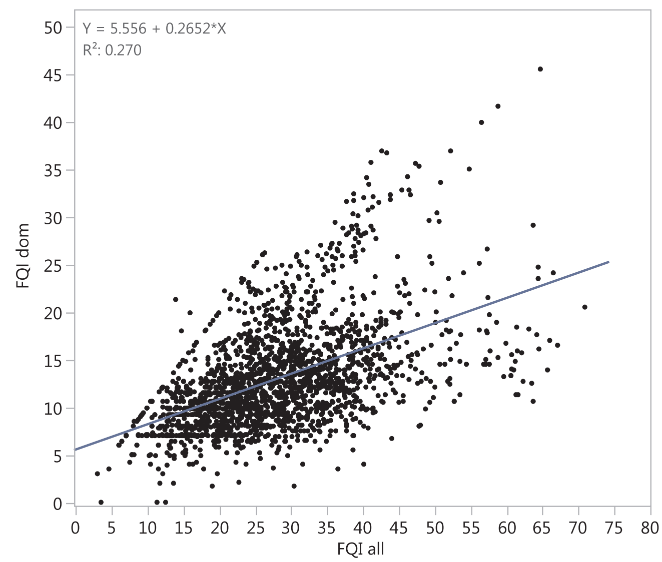

Fig. 3. Pearson correlation of FQI_{dom} (dominant species only) with FQI_{all} (all species) ($r = 0.52$, $p < 0.0001$, n = 2030).

significant difference between the rapid FQI and the full FQI in Minnesota. A rapid FQI based only on cover-dominant species has also been tested in Pennsylvania with promising results, but it was only tested for

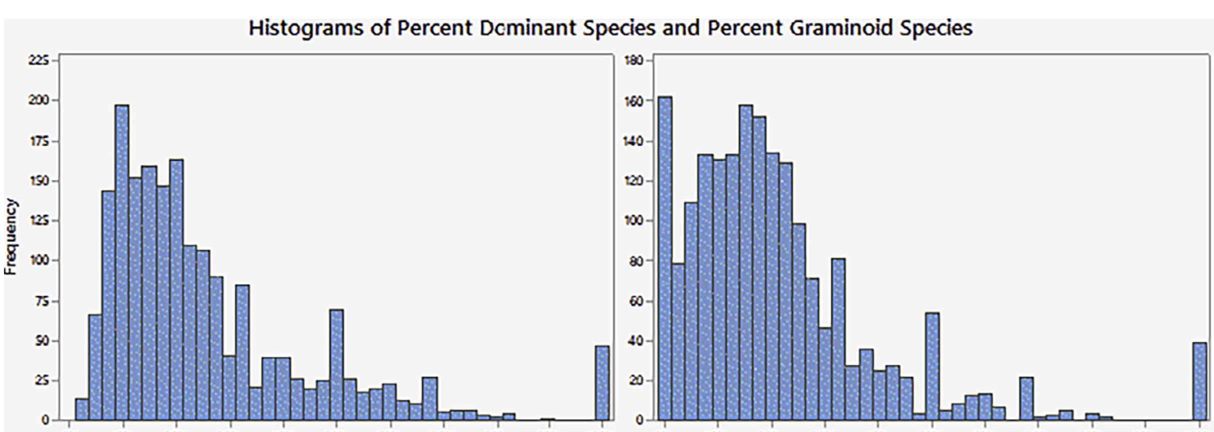

Fig. 2. Histograms of percentage of total species which qualified as cover-dominant species and percentage of graminoid species (n = 2030).

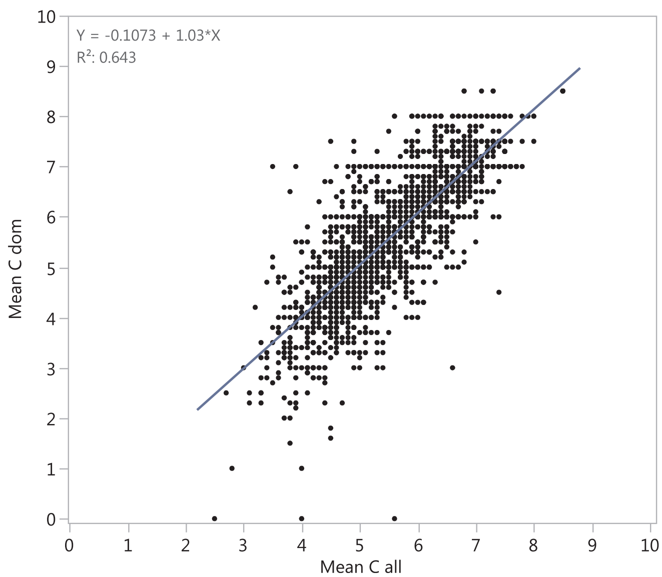

Fig. 4. Pearson correlation of Mean C_{dom} (dominant species only) with Mean C_{all} (all species) ($r = 0.80$, $p < 0.0001$, $n = 2030$).

one wetland type in that state, forested headwater wetlands (Chamberlain and Brooks, 2016).

North Carolina, and the Southeast in general, contains many wetland types, as well as an exceptional level of biodiversity within those wetlands. The purpose of this project was to test rapid indices with data from a variety of North Carolina wetland types. Recording information from only dominant species or only non-graminoids, which tend to be more limited in number, would save time and reduce expertise required for data collection. It also would result in fewer unknown species requiring expert identification and shorter data processing time.

A rapid index would be broadly applicable for use in refining Level 2 rapid assessment methods, impact area assessment for regulatory applications, identifying reference wetlands, restoration assessment, and wetland condition monitoring. Its availability as a condition measure to a wider professional population (such as conservation organizations, consultants, mitigation banks, regulatory staff) could result in identification of high quality wetlands for impact avoidance or conservation efforts. Furthermore, mitigation or restoration techniques that result in higher index values could inform future efforts.

2. Methods

2.1. Vegetation plot data compilation

Vegetation plot data were obtained from a variety of sources, including past NC DWR wetlands monitoring projects, EPA's 2011 and 2016 National Wetland Condition Assessment (NWCA), the National Park Service vegetation PLOTS database (NPS), and the Carolina Vegetation Survey (CVS) (Peet et al., 1998). All sources utilized a plot sampling design, in which every species present within a plot was recorded and percent cover noted. Data were collected under standardized protocols and underwent quality control measures prior to release. Plot descriptions included location, number, project name, sampling date, natural vegetation community classification (CEGL code – Community Element Global code), and other information. Because NPS and CVS plot data were collected in both upland and wetland habitats, CEGL codes were used to detect wetland plots and exclude other plots (upland or unreported CEGL). Plot size among these different data sources varied, but was not considered a problem in calculating FQI values because all species in each plot were recorded and plot size was designed to be large enough to be representative of the surrounding area. In the end, vegetation data were utilized from 2030 plots located throughout North Carolina (Fig. 1; Table 1).

Data from two Level 2 rapid assessment methods (Ohio Rapid Assessment Method [ORAM] and North Carolina's Wetland Assessment Method [NCWAM]) were compiled for 162 wetlands, where they were used at NC DWR and North Carolina's NWCA sites. The ORAM is a habitat quality focused assessment which yields a numerical score based on 6 major aspects of a wetland, including size, buffers/land use, hydrology, habitat alteration, special wetland types, vegetation characteristics (Mack, 2001). In North Carolina wetland assessments, we calculate the ORAM excluding the special wetland types metric, as it is mostly unique to Ohio. The NCWAM is a short assessment of hydrological, water quality, and habitat functions a wetland is performing and has the potential to perform, yielding a rating of High, Medium, or Low (NC Wetland Functional Assessment Team, 2010, 2016).

3. Testing rapid floristic quality indices

The Southeast Wetland Plant Coefficients of Conservatism database (Gianopulos, 2014) was used to match C values with species identified for all sites compiled. The Taxonomic Name Resolution service (Boyle et al., 2013) was employed to ensure all species lists conformed to the USDA's naming convention before matching them to the C value database (USDA, NRCS, 2018). In the database, non-native species were assigned a rating of zero, as they are considered to contribute no conservation value to an area. Floristic Quality Index values were computed for each site using the following FQI formula, where number of species included native and non-native species (Swink and Wilhelm, 1994):

$$FQI = \bar{C} \times \sqrt{N}$$

Where:

$\bar{C}$ = Mean Coefficient of Conservatism
N = Number of species, including non-native species

Mean C was tested for performance alongside FQI. Taxa were only included if they were identified to species level or lower [variety or subspecies] because C values are not available at the genus level.

For calculation of dominance based rapid indices Mean C_{dom} and FQI_{dom}, dominance was determined based on percent cover using the 50/20 rule for wetland delineations, which defines dominance as "the most abundant plant species (when ranked in descending order of abundance and cumulatively totaled) that immediately exceed 50% of the total dominance measure for the stratum, plus any additional species that individually comprises 20% or more of the total dominance measure for the stratum" (Gage and Cooper, 2010). Herbaceous and vine species were treated as one stratum; tree and shrub species were combined as one stratum, then dominant species flagged for each stratum using the rule. Mean C_{dom} and FQI_{dom} were calculated using all dominant species.

Graminoids (grasses, sedges, and rushes) can be particularly challenging to identify, often require flowers for identification, and may be excluded intentionally or unintentionally from data collection. To understand the impact of excluding difficult-to-identify graminoid species, indices were tested for sensitivity to the selective removal of graminoids in forested, shrub and herbaceous wetlands.

All data were normally distributed, so Pearson product-moment correlation was used to test how well the rapid indices correlated with the full species list indices for wetlands across NC, as well as how well the rapid indices correlated with numerical ORAM scores. ANOVA and Tukey's tests were used to determine examine whether the rapid indices differed across categorical NCWAM ratings. To determine whether wetland type affected the results, wetlands were categorized by plant structure (forested, shrub, herbaceous) and salinity (freshwater, brackish and saltwater). Each data source differed in degrees of defining and reporting wetland habitat types for their plots, so consistency

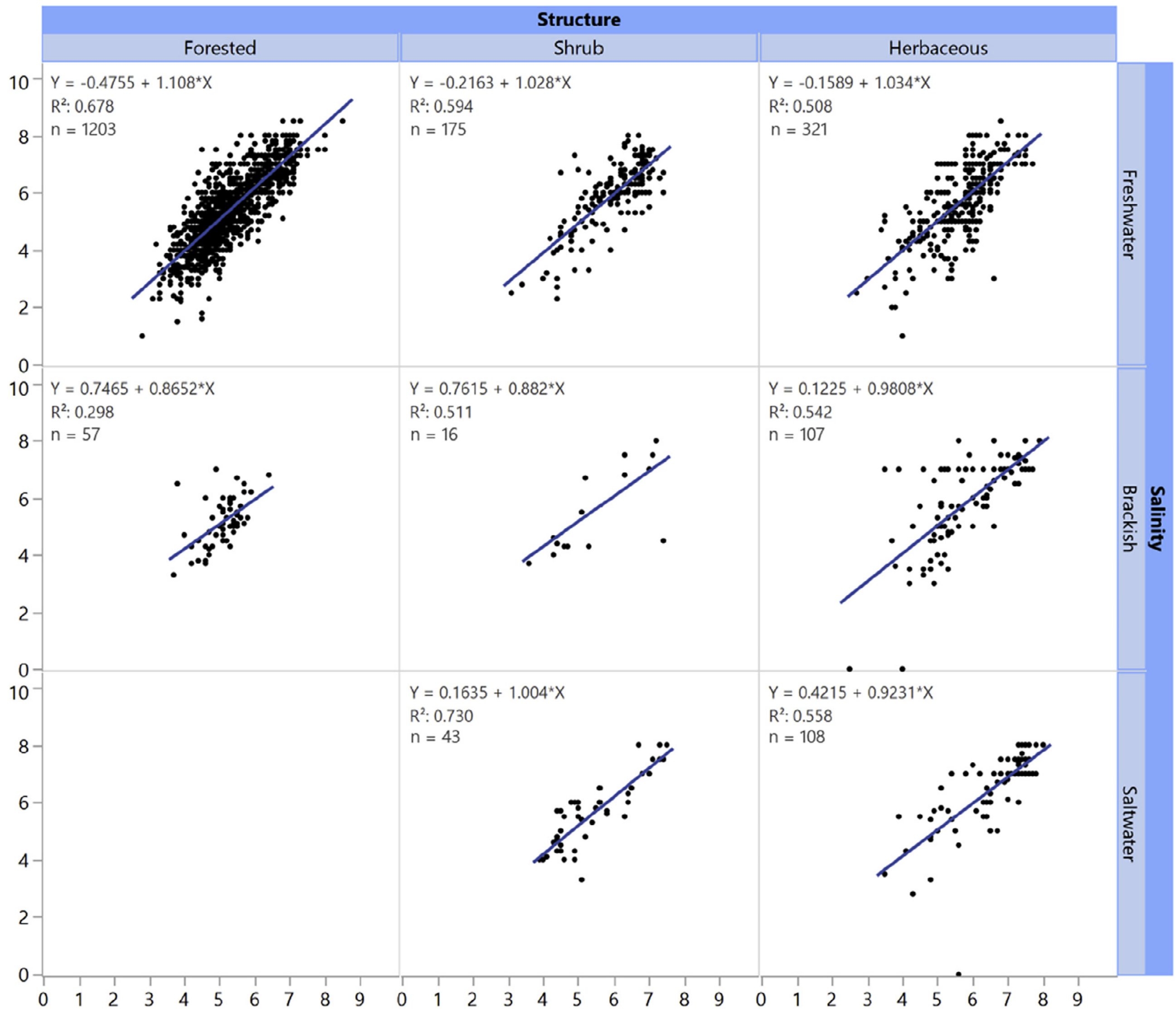

Fig. 5. Correlations between Mean C_{all} and Mean C_{dom}, by plant structure and salinity, for North Carolina wetland plots ($p < 0.002$ for all relationships). No plots were in forested saltwater wetlands.

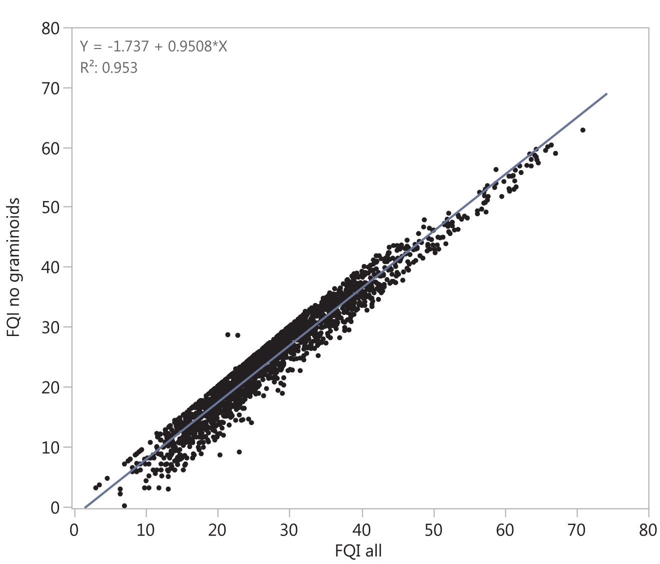

Fig. 6. Pearson correlation between $FQI_{no\text{-}gram}$ (graminoids excluded) and FQI_{all} (all species) ($r = 0.98$, $p < 0.0001$, $n = 1987$).

across data sources was achieved using these broader structure and salinity type categories.

4. Results

Percentage of total species in each plot which met the definition of cover-dominant species varied from zero to 100 percent, with a median of 20 percent (Fig. 2). Nearly all vegetation plots with very high percentage of cover-dominant species (90–100%) were herbaceous marshes of all salinity types. Percentage of total species which were graminoids also varied from zero to 100 percent, with a median of 17 percent.

4.1. Index performance

FQI_{dom} was significantly correlated with FQI_{all} ($r = 0.52$, $p < 0.0001$, $n = 2030$) and Mean C_{dom} was significantly correlated with Mean C_{all} ($r = 0.80$, $p < 0.0001$, $n = 2030$), but the correlation for Mean C was stronger the FQI (Figs. 3 and 4). Low species richness in a plot did not appear to affect the relationship between C_{dom} and C_{all}. For plots with fewer than 10 species or 5 species, C_{dom} was still significantly correlated with C_{all} (species < 10: $r = 0.77$, $p < 0.0001$,

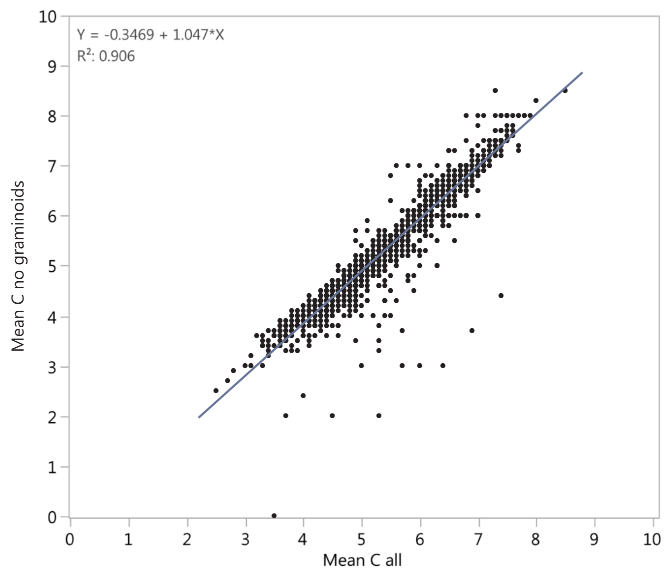

Fig. 7. Pearson correlation Mean $C_{no\text{-}gram}$ (graminoids excluded) and Mean C_{all} (all species) ($r = 0.95$, $p < 0.0001$, $n = 1987$).

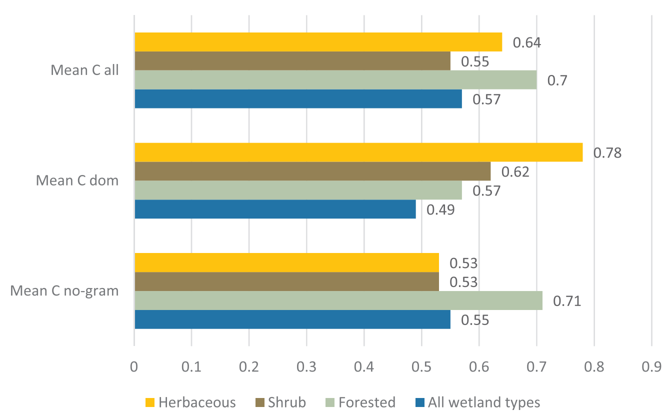

Fig. 8. Pearson correlation coefficients for correlations between Mean C and ORAM by wetland plant structure (all $p < 0.01$).

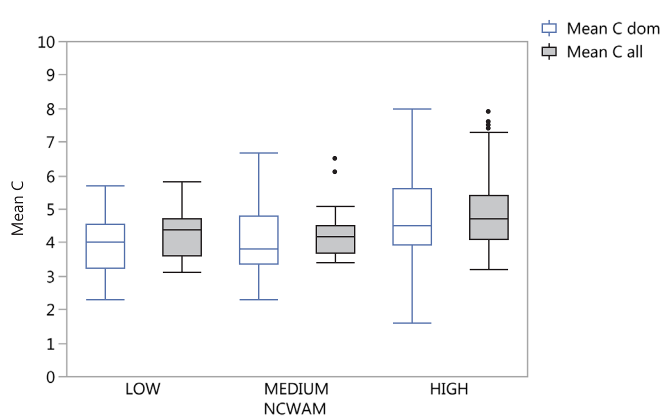

Fig. 9. Boxplot of Mean C and NCWAM quality ratings at 162 North Carolina wetland sites.

$n = 321$; species < 5: $r = 0.87$, $p < 0.0001$, $n = 121$). Wetland structure and salinity type did not change the significance of the correlation between Mean C_{dom} and Mean C_{all} (Fig. 5). No plots were in forested saltwater wetlands.

Selectively removing graminoids (Cyperaceae, Juncaceae, and Poaceae families) did not change the indices by much. The correlation between non-graminoid indices ($FQI_{no\text{-}gram}$ and Mean $C_{no\text{-}gram}$) and those calculated using all species was very strong (Figs. 6 and 7). These correlations persisted across all wetland types, although 43 wetland sites had to be excluded because all species within sampled plots were graminoids.

Mean C was significantly correlated with ORAM scores for wetlands where ORAM results were available (Pearson's r ranged from = 0.49 to 0.78, $p < 0.0001$, $n = 162$) (Fig. 8). Of the three main wetland structure types (forested, shrub, and herbaceous), Mean C_{dom} was most highly correlated with ORAM scores for herbaceous wetlands, though the relationship was significant for each wetland type ($p < 0.03$). Evaluation by salinity and ecoregion showed no change to these results. With regard to NCWAM ratings, both Mean C_{dom} and Mean $C_{no\text{-}gram}$ showed no difference between sites with "Low" or "Medium" ratings, but "Low" and "Medium" quality sites both had significantly lower rapid index values than "High" quality sites (ANOVA, Tukey's test, $p < 0.01$) (Fig. 9). Sample sizes of "Low" and "Medium" quality sites precluded analysis by salinity and ecoregion subgroup.

Floristic Quality in North Carolina Wetlands

Total plant species richness in wetland plots across North Carolina ranged from one to 170, with a mean of 31 species. Mean C_{all} ranged from 0.0 to 8.5 and was generally lower in the Piedmont and inner Coastal Plain ecoregions (Fig. 10). Wetlands with the highest floristic quality were located in the Mountains and outer Coastal Plain ecoregions, along with wetlands in the Sand Hills ecoregion and southeastern quarter of the state (Fig. 11). The highest quality wetlands within this dataset included 185 CVS sites, two NPS sites, and 9 NWCA plots (Mean $C_{all} > 7.0$). Shrub and herbaceous wetlands showed significantly higher quality than forested wetlands (shrub Mean $C_{all} = 5.9 \pm 1.0$; herbaceous Mean $C_{all} = 5.9 \pm 1.0$; forested Mean $C_{all} = 5.3 \pm 0.9$)(ANOVA, Tukey's test, $p < 0.05$).

5. Discussion

FQI_{dom} did not correlate with the full index as well as Mean C_{dom} because it includes number of species (N). The number of dominant species in a plot ranged from including an entire species list to only one species, so using only dominant species reduced N by an inconsistent amount. Mean C_{dom}, being unaffected by N, is a more robust measure when considering a subset of the total species list (this study; Chamberlain and Brooks, 2016). Mean C also has the added benefit of being on a closed-ended scale, making it easier to understand and compare among sites. Definitions of C values exist, and they make Mean C meaningful on a scale from zero to 10.

The rapid Mean C indices tested here were able to provide the information of a more intensive vegetation site assessment while reducing time and expertise required. However, rapid indices in general represent a tradeoff between accuracy available through intensive monitoring and the ability to get an answer. They can be useful to practitioners interested in cost-effectively monitoring condition of a large number of sites or large areas, where time and cost constraints make intensive monitoring difficult or impossible. Dominance based rapid indices would not be appropriate for other uses, such as detection of rare or uncommon species, detection of high diversity areas, or species specific management. By their nature, many rapid indices would exclude rare species, which may be of particular interest. In instances where a more complete census is required or desired, these results show that excluding difficult-to-identify graminoids did not have a major impact on Mean C or FQI, regardless of wetland type. Chamberlain and Brooks (2016) found that removing graminoid species had no significant effect on Mean C in forested headwater wetlands. Bourdaghs (2012) also found that removing difficult-to-identify species, many of which are graminoids, had no effect on overall FQI. However, especially in coastal wetland areas, many marshes consist only of graminoid species where a non-graminoid index would not be useful, but Mean

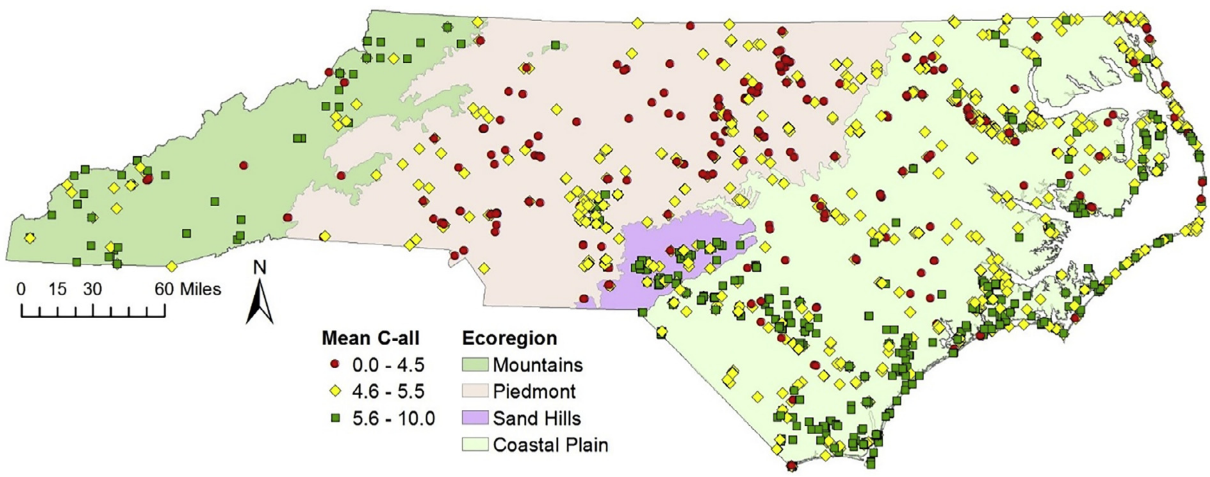

Fig. 10. Mean C_{all} in wetlands across North Carolina (n = 2030; years 1981–2016).

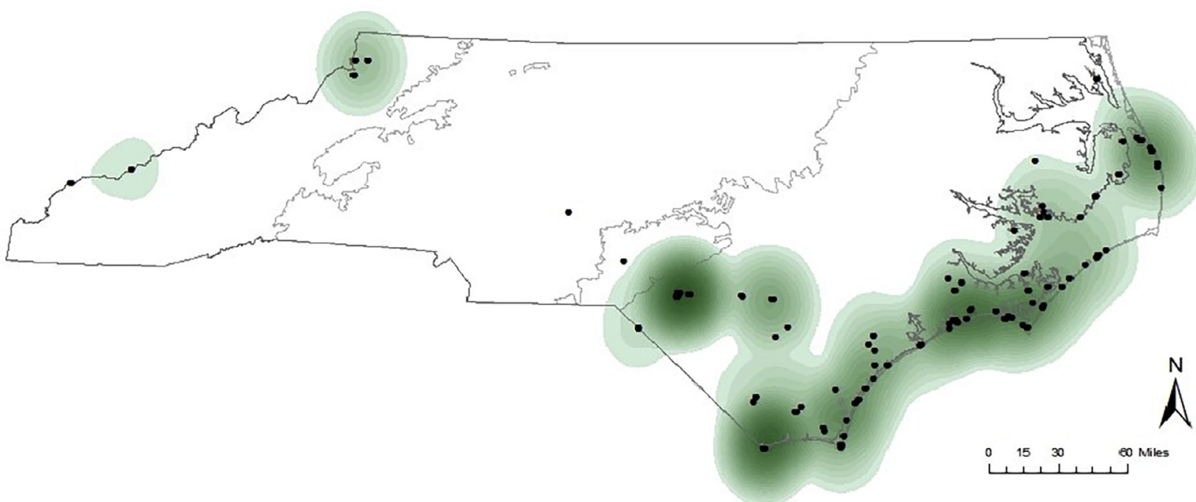

Fig. 11. Cluster map of North Carolina wetland sites with the highest floristic quality (Mean $C_{all} > 7.0$) (n = 196, years 1981–2016).

C_{dom} still could be.

The NCWAM is currently used to report baseline wetland condition as part of the US Army Corps of Engineers' mitigation permitting process in North Carolina. Since NCWAM ratings showed limitations in indicating floristic quality, mean C should be used as supplemental information. To complete the NCWAM forms, an assessor is required to rate whether wetland vegetative composition (species diversity and proportions) is "close to reference condition", "different from reference condition", or "severely altered from reference condition". The NCWAM User Manual could be modified to include ranges of reference wetland Mean C or FQI values to define these categories more clearly. Utilizing a rapid index, Mean C_{dom}, could allow practitioners to more quickly identify reference condition as well as the extent of deviation from reference. All mean C indices were significantly correlated with ORAM, which reflects ORAM's focus on habitat quality and further supports its use in assessing wetland biological condition and quality, including areas outside of Ohio.

The results of this project, along with Chamberlain and Brooks' study (2016), show that a rapid index of floristic quality, in the form of Mean C_{dom}, is a useful tool for practitioners to gauge condition of North Carolina's wetlands, even in situations of low total plant species diversity.

The availability of Mean C_{dom} or Mean $C_{no\text{-}gram}$ as available tools will increase cost effectiveness of wetland condition assessment by decreasing time and expertise required and expediting data processing. The availability of these tools will also make it possible to assess more wetlands across the state, a real need in rapidly changing landscapes. Natural Heritage Programs, which track high quality ecosystems, could find these tools valuable. Awareness of where high-quality wetland plant communities are clustered can help focus conservation and preservation efforts and inform permitting decisions. Also, an understanding that wetlands in the Piedmont and inner Coastal Plain, the most agricultural regions of North Carolina, show the lowest floristic quality could encourage wetland restoration efforts focused on these areas.

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