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Using the floristic quality concept to assess created and natural wetlands: Ecological and management implications

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ABSTRACT

We applied the floristic quality index (FQI) to vegetation data collected across a chronosequence of created wetland (CW) sites in Virginia ranging in age from one to 15 years post-construction. At each site, we also applied FQI to a nearby forested reference wetland (REF). We tested the performance of the index against a selection of community metrics (species richness, diversity, evenness, percent native species) and site attributes (age, soil physiochemical variables). FQI performed better when non-native species (*C*-value = 0) were removed from the index, and also when calculated within rather than across vegetation layers. A modified, abundance-weighted FQI showed significant correlation with community and environmental variables in the CW herbaceous layer and REF herbaceous and shrub-sapling layers based on Canonical correspondence analysis (CCA) ordination output. These results suggest that a "natives only", layer-based version of the index is most appropriate for our region, and an abundance-weighted FQI may be useful for assessing floristic quality in certain layers. The abundance-weighted format has the advantage of preserving the "heritage" aspect of the species conservatism concept while also entraining the "ecology" aspect of site assessment based on relative abundances of the inhabiting species. FQI did not successfully relate CW sites to REF sites, bringing into question the applicability of the FQI concept in comparing created wetlands to reference wetlands, and by analogy, the use of forested reference wetlands in general to assess vegetation development in created sites.

1. Introduction

Wetlands created as mitigation sites under the regulatory purview of federal and state wetland law typically carry a monitoring requirement based on pre-established performance standards (USACE, 2002). This "compliance monitoring" is used by natural resource agencies to gauge the effectiveness of created wetland projects over time, and the performance of vegetation has been a key criterion in the assessment of mitigation success (DeBerry and Perry, 2012). Lack of consistency in evaluation techniques for compliance monitoring, particularly in the vegetation criterion, is a problem that has garnered the attention of regulatory agencies, scientists, and resource managers since the 1980s (Erwin et al., 1989; Streever and Portier, 1994; Hammer, 1996; Campbell et al., 2002; Mitsch et al., 2012). The problem can be exacerbated in forested wetland mitigation by differences in age and successional stage between young created sites and the natural forested systems they are built to replace (Spieles, 2005). The same problem can occur when reference sites are used as ecological benchmarks for gauging the success of created sites—the disparity in age between young created sites and much older reference sites is often difficult to reconcile when analyzing typical vegetation parameters based on species abundance (National Research Council, 2001). Use of the floristic quality index (FQI) may improve this aspect of compliance monitoring by focusing on properties that are not directly dependent upon species abundance measures within the vegetation system.

FQI is a weighted metric developed for evaluating the quality of native plant communities (Swink and Wilhelm, 1979, 1994). A high FQI value indicates that a vegetation assemblage is highly "conservative"—that is, closer to conditions that would have been present prior to European settlement in North America (Noss, 1985; Maser, 1990). Disturbance in natural communities represents a mode of introduction for species with low floristic integrity (e.g., invasive or cosmopolitan species); therefore, sites dominated by such species typically have low FQI values. The floristic quality approach provides a potentially robust tool for vegetation monitoring by focusing on these conservative attributes of the inhabiting species rather than on specific quantitative characteristics of the

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vegetation (Herman et al., 1997; Balcombe et al., 2005). In natural wetlands, FQI is typically evaluated by testing for linear relationships against a gradient of human alteration in which sites are ranked according to some disturbance criteria such as hydrologic modification, eutrophication, sedimentation, destruction of vegetation, buffer encroachment, or watershed development (i.e., dose–response curve; see US EPA, 2002b; Chamberlain et al., 2013). This approach can be problematic in assessing created wetlands because created sites are typically subjected to disturbance involving mass grading during site construction (DeBerry et al., 2004), leaving little discernable "gradient" upon which to rank disturbance. Therefore, evaluating the effectiveness of FQI in created wetland assessment requires an alternative set of criteria that can represent relative biological integrity (Karr and Dudley, 1981) in the context of floristic quality.

Site age is one such criterion that may be used as a surrogate measure of disturbance gradient, since older sites are less likely to show the effects of disturbance incurred during site construction (Odum, 1969). A useful approach for evaluating site age is to study "chronosequences" of different-aged sites with a similar geomorphic setting, allowing researchers to view floristic composition at different developmental stages following site construction (Spencer et al., 2001; Atkinson and Cairns, 2001; Frelich, 2002). Soil physiochemical properties may also be useful in this regard, because soils provide a window to an onsite record of the physical, chemical, and biological attributes in residence at a site over recent time (i.e., time since the last soil disturbing event) (Odum, 1985; Richardson et al., 2001; Lopez and Fennessey, 2002). In addition, community-level vegetation indices such as species richness, diversity, evenness, and percent native species have been used to assess vegetation quality in wetlands (Balcombe et al., 2005; Matthews et al., 2005; Spieles, 2005), and can function as independent measures of relative floristic quality against which FQI may be tested.

The purpose of our study was to evaluate the performance of FQI on vegetation data collected from a chronosequence of non-tidal created wetland sites, and to analyze the ecological and management implications of using FQI as a tool for performance evaluation and assessment. Further, we proposed several versions of the index and tested each against a background of community-based measures including species richness, diversity, evenness, and percent native species, as well as abiotic factors including soil physiochemical properties and site maturity (age). In evaluating FQI as an assessment method in wetlands, we address the following questions: (1) What is the most appropriate form (i.e., method of calculation) of FQI when applied to created wetland sites and/or reference sites? (2) Can FQI be used to infer ecological differences among sites? And finally, (3) Does FQI provide a potentially useful tool for assessment of created wetlands, and can it be used to compare created sites to their respective reference wetlands in a meaningful sense?

2. Methods

2.1. Study sites

Fifteen non-tidal created wetlands of different ages (i.e., years following construction) were studied, each site used by the Virginia Department of Transportation (VDOT) as mitigation for impacts to forested wetlands (Fig. 1). Selection criteria, location, size, and site history for each created wetland (CW) are detailed in DeBerry (2006) and DeBerry and Perry (2012). In addition, 15 reference wetlands (REF) were selected from nearby locations (one near each mitigation site), reflecting the proposed community type for the respective CW. Most REF sites were located within 1 km of the respective CW site, with a few exceptions as noted in DeBerry (2006). Reference wetlands are forested systems with no recent disturbance or clearing, such that the predominant cover type is canopy-sized trees supporting a stratified understory. REF site selection was based on the "minimal impairment" concept, which identifies the reference condition as the least degree of detrimental effect from anthropogenic disturbance (US EPA, 2002a). The REF wetlands selected for this study were generally over 40 years in age (time since last significant disturbance).

2.2. Vegetation sampling

At each wetland (CW and REF sites), we sampled vegetation within a pre-determined 1-ha rectangular area (approximately 150 m × 67 m) during late summer site visits (August/September) in 2004 and 2005. The late summer time period represents peak growing season for created wetland sites within the region (DeBerry and Perry, 2004). The 1-ha areas were demarcated in zones representing relatively homogeneous stand composition and age (Parsons and Ware, 1982; Glascock and Ware, 1979). In addition, we prepared a floristic survey of a randomly-chosen subset of sites ($n = 5$) in which a general site reconnaissance was conducted within each pre-determined 1-ha area over a day (approximately 8 h), generating a species list. The purpose for the floristic survey data set was to test FQI calculation using the "walk-through species list" methods prescribed by the authors of the index (Swink and Wilhelm, 1994) against the plot-based methods used throughout the remainder of the study.

For vegetation measurements, we used a stratified-random sampling design to determine plot location (Mueller-Dombois and Ellenberg, 1974). At each site, we established a baseline along the 1-ha area perimeter and divided the baseline into segments, each approximately 30 m in length. We then set transects within each segment oriented perpendicular to the baseline and extending into the wetland (Tiner, 1999). Each transect point-of-origin along the baseline was randomized within each baseline segment using a random numbers table. We then established a single plot on each transect based on a similar random numbers draw, taking the transect length as the domain for the available random numbers set. Trees, including woody species greater than 10 cm diameter at breast (dbh), were sampled from 0.04-ha plots (11.3 m radius; 5 plots per site) (Johnson, 2000). Saplings, shrubs, and woody vines greater than 1 m in height but less than 10 cm dbh were sampled from a 5 m radius sub-plot centered on each 0.04-ha plot (Spencer et al., 2001). Herbaceous vegetation (including woody plants less than 1 m in height) was sampled from three randomly placed 1 m^2 quadrats within each 0.04-ha plot. A more detailed description of the sampling strategy within the CW sites is provided in DeBerry (2006) and DeBerry and Perry (2012).

Within 1 m^2 herbaceous quadrats, we recorded aerial coverage estimates as a measure of relative dominance for each species using a modified cover class scale (Mueller-Dombois and Ellenberg, 1974). We also determined plant density as a direct count of individuals within 0.25 m^2 sub-quadrats randomly selected within a corner of each 1 m^2 quadrat. Plant frequency (presence/absence within quadrats) was determined from cover data. Relative dominance, density, and frequency were then calculated for each species, and the three values were averaged to develop relative Importance Values (IV) by species for each site (Perry and Atkinson, 1997).

Within 0.04-ha plots, we measured dbh on all trees using a set of Halgof 95 cm tree calipers and/or a Forestry Suppliers 8 m dbh tape. We then calculated basal area (BA) by species (Johnson, 2000) using PC-ORD (McCune and Mefford, 1999). Density for saplings, shrubs, and woody vines was recorded by direct counts within the nested 5 m-radius sub-plots, and estimates of aerial coverage were made using a cover class scale. Relative IV for each woody species was calculated by combining relative dominance (cover or BA) and density.