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Floristic Quality Index for woodland ground flora restoration: Utility and effectiveness in a fire-managed landscape

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ABSTRACT

Monitoring is a critical component of ecological restoration and requires the use of metrics that are meaningful and interpretable. We analyzed the effectiveness of the Floristic Quality Index (FQI), a vegetative community metric based on species richness and the level of sensitivity to anthropogenic disturbance of individual species present (Coefficient of Conservatism (CC)), using ground layer vegetation data from forests and woodlands with different fire histories in the Missouri Ozarks, USA. Specifically, we used total species richness, mean CC, and FQI to quantify differences in ground layer vegetation between burned and unburned sites, determine if relationships between richness and mean CC were consistent at local and landscape-scales, and evaluate the influence of richness and mean CC on FQI values using empirical data. Concerns regarding FQI identified in previous studies were also observed in this study, including a negative relationship between richness and mean CC. However, we observed this negative relationship using data from all study plots (landscape-scale) but not within discrete site types (local-scale). Relationships among mean CC, richness, and FQI were complicated because species richness was strongly correlated to FQI values across plots in which richness was low, whereas mean CC was only correlated with FQI values across plots in which richness was high. We conclude that the interpretation of the Floristic Quality Index may be challenged by: (1) the possibility of obtaining the same FQI value through different combinations of mean CC and richness; and (2) the dominating effect of richness on FQI. Although the FQI metric appears responsive to prescribed fire effects on plant communities in the Missouri Ozarks, the inclusion of species richness and mean CC provide more complete indication of plant community response than FQI alone.

1. Introduction

Ecological restoration has become an increasingly common goal for public and private land managers, and monitoring the outcomes of restoration activities is important for evaluating success (Hobbs and Harris, 2001; Jordan et al., 1990). In terrestrial wooded ecosystems, characteristics of plant communities are often used to evaluate the response to restoration treatments and to compare restoration sites to reference communities (Apfelbaum et al., 2000; Barrioz et al., 2013; Elliott et al., 2009; Kinkead et al., 2013). The metrics developed to describe plant communities are numerous but are commonly based on quantifying plant abundance (e.g., estimates of cover or density), numbers of species present (e.g., species richness), and the distribution of plant abundance among the species present (e.g., evenness, Shannon–Wiener Index of Diversity). Each metric provides different information and is subject to limitations to their use (Taft et al., 2006). For example, Alatalo (1981) argued that evenness measures that include richness in their calculation are limited by sampling biases, and Wilsey et al. (2005) found that diversity metrics that include measures of abundance more accurately captured biodiversity in grasslands than simple species richness.

Many commonly used metrics, such as diversity and abundance measures, describe important characteristics of plant communities but are unweighted by species composition (Taft et al., 1997). Plant community composition (i.e., which species are present) may be an indicator of ecosystem functional diversity (Cadotte et al., 2011) or may reflect site conditions or disturbance history. Metrics weighted by species composition have been proposed for restoration monitoring. Wilhelm (1977) introduced a method for quantifying the

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Table 1
Coefficient of Conservatism (CC) value ranges and descriptions.

CC values	Disturbance tolerance	Site fidelity
0–3	Common in disturbed sites	Widely distributed
4–6	Resilient to moderate disturbance	Matrix species of plant communities
7–10	Resilient to minor disturbance	Site-specific to mature communities

Source: Adapted from Taft et al. (1997).

sensitivity of each region's native flora to anthropogenic disturbance (Coefficient of Conservatism (CC)), and Swink and Wilhelm (1994, 1979) and Taft et al. (1997) combined the vulnerability measure (CC) with native species richness to create the Floristic Quality Index (FQI). In this system, each native plant species in a region is assigned a CC score from 0 to 10, based on the species' association with habitats that are relatively unaltered as compared to pre-European settlement (Swink and Wilhelm, 1994; Taft et al., 1997). Species that proliferate with anthropogenic disturbances (i.e., ruderal species) are ranked with CC values from 0 to 3 (Table 1). Matrix species, those that are somewhat tolerant of post-industrial human activity and occur in common plant communities, are ranked with CC values from 4 to 6, while species dependent on largely undisturbed sites (conservative species) are ranked with CC values from 7 to 10 (Taft et al., 1997). The FQI value for a particular site is calculated by multiplying the mean CC value for a site by the square root of native species richness for the same sampling unit (Taft et al., 1997), thus integrating measures of plant diversity with weighted measures of species composition.

The use of FQI for monitoring restoration outcomes has increased among land managers (MTNF, 2010, 2011), despite several criticisms recently discussed in the scientific literature. For example, there is no consensus concerning the effectiveness of the subjective Coefficients of Conservatism when utilized to calculate a mean value to describe plant community integrity. Some scientists accept that CC values capture a species' fidelity and resilience to disturbances (Chamberlain and Ingram, 2012; Cohen et al., 2004; Cretini et al., 2012; Francis et al., 2000), while others argue against the subjectivity of assigning CC values (Bowles and Jones, 2005; Landi and Chiarucci, 2010). Bried et al. (2012) found that while botanists confidently assigned extreme rankings (0–1 and 9–10) in New York and New England, they did not concur as readily regarding matrix species. Bourdaghs et al. (2006) computed mean CC and FQI values for wetland communities sampled in Wisconsin and Michigan with each state's independently-assigned CC values, finding that CC values were significantly higher in Wisconsin than in Michigan. Thomas (2013) argued against using anthropogenic boundaries as CC scoring boundaries, and stated that scoring by ecologically meaningful units may diminish some of the subjectivity relating to CC value assignation. However, Matthews et al. (2015) showed that a CC value of an individual species could be used to predict the values of co-occurring species in Illinois forests and wetlands, leading to the conclusion that the CC system has relevant ecological value.

Previous authors have also discussed concerns with the interpretation of FQI. Because richness is incorporated in the FQI calculation, factors such as sampling intensity and sampling area will affect FQI values (Bried et al., 2013; Francis et al., 2000; Matthews et al., 2005; Taft et al., 1997). In contrast, mean CC has been observed to remain fairly constant with increasing sampling area (Bourdaghs et al., 2006; Taft et al., 1997). Therefore mean CC may exhibit scale-independence, and it has also been shown to be more sensitive than FQI for ranking anthropogenic disturbance in wetlands in New York (Bried et al., 2013). An additional concern is that a single FQI value may be derived from numerous

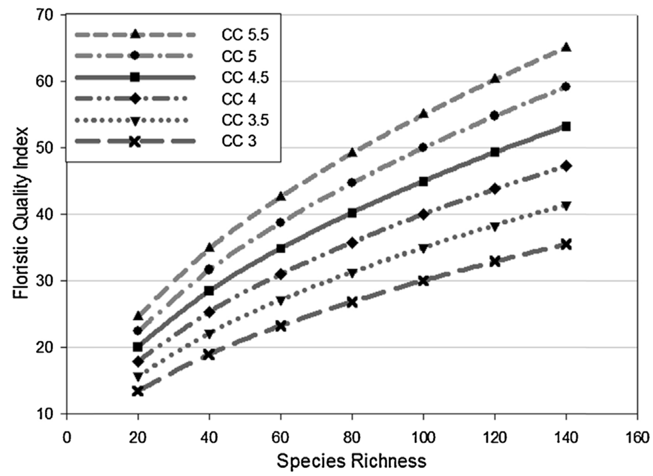

Fig. 1. Relationship between species richness and FQI for different levels of hypothetical mean CC. Similar FQI values can be calculated from differing combinations of richness and mean CC, and the relationship graphs as a power function when richness is on the *x*-axis.

combinations of richness and mean CC values (Fig. 1) (Taft et al., 1997). Moreover, the interpretation of FQI values across ecological communities may be confounded by the presence of different local species pools (DeBerry and Perry, 2015; Nichols et al., 2006; Rooney and Rogers, 2002; Spyreas and Matthews, 2006; Taft et al., 1997). Not only are CC values assigned independently within each state or region (Bried et al., 2012), but also communities and vegetative composition differ across landscapes (Turner, 1989). Due to these differences, FQI may not be comparable across scale or community gradients. Finally, previous studies have found negative correlations between richness and mean CC (Bowles and Jones, 2005; Thomas, 2013), suggesting that plant communities with high richness tend to have relatively low mean CC values. If this correlation is consistent across ecosystems, interpreting FQI could be challenging due to its constituents exhibiting an inherent negative relationship. The consistency of these patterns across sites or ecological communities (both at the landscape and local scales) has not been established, and the effectiveness of the FQI metric has not been evaluated in all vegetative systems and may be limited by community type (Taft et al., 2006).

Despite the criticisms regarding FQI, several studies have reported it to be effective for describing floristic sensitivity to anthropogenic disturbance, particularly in wetland ecosystems (Bried et al., 2014; Lopez and Fennessy, 2002; Matthews et al., 2015; Rothrock and Homoya, 2005). For example, in forested wetlands in Virginia, herbaceous FQI was negatively correlated with increasing anthropogenic disturbance (Nichols et al., 2006), and FQI was found to outperform mean CC at ranking locations based on anthropogenic disturbance in wetlands in the Great Lakes region (Bourdaghs et al., 2006). In Illinois tallgrass prairies, Taft et al. (2006) reported that FQI and mean CC were more effective at differentiating between restoration and reference sites than more traditional metrics of diversity and richness. Although most commonly used in wetlands and open ecosystems such as prairies, the use of FQI has recently been extended to applications in monitoring restoration of woodland and forest ecosystems (DeBerry et al., 2015; MTNF, 2010).

Restoration of woodland, savanna, and prairie plant communities has increasingly become an important management goal in the central hardwood region of the United States, and prescribed fire is commonly used to meet those objectives (Yaussy et al., 2004). Few studies have assessed the utility of FQI in regards to woodland communities and prescribed fire, despite the conflicting results