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Temporal stability of vegetation indicators of wetland condition

Elizabeth Deimeke[a,1], Matthew J. Cohen[a,*], Kelly C. Reiss[b]

[a] School of Forest Resources and Conservation, University of Florida, Gainesville, FL 32611, United States
[b] Environmental Engineering Sciences, University of Florida, Gainesville, FL 32611, United States

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ABSTRACT

Vegetation indices are widely employed to evaluate wetland ecological condition, and are expected to provide sensitive and specific detection of environmental change. Most studies evaluate the performance of condition assessment metrics in the context of the data used to calibrate them. Here we examined the temporal stability of the Florida Wetland Condition Index (FWCI) for vegetation of depressional forested wetlands by resampling sites in 2008 that were previously sampled to develop the FWCI in 2001. Our objective was to determine if FWCI, a composite of six vegetation-based metrics, provides a robust measure of condition given inter-annual variation in environmental conditions (i.e., rainfall) between sampling periods. To that end, we sampled 22 geographically isolated wetlands in north Florida that spanned a wide land use/land cover intensity gradient. Our results suggested the FWCI is robust. We observed no significant paired difference in FWCI across or within land use categories, and the relationship between FWCI in 2001 and 2008 was strong ($r^2 = 0.88$, $p < 0.001$). This was despite surprisingly high composition change. Mean Jaccard community similarity within sites between years was 0.30, suggesting that most of the herbaceous taxa were replaced, possibly because of different antecedent rainfall conditions or sampling during different phenological periods; both are contingencies to which condition indices must be robust. We did observe some evidence of convergence toward the mean in 2008, with the fitted slope relating 2001 and 2008 FWCI scores significantly below one (0.63, 95% CI = 0.53–0.73). The most variable FWCI component metric was the proportional representation of obligate wetland taxa, suggesting that systematic changes may have been induced by different hydrologic conditions prior to sampling; notably, however, FWCI computed without this component still exhibited a slope significantly less than 1 (0.72, 95% CI = 0.61–0.88). Moreover, there was evidence that species lost from reference sites (higher condition) were replaced by taxa of lower floristic quality, while species lost from agricultural sites (consistently the lowest condition land use category) were replaced by species of higher quality. A significant positive association between FWCI and the ratio of coefficients of conservatism (CC) of species lost to those gained suggests some overfitting in FWCI development. However, despite modest evidence of overfitting, FWCI provides temporally consistent estimates of wetland condition, even under conditions of substantial taxonomic turnover.

1. Introduction

Wetlands provide a variety of important goods and services (Costanza et al., 1997; MEA, 2000), delivery of which may be affected by anthropogenic impacts. In recognition of their value and modern decline in extent, wetlands are increasingly assigned special protections against these impacts. For example, beginning in 1988 there has been an effort by national policies to encourage *no net loss* of wetlands in the United States. A result of this attention to protecting wetland ecosystems is the widespread development and maturation of assessment tools that are used to evaluate wetland condition, impact, restoration and mitigation. Wetland condition assessments measure site departure from conditions observed in minimally impacted settings (Karr and Chu, 1997). This facilitates understanding of the variety of wetlands in the landscape and prioritizes sites for conservation or restoration efforts, but the central use of these assessment scores is in determining the level of mitigation necessary if the wetland was degraded or removed from the landscape (Fennessy et al., 2004).

Many wetland condition assessment tools are based on rapid site reconnaissance combined with landscape setting (e.g., Brown and Vivas, 2005; Mack, 2006; Reiss and Brown, 2007), but more intensive assessments of condition typically investigate the biota that inhabit a site. Indices of biological integrity (IBIs) compare the composition of minimally impacted reference sites to those that span a gradient of human impacts (Karr and Chu, 1997); multiple

* Corresponding author. Tel.: +1 352 846 3490; fax: +1 352 846 1277.
E-mail addresses: deimekee@gmail.com (E. Deimeke), mjc@ufl.edu (M.J. Cohen), kcr@ufl.edu (K.C. Reiss).
[1] Present address: 633 Moreland Avenue #1, Atlanta, GA 30307, United Sates.

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axes are possible, including the prevalence of certain taxonomic groups and/or functional guilds. Examples include the use of benthic invertebrates for the assessment of stream condition (e.g., Southerland et al., 2008) and the use of vegetation and/or fish as an index of lake condition (e.g., Beck and Hatch, 2009). Strong benthic invertebrate metrics have not been consistently developed for wetland systems, so most attention has been focused on the autotrophic communities (e.g., diatoms – Lane and Brown, 2007, vascular plants – Lopez and Fennessy, 2002; Miller et al., 2006). These have generally shown strong covariance with human disturbance gradients, and benefit from their basis in minimally ambiguous taxonomic inventories.

The use of vegetative communities in wetland condition assessment implicitly assumes stability in the quality if not the composition of wetland communities. These communities are temporally dynamic with natural background rates of species recruitment and displacement (e.g., by competition, herbivory, successional trajectories, or environmental variability). They are also subject to changes in response to anthropogenic stressors. Clearly, the goal is enumerate vegetation indices that are sensitive to human disturbances but also specific to those changes; in other words, condition assessment scores should respond predictably to one set of community-level changes or stressors. Indeed, it would be highly informative and would explicitly validate the approach were condition scores to remain constant at a site with unchanging land use in spite of composition changes over time. Despite the critical importance of vegetation indices for evaluating wetland condition, there is little evidence to evaluate their sensitivity and specificity.

The objective of this study was to assess changes in vegetation condition scores over time, comparing an early set of measurements from 2001 with more recent measurements in 2008 at sites where land use remained unchanged. Our focus was on the Florida Wetland Condition Index (FWCI), a composite of six vegetation-based metrics developed to assess geographically isolated depressional forested wetlands (Reiss, 2004, 2006). If, as we predict, FWCI is a robust measure of wetland condition (i.e., both sensitive and specific), both overall condition scores and the six individual component metrics from 2008 should not be systematically different from 2001, even where taxonomic changes occurred.

2. Methods

2.1. Study area and site selection

Twenty-two palustrine depressional forested wetlands (principally cypress domes) in north Florida were visited between July and October in 2008 (Fig. 1); all sites had been sampled in 2001/2002 (hereafter 2001) also between May and August as part of a statewide effort that culminated in development of the FWCI (Reiss and Brown, 2007). Sampling Julian dates differed between sites, with all sites sampled later in the year in 2008 than in 2001. Mean Julian day for 2001 sampling was 178, while it was 261 for 2008; the difference ranged from 4 to 152 days, with a mean of 83 days later in 2008. Sites were located in three land use settings identified in 2001 as "reference" ($n = 12$), "agricultural" ($n = 4$), and "urban" ($n = 6$) based on land use within a 500 m wetland buffer (Reiss, 2004); land use was verified visually during 2008 site visits and no changes in site land use categorization were observed.

2.2. Florida Wetland Condition Index: past and present

All sites were evaluated using the FWCI, developed in 2001 using biological observations at these and other sites across Florida (Reiss, 2006). For the vegetation survey, wetland boundaries were approximated using hydrology and vegetation (Reiss, 2006). Four

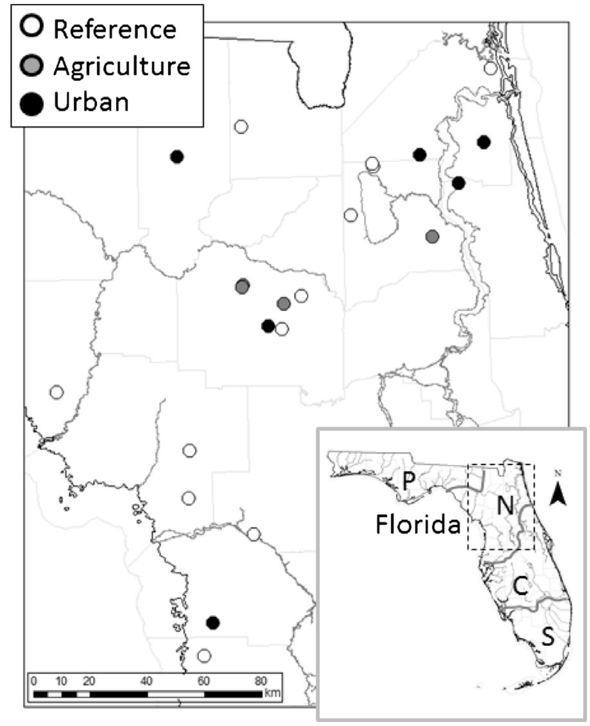

Fig. 1. Location of 22 isolated wetland sites in north Florida, USA. Gray circles represent agricultural sites ($n = 4$), white circles are reference standard sites ($n = 12$), and black circles are urban sites ($n = 6$). All sites fell within the same statewide ecoregion (North Region; Lane, 2000).

1-m wide belt-transects radiating in cardinal directions from the center to edge of each wetland were used to measure community composition; no attempt was made to ensure consistent transect length between sampling periods. Each transect was subdivided into 5-m sections in which presence/absence of each taxa was recorded, along with ancillary information about each species (growth form: aquatic, fern, grass, herb, sedge, shrub, tree, or vine; annual/perennial; evergreen/deciduous; and native/exotic) based on Wunderlin and Hansen (2008).

FWCI scores were computed from six floristic metrics as described and defined in Reiss (2004): (1) proportion of tolerant indicator species; (2) proportion of sensitive indicator species; (3) floristic quality assessment index (FQAI); (4) proportion of exotic species; (5) proportion of native perennial species; and (6) proportion of species with obligate or facultative-wetland status. All metrics excluding FQAI were calculated as site proportions in which the number of taxa in each metric (e.g., tolerant, sensitive, exotic) (N) was divided by site species richness (R).

FQAI is the sum of coefficients of conservatism (CC) scores for all species divided by site species richness (i.e., omitting any effect of species richness on floristic quality):

$$\mathrm{FQAI} = \frac{\sum (C_1 + C_2 + \ldots C_n)}{R}$$

CC scores were determined by a survey of expert Florida botanists in 2001 according to species fidelity to a gradient of wetland conditions, and range from 0 (opportunistic invaders) to 10 (species with high affinity for reference standard wetland conditions) modeled on earlier FQAI work by Wilhelm and Ladd (1988). Values of CC scores reported in Reiss (2004) were used to compute FQAI in this study. Vegetation not identified to species level was excluded from metric calculations because CC, nativity status and tolerance/sensitivity classifications, all integral to FWCI calculation, are species specific. The original implementation of FWCI scaled each