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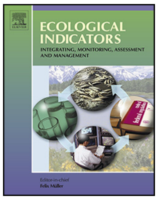

Effect of time on consistent and repeatable macrophyte index for wetland condition

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ABSTRACT

The vegetation portion of the Florida Wetland Condition Index (FWCI), an index of biological integrity, provided consistent and repeatable measures of condition at eighteen wetlands sampled in two consecutive growing seasons. The sample wetlands reflected a gradient of adjacent land use from non-impacted reference areas to wetlands imbedded within silviculture, cattle pasture and residential areas. Wetlands were described as herbaceous depression ($n = 6$), forested depression ($n = 5$) and forested strand or floodplain wetlands ($n = 7$), and represented different states of succession. Even though the wetlands were unique from one another and occurred across a large geographic area in Florida, the FWCI results calculated for all the wetlands were representative of adjacent land use impacts and not sensitive to natural variation. During the duration of this study, changes in weather from drought to tropical storm conditions, as well as management activities such as fire and herbivory, impacted wetlands. These effects were apparent in the change of species composition between sampling periods; 23–56% of species were different when resampled. Even though composition changed, the proportion of indicators remained consistent. The resulting condition scores suggested a one-to-one relationship between sampling periods.

1. Introduction

Biological integrity was introduced as a concept by Karr and Dudley (1981) as the capacity of an ecosystem to maintain “a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitat of the region.” In theory, an ecological system either has integrity or does not. In practice, an index of biological integrity (IBI) provides a quantitative means of assigning a numeric value of “condition” based on a specific community assemblage (e.g., diatoms, plants, macroinvertebrates, fish). The assessment of biological condition with an IBI consists of measuring the biological community in terms of a gradient from reference standard condition (i.e., ecological system surrounded by natural landscapes with no apparent anthropogenic alterations) to severely degraded. In developing an IBI, biological data are supported by physical and chemical parameters along a gradient of human disturbance (U.S. EPA, 2002), thereby identifying biological indicators of environmental stress.

IBIs have been widely developed for wetland ecosystems (e.g., Reiss and Brown, 2007; Ruaro and Gubiani, 2013). They have strong correlation with changes to adjacent land use; as land use intensity increases around a wetland, sensitive species are replaced by species tolerant of disturbance (Lopez and Fennessy, 2002; Miller et al., 2006; Reiss et al., 2009; Kutcher and Bried, 2014). This makes IBIs effective tools for monitoring if anthropogenic impacts are altering condition in wetland ecosystems (Karr and Chu, 1997) or if wetland condition responds to restoration (Matthews et al., 2009). Wetland IBIs can also be applied to inform trends of net loss of biological integrity (Scozzafava et al., 2009).

Herricks and Schaeffer (1985) recommended effective biological indicators should be interpretable at several trophic levels and connected to organisms not directly monitored. As primary producers, vegetation is part of the foundation of trophic interactions in wetlands, and supports many life history requirements of fauna species (Mitsch and Gosselink, 2000). Vascular plants are ubiquitous, generally immobile, respond to environmental changes, and

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are relatively easy to identify to species level (U.S. EPA, 2002). Many wetland IBIs are based on vegetation because they are good indicators of wetland condition (Miller et al., 2006; Mack, 2007; Stapanian et al., 2013) and are responsive to hydro-period, water chemistry, substrate type, landscape connectivity to seed sources, edge effects and climate change (Reiss and Brown, 2005a).

1.1. *Natural variability and IBI methods*

Practitioners should have confidence in an IBI that has shown consistency and repeatability when land use surroundings are constant (Karr et al., 1987). Further, these methods should be effective at determining the difference in biological response to natural variation and human caused impacts (Karr et al., 1987). A robust IBI methodology should be validated by assessing wetlands not included in IBI development (Karr et al., 1986; Reiss, 2006). While many wetland IBIs have been developed since these suggestions by Karr et al. (1986, 1987), there are not many examples of studies validating IBIs in this way. Where further research is needed is in determining if IBI measures are consistent and repeatable in light of natural variation due to effects of time and climatic variability (Wilson et al., 2013).

Unique physical and chemical attributes of wetlands make vegetation composition and structure dynamic, sometimes fluctuating greatly along temporal and spatial gradients (Chapin and Paige, 2013). Fluctuations due to season, weather impacts on hydrology, and stochastic events can affect biological populations within wetlands (Jeffries, 2008; Ramberg et al., 2010; Scarsoglio et al., 2012; Chapin and Paige, 2013). This type of natural change could confound IBI condition results if metrics are too sensitive to normal variation. Some studies testing condition variability using more mobile indicators such as macro-invertebrates (Mazor et al., 2009) and fish (Angermeier and Karr, 1986; Fore et al., 1994) in stream based IBIs found high year-to-year and seasonal variability in population richness and distribution, suggesting longer time frames were needed to develop consistent IBIs capable of reflecting representative condition. Some communities such as coastal wetlands in the Great Lakes are also highly mobile due to dramatic changes in lake levels. Other wetlands with ephemeral hydrologic regimes such as prairie potholes may experience high turnover of species or community shifts along hydrologic gradients. Even in Florida, where the growing season is longer than most parts of North America, identifying plant species without an inflorescence due to sampling season can challenge species detection in a wetland.

Wilcox et al. (2002) concluded that high variability in lake levels in the North American Great Lakes made the development of an IBI for coastal vegetation too complex to separate biological response from anthropogenic caused change. In 2008, Mack et al. addressed Wilcox et al. (2002) concerns by applying an inland vascular plant-based IBI created for Ohio to the Great Lakes coastal wetlands, concluding the interior wetlands also experienced extreme hydrologic events and had significant floristic similarities. After correlating the two wetland types by grouping land use gradients, the authors determined with some modification an IBI could be developed for the coastal marshes of Lake Erie and other communities that experience plant community migration and dynamic hydrologic conditions.

North Dakota prairie potholes also have large natural shifts in plant communities due to high variance in hydrologic regimes. In a 4 year study, Euliss and Mushet (2011) determined the prairie pothole IBI scores were not reliably consistent in these wetlands due to variable water levels and natural dry down impacts to plant composition. In open water marshes in northern Canada prairies, wetlands had less seasonal variation in hydrology in a study by Wilson et al. (2013); standing water was typically present and vegetation was dominated by native perennial species. The wet meadow zone being sampled did shift along a hydrologic gradient between years; by sampling in the most representative central area of the zone, IBI condition scores were consistent in both wet and dry years (Wilson et al., 2013). In Florida, Deimeke et al. (2013) resampled forested wetlands where surrounding land use had not changed in the several years since they were first assessed for the development of an IBI. Authors found condition scores to be significantly correlated between years. Both Mack et al. (2008) and Wilson et al. (2013) recommend not sampling a community if an extreme weather event such as drought or flooding had occurred because the event could preclude the collection of a representative sample.

1.2. *Study objectives*

It remains unclear if wetland IBIs identify condition consistently in different seasons and over time in light of potential biological response to natural and anthropogenic changes. This question is best addressed by each regionally developed and tested IBI method. The main objective of this study was to make repeat field measurements on vegetative communities in 18 wetlands in Florida over two consecutive growing seasons. Community data were applied to the vegetation portion of the Florida Wetland Condition Index (FWCI), a multi-metric index of biotic integrity developed for geographically isolated herbaceous and forested wetlands as well as forested strand and floodplain wetlands. It was hypothesized that macrophyte community composition would remain relatively constant within the expected range of variation due to normal fluctuations in climatic regime, and therefore FWCI scores would remain constant. This study tested the consistency and repeatability of FWCI scores between sampling periods.

2. Methods

Employing standardized field sampling methods and several statistical analysis techniques, this study examined the impact of time (1 year) between sampling events on the consistency of wetland condition scores derived from analysis of the macrophyte community. In the following section, descriptions of the wetland sites and the macrophyte FWCI are given first, and then field sampling methods and finally statistical methods that were employed are given.

2.1. *Site description*

Eighteen wetlands in Florida were selected for this study from a larger population of wetlands sampled as part of the U.S. Environmental Protection Agency's 2011 National Wetland Condition Assessment (NWCA). The 2011 NWCA study consisted of 67 wetlands in Florida selected from the U.S. Fish and Wildlife status and trends database. The NWCA site selection method employed the General Random Tessellation Stratified survey design (Stevens and Olsen, 2004), which generated a random point in each wetland as the center for the sample area.

Wetland classes chosen from the NWCA study for FWCI application complied with wetland type under which the FWCI was developed. These were: herbaceous depression (HD, *n* = 6), forested depression (FD, *n* = 5) and forested strand or floodplain wetlands (FSF, *n* = 7). The sites were stratified across Florida using Lane's (2000) proposed classification of freshwater wetland regions south (*n* = 2), central (*n* = 5), north (*n* = 7), and panhandle (*n* = 4) (Fig. 1). The selected sites were also stratified along a priori categories interpreted from remotely sensed aerial imagery representing a gradient of adjacent land use intensities. Land use for wetlands included agriculture (cattle grazing) (*n* = 3), urban residential (*n* = 2), reclaimed phosphate mine (*n* = 1), silviculture