Ecological Indicators 81 (2017) 65–73

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

Transferability of bioassessment indices among water body types and ecoregions: A California experiment in wetland assessment

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ARTICLE INFO

Keywords:
Bioassessment
Index transferability
Index of biotic integrity
Diatoms
Macroinvertebrates
Depressional wetlands

ABSTRACT

Biological assessment of aquatic resources requires the availability of bioassessment tools that work in all waterbody types and regions of interest. Developing new assessment tools may require several years of data collection and substantial investment of resources, which may not be an option for some aquatic resource managers. Adapting tools developed for different regions or wetland types may be an attractive alternative to developing new indices, provided they work well in the novel setting. In this study, we explore the transferability of two bioassessment indices for application to depressional wetlands in California, which are wetland type of management concern but for which bioassessment tools don't currently exist. We tested the applicability of a depressional wetland invertebrate index of biotic integrity (IBI) developed in the San Francisco Bay region of northern California for application in the drier regions of southern California (i.e. geographic transferability), and the ability to apply a riverine benthic diatom IBI to benthic diatoms in depressional wetlands (i.e. water body type transferability). We evaluated the accuracy and responsiveness of the existing Indices for use in depressional wetlands and refined reference definitions and recalibrated thresholds relative to stressor gradients to maximize index performance. Performance of the adapted indices was compared to that of an existing habitat assessment tool (the California Rapid Assessment Method; CRAM) that has been developed for statewide application of depressional wetlands. Finally, we demonstrate application of the revised indices for ambient assessment of depressional wetland condition in southern California. Recalibrating both the macroinvertebrate and diatom indices to reference thresholds based on nutrient concentrations resulted in lower coefficient of variation among reference sites, greater differentiation between reference and non-reference and stronger relationship with stressors than when reference thresholds were based on landscape disturbance. Overall, the simple adjustment of the reference definition allowed us to transfer the indices with no structural changes to the metrics. This approach can facilitate future index adaptations that allow practitioners to include waterbody types for which there is no current index into routine biomonitoring programs.

1. Introduction

Wetland and stream health is often judged based on composition of resident or transient biological assemblages (Karr and Chu, 1999). Routine monitoring and evaluation of streams and wetlands requires a robust set of assessment tools that can be used to inform management decisions. It is rare, however, that standardized bioassessment tools exist for all wetlands and stream types within a region of interest; rather, tools often exist for subset of wetland types based on management priorities.

Developing new assessment tools often requires several years and substantial investment. Adapting existing tools developed for similar wetlands from different geographies or for other wetland types within the same geography is an attractive alternative to developing assessment tools *de novo*. However, transferability of tools between geographies or wetland types can be complicated by several factors, including the definition of reference and responsiveness to stressor gradients. Wilcox et al. (2002), postulated that adapting bioassessment indicators from streams to wetlands can be problematic, due to differences in hydrology between these habitat types, but that indices can be used if they are calibrated to account for fluctuations in wetland hydrology along known stressor gradients. More recently, Calabro et al. (2013) investigated the transferability of lacustrine wetland indices of biotic integrity (IBIs) in the Great Lakes, USA region and concluded that the IBIs were not directly transferable due to differential response to stressor gradients and may require substantial modification. However,

Abbreviations: CRAM, California rapid assessment method; MI, macroinvertebrate; IBI, index of biotic integrity

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http://dx.doi.org/10.1016/j.ecolind.2017.05.056
Received 7 November 2016; Received in revised form 19 May 2017; Accepted 22 May 2017
Available online 30 May 2017
1470-160X/

Table 1
Definitions of wetland use-types and potential disturbances associated with increasing intensity of use.

Wetland use-type	Characteristics and potential disturbances
No active use	Natural pond with limited human activity.
Abandoned stock pond	Historically created or used to provide water for cattle, but has become naturalized through lack of use.
Habitat/stormwater	Dual purpose wetland, managed to provide habitat but uses dry weather urban runoff and stormwater as a principle source of hydrology
Golf course	Usually surrounded by manicured lawn. Not designed for wildlife habitat, although some courses have added limited native landscaping.
Flood control	Not managed to provide habitat. Sides may be steep (minimal littoral zone) to maximize water-holding capacity. May employ vector controls.
Water supply	Not managed to provide habitat. Surrounding area often cleared of vegetation. Hydrologic manipulation draws down water levels as needed for agricultural, industrial or golf course purposes.
Recreation	Water body managed for recreation (e.g., fishing, pedal boats), not habitat. May have manicured lawn.
Stock pond (active)	Signs of cattle present. Animal waste may elevate nutrients, while trampling increases bank erosion.

they did not attempt to recalibrate the indices to accommodate the different stressor gradients. Several studies have suggested that transferability of biological indices can be improved if metrics are based on functional or trait relationships as opposed to measures of richness or diversity (Pont et al., 2006; Pease et al., 2015).

In this study, we explore the transferability of two bioassessment indices for application to depressional wetlands in southern California, which are wetland type of management concern but for which bioassessment tools don't currently exist. Depressional wetlands occur in topographic low points and are dominated by fluctuation in subsurface water levels and evapotranspiration (Brinson, 1993). They include a diversity of freshwater habitats, such as perennial and seasonal emergent marshes, shallow open water habitats, scrub shrub wetlands, and seasonal ponds and pools. Nationally, freshwater ponds and emergent marshes comprise approximately 32% of the total wetland area in the coterminous United States (Dahl, 2011). However, they are particularly important in California, where they comprise approximately 45% of the State's 3.6 million acres of wetlands (Sutula et al., 2008). Their relatively small size and dispersed nature places them at substantial risk from contaminants in urban and agricultural runoff (e.g., Castro-Roa and Pinilla-Agudelo, 2014; Riens et al., 2013), direct habitat loss (Dahl, 1990; Holland et al., 1995), and colonization by invasive species (Brinson and Malvarez, 2002). Despite these threats, they are seldom systematically monitored (Brown et al., 2010) due to lack of established assessment tools or monitoring programs.

In evaluating the ability to transfer bioassessment tools between wetland types, we consider several factors. First, assessment tools must be responsive to a variety of different stressors. For example, wetlands in urban settings are likely to receive runoff containing metal and petroleum-derived contaminants associated with transportation (Maltby et al., 1995a,b; Characklis and Wiesner, 1997), while agriculture and golf course runoff may contain high levels of nutrients and pesticides (Glenn et al., 1999; Weston et al., 2004; King et al., 2007). Consequently, well-designed ambient programs must rely on indicators that integrate effects from diverse stressors. Second, tools must be applicable across a range of environmental settings where assessments are needed (Mazor et al., 2016). Environmental factors, such as wetland size, hydrologic regime, geology and climate, influence the biological communities a wetland can support, and may affect the interpretation of a bioassessment tool (Batzer, 2013; Lunde and Resh, 2012). Bird et al. (2013) suggested that developing indicators on smaller geographic scales, being cognizant of natural spatial heterogeneity, may improve the ability to detect human disturbance where natural environmental variability is high.

To address these challenges, we tested (1) the applicability of a depressional wetland benthic invertebrate index of biotic integrity (IBI) developed in the San Francisco Bay region of northern California for application in the drier regions of southern California (i.e. geographic transferability), and (2) the ability to apply a riverine benthic diatom IBI to depressional wetlands (i.e. water body type transferability). Indices were adapted for use in depressional wetlands by refining reference thresholds and recalibrating metric scores relative to stressor gradients. Performance of the adapted indices was compared to that of a habitat assessment tool (the California Rapid Assessment Method; CRAM CWMW, 2013) that has been developed for statewide application of depressional wetlands. Finally, we demonstrate application of the revised indices for ambient assessment of depressional wetland condition in Southern California.

2. Materials and methods

We evaluated the transferability the benthic invertebrate and diatom IBIs at a set of probabilistically selected wetlands in southern California. We compared the accuracy and precision of the two indices across natural gradients at defined reference sites, and evaluated their responsiveness to stressor gradients at sites along a gradient of disturbance. Results of the analysis were used to refine reference thresholds and calibrate the indices responses to stress.

2.1. Sampling approach

Fifty-three wetlands were sampled in southern California during the spring or early summer of 2011, 2012 or 2013. Sites were probabilistically selected from a candidate pool of sites using the generalized random tessellation stratified sampling approach (Stevens and Olsen, 2004). The sample draw that produced the candidate pool of sites was conducted from southern California wetland maps produced using the enhanced National Wetland Inventory (NWI) protocols and base imagery from year 2005 or newer.

Both seasonal and perennial wetlands were sampled, and the wetlands represented a range of intensity of use-types (Table 1). Wetlands varied in size from 101 to 64,500 m^2, and the level of urbanization within 500 m of the wetlands ranged from 0 to 90%. Wetlands were not considered for this study if they were concrete-lined, marine-influenced, treatment ponds, livestock wastewater ponds, riverine (i.e. dominated by riverine hydrology, or on military bases (due to access issues)). Vernal pools were also excluded; while these are considered a subclass of depressional wetlands, there are existing assessment tools developed specifically for the relatively specific habitats associated with vernal pools due to their sensitivity, rarity and tendency to support sensitive species (Bauder et al., 2009). Furthermore, given their rarity and ecological sensitivity they are often assessed through focused studies. Therefore, we excluded them from this analysis.

2.2. Field sampling

At each site, we sampled aquatic macroinvertebrates (MI), diatoms and the California Rapid Assessment Method (CRAM), which is a visual assessment of the plants and physical habitat (CWMW, 2013). Chemistry in the overlying water was measured as potential indicators of stress that could be affecting wetland condition. Sediment grain size and total organic carbon (TOC) were also measured at all sites. General water quality constituents were analyzed during all three years, while