Ecological Indicators 90 (2018) 79–89

Contents lists available at ScienceDirect

Ecological Indicators

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

Original Articles

Assessment of wetland health status of Poyang Lake using vegetation-based indices of biotic integrity

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ARTICLE INFO

Keywords:
Bio-assessment
Index of Biotic Integrity (IBI)
Disturbance gradient
Land cover
Poyang Lake wetland
Water quality

ABSTRACT

Poyang Lake wetland in China has extraordinary importance to millions of people in middle and lower Yangtze River Basin, and is also recognized globally for its remarkable biodiversity. However, it has been experiencing degradation for the past decades that is caused by human disturbances. Developing practical indicators for assessing ecological condition of this wetland is urgently needed. The index of biotic integrity (IBI) is a widely used approach for assessing ecological health of aquatic ecosystems. However, the methods for IBI metric selection are highly variable, hindering a consistent implementation of IBIs in assessment research and practice. In this article, we aim to develop a vegetation-based IBI (V-IBI) for the assessment of ecological status of Poyang Lake wetland, and to test whether adopting different methods for metric selection would present impacts on the assessment of wetland health condition. We conducted field surveys for obtaining the data of plant assemblages, water quality and human-induced disturbances at 30 sites in 2015 and 2016, respectively. We tested six different methods for V-IBI metric selection.

The study found that the selection of V-IBI core metrics varied considerably by using different methods. Wetland health status of sample sites assessed by the tested methods only showed moderate correlations (mean $r = 0.67$), suggesting that using different methods for metric selection would affect the assessment output. The method that took account of three important aspects of wetland environment (i.e. water quality, land use and field-observed disturbances) for metric selection yielded the most plausible assessment results. We selected seven metrics to construct the V-IBI for Poyang Lake wetland, i.e. cover of *Phalaris arundinacea* L. and numbers of submerged species, invasive species and tolerant species in a sample site, percentages of perennial species, obligate wetland species and species with both sexual and vegetative propagation (calculated as the ratio of the number of species concerned to the total number of plant species in a sample site). The assessment indicated that the overall health condition of Poyang Lake wetland was in a “good” category, while the estuarine wetland was in either “poor” or “very poor” categories, suggesting that controlling pollutant input from rivers should be an important measure for wetland restoration and conservation. This study highlighted the importance of standardizing the methods for metric selection in IBI development so that assessments from different studies, such as in other large lakes and wetlands along the Yangtze River Basin, could be comparable. The V-IBI developed in this study can serve as a protocol for monitoring ecological security of Poyang Lake wetland.

1. Introduction

Wetlands are important ecosystems that provide numerous beneficial services (Zedler and Kercher, 2005; Pan et al., 2011). A number of studies indicate that the loss and degradation of wetlands have been accelerated in the past decades (Dixon et al., 2016). Developing methods to assess health condition of wetlands has been recognized as a key issue for wetland protection and management (Fennessy et al., 2009). Poyang Lake is the largest fresh water lake in China with one of the most important wetlands in the world recognized by the International Union for the Conservation of Nature (Han et al., 2015). The Poyang Lake wetland provides critical wintering habitats for Siberian migratory birds where abundant aquatic plants, benthic invertebrates and fishes serve as critical food resources (Tang et al., 2016). However,

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https://doi.org/10.1016/j.ecolind.2017.12.056
Received 15 July 2017; Received in revised form 22 December 2017; Accepted 24 December 2017
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Poyang Lake wetland has been severely disturbed by human activities, including reclamation in the emerged floodplains, mowing and grazing, and sand mining (Jin et al., 2012). Currently, there is no ecological indicator or quantitative index applied to assess health condition of Poyang Lake wetland in order to support effective monitoring and reporting in management practice and policy decision making.

The index of biotic integrity (IBI), originally developed by Karr (1981), is a widely used method for evaluating anthropogenic pressures on aquatic and wetland ecosystems. This method integrates selected attributes of biological assemblages into a single index based on the assumption that biological assemblages in human-influenced habitats should be different from those in natural habitats of the region (Ruaro and Gubiani, 2013). Individual metrics of an IBI reflect biotic condition by measuring aspects of the structure or composition of biological assemblages that respond to anthropogenic pressures in a predictable manner (Vondracek et al., 2014).

The selection of suitable metrics is key to the development of IBIs (Stoddard et al., 2008; Ruaro and Gubiani, 2013). However, methods for metric selection varied considerably in published studies. One commonly used method is to base the evaluation of the suitability of a metric on its ability to distinguish reference (undisturbed or least-disturbed) from impaired (moderately or heavily disturbed) conditions (e.g. Stoddard et al., 2006; Huang et al., 2015). In this approach, only the metrics which the values exhibit significant difference between reference and impaired conditions will be selected as the IBI metrics (Fig. 1A). Other methods test the effectiveness of a metric on the basis of its responsiveness to disturbance gradients (e.g. Mack et al., 2008; Fig. 1B). Disturbance gradients are established using variables indicating specific human-related stressors (Mccormick et al., 2001). Metrics significantly correlating with disturbance gradients will be selected as the IBI metrics. Yet, it is still controversial about which stressor variables should be considered for quantifying anthropogenic pressures (Niemi et al., 2011). For instance, Grabas et al. (2012) used a water quality index to indicate the intensity of anthropogenic pressures on coastal wetlands, whereas Ligeiro et al. (2013) established a gradient by summarizing disturbances measured at both local (e.g. pasture and mining) and landscape (e.g. altered land cover) scales. The third kind of methods selects the metrics either showing striking difference between reference and impaired conditions or having significant correlations with disturbance gradients (Uzarski et al., 2004; Fig. 1C). It has not yet been tested in a common framework whether adopting different methods for metric selection would have significant influences on the selection of IBI metrics and consequently the assessment of wetland health status.

A couple of biological taxa have been proposed for the development of IBIs, including fishes, invertebrates, birds, amphibians and plankton (Barbour et al., 1996; Simon et al., 2000; Uzarski et al., 2005; Baek et al., 2014). Plants are quickly emerging as one of the important indicators of ecological health because they are immobile, relatively easy to sample and identify, and respond to anthropogenic disturbances on an ecological time scale (Beck et al., 2010; Brieda et al., 2013; Gara and Stapanian, 2015). Moreover, as important components of wetland ecosystems, plants intricately shape trophic web dynamics by providing oxygen, food and shelter to other biological organisms (such as fishes and waterfowls). In addition, a vegetation-based IBI is a useful tool for monitoring wetland restoration efforts, because seed banks retained in sediment are a viable source for species recolonization that responds to environmental condition (Xu et al., 2017). In this study, we aimed to develop a vegetation-based index of biotic integrity (V-IBI) for assessing health status of Poyang Lake wetland. We conducted the comprehensive comparative analysis of different methods for metric selection and tested whether the evaluation of wetland health condition would be affected by the application of different methods.

2. Materials and methods

2.1. Study area

Poyang Lake is situated between 28°22′–29°45′ N and 115°47′–116°45′ E, and lies at the southern bank of the middle reach of

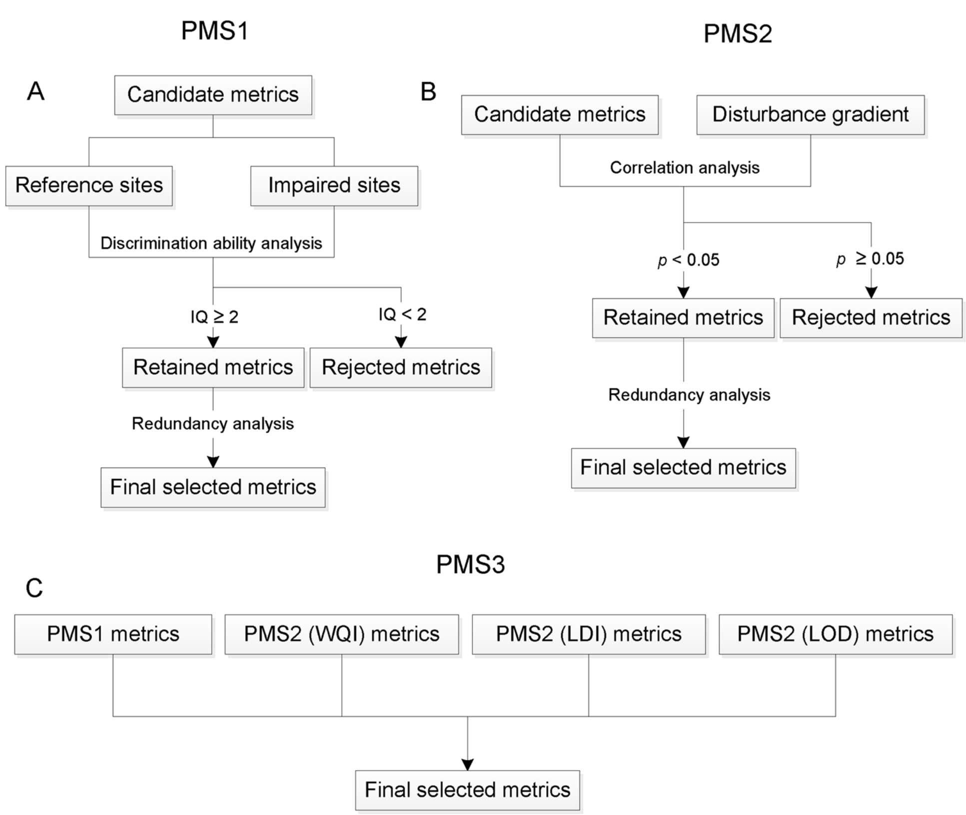

Fig. 1. Three different processes for aquatic index of biotic integrity (IBI) metric selection. PMS1, the first process for metric selection. IQ, inter-quartile range score. PMS2, the second process for metric selection. PMS3, the third process for metric selection. PMS1 metrics, metrics finally selected in PMS1. PMS1 (WQI) metrics, metrics selected in PMS2 with water quality index (WQI) as the measurement of disturbance gradient. PMS1 (LDI) metrics, metrics selected in PMS2 with landscape development intensity index (LDI) as the measurement of disturbance gradient. PMS1 (LOD) metrics, metrics selected in PMS2 with local disturbance index (LOD) as the measurement of disturbance gradient.

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