**Abstract:** Quantitative evaluation of the aquatic ecosystem health is crucial to the policy formulation of water environmental management and ecological restoration. However, it is often difficult to quantitatively compare or estimate the health of aquatic ecosystems for different watersheds. In this study, we developed an index of aquatic ecosystem health (AEHI) based on a modified zooplanktonic IBI (ZIBI) to address this difficulty. The ZIBI was developed based on 32 zooplankton community indicators through principal component analysis. The AEHI was transformed from the ZIBI by the arc-tangent function. The rating scales of AEHI were defined as ‘Bad’ for 0<AEHI<0.2, ‘Poor’ for 0.2≤AEHI<0.4, ‘Fair’ for 0.4≤AEHI<0.6, ‘Good’ for 0.6≤AEHI<0.8, and ‘Excellent’ for AEHI≥0.8. Moreover, six models, corresponding to five zooplankton community indicators (total taxonomic composition, taxa composition of *Cladocera* or *Copepoda*, and individual abundance of *Cladocera* or *Copepoda*) and one water environmental parameter (total nitrogen concentration), were established to estimate the AEHI values. These models were then applied to evaluate three lakes and four river basins in eastern China. The results showed that the aquatic ecosystem health was ‘Good’ in areas that included rivers in Tongxiang plain, Meiliang Bay of Taihu Lake, rural area of Qinhuai River basin, Shahu of Poyang Lake during Summer/Autumn. However, the aquatic ecosystem health was ‘Bad’ or ‘Fair’ in Xuanwu Lake (an urban shallow lake), urban area of Qinhuai River basin, Huai River basin, Ying River basin, and Shahu Lake in Winter. This study provides a new approach for quantitative evaluation/estimation of freshwater aquatic ecosystem health, and provides a strong case for the cross-basin analysis of aquatic ecosystem health in eastern China.

**Keywords:** aquatic ecosystem health; quantitative evaluation; index of biotic integrity; zooplankton; eastern China

# Introduction

Quantitative evaluation of aquatic ecosystem health is a key component of the policy formulation for water environmental management and ecological restoration (Schwarzenbach et al., 2006; Xu et al., 2001b). Despite much relevant traditional knowledge and scientific knowledge, quantitatively evaluating aquatic ecosystem health is still a challenging research hotspot (Mantyka-Pringle et al., 2017), especially for comparing quantitatively the aquatic ecosystem health among different watersheds (Ogren and Huckins, 2015).

As an effective tool in aquatic ecosystems health quantitative evaluation, index of biotic integrity (IBI) has been widely adopted for over 30 years (Ruaro and Gubiani, 2013). The first version of the IBI was the fish-based index proposed by James R. Karr (1981) for rivers in northeastern United States. A series of IBIs have then been published based on other ecological taxa, these include the benthic invertebrate-based IBI (Fore et al., 1996), bird-based IBI (O'Connell et al., 1998), phytoplankton-based IBI (Lacouture et al., 2006), zooplankton-based IBI (Carpenter et al., 2006), plant-based IBI (Rothrock et al., 2008), and bacteria-based IBI (Li et al., 2017). Historically, IBIs based on fish or benthic invertebrate were used most frequently (O'Brien et al., 2016; Ruaro and Gubiani, 2013). Different ecological taxa have different sensitivities to environmental stressors (Griffith et al., 2005). Knowledge of the indication of the IBI and its response to environmental stressors are can help us understand better the aquatic ecosystem health.

In most cases, the evaluation of aquatic ecosystem health was conducted for a continuous water body or water areas in the same watershed. However, efforts have been attempted to use IBIs to quantitatively evaluate and compare the aquatic ecosystem health of different basins. For example, four IBIs were used to evaluate the influences of different environmental stressors on the aquatic ecosystems for 185 rivers distributed in 9 European countries (Hering et al., 2006). The fish-based IBI was used to compare the ecological condition of 67 reservoirs and 24 natural lakes in France (Launois et al., 2011) and 1843 rivers in Europe (Pont et al., 2006). A benthic macroinvertebrate-based IBI was developed to assess and predict the ecological condition of more than 900 rivers in Germany (Bohmer et al., 2004). In above studies, the databases for IBIs development or application were huge with relatively complex constructions. Usually, the historical records of the biological community in a watershed were not complete and may not well meet the requirements of IBI development. Effective utilization of the historical ecological investigation records poses a major challenge for estimating aquatic ecosystem health based on the IBI.

Zooplankton, as the secondary producer in aquatic ecosystems, can efficiently respond to environmental changes via community features (Albaina et al., 2009; Azevedo et al., 2015; Gokce and Ozhan Turhan, 2014). The first version of the zooplankton-based IBI (ZIBI) was proposed in 2006 for the Chesapeake Bay (Carpenter et al., 2006). An updated version was developed in 2019 for seven Brazilian reservoirs (De-Carli et al., 2019). More commonly, different zooplankton community indicators were considered into the synthetic indexes for the aquatic ecosystem health evaluation, such as the wetland zooplankton index for the Laurentian Great Lakes basin and Pearl River estuary (Lougheed and Chow-Fraser, 2002; Zhang et al., 2012), and the ecosystem health index and planktonic IBI for lakes (Kane et al., 2009; Qi et al., 2018; Simcic and Brancelj, 2009; Xu et al., 2001a). The methodology used in IBI development is still evolving. How to improve the accuracy, applicability, and rapidity of ZIBI is a problem need more practical experience at present.

Eastern China has many complex rivers and lakes that belong to different watersheds. With the rapid development of economy, aquatic ecosystems in eastern China are facing severe degradation (Yu et al., 2014). IBIs, based on fish (Jia et al., 2013), diatom (Tan et al., 2015), microbial community (Li et al., 2017; Niu et al., 2018), and vegetation (Yang et al., 2018), have been applied or developed for some rivers and lakes in this area. Moreover, IBIs have been considered in a health warning system for river management (Chen et al., 2019). However, very few studies have focused on using the ZIBI.

The purpose of this study was to develop a new approach for the quantitative cross-basin analysis of the aquatic ecosystem health in eastern China. The first objective was to develop an ZIBI, based on a cross-basin database. The second objective was to establish the estimation models of AEHI based on the developed ZIBI. The third objective was to train the estimation models of AEHI using the single zooplankton community indicator or water environmental parameter to estimate the aquatic ecosystem health. The last objective was to quantitatively evaluate and compare the aquatic ecosystem health of several important water areas in eastern China.