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Editorial

Ecology of China's pilot cities for creating healthy aquatic communities: heterogeneity, niches and environmental factors

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Abstract. Globally, climate change and human activities have greatly stressed the health of water ecological communities (WECs) in cities, and WEC restoration is therefore a critical issue, especially for developing cities. To restore healthy WECs and support humans into the future, the Ministry of Water Resources, China, proposed a project to build cities with healthy WECs. Jinan was designated the first pilot city for this project. The exploration of methodologies on WEC restoration in pilot cities is important because it can provide reliable theoretical evidence and methodological references for researchers and managers, and serve as an important decision-making basis for ecological resources management and remediation of fresh waters. In this Research Front, we have brought together studies on aquatic ecosystems of the first pilot cities project to build healthy WECs in China, including studies on the health, temporospatial heterogeneity and niches of WECs, as well as environmental factors. These studies can significantly increase our understanding of the ecology of the aquatic systems in China's pilot cities. It is anticipated that this ecosystem knowledge will help assess the effects of climate- and human-induced stress changes, and form the basis for making aquatic ecosystem protection and restoration decisions across the globe.

Additional keywords: China project to build cities with healthy water ecological communities, Jinan City, water ecological communities, WEC.

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Introduction

Healthy water ecological communities (WECs) are essential for the maintenance of freshwater functions and services. However, the rapid development of economies in recent decades has led to intensive human activities across the world, such as urbanisation, industrialisation and increased domestic sewage discharge, which have greatly stressed the health of WECs in cities (Kagalou *et al.* 2010). Healthy WECs form the foundation of ecosystems and many freshwater services (Zhao *et al.* 2018*a*). WEC restoration is a critical issue for developing cities. Exploration of methodologies regarding WEC restoration, such as ameliorating hydrological regimes, improving water quality, increasing biodiversity, prioritising water-saving strategies through scientific research and engineering construction, is high on the agenda in China (Zhao 2014; Cai *et al.* 2015).

In 2013, the Ministry of Water Resources, China, proposed a project to build cities with healthy WECs to support humans into the future (Ministry of Water Resources 2013*a*, 2013*b*, 2013*c*). Jinan was designated the first pilot city for this project (Jinan People's Government 2013), and later another 104 cities were included for restoration. The outcomes of water ecosystem restoration in the first pilot city will directly affect the processes for the other cities. It is important for governments and stakeholders to evaluate the outcomes of the pilot cities project and to use this information to make good decisions for the other WEC areas (Zhao *et al.* 2019*a*, 2019*b*). The success of ecological restoration in the pilot cities will provide fundamental improvements in the living environment for people in China.

The exploration of methodologies regarding WEC restoration in pilot cities is important because it can provide reliable theoretical evidence and methodological reference for researchers and managers, and serve as an important decision-making basis for ecological resources management and remediation of fresh waters. This can facilitate sustainable water resource management, protection and restoration of water ecosystems.

In this Research Front, we have brought together a range of different studies on aquatic ecosystems of the first pilot cities project to build healthy WECs in China. These studies assessed water ecosystem health and its heterogeneity at different spatial and temporal scales, analysed hydrological and water quality niches of biota, identified driving factors for water ecological communities and identified regions for WEC restoration. We hope this will improve the knowledge base for WEC restoration and provide important references for WEC restoration in other developing cities in China and across the world.

Health of WECs

The health of urban hydroecology directly affects the development of healthy water communities (Swyngedouw *et al.* 2002; Parkes and Horwitz 2008; Jenerette *et al.* 2016). Evaluation of the conditions of urban hydroecological health can help governments make reasonable decisions for ecological restoration. Fish are at the top of the food chain in these aquatic ecosystems and can reflect the health status of the entire aquatic ecosystem (Liu *et al.* 2011; Zhao *et al.* 2015*a*, 2015*b*). Thus, Zhao *et al.* (2019*c*) evaluated the urban hydroecological health conditions in the first pilot city in China and found that chemical oxygen demand (COD) had the greatest effect on the health of fish communities, followed by discharge as a hydrological factor; turbidity, as a physical factor, had the lowest effect. *Macropodus chinensis* (Bloch, 1790) was sensitive to the changes in COD, *Saurogobio dumerili* (Bleeker, 1871) and *Pseudolaubuca engraulis* (Nichols, 1925) were sensitive to discharge and flow velocity and *Saurogobio gymnocheilus* (Lo, Yao and Chen, 1977) and *Spualiobarbus curriculus* were only sensitive to discharge.

Plankton communities are the foundation of freshwater food webs, playing critical roles in biogeochemical cycling and energy flows (Liu *et al.* 2010). Their biodiversity is often used to assess the health of rivers (Dukes 2001; Haines-Young and Potschin 2010; Fu *et al.* 2017). Globally, river ecosystem restoration is a critical issue and many freshwater ecosystems, especially in urban areas, are degraded because of intensive human activities (Dodson *et al.* 2008; Dickerson *et al.* 2010; Van Egeren *et al.* 2011). To facilitate assessing the health of plankton communities in the pilot city, Shao *et al.* (2019) developed a novel plankton health assessment model with which stakeholders can easily analyse the temporal and spatial distribution of plankton for a better understanding of community composition and identify driving principal environmental factors. Shao *et al.* (2019) found that in the pilot city the species composition of both phytoplankton and zooplankton was stable; the health status in the north and south of the city was significantly better than that of the city centre and that seasonally, spring ecosystem health was better than in summer and autumn. In general, eutrophication and an increase in reducing substances in the water caused by anthropogenic activities combine to increase the risk of phytoplankton blooms (McCauley *et al.* 2015; Andersen *et al.* 2017). Future management should include plans to reduce the load of pollutants discharged into rivers to reduce the risk of phytoplankton blooms (Yang *et al.* 2019*a*).

Temporospatial heterogeneity of WECs

Understanding the heterogeneity of water communities and their health is useful for selecting areas for ecological remediation (Okun and Mehner 2005; Visintainer *et al.* 2006; Zhao *et al.* 2018*b*). Temporospatial heterogeneity of environmental factors, such as the physical water quality factor turbidity, the water quality chemical factor COD and the hydrological factor discharge, affects the temporospatial heterogeneity of river health (Zhao *et al.* 2019*c*). Yang *et al.* (2019*b*) found that temporospatial heterogeneity of the aquatic ecosystem in the first pilot city of China was high and that eutrophication and an increase in reducing substances in the water caused by human pollution combined to increase the risk of algal proliferation and potentially cause harm to the WEC. The principal driving environmental factors were flow velocity and total nitrogen concentration, which were slower and higher respectively, in the plains areas compared with mountain areas.

Because biodiversity is often used to reflect the health of aquatic ecosystems (Dukes 2001; Fu *et al.* 2017), prediction and assessment of the effects of habitat change on aquatic biodiversity remain hot issues globally and are important for the restoration of WECs. To comprehensively assess the effects of habitat changes on aquatic biodiversity, Zhao *et al.* (2019*d*) developed a practical methodology based on food web models. The biomass of aquatic organisms under undisturbed conditions was simulated using the food web model Ecosim and compared with measured aquatic biodiversity to obtain biodiversity variation. The differences between the variance and mean values of the predicted and measured biodiversity in the first pilot city in China were not statistically significant ($P > 0.05$). This suggests that the model can accurately reflect the dynamic relationship of riverine hydrology, water quality and biodiversity, and can be used to comprehensively assess the effects of habitat changes on aquatic biodiversity.

Niches of WECs and environmental factors

In aquatic ecosystems, each species has an ecological niche. The ecological niche is an important means for analysing and evaluating relationships among different species and populations within communities (Chen and Yin 2008). Maintenance of appropriate niches of environmental factors (e.g. of hydrology and water quality) for different species can help maintain the biodiversity of the ecological communities. To achieve this goal, Yang *et al.* (2019*a*) identified keystone species using the Ecopath with Ecosim food web model for hydrological niche analysis. In addition, Yang *et al.* (2019*c*) performed niche analysis to study the niche breadth and overlap between key species and water quality factors after identifying keystone dominant species with the Ecopath model. Stream flow was the most important hydrological factor affecting the phytoplankton, zooplankton, zoobenthos and fish communities. Exceptionally excess variation in stream flow had an adverse effect on the normal evolution of the four biotic communities. *Pseudorasbora parva* and *Carassius auratus* (fish), *Navicula* sp. (phytoplankton), *Phryganella nidulus* and *Brachionus calyciflorus* (zooplankton), *Limnodrilus claparedianus* and *Assimineidae* sp. (zoobenthos) had the highest niche breadth, indicating that they have strong adaptability to water quality variations.

Final comment

Collectively, the papers in this Research Front increase our understanding of the ecology of the aquatic systems of the WECs in China's pilot cities. This provides a reliable theoretical basis and direction for the management and restoration of these aquatic ecosystems in developing countries (Sabo *et al.* 2010). This is especially relevant in the context of climate change and human activities, because previous restoration projects have not proved to be very successful and have led to a substantial waste of resources (Suding *et al.* 2015). Aquatic ecosystem restoration under climate change and human activities requires methodologies for the identification of environmental and pressure gradients, selection of priority restoration areas and assessment of habitat quality before, during and after project restoration (Hughes *et al.* 2010; Zhao *et al.* 2015*a*). It is anticipated that this ecosystem knowledge will help assess the effects of climate- and human-induced stress changes, and form the basis for aquatic ecosystem protection and restoration decisions (McCann 2007; Harvey *et al.* 2017).

Conflicts of interest

The authors declare that they have no conflicts of interest.

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