Ecological Indicators 84 (2018) 488–496

Contents lists available at ScienceDirect

Ecological Indicators

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

Research paper

Factors determining zooplankton assemblage difference among a man-made lake, connecting canals, and the water-origin river

Kun Zhao[a,f], Lizhu Wang[b], Catherine Riseng[c], Kevin Wehrly[d], Yangdong Pan[e], Kun Song[f], Liangjun Da[f], Wanting Pang[a], Qingmin You[a], Hua Tian[g], Shuiqin Liu[g], Quanxi Wang[a,*]

[a] College of Life and Environmental Sciences, Shanghai Normal University, China
[b] International Joint Commission, Detroit, USA
[c] School for the Environment and Sustainability, University of Michigan, USA
[d] Institute for Fisheries Research, Michigan Department of Natural Resources and University of Michigan, USA
[e] Environmental Sciences and Management, Portland State University, USA
[f] School of Ecological and Environmental Sciences, East China Normal University, China
[g] Shanghai Municipal Hydrology General Station, Shanghai, China

ARTICLE INFO

Keywords:
Zooplankton assemblage
Man-made lake
Connecting canal
Dispersal
Influential factor

ABSTRACT

Zooplankton play an important role in the pelagic food web as a mediator of nutrient and energy fluxes. Understanding factors determining zooplankton abundance, composition, and dispersal provides information needed for improving plankton dynamic predictions and enhancing effective water resource management and biodiversity conservation. We studied zooplankton dispersal and identified factors influence zooplankton composition and abundance under a unique *in situ* environment with four connected water types from the natural river to a man-made main canal, then interior canal-web, and finally lake that have different flow regimes. We found that, after seven years creation of the water system and zooplankton community development, the main canal, interior canal-web, and lake had 53%–64% zooplankton taxa similar to their water origin river but that each water type was represented and dominated by different zooplankton taxa. Our optimal model identified three key local factors that affected the difference in zooplankton abundance and composition among the four water types: Chlorophyll *a* concentration, turbidity, and salinity. We concluded that both zooplankton dispersal through watercourse and species sorting by local factors were important for structuring communities in our study system. Since most studies on dispersal and influence of local factors on zooplankton assemblages in new environment have been done largely in temporal ponds, our findings provide unique insights on how zooplankton communities are jointly regulated by their species dispersal origins and local environmental factors in newly created canals and lakes.

1. Introduction

Zooplankton communities play an important role in the function of aquatic ecosystems by providing linkages in food webs through consuming primary and small secondary production and providing food to higher trophic consumers (Capriulo et al., 2002; Sotton et al., 2014; Turner, 2004). Zooplankton are sensitive to changes in aquatic environment and have been suggested to be good biological indicators for water quality, lake trophic state, and types of water mass (Bays and Crisman, 1983; Gannon and Stemberger, 1978; Pagès et al., 2001). The effects of environmental variation can be detected through changes in species composition and abundance.

It is well recognized in ecology that biological assemblages, including zooplankton, can be explained by a traditional niche-based paradigm (Drake, 1990) that predicts the match between species and their environment or species responses to both abiotic physicochemical factors and biotic competition and predation (Amarasekare, 2002; Cottenie and De Meester, 2004; Louette et al., 2008; Shurin and Allen, 2001). This combination of processes can be seen as initial exclusion of species that are unable to tolerate the abiotic environment (*e.g.*, environmental filtering), followed by the operation of assembly rules (*e.g.*, biotic filtering; Goberna et al., 2014; Keddy, 1992). For example, Cottenie et al. (2003) reported that local environmental constraints could be strong enough to structure local zooplankton communities among highly interconnected ponds. Zhao et al. (2017) found that zooplankton community structure was correlated to both local

* Corresponding author at: College of Life and Environmental Sciences, Shanghai Normal University, No. 100 Guilin Road, Xuhui District, Shanghai 200234, China.
E-mail address: wangqx@shnu.edu.cn (Q. Wang).

http://dx.doi.org/10.1016/j.ecolind.2017.07.052
Received 31 March 2017; Received in revised form 29 June 2017; Accepted 26 July 2017
Available online 25 September 2017
1470-160X/

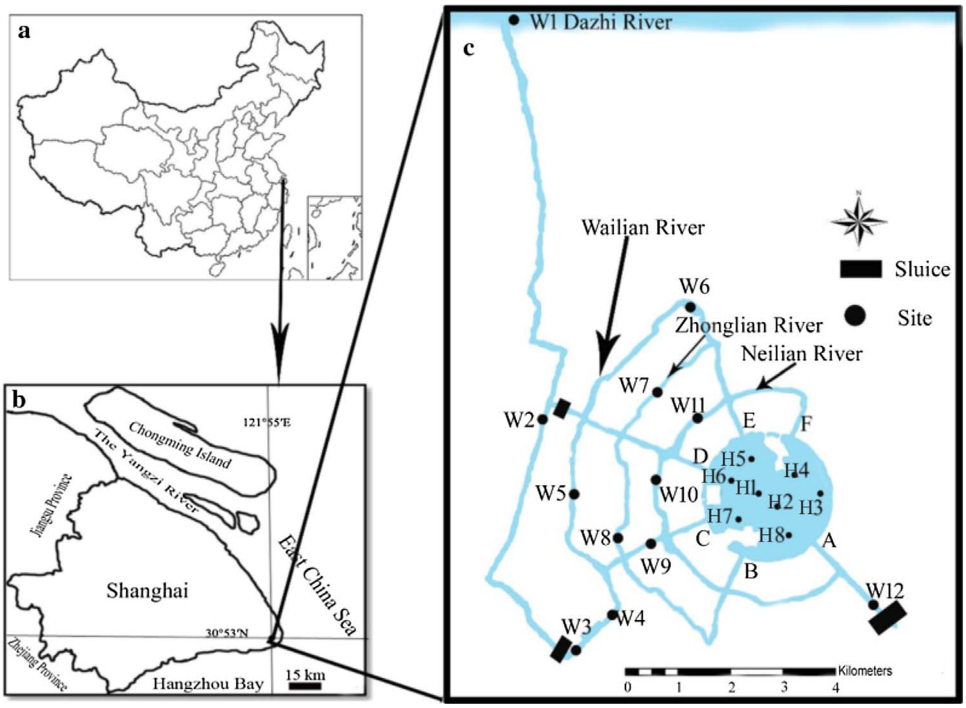

Fig. 1. Map of China showing the location of Lake Dishui (a); Lake Dishui and its surroundings (b); and locations of the sampling sites in Lake Dishui and connecting canals (c).

environmental factors and spatial process, of which zooplankton community variation was best explained by local environment in the dry season while spatial factors were significant in the wet season. These findings imply that zooplankton assemblages are influenced by both temporal variation of local conditions and spatial gradients of environment among different types of waters, resulting in a set of dominant species best suited to thrive in the selective forces of environment. Hence, understanding how zooplankton assemblages vary according to temporal and spatial variations of environmental conditions will improve the prediction of zooplankton population dynamics and detection of environmental degradation or improvement (Jeppesen et al., 2011).

Effects of abiotic and biotic factors on zooplankton communities have been well documented. Abiotic factors driving variation in zooplankton communities among rivers and lakes include water chemistry (*e.g.*, nutrient concentration, pH, conductivity, salinity, and turbidity; Jeppesen et al., 2003; Peck et al., 2015), hydrodynamics (*e.g.*, current, waves, water turnover; Chen and Chen, 2017; Lacroix and Lescher-Moutoué, 1995; Li et al., 2017), thermal regime (*e.g.*, temperature fluctuation and duration; Havens et al., 2015; Šorf et al., 2015), and water body type (*e.g.*, lentic, lotic, semi-lotic; Basu and Pick, 1996; Walks and Cyr, 2004). Biotic driving forces can be both bottom-up factors involving natural productivity and resource limitation and top-down factors including resource competition and predator-prey interactions (Carpenter et al., 1985; Hulot et al., 2014; McQueen et al., 1989).

These abiotic and biotic drivers are often distinctive between lentic and lotic systems, which makes it relatively easy to identify key factors influencing zooplankton community structure between lakes and rivers. Studies have shown that current velocity and water residence time is of greater importance to planktonic community development in rivers than in lakes (Basu and Pick, 1996; Pace et al., 1992). Mean river zooplankton biomass was low compared to lakes of similar chlorophyll *a* concentration (Basu and Pick, 1996). It is generally considered that zooplankton dynamics in lentic systems are predictable and driven predominantly by biological process (Sommer et al., 1986), whereas zooplankton dynamics in lotic systems are largely driven by physical processes dictated by hydrological conditions (Lair, 2006).

In contrast, these abiotic and biotic drivers for semi-lotic systems are less well understood. Because hydrological characteristics of semi-lotic systems are between lentic and lotic environments, it can be assumed that the abiotic and biotic drivers are less variable and indistinctive than between lentic and lotic systems, which makes it challenging to clearly define the difference in their effects on zooplankton. It is even more challenging to generalize the driving forces determining zooplankton communities for river-lake connecting canals because their hydrological settings could vary anywhere along the gradient between rivers and lakes.

Biological colonization theory suggests that successful zooplankton colonization in a new habitat depends on both the arrival of the species and subsequent successful settlement in the habitat (Caley and Schluter, 1997; Louette et al., 2008). Studies testing this theory are largely carried out under the condition of newly created temporal ponds (*e.g.*, Frisch et al., 2012; Frisch and Green, 2007; Louette et al., 2008). For example, successful colonization depended on newly arrived species interactions with local abiotic and biotic conditions (Louette et al., 2008; Shurin and Allen, 2001). Studies of zooplankton colonization and controlling factors under the conditions of newly created canals and lakes are rare.

Lake Dishui, located in the vicinity of Shanghai, China, is a man-made shallow coastal lake fed by water from the Dazhi River through a nest of connecting canals that were created and connected with water origin in October 2003. Such a man-made lake and surrounding canals provide an ideal environment to test the biological colonization theory. Answering the question of how zooplankton communities have colonized in such a lake and its connecting canals after seven years of their creation not only improves our understanding of the biological colonization processes, but also provides insights on zooplankton dispersal capacity and controlling mechanisms for the development of strategies and measures for conserving species diversity under environmental change (*e.g.*, human disturbance and climate change).

The objectives of this study were to: (1) compare the difference in zooplankton communities along a gradient of conditions from lotic to lentic and from natural to man-made (from dispersal origin natural river, man-made connecting canals, to man-made shallow lake) seven years after creation of the canal-lake water system, and (2) identify the main factors that contributed to the differences in zooplankton community composition and dispersal mechanisms among the different types of connected water bodies.