Water Research 124 (2017) 11–19

Contents lists available at ScienceDirect

Water Research

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

The relative importance of water temperature and residence time in predicting cyanobacteria abundance in regulated rivers

YoonKyung Cha [a], Kyung Hwa Cho [b], Hyuk Lee [c], Taegu Kang [d], Joon Ha Kim [e, *]

[a] Department of Environmental Engineering, University of Seoul, Seoul, Republic of Korea
[b] School of Urban and Environmental Engineering, Ulsan National Institute of Science and Technology, Ulsan, Republic of Korea
[c] Water Quality Assessment Research Division, National Institute of Environmental Research, Incheon, Republic of Korea
[d] Yeongsan River Environment Research Center, National Institute of Environmental Research, Gwangju, Republic of Korea
[e] School of Environmental Science and Engineering, Gwangju Institute of Science and Technology, Gwangju, Republic of Korea

A R T I C L E I N F O

Article history:
Received 20 December 2016
Received in revised form
30 June 2017
Accepted 16 July 2017
Available online 18 July 2017

Keywords:
Cyanobacteria
Rivers and streams
Temperature
Residence time
Bayesian hierarchical model
Overdispersed Poisson regression

A B S T R A C T

Despite a growing awareness of the problems associated with cyanobacterial blooms in rivers, and particularly in regulated rivers, the drivers of bloom formation and abundance in rivers are not well understood. We developed a Bayesian hierarchical model to assess the relative importance of predictors of summer cyanobacteria abundance, and to test whether the relative importance of each predictor varies by site, using monitoring data from 16 sites in the four major rivers of South Korea. The results suggested that temperature and residence time, but not nutrient levels, are important predictors of summer cyanobacteria abundance in rivers. Although the two predictors were of similar significance across the sites, the residence time was marginally better in accounting for the variation in cyanobacteria abundance. The model with spatial hierarchy demonstrated that temperature played a consistently significant role at all sites, and showed no effect from site-specific factors. In contrast, the importance of residence time varied significantly from site to site. This variation was shown to depend on the trophic state, indicated by the chlorophyll-a and total phosphorus levels. Our results also suggested that the magnitude of weir inflow is a key factor determining the cyanobacteria abundance under baseline conditions.

1. Introduction

Recurring cyanobacterial blooms are prevalent in freshwater ecosystems globally (Paerl and Huisman, 2008; Pick, 2016). Cyanobacteria often form unsightly scum, can produce toxins, and taste and odor compounds, that may negatively impact drinking water supplies and recreational activities (Codd et al., 2005; Srinivasan and Sorial, 2011). These blooms therefore have adverse ecological and economic impacts, and are a major concern in water quality management (Dodds et al., 2008; Paerl and Otten, 2013).

Over several decades, efforts have been made to identify the drivers of cyanobacterial blooms. Traditionally, the link between nutrient inputs and eutrophication has been considered a key process controlling algal productivity and cyanobacteria dominance (Schindler, 1978; Smith, 1982). It is generally agreed that excess nutrient inputs from urban, industrial, and agricultural watersheds create an environment susceptible to proliferation of cyanobacteria (Conley et al., 2009; Downing et al., 2001; Lewis et al., 2011.

An increasing number of studies have focused on the role played by temperature (Elliott, 2010; Kosten et al., 2012; Ndong et al., 2014; Trolle et al., 2015). Increases in the frequency and distribution of cyanobacterial blooms over time have been attributed, in part, to global warming (Carey et al., 2012; Deng et al., 2014; Ma et al., 2016; Vilhena et al., 2010; Zhang et al., 2012). Empirical evidence suggests that warmer, stratified waters are more susceptible to cyanobacteria dominance, because the optimal temperatures for cyanobacteria growth are generally higher than those for eukaryotic phytoplankton, and some cyanobacteria can control buoyancy in stratified water columns (Carey et al., 2012; Jönk et al., 2008; Wagner and Adrian, 2009).

A number of empirical models have been developed in the attempt to assess the relative importance of the factors driving cyanobacterial blooms in lakes and reservoirs (Kosten et al., 2012;

* Corresponding author.
E-mail address: joonkim@gist.ac.kr (J.H. Kim).

http://dx.doi.org/10.1016/j.watres.2017.07.040
0043-1354/