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Effects of increased zooplankton biomass on phytoplankton and cyanotoxins: A tropical mesocosm study

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ABSTRACT

Zooplankton are important biocontrol agents for algal blooms in temperate lakes, while their potential in tropical and subtropical environments is not well understood. The aim of the present study was to evaluate the influence of increased zooplankton biomass on phytoplankton community and cyanotoxins (microcystins and saxitoxin) content of a tropical reservoir (Ipojuca reservoir, Brazil) using *in situ* mesocosms. Mesocosms consisted of 50 L transparent polyethylene bags suspended in the reservoir for twelve days. Phytoplankton populations were exposed to treatments having 1 (control), 2, 3 and 4 times the biomass of zooplankton found in the reservoir at the beginning of the experiment. Filamentous cyanobacteria such as *Planktothrix agardhii* and *Cylindrospermopsis raciborskii* were not negatively influenced by increasing zooplankton biomass. In contrast, the treatments with 3 and 4 times zooplankton biomass negatively affected the cyanobacteria *Aphanocapsa* sp., *Chroococcus* sp., *Dolichospermum* sp., *Merismopedia tenuissima*, *Microcystis aeruginosa* and *Pseudanabaena* sp.; the diatom *Cyclotella meneghiniana*; and the cryptophyte *Cryptomonas* sp. Total microcystin concentration both increased and decreased at different times depending on zooplankton treatment, while saxitoxin level was not significantly different between the treatments and control. The results of the present study suggest that zooplankton biomass can be manipulated to control the excessive proliferation of non-filamentous bloom forming cyanobacteria (e.g. *M. aeruginosa*) and their associated cyanotoxins.

1. Introduction

A common result of anthropogenic activities is the eutrophication of aquatic systems. Under eutrophic conditions, cyanobacterial species such as *Anabaena*, *Cylindrospermopsis*, *Microcystis* and *Planktothrix* tend to dominate phytoplankton community and negatively affect food-web processes (Ger et al., 2014; Chia and Kwaghe, 2015). In addition to the unpleasant odor and taste associated with cyanobacterial blooms, human intoxication (Zanchett and Oliveira-Filho, 2013) and animal deaths (Hilborn and Beasley, 2015) from cyanotoxins exposures have been reported. Laboratory and field studies show that changing global climate conditions coupled with increased eutrophication will lead to increased frequency of cyanobacterial blooms and cyanotoxins production (Paerl and Huisman, 2009; O'Neil et al., 2012).

Zooplankton have been employed as important biocontrol agents for algal blooms in temperate lakes (Ekvall et al., 2014). In tropical and subtropical environments, the potential of these organisms to reduce cyanobacterial biomass is not well understood (Jeppesen et al., 2005; Ger et al., 2014). The current understanding of the effects of cyanobacteria on zooplankton dynamics remains inadequate and contradictory (Wilson et al., 2006; Sarnelle, 2007). Compared with other phytoplankton species, cyanobacteria are considered nutritionally poor and unpalatable to zooplankton. Cyanobacteria produce toxic metabolites (Wilson et al., 2006), are

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deficient of sterol and long-chain polyunsaturated fatty acids (Martin-Creuzburg and von Elert, 2009), and have various morphological adaptations that make ingestion difficult (Reynolds, 2007). These characteristics reduce the feed rate, growth and reproduction of zooplankton (Wilson et al., 2006; Paerl and Paul, 2012). When zooplankton are unable to consume cyanobacteria, the lack of grazing tends to give cyanobacteria a competitive advantage over other phytoplankton (Haney, 1987). In contrast, Agrawal (1998) demonstrated that increased grazing pressure by herbivores may not result in higher biomass of unpalatable algae and cyanobacteria.

Biomanipulation is a management technique employed to control the excessive proliferation of cyanobacteria/algae by increasing the biomass and grazing pressure of zooplankton (An et al., 2010). The success of biomanipulation depends on the hypothesis that zooplankton will consume cyanobacteria and assimilate their carbon efficiently, grow and reproduce (Ger et al., 2014). In temperate environments, biomanipulation is often used to control blooms of toxic cyanobacteria such as *Microcystis* spp. and *Anabaena* spp. (Ekvall et al., 2014). The efficiency of this technique relies on the dominance of *Daphnia* in temperate water bodies (Jeppesen et al., 2005; Peretyatko et al., 2012; Ekvall et al., 2014). The crustacean has a large body, and is a generalist consumer, ingesting both toxic and non-toxic algae. In contrast, the use of zooplankton for biocontrol of cyanobacteria in tropical and subtropical reservoirs has not been successful (Crisman and Beaver, 1990; Jeppesen et al., 2005). This is likely due to the fact that the structure of zooplankton communities in the tropics is different from that of the temperate region. The species of *Daphnia* are scarce or absent in tropical aquatic ecosystems, where zooplankton communities are often characterized by the dominance of rotifers, copepods and small sized cladocerans such as *Diaphanosoma, Ceriodaphnia* and *Bosmina* (Sarma et al., 2005). Most of these organisms are more selective consumers than *Daphnia*, and prefer nutritious and palatable foods (Ger et al., 2014). Despite these observations, very few studies have evaluated *in situ* cyanobacterial-zooplanktonic interactions in the tropics, especially in the Southern American region (Bouvy et al., 2001). Rotifers and copepods are dominant in water bodies with perennial cyanobacterial blooms. This suggests potential strategies that allow zooplankton to co-exist with cyanobacteria (Bouvy et al., 2001; Ger et al., 2014). In addition, recent laboratory studies have demonstrated that tropical zooplankton can tolerate the ingestion of cyanobacteria (Panosso et al., 2003; Kâ et al., 2012).

The aim of the present study was to evaluate the influence of increased zooplankton biomass on phytoplankton community and cyanotoxins content of a tropical reservoir with frequent occurrence of cyanobacterial blooms. It is hypothesized that increased zooplankton biomass would negatively affect bloom forming

Table 1
Factorial ANOVA results for phytoplankton taxa, microcystin, saxitoxin and nutrients recorded during the experiment. Only significant results ($p < 0.05$) are presented. d.f. = ° of freedom; F = factor; p = significance level.

	Treatment			Time			Treatment x Time		
	d.f	F	*p*	d.f	F	*p*	d.f	F	*p*
Phytoplankton									
Cyanobacteria									
Aphanocapsa sp.	3	8.45	<0.001						
Chroococcus sp.	3	10.05	<0.001						
Cylindrospermopsis raciborskii				6	7.68	<0.001	18	3.20	<0.001
Dolichospermum sp.	3	10.32	<0.001	6	6.65	<0.001	18	2.71	0.0023
Geitlerinema amphibium	3	11.03	<0.001	6	58.40	<0.001	18	20.30	<0.001
Merismopedia tenuissima				6	4.46	<0.001			
Microcystis aeruginosa	3	6.44	<0.001	6	42.70	<0.001			
Planktothrix agardhii									
Pseudanabaena sp.	3	9.04	<0.001	6	15.08	<0.001	18	6.21	<0.001
Sphaerospermopsis aphanizomenoides	3	3.49	0.021	6	9.94	<0.001	18	3.32	<0.001
Bacillariophyceae									
Cyclotella meneghiniana	3	4.35	0.008	6	82.79	<0.001	18	2.13	0.016
Ulnaria ulna	3	2.79	0.049	6	13.50	<0.001	18	3.29	<0.001
Chlorophyceae									
Actinastrum hantzschii				6	45.51	<0.001	18	2.86	0.0014
Closterium sp.				6	7.65	<0.001	18	0.38	0.988
Dictyosphaerium pulchellum				6	18.15	<0.001	18	3.64	<0.001
Lagerheimia genevensis	3	13.20	<0.001	6	84.38	<0.001	18	8.40	<0.001
Dinophyceae									
Peridinium sp.				6	4.00	0.002	18	4.00	<0.001
Cryptophyceae									
Cryptomonas sp.	3	9.24	<0.001	6	16.79	<0.001			
Rhodomonas sp.	3	3.52	0.021	6	11.43	<0.001	18	3.64	<0.001
Crysophyceae									
Mallomonas sp.				6	13.48	<0.001			
"unidentified phytoflagellate"				6	14.15	<0.001			
Cyanotoxins									
Total microcystins	3	6.857	<0.001	5	42.13	<0.001	15	3.66	<0.001
Saxitoxin				5	35.09	<0.001			
Nutrients									
Ammonia	3	3.81	0.019	3	52.13	<0.001	9	2.47	0.029
Nitrate				3	42.55	<0.001	9	5.54	<0.001
Nitrite									
Dissolved inorganic nitrogen									
Total phosphorus				3	39.44	<0.001	9	5.57	<0.001