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The contribution of volunteer-based monitoring data to the assessment of harmful phytoplankton blooms in Brazilian urban streams

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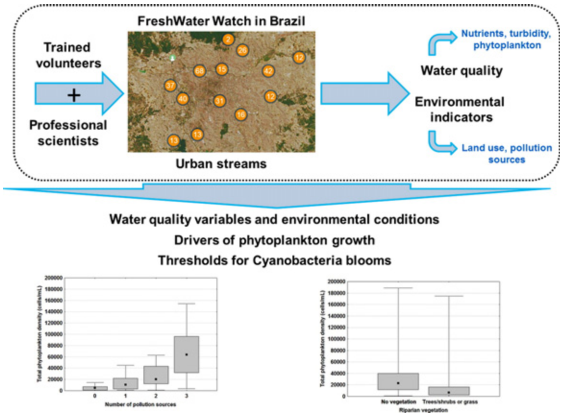
HIGHLIGHTS

- Data from Brazilian urban streams were successfully collected by trained volunteers.
- Relatively high nutrient and turbidity levels were observed in the streams.
- Pollution sources and riparian vegetation were related to phytoplankton abundance.
- Phytoplankton densities and phosphate (not nitrate) were positively correlated.
- Thresholds for *Cyanobacteria* blooms were established based on volunteers' data.

GRAPHICAL ABSTRACT



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ABSTRACT

Urban streams are vulnerable to a range of impacts, leading to the impairment of ecosystem services. However, studies on phytoplankton growth in tropical lotic systems are still limited. Citizen science approaches use trained volunteers to collect environmental data. We combined data on urban streams collected by volunteers with data obtained by professional scientists to identify potential drivers of phytoplankton community and determine thresholds for *Cyanobacteria* development. We combined datasets ($n = 117$) on water quality and environmental observations in 64 Brazilian urban streams with paired data on phytoplankton. Sampling activities encompassed dry (July 2013 and July 2015) and warm (February and November 2014) seasons. Volunteers quantified phosphate (PO_4^{3-}), nitrate (NO_3^-) and turbidity in each stream using colorimetric and optical methods and recorded environmental conditions in the immediate surroundings of the sites through visual observations. We used non-parametric statistics to identify correlations among nutrients, turbidity and phytoplankton. We also looked for thresholds with respect to high *Cyanobacteria* abundance (>50,000 cells/mL). The streams were characterized by relatively high nutrient concentrations (PO_4^{3-}: 0.11 mg/L; NO_3^-: 2.6 mg/L) and turbidity (49 NTU). Phytoplankton densities reached 189,000 cells/mL, mainly potentially toxic *Cyanobacteria* species. Moderate but significant ($p < 0.05$) correlations were observed between phytoplankton density and turbidity ($\rho = 0.338$, Spearman) and PO_4^{3-} ($\rho = 0.292$), but not with NO_3^-. Other important variables (river flow, temperature

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and light) were not assessed. Volunteers' observations covaried with phytoplankton density ($p < 0.05$, Kruskal-Wallis), positively with increasing number of pollution sources and negatively with presence of vegetation in the riparian zone. Our results indicate that thresholds for PO_4^{3-} (0.11 mg/L) can be used to separate systems with high *Cyanobacteria* density. The number of pollution sources provided a good indicator of waterbodies with potential cyanobacteria problems. Our findings reinforced the need for nutrient abatement and restoration of local streams and highlighted the benefits of volunteer-based monitoring to support decision-making.

1. Introduction

The process of urbanization impacts both qualitative and quantitative aspects of water bodies, leading to a chain of processes known collectively as the "urban stream syndrome" (Meyer et al., 2005). Increased population densities and land cover change threaten fundamental ecosystem services (Angela et al., 2015; Garcia et al., 2016), causing unprecedented loss of habitats and biodiversity (McKinney, 2002), with public health implications (Gaffield et al., 2003) and challenges to the water management (Varis et al., 2006). To address these impacts requires new approaches to monitoring and public engagement to favour ecological restoration and the integration of environmental, social and economic dimensions (Walsh et al., 2005; Palmer et al., 2014). In Brazil, urban areas provide multiple stressors to local streams, leading to flood hazards (Haddad and Teixeira, 2015), impairments to biological communities (Couceiro et al., 2012), water pollution (Ribeiro et al., 2012), with direct and indirect interferences on water uses (Dodds and Welch, 2000).

The anthropogenic eutrophication of water resources is a global issue with negative impacts for society and requiring urgent and cost-effective actions (Codd, 2000; Heisler et al., 2008). Managing changes in trophic state (e.g., through nutrient loads abatement and control of algal blooms) is still a challenge to the maintenance of ecosystem health and the services they provide (Smith and Schindler, 2009). Compared to lakes and reservoirs, hydrology and local land use can play an increasingly important role in the eutrophication of lotic water bodies. Water residence time and hydraulic flushing can determine phytoplankton domination or benthic and filamentous algal prevalence (Hilton et al., 2006). Nutrient availability (Okogwu and Ugwumba, 2013), land use patterns (Schuster et al., 2015), sewage inputs, seasonal variations in discharge and dilution capacity (Soares et al., 2007) can also influence phytoplankton dynamics.

Nutrient enrichment in streams have been associated with significant economic losses (Dodds et al., 2009), hypoxia and anoxia episodes (Aguiar et al., 2011) and other indicators of decrease in water quality (Akkoyunlu and Akiner, 2012). Nutrient criteria for trophic states are defined as the concentrations of available nutrients above which different responses in terms of algal biomass are expected. Compared to lentic systems, less information is available for rivers and streams (Dodds, 2006; Dodds and Smith, 2016), especially in tropical and subtropical regions (Cunha et al., 2011).

The probability of algal bloom occurrence in relation to suitability of water use has been modelled in semi-urban river systems (Pinto et al., 2012), as well as the dynamics of phytoplankton groups (e.g., chlorophytes, diatom, *Cyanobacteria*) in temperate rivers (Whitehead et al., 2015). However, the understanding of the main drivers of phytoplankton dynamics in tropical urban waters requires new approaches that consider tropical drivers on land use change, wastewater management (including sewer overflows) and riparian vegetation condition (e.g., Ramirez et al., 2009). The lack of high spatial resolution on local information limits our capacity to identify the drivers and effects of trophic state changes in tropical river and stream ecosystems. The acquisition of high resolution data using volunteer-based local monitoring programs represents an opportunity to acquire new information for research and decision-making.

Citizen scientists have been shown to provide robust detailed information on a range of environmental components, such as water, soil, and biodiversity (Theobald et al., 2015). The role of the volunteers (e.g., data collection, data analyses and interpretation) and the selection of communication features (e.g., regular meetings, online interactions) and scientific methods (e.g., observational or quantitative, training required or not) can vary across projects (Brook et al., 2009; Ferreira et al., 2012; Rotman et al., 2012). Adequate training protocols and robust methods, quality control procedures and data cross-checking can improve the quality of information acquired by volunteers and the acceptance by the scientific community (Bird et al., 2014; Follett and Strezov, 2015). The success of many initiatives over the last decade has allowed citizen science to become a viable approach to collecting highly resolution spatial and temporal data in a cost-effective way (Newman et al., 2011; Krasny et al., 2014; Loiselle et al., 2016).

In the present study, we combined qualitative and quantitative data gathered by volunteers in 64 urban streams in Brazil with data about their phytoplankton communities analysed by professionals to help identify potential drivers of phytoplankton community structure. This data included water quality measurements (nutrients and turbidity) and general environmental conditions. We estimated thresholds at which *Cyanobacteria* density reached elevated levels. The results of this study provide a useful information basis for the management of urban streams in Brazil with respect to a reduction in harmful algal blooms.

2. Material and methods

We studied 64 urban stream sites located in three highly urbanized Brazilian south/south-eastern cities: Curitiba, São Paulo and Rio de Janeiro, with 1.8, 11.3 and 6.3 million inhabitants, respectively (IBGE, 2010). Streams were monitored by volunteers from a mass citizen science project (FreshWater Watch, see Castilla et al., 2015) starting in July 2013 and continuing into the present (December 2016). Samples were collected by citizen scientists in July 2013 and July 2015 (colder/dry season) and February 2014 and November 2014 (hotter/wet season). On each sampling occasion, phytoplankton samples were obtained alongside measures of water quality and environmental observations (described below). Each site was visited at least once, for a total of 117 datasets. All volunteers were trained for field sampling, data acquisition and health and safety procedures in a full day training session and assigned to work in groups of two or three to collect data from the study streams on prescribed sampling days (for locations and a map of the sites see Supplementary Material). Direct feedback and support to the participants from learning and scientific leads was provided through online interaction (Lind et al., 2017).

Participants recorded a suite of information that balanced volunteer ability with methodological complexity. The observations on general environmental conditions included i) land use in the surroundings of the sampling site (forest, urban park, urban residential or industrial zone); ii) the presence and number of potential pollution sources (urban or road runoff/drainage, residential and/or industrial discharges); and iii) the conditions of the riparian vegetation (absent, grass or trees/shrubs). All observations were limited to the immediate area of the surveyed site (i.e. about 10–20 m upstream, downstream and inland).

The volunteers also made direct *in situ* measurements of water quality variables, with surface mid-stream water samples collected with buckets, plastic bottles or homemade collectors. A common measurement methodology was used by all participants that was appropriate