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Short Communication

Are diatom-based biotic indices developed in eutrophic, organically enriched waters reliable monitoring metrics in clean waters?

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ABSTRACT

The application of diatom indices developed for organically enriched and eutrophic waters in oligotrophic and relatively pristine streams in the Eastern Highlands of Zimbabwe was investigated based on data collected in May–August 2007. Better suitability of diatom indices in investigating the quality of eutrophic, organically enriched waters compared to oligotrophic waters is demonstrated. More robust data sets on taxonomy and autecology of a great number of diatom species are required to make the indices more powerful tools in monitoring water quality and ecological integrity of streams in the region.

1. Introduction

Pollution monitoring programmes routinely include the examination of diatoms to investigate the ecological integrity of aquatic systems as they give a time-integrated indication of the water quality components (Lobo et al., 2004; Taylor et al., 2007a,b; Phiri et al., 2007; Bere and Tundisi, 2011; Bere et al., 2013, 2014). Several diatom indices have been developed, most of which are general pollution indices, especially indicative of eutrophication and organic pollution. These indices are thought to have universal applicability across geographic areas and environments because of the cosmopolitan nature of most diatom species (McCormick and Cairns, 1994; Bere and Tundisi, 2011; Bere et al., 2014). For this reason, and due to lack of information on ecological preferences and tolerances of diatoms in some regions, indices developed in other regions are often borrowed.

There is, however, evidence that diatom indices developed in one geographic area or environment are less successful when applied in other areas (Pipp, 2002). This is due to the floristic differences among regions (Taylor et al., 2007a) and the environmental differences that modify species responses to water-quality characteristics (Potapova and Charles, 2002). The objective of this study was to test the applicability of the diatom indices developed in other regions and calculated by the OMNIDIA version 5.3 software in high altitude, cool and relatively pristine streams draining the protected Afro-montane Nyanga National Park in the Eastern Highlands of Zimbabwe. Diatom index scores were calculated and correlated to physico-chemical water quality data. The results of these correlation analyses were compared to results obtained in studies carried out in eutrophic organically enriched waters in Chinhoyi Town (Zimbabwe) as well as from other parts of the world (Prygiel and Coste, 1993; Kwandrans et al., 1998; Taylor et al., 2007a,b; Bere and Tundisi, 2011; Bere et al., 2014).

2. Materials and methods

Headwaters of the study streams fall within the protected Nyanga National Park (Fig. 1). As the rivers leave the park, they flow into low-lying relatively pristine areas characterised by plantations and rural communities with highly preserved riparian buffer zones. A total of 21 sites were established in the study area (Fig. 1). The rationale for choosing the sampling sites was to obtain an altitudinal profile of all the river systems. Thus, along the Nyangombe River, sites N1 to N6 were located in high altitude (1585–1933 m), protected areas while sites N6 to N 9 were located in low altitude (1067–1125 m), unprotected areas. Along the Pungwe River, sites P1 to P5 were located in high altitude (1689–2014 m), protected areas while sites P6 and P7 were located in low altitude (729 and 657 m respectively), unprotected areas. All the 5 sites sampled along the Kairezi River were located in unprotected areas except K3, which was located in communal areas management programme for indigenous resources (CAMPFIRE),

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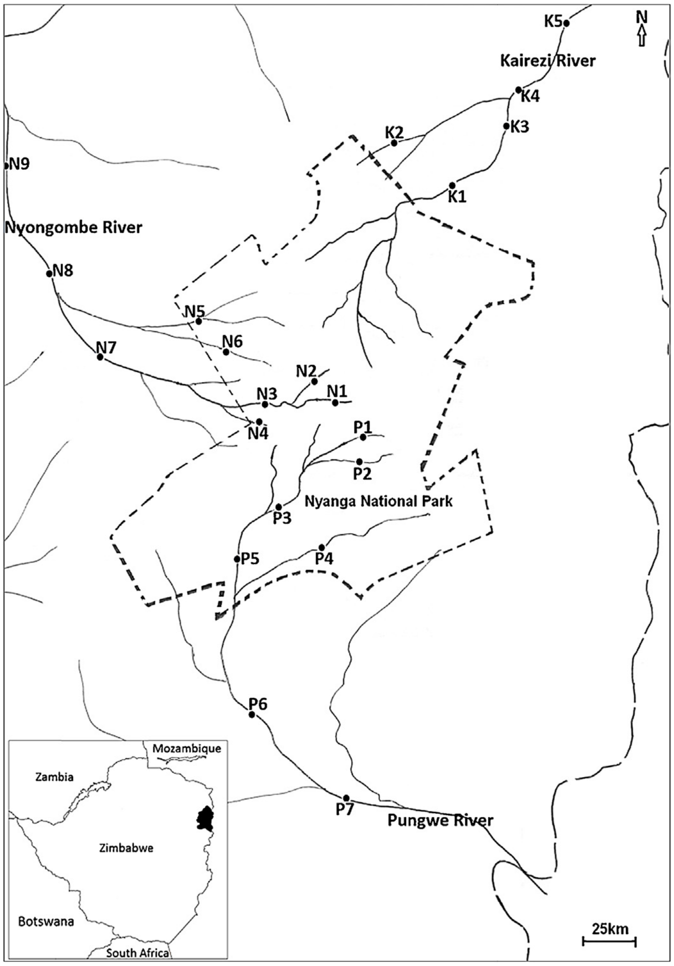

Fig. 1. Location of sampling sites within the study areas.

a semi-protected area. Sites K1 and K2 were located at relatively higher altitude compared to the other sites (K3 to K5).

Diatom and water quality sampling were recorded once off at 21 sites during the dry season (May–August 2007). Traditional water quality variables, temperature, dissolved oxygen (DO), electrical conductivity, pH, total dissolved solids and nitrate ion concentrations were measured at each site using a Horiba U-23 and W-23XD Water Quality Meter (Horiba Ltd, Japan). Biological oxygen demand, an important indicator of organic pollution, was not measured due to resource unavailability.

Epilithic diatoms were sampled by brushing five pebble-to-cobble sized stones with a toothbrush (Biggs and Kilroy, 2000). In the lab, subsamples of the pooled diatom suspension were cleaned of organic material using wet combustion with concentrated sulphuric acid and mounted in Naphrax (Northern Biological supplies Ltd., UK, RI = 1.74) following Biggs and Kilroy (2000). Three replicate slides were prepared for each sample. A total of 250–600 valves per sample (based on counting efficiency determination method by Pappas and Stoermer, 1996) were identified and counted using a phase-contrast light microscope (1000×; Leica Microsystems, Wetzlar GmbH, Type – 020-519.503 LB30T, Germany). The diatoms were identified to species level based mainly on studies from South Africa (Taylor et al., 2007c), as well as other studies (e.g. Metzeltin and Lange-Bertalot, 1998, 2007). The diatom species counts were entered into the diatom database and index calculation tool OMNIDIA version 5.3 (Lecointe et al., 1993). Seventeen indices were calculated and tested (Table 1).

For full data analysis, results and discussion of benthic diatom communities in relation to environmental variables in the study area refer to Bere et al. (2013). The data were tested for homogeneity of variances (Levene's test, $p < 0.05$) and normality of distribution (Shapiro–Wilk test, $p < 0.05$), log transforming where necessary. Pearson's correlation was used to determine the relationship between the calculated index scores and measured physical and chemical water quality data. Levene's test, Shapiro–Wilk test and Pearson's correlation test were performed using Palaeontological Statistics (PAST) software version 2.16 (Hammer et al., 2012).

3. Results and discussion

Most of the sites in the study area were pristine, especially those within Nyanga National Park (Table 2). Ninety-eight (98) diatom species were recorded during this study (Table 3). Of these species, 60 were entered in to OMNIDIA for calculation of indices, while 38 were not used to calculate the indices. This is because ecological preferences of these diatoms species have yet to be determined (Bere et al., 2013), with some probably being endemic to the study region (Taylor et al., 2007a), rendering them useless in the calculation of index scores using OMNIDIA. Incorporation of these taxa in index calculation may give a better picture of the investigated water. There were also a large number of unidentified taxa that require further taxonomic work.

In general, significant correlations ($p < 0.05$) were observed between some index scores and some environmental variables

Table 1
List of diatom indices for water pollution monitoring calculated in this study.

Index name	Index abbreviation	Type of pollution assessed	Reference
Saprobity Index (Sládeček's index)	SLA	Organic	Slàdeček, 1986
Descy's pollution Index	DES	General	Descy, 1979
Leclercq and Maquet's Index	LMI		Leclerq and Maquet, 1987
Schiefele and Schreiner's index	SHE	Trophic	Schiefele and Schreiner, 1991
Watanabe index	WAT	General	Watanabe et al., 1986
Trophic diatom index	TDI	Trophic	Kelly and Whitton, 1995
% pollution tolerant taxa	%PT	General	Kelly and Whitton, 1995
Commission for Economical Community Index	CEC	Organic	Descy and Coste, 1991
Specific pollution sensitivity index	SPI	General	Cemagref, 1982
Biological diatom index	BDI	General	Lenoir and Coste, 1996
Artoise-picardie Diatom index	APDI	General	Prygiel et al., 1996
Eutrophication/Pollution index	EPI-D	Organic, trophic	Dell'Uomo, 1996
Swiss Diatom Index	DI-CH		BUWAL, 2002
Pampean Diatom Index	PDI	Organic, trophic	Gómez and Licursi, 2001
Biological water quality index	BWQI	Organic, trophic	Lobo et al., 2004
Saprobic Index	SI	Organic	Rott et al., 1997
Trophic Index	TI	Trophic	Rott et al., 1999