South African Journal of Botany xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

South African Journal of Botany

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

Distribution of benthic diatom communities in a permanently open temperate estuary in relation to physico-chemical variables

Tatenda Dalu *, Nicole B. Richoux, P. William Froneman

Zoology and Entomology, Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa

ARTICLE INFO

Available online xxxx

Edited by JB Adams

Keywords:
Benthic diatoms
Diversity
Kowie Estuary
Nutrients
Hydrology

ABSTRACT

The spatial and temporal patterns in benthic diatom community structure in temperate permanently open estuaries are poorly understood. In this study, we used a combination of multivariate and diversity indices to elucidate environmental factors associated with diatom community structure in the Kowie Estuary, South Africa. Benthic diatom samples were collected from three sites corresponding to the upper, middle and lower reaches of the estuary on four occasions over the period early spring 2012 to winter 2013. Among the 89 benthic diatoms observed, *Entomoneis paludosa* (W Smith) Reimer, *Nitzschia reversa* W Smith, *Nitzschia closterium* (Ehrenberg) W Smith, *Pleurosigma elongatum* W Smith, *P. salinarum* (Grunow) Grunow, *Staurosira elliptica* (Schumann) DM Williams & Round, *Surirella brebissonii* Krammer & Lange-Bertalot, and *Surirella ovalis* Brébisson were the numerically dominant species. Principal component analysis demonstrated that the diatom community structure was determined by a variety of factors including nutrient (ammonia, nitrate) concentrations, hydrology (e.g., water depth and flow) and pH. Hierarchical cluster analysis revealed the absence of any distinct spatial patterns, although distinct benthic diatom communities were recorded during the different sampling periods. The species richness was highest in the middle reach, decreasing from early spring to summer in all reaches. The results of the study provide important insights into the various factors that structure benthic diatom community composition within a permanently open temperate southern African estuary.

1. Introduction

Estuaries and their associated ecosystems form transition zones between freshwater and marine biomes and are among the most productive ecosystems in the world because they receive nutrients from both terrestrial and marine sources, and more recently, anthropogenic sources (Anderson et al., 2002; Bazin et al., 2014). Due to the mixing of both marine and freshwater systems and groundwater exchange, they are typically characterized by pronounced gradients of physico-chemical variables (McLusky, 1993; Nodine and Gaiser, 2014), which control the composition and spatial distribution of fauna and flora within these systems (Nixon, 1995; Trigueros and Orive, 2000; Glibert et al., 2006; Zhang et al., 2009; Bazin et al., 2014; Nodine and Gaiser, 2014). Diatom-dominated phytoplankton biofilms are important in the ecology of estuarine mudflats, as they exhibit high rates of primary production (Brotas and Catarino, 1995; Underwood et al., 1998), influence deposition and erosion of sediment (Paterson, 1994), affect sediment–water nutrient fluxes (Rysgaard et al., 1995), and represent an important carbon source (Adams and Bate, 1999; Bate et al., 2002; Carvalho et al., 2002). Estuarine ecosystems are particularly sensitive to human alterations of runoff, terrestrial nutrient inputs, and sea level fluctuations (Esparza et al., 2014; Nodine and Gaiser, 2014).

In South African aquatic ecosystems, the taxonomic classification of diatoms has been studied extensively for several decades (Cholnoky, 1963; Giffen, 1963; Cholnoky, 1965, 1968; Giffen, 1970a,b, 1971, 1973; Schoeman and Archibald, 1976; Schoeman, 1982). These studies indicated that although some species are endemic to the region, the majority of species are common in other parts of the world. Thus, the taxonomic value of the work by the diatom scholars in South Africa has been tremendous (Cholnoky, 1963; Giffen, 1963; Cholnoky, 1965, 1968; Giffen, 1970a,b, 1971, 1973; Schoeman and Archibald, 1976; Schoeman, 1982; Bate et al., 2002, 2013). The bulk of the previous South African studies on diatoms have focused on the taxonomic identification and classification of the diatom species, with a few studies, i.e., Minne (2003) and Bate and Smailes (2008), focusing on the relationships between physico-chemical variables and diatoms.

Benthic diatoms are considered the main source of primary production in estuaries, streams and river systems (Wetzel, 2001; Perissinotto et al., 2002; Skinner et al., 2006) and they are functionally important in sequestering and transforming many inorganic nutrients into organic forms (Newbold et al., 1982; Stevenson, 1996). Additionally, several benthic diatom species belonging to genera such as *Epithemia* and *Rhopalodia* are capable of converting atmospheric nitrogen into ammonia or amino acids (Borchardt, 1996). The benthic diatoms themselves

* Corresponding author.
E-mail address: dalutatenda@yahoo.co.uk (T. Dalu).

http://dx.doi.org/10.1016/j.sajb.2015.06.004
0254-6299/© 2015 SAAB. Published by Elsevier B.V. All rights reserved.

constitute a significant source of energy for higher trophic levels (Adams and Bate, 1999; Bate et al., 2002; Carvalho et al., 2002). Despite their ecological importance, the various factors that regulate the community distribution and structure are poorly understood in comparison to pelagic phytoplankton communities (Carvalho et al., 2002). At present, no dataset exists for inference of historical estuarine benthic diatom communities and physico-chemical variables in South Africa. The main aims of this study were to characterize spatio-temporal patterns in the benthic diatom community within the permanently open temperate Kowie Estuary and assess the influence of physico-chemical variables in determining the diatom community composition.

2. Materials and methods

2.1. Study area

The Kowie Estuary is located in the temperate coastal region of the Eastern Cape, South Africa (Fig. 1). The estuary is approximately 21 km in length and varies in width and depth between 30 and 150 m and 2–8 m, respectively (Heydorn and Grindley, 1982; Whitfield et al., 1994). The upper reaches have steep banks, often vegetated right down to the water's edge. The estuary substratum is comprised mainly of very fine sand and silt. The estuary has a very narrow intertidal zone, generally <10 m wide (Whitfield et al., 1994). The middle reaches broaden out to about 100 m in width, with a mean depth of about 3 m. Intertidal salt marshes and mud banks >50 m wide occur in some sections within the middle reaches. The lower reaches consist of an artificial channel about 80 m wide linked to the Kowie marina, which covers an area of about 45 ha. The channel and marina canal walls comprise granitic blocks which drop almost vertically to a sandy bottom 24 m deep (Heydorn and Grindley, 1982; Whitfield et al., 1994).

The min–max annual air temperatures of the Kowie system are ~1.5 °C and 39.8 °C, respectively, with an average daily temperature of 10.6 °C (Whitfield et al., 1994). Mean annual rainfall is estimated at approximately 650 mm and is evenly distributed over the entire catchment area (Heydorn and Grindley, 1982). A strong flooding of freshwater (2.7×10^8 m^3) occurred in the Kowie River during 2012 as a result of heavy rainfall (418 mm) for 12 days between October and November. The estuary volume and discharge rate increased from 6.0×10^4 m^3 and 0.70 m^3 s^{-1} on October 16 to a peak of 6.0×10^7 m^3 and 699.14 m^3 s^{-1} on October 21, respectively (Dalu et al., 2014a).

Three study sites were selected based on the geo-hydromorphological characteristics for each estuary section. The lower reach site was located adjacent to the sewage treatment plant discharge point in Port Alfred (~5.8 km from the ocean; Fig. 1). The middle reach site was located in the central estuary (~12 km from ocean) and the upper reach site was located at the Horseshoe, ~17.9 km from the ocean and near the confluence of the fresh and saline water (Fig. 1). The study was carried out over four time periods: September (early spring 2012), December (late spring 2012), February (summer 2013) and May (winter 2013).

2.2. Physico-chemical and nutrient analysis

Hydrological conditions (water depth, current velocity) and chemical variables (dissolved oxygen, pH, conductivity, water temperature, total dissolved solids (TDS) and salinity) were measured onsite using portable probes (CyberScan Series 600, Eutech Instruments, Singapore) according to Dalu et al. (2014b). Water depth was measured using a graduated rod. Integrated water samples were collected from each site for the determination of macronutrient (ammonium, phosphates and nitrates) concentrations in the laboratory using a HI 83203 multiparameter bench photometer for aquaculture (Hanna Instruments Inc., Rhode Island): ammonia (photometer range 0–10 mg L^{-1} ± 0.05 mg L^{-1} accuracy), nitrates (photometer range 0–50 mg L^{-1}, ±0.5 mg L^{-1} accuracy) and phosphates (photometer range 0–30 mg L^{-1}, ±1 mg L^{-1} accuracy). Water samples were kept in the dark on ice and analyses conducted in the laboratory within 6 h of collection. Prior to nutrient analyses, all water samples were filtered through 0.2 μm PTFE Nylon syringe filters with 25 mm membrane diameter (GVS Filter Technology, USA).

2.3. Benthic diatom sampling and processing

Diatom samples were collected from the sediment (epipsammic) from the intertidal zone at each site during low tide. Benthic diatoms found on the sediment were sampled using a syringe (Taylor et al., 2005; Dalu et al., 2014c). The contents in the syringe were emptied into polyethylene containers and preserved in Lugol's iodine solution.

Two days after collection, the benthic diatom samples were digested in potassium permanganate and hydrochloric acid and mounted in Pleurax (r.i. 1.73), for details see Taylor et al. (2005). The benthic diatoms were identified and counted using the phase-contrast light

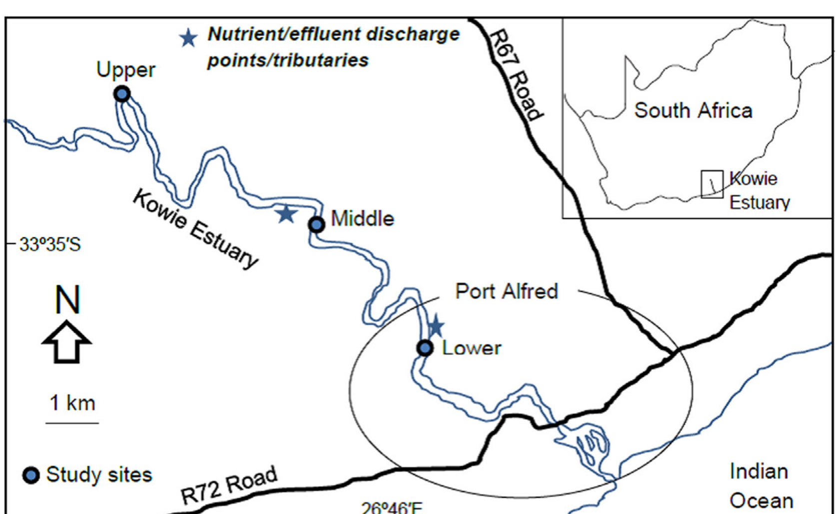

Fig. 1. Study site location on the Kowie Estuary, with the insert showing the location of the estuary in South Africa.

Please cite this article as: Dalu, T., et al., Distribution of benthic diatom communities in a permanently open temperate estuary in relation to physico-chemical variables, South African Journal of Botany (2015), http://dx.doi.org/10.1016/j.sajb.2015.06.004