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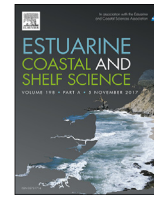

Abiotic characteristics and microalgal dynamics in South Africa's largest estuarine lake during a wet to dry transitional phase

Monique Nunes [a,*], Janine B. Adams [a], Guy C. Bate [a], Thomas G. Bornman [a,b]

[a] Botany Department, Institute for Coastal and Marine Research, Nelson Mandela University, PO Box 77000, Port Elizabeth 6301, South Africa
[b] South African Environmental Observation Network, Elwandle Coastal Node, Port Elizabeth 6031, South Africa

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ABSTRACT

The summer of 2012/2013 signified the end of the dry phase in the St Lucia estuarine system that lasted for over a decade. The increased rainfall coupled with the partial re-connection of the Mfolozi River to the estuarine system shifted St Lucia to a new limnetic state. With the increased availability of habitat due to the higher water level, it was expected that microalgal biomass and abundance would rapidly increase through recruitment from refuge areas i.e. South Lake and new introductions. Microalgal and physico-chemical data were collected at three sites within the Mfolozi/Msunduzi River and at 23 sites within the St Lucia estuarine system between June 2014 and February 2015. Results from this study indicated low biomass for both phytoplankton (<5 μg l^{-1}) and microphytobenthos (<60 mg m^{-2}) because of local and external drivers. These included limited nutrient and light availability, variable water residence times, biomass dilution and heterogeneity of the sediment. The high spatio-temporal variability limits the effectiveness of using the microalgal communities to detect change in the estuarine lake. In addition, significant intrasystem differences were observed between the three main lake basins and Narrows, due to the influence of the freshwater input from the Mfolozi River. This study provides insight into the spatio-temporal variability of physico-chemical conditions and microalgal communities during the 2014–2015 limnetic state.

1. Introduction

Globally the cumulative environmental pressure on estuarine ecosystems brought on by natural (i.e. seasonal and climatic changes) and human induced perturbations (i.e. coastal economic demand and urbanization) (Van Niekerk et al., 2013; Chrystal and Scharler, 2014; Fan et al., 2017; Mahoney and Bishop, 2017) has led to eutrophic conditions, which can induce changes in ecosystem structure and trophic dynamics (Wetz and Yoskowitz, 2013). In turn, this complex suite of pressures has made it increasingly difficult to relate anthropogenic stresses to the relevant abiotic and biotic responses (Wainger et al., 2016). As such many countries apply ecological and chemical monitoring techniques to quantify the level and type of pressure imposed on coastal environments (Desrosiers et al., 2013).

Biodiversity indicators often form the basis for setting relevant and measurable policy targets (Van Strien et al., 2009). In turn, the information derived from the indicator response provide an immediate evaluation of the current ecosystem health state (Lemley et al., 2015, 2016). Microalgae for example - the base of aquatic food webs, contributing up to 50% of the total estuarine autochthonous primary production (Underwood and Kromkamp, 1999; Anandraj et al., 2007) - are vulnerable to environmental alterations (Sharma and Rai, 2011; Leterme et al., 2015). Changes in the microalgal community composition often leads to alterations in food web dynamics, influencing the higher trophic levels such as zooplankton and fish (Leterme et al., 2015). Therefore, microalgae are widely used as indicators of ecological change (Tas et al., 2009; Nodine and Gaiser, 2014).

Recognised as an important nursery area for fish and macrocrustaceans (Whitfield et al., 2013; Gordon et al., 2016), the St Lucia estuarine system forms part of a UNESCO World Heritage site and is listed as a RAMSAR wetland of international importance (Lawrie and Stretch, 2011). Characterised by regime shifts from dry to wet, as determined by the different climatic cycles (Gordon et al., 2016), the ecology of this dynamic estuarine system is largely dependent on the immediate physico-chemical conditions (Taylor,

* Corresponding author.
E-mail address: mnunes3712@gmail.com (M. Nunes).

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2006). Despite the global importance, this system has experienced numerous anthropogenic impacts including freshwater abstraction, catchment development and mouth manipulation (Whitfield and Taylor, 2009; Chrystal and Scharler, 2014).

The artificial separation of the joint inlet previously (pre-1954) shared between the St Lucia estuarine system and the Mfolozi River is, however, considered the most significant anthropogenic impact (Whitfield et al., 2013). This artificial separation of the two mouths occurred more than 60 years ago in response to the deteriorating water quality of the Mfolozi River because of the expanding agricultural development (i.e. sugarcane farming) within the river catchment (Whitfield et al., 2013). As such, the artificial separation compromised the long-term survival of the estuarine system, as it was subjected to artificial extremes in environmental conditions (e.g. hypersalinity) due to a shortage of freshwater in times of drought (Whitfield et al., 2013). This was especially clear during the 2002–2012 drought phase when below average rainfall resulted in low water levels and the desiccation of almost 90% of the lake (Tirok and Scharler, 2014). Other drought related effects included habitat fragmentation (Pillay and Perissinotto, 2008), a marked reduction in the species richness and diversity of the meio-and macrofaunal populations (Pillay and Perissinotto, 2009) and the development of nuisance microalgal blooms (i.e. *Cyanothece* sp. and *Synechococcus* sp.) (Perissinotto et al., 2013a).

The start of the regime shift from dry to wet was signalled in 2012, when above average rainfall (>35%) led to the progressive increase in water level and decrease in salinity of the estuarine system (Taylor et al., 2013). In addition, intermittent freshets during flooding events also entered the St Lucia estuarine system from the Mfolozi River through the link canal (Taylor et al., 2014), and the beach spillway. The beach spillway was excavated between the mouths of the river and estuarine system (Perissinotto et al., 2014) through a joint effort by the iSimangaliso Wetland Park Authority and Ezemvelo KZN Wildlife in June 2012 (Whitfield, 2014). As such the low salinity state and moderate water levels were stable from July 2013 to February 2014 (Taylor et al., 2014). Considering that freshwater inflow essentially determines the state and functioning of the St Lucia estuarine system and the prevailing abiotic characteristics (Perissinotto et al., 2014), the aim of this study was to a) gain insight into the abiotic characteristics and microalgal dynamics of the St Lucia estuarine system as defined by the wet cycle (i.e. limnetic state) and b) to observe the extent to which the intermittent freshets from the Mfolozi River influenced the water quality characteristics and microalgal dynamics of the entire estuarine system.

2. Materials and methods

2.1. Study area

The St Lucia estuarine system (Fig. 1) is the largest estuarine lake in Africa with a water surface area of 350 km^2 at full capacity. Situated in the northern parts of the KwaZulu-Natal Province on the subtropical east coast of South Africa it forms part of the iSimangaliso Wetland Park (Lawrie and Stretch, 2011). Characterised by a subtropical coastal and temperate inland climate, the estuarine system experiences thunderstorms in summer (October–March) and mid-latitude cyclonic activity in winter (April–September) (Bate et al., 2011). However, on average the annual rainfall is estimated at approximately 1100 mm (Lück-Vogel et al., 2016). In addition, the estuarine system is also known to experience cyclical changes in rainfall, with floods interspersed with droughts resulting in the different abiotic states i.e. limnetic and hypersaline (Perissinotto et al., 2013b).

The St Lucia estuarine system lies parallel to the Indian Ocean and is separated from the sea by a barrier of tall coastal dunes (Taylor, 2006). It has four physically distinct regions consisting of three interconnected shallow lakes (i.e. False Bay, North Lake, South Lake) and the Narrows (Muir and Perissinotto, 2011). The interconnected lakes discharge into the 21- km long channel (the Narrows) that empties to the Indian Ocean through the mouth (Perissinotto et al., 2010). The St Lucia catchment area is approximately 8750 km^2 and has five main tributaries, i.e. Mfolozi, Mzinene, Hluhluwe, Nyalazi and the Mkhuze rivers. However, only approximately 50% of the freshwater inflow to the estuarine system comes from these rivers. Under normal rainfall conditions, 45% is derived from direct precipitation on the water surface area and 6–7% from groundwater inflow (Taylor et al., 2006; Kelbe et al., 2013).

2.2. Sampling design

Sampling was undertaken every second month at 26 sites (Fig. 1), 3 within the Mfolozi/Msunduzi River (Msunduzi, Mfolozi 1 and 2) and 23 within the St Lucia estuarine lake between June 2014 and February 2015. The sampling frequency was selected with the aim of collecting a logistically manageable and representative baseline dataset of the wet phase. The 23 stations included the 14 historical stations (Pillay and Perissinotto, 2008; Perissinotto et al., 2010), the 5 inlets of the main tributaries and 4 additional sites (Mpate, Most Northern Point, Lister's Point deep and Middle Lake). The additional sites were selected to reduce the distance between the neighboring sites/lake compartments. The beach spillway that, when open, connects the mouth of the St Lucia estuarine system to the mouth of the Mfolozi River became constricted with sediment before the start of this study. Therefore, for the duration of sampling the mouth of Lake St Lucia was closed. However, freshwater inflow from the Mfolozi River still entered the estuarine system through the link canal and back channel. The parameters recorded at each site were selected based on existing long-term datasets (Bate and Smailes, 2008; Perissinotto et al., 2010, 2013a, 2013b) to facilitate comparisons of the present estuarine condition to the most recent dry phase.

2.2.1. Hydrodynamic and climatological data

Daily water level data were provided by Ezemvelo KwaZulu-Natal Wildlife and rainfall data were obtained from the South African Sugarcane Research Institute (SASRI) situated near the estuary and lake system. The stream flow dataset was obtained from the South African Department of Water and Sanitation for the Mfolozi River. The mean monthly discharge was calculated using all available records from the Mfolozi gauge W2H032 located on the lower floodplain.

2.2.2. Physico-chemical variables

Measurements of salinity, temperature (°C), dissolved oxygen (mg l^{-1}), and pH were recorded using a YSI ProPlus Professional Series multiparameter probe at the surface and bottom of the water column for each site. Water depth (m) measurements were recorded using a measuring stick and Secchi depth (m) measurements (water clarity) using a Secchi disc. Water samples (two per site) for total oxidised nitrogen (NO^{-}_{3} + NO^{-}_{2}), ammonium (NH_4^+) and soluble reactive phosphorous (PO_4^{3-}) determination were collected at the surface and bottom of the water column. The bottom samples were collected using a 500 ml weighted pop-bottle. The reduced copper cadmium method as described by Bate and Heelas (1975) was used to analyse the water samples for TOxN and thereafter analyses for ammonium, SRP and silicate were done using standard spectrophotometric methods (Parsons et al., 1984). Inorganic nutrients were categorised as dissolved inorganic nitrogen