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Microalgal dynamics in a shallow estuarine lake: Transition from drought to wet conditions

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ABSTRACT

Shallow coastal lakes are under increasing pressure from climate change. Low rainfall and reduced run-off contributed to an unprecedented drought in Lake St. Lucia since 2002. Physico-chemical variables and microalgal biomass are analysed, tracking the transition from drought (2009) to wet conditions (2014). Despite low water levels and habitat loss due to desiccation, microalgal biomass remained high mainly due to cyanobacterial contribution. The system exhibited distinct spatio-temporal patterns in terms of salinity, water level, DIN, microalgal biomass and class composition associated with the drought, transition and wet climatic phases. Regime shifts were detected, coinciding with the end of the drought and the beginning of the wet phase. The St. Lucia ecosystem responds rapidly to changes in climatic phases while sustaining microalgal stocks; it may therefore be relatively resilient to extreme drought events.

1. Introduction

Globally, coastal environments are experiencing increased natural and anthropogenic impacts that threaten not only economic development, but also ecological functioning. Increased environmental stress due to global warming and eutrophication has resulted in the loss of coastal biodiversity and its associated ecological productivity (Billen et al., 1991; Caldeira and Wickett, 2003; Harashima et al., 2006; Flöder et al., 2010). Increases in coastal developments, habitat destruction and altered flow patterns have amplified stochastic events such as droughts, storms and floods, and the exploitation of biota has greatly altered food web structures (Christia et al., 2014). Shallow estuarine lakes are particularly dynamic ecosystems that undergo regular climatic shifts between dry and wet phases (Tyson and Preston-Whyte, 2000; Taylor et al., 2006), as well as water level fluctuations resulting from tidal exchange, terrestrial runoff, winds and precipitation. All these factors strongly influence the physical and chemical environment of shallow water bodies, (Woelfel et al., 2007; Christia et al., 2014) and affect their biota, especially at the lower trophic levels, with cascading effects throughout the food web (Williams et al., 2002; Duffy, 2003; Deudero et al., 2014). Understanding how lower trophic levels have been altered by disturbance events, both natural and human-induced, can provide valuable insight into a system's ability to return to its original or near-original state after being disturbed (Folke et al., 2004; Elliott et al., 2007; Borja, 2014). Long-term monitoring provides valuable information towards understanding how natural versus anthropogenic activities impact a particular ecosystem, especially in systems that exhibit naturally high variability, such as Lake St. Lucia in South Africa.

Lake St. Lucia is a globally important nursery area for fish (Wallace and van der Elst, 1975), macrofauna (Forbes and Cyrus, 1992; Owen and Forbes, 1997) and birds (Cyrus, 1991). However, alternating dry and wet climatic cycles characterise the system and have profound effects on its physical and chemical environment, and consequently on its biota. Recent studies have focused on the latest drought (dry phase) and its impacts on the system. Low rainfall and reduced run-off have greatly contributed to an unprecedented drought since 2002, marked by very low water levels and prolonged mouth closure (Cyrus et al., 2010). Salinity is one of the main ecological drivers of the system and hypersaline conditions occur frequently in the northern basins, resulting in a reverse salinity gradient (Taylor et al., 2005; Cyrus and Vivier, 2006). St. Lucia has essentially remained closed from the sea since 2002, being only opened for six months in 2007 by a unique combination of rough seas, spring tide and strong onshore winds (see Taylor, 2011; Perissinotto et al., 2000; van der Molen and Perissinotto, 2011). In addition to prevailing hypersaline conditions, the physico-chemical variability of the system was exacerbated by the fragmentation of the different basins due to

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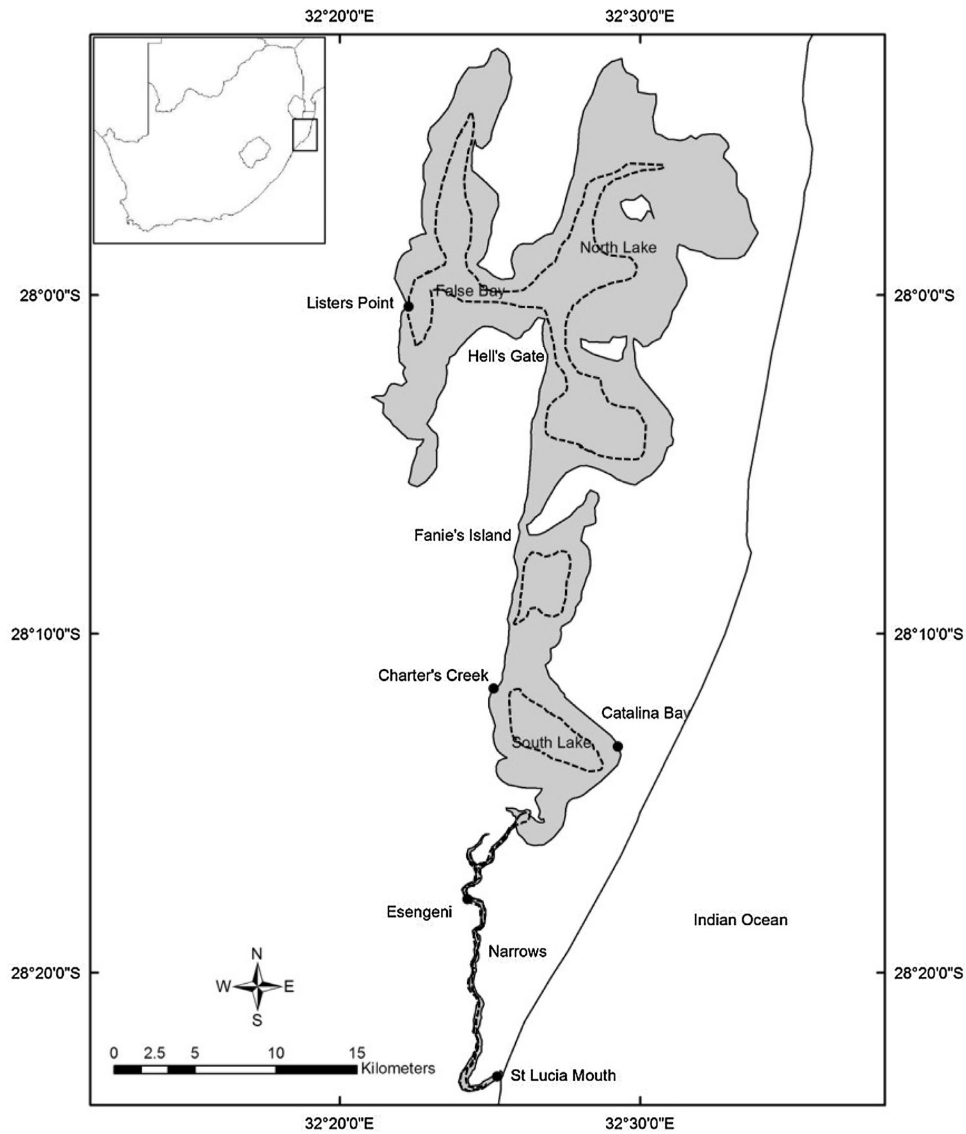

Fig. 1. Area map of the St. Lucia estuarine system (St. Lucia Estuary) indicating the various littoral (benthic) and nearshore (pelagic) sampling sites (dashed lines represents lowest water levels recorder in 2003 by Ezemvelo KZN Wildlife).

reduced water levels. Changes in circulation patterns have affected nutrient distribution and the dispersal of phytoplankton, as well as migration patterns of higher trophic level species (Pillay and Perissinotto, 2008). Despite this, Lake St. Lucia appears to be highly resilient to extreme disturbances, especially drought (Forbes and Cyrus, 1992; Carrasco and Perissinotto, 2012; Scharler and MacKay, 2013). The mechanism of this resilience, however, is not fully understood and alternation of stable and transient states have being proposed for the system (Scharler and MacKay, 2013). Investigating the microalgal community may provide some insight, as previous studies have shown that both pelagic and benthic primary productivity have continued, and at times flourished, under extreme drought conditions (van der Molen and Perissinotto, 2011). This suggests that the system may undergo regime shifts while maintaining ecological function during different climatic phases. A regime shift is a change between contrasting persistent states of an ecosystem which may happen within a few years (DeYoung et al., 2008). Long-term monitoring of the system since the start of this latest drought (2002), through its transition (~2009) and the current wet phase, provides an excellent opportunity to track changes in microalgal communities through each phase. The aim of this study is, therefore, to provide an account of microalgal biomass and algal group diversity across the different lake basins during the various climatic phases the system has undergone since the onset of the last drought. The specific objectives are: 1) to reveal spatio-temporal patterns in environmental variables, microalgal biomass and class composition associated with each climatic phase; and 2) to test whether regime shifts coinciding with these climatic phase changes can be detected.

2. Materials and methods

2.1. Study area

The St. Lucia estuarine lake is situated in northern Kwazulu-Natal and covers an area between 300 and 350 km^2, depending on water levels. The system consists of three shallow lakes, i.e. False Bay, North Lake and South Lake, connected to the Indian Ocean by the Narrows and Mouth (Fig. 1). It is the largest system of its kind in Africa (Cyrus and Vivier, 2006) and represents nearly 30% of the total estuarine area of South Africa (Turpie et al., 2012). Also known as Lake St. Lucia, it has international recognition as both a RAMSAR Wetland of International Importance and as a cru-