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Interannual and cyclone-driven variability in phytoplankton communities of a tropical coastal lagoon

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ABSTRACT

One of the main challenges in phytoplankton ecology is to understand their variability at different spatiotemporal scales. We investigated the interannual and cyclone-derived variability in phytoplankton communities of Chilika, the largest tropical coastal lagoon in Asia and the underlying mechanisms in relation to environmental forcing. Between July 2012 and June 2013, Cyanophyta were most prolific in freshwater northern region of the lagoon. A category-5 very severe cyclonic storm (VSCS) *Phailin* struck the lagoon on 12th October 2013 and introduced additional variability into the hydrology and phytoplankton communities. Freshwater Cyanophyta further expanded their territory and occupied the northern as well as central region of the lagoon. Satellite remote sensing imagery revealed that the phytoplankton biomass did not change much due to high turbidity prevailing in the lagoon after *Phailin*. Modeling analysis of species–salinity relationship identified specific responses of phytoplankton taxa to the different salinity regime of lagoon.

1. Introduction

Coastal lagoons are among one of the most productive, complex, and dynamic ecosystems as they are positioned at the interface of rivers and sea. One of the typical features of coastal lagoon is steep changes in biophysical and chemical properties due to the mixing of freshwater riverine flow with seawater brought in by the tides. The variability in these properties and their interaction with each other makes coastal lagoon an excellent experimental model site to assess the influence of environmental forcing on phytoplankton as these communities respond rapidly to changing environment (Reynolds et al., 2001; Quinlan and Phlips, 2007). In coastal estuarine ecosystems, phytoplankton show variability over multiple spatial and temporal scales due to diurnal, tidal, and seasonal changes in hydrology (e.g., Brockmann et al., 1994). Although, extreme weather events such as cyclone appear to be transient, they also cause a dramatic change in the ecological functioning of estuarine ecosystems (McKinnon et al., 2003; Tsuchiya et al., 2013).

One of the major challenges in phytoplankton ecology is to understand their variability across spatial and temporal scales. Most of the studies have captured phytoplankton variability at annual scales (Torremorell et al., 2009; Pednekar et al., 2014; Chu et al., 2014), while some have extended their time-scale to multiple years (Damme et al., 2005; Paerl et al., 2010; Jendyk et al., 2014). Many of these investigations have recorded inter-annual changes in phytoplankton communities through biomass analyzed as chlorophyll-*a* (Chl *a*) and or group-level photopigment measurements which can reveal changes in communities as a whole in context to environmental variables (Gameiro et al., 2007; Abreu et al., 2010). However, Chl *a* or photopigments can provide limited information on the underlying phytoplankton community composition compared to taxonomic approaches through which genus/species-level changes could be captured. There are few long-term studies from tropical estuaries in which changes in community composition were assessed with respect to the seasonal and interannual variability (Gameiro et al., 2007; Jendyk et al., 2014).

Chilika is the largest (~900 km^2) brackish water tropical lagoon in Asia located along the East coast of India in Odisha State (Fig. 1). Detailed description of the lagoon with respect to important biophysical and socioeconomic characteristics has been described elsewhere (Srichandan et al., 2015). Because of high biodiversity and socio-ecological values, the lagoon is a designated 'Ramsar site'. Chilika lagoon is strongly influenced by monsoon and exhibits a salinity continuum typical to many estuarine ecosystems. The freshwater flows are mostly from twelve major rivers which together constitute a catchment area of ~4146 km^2 (Gupta et al., 2008).

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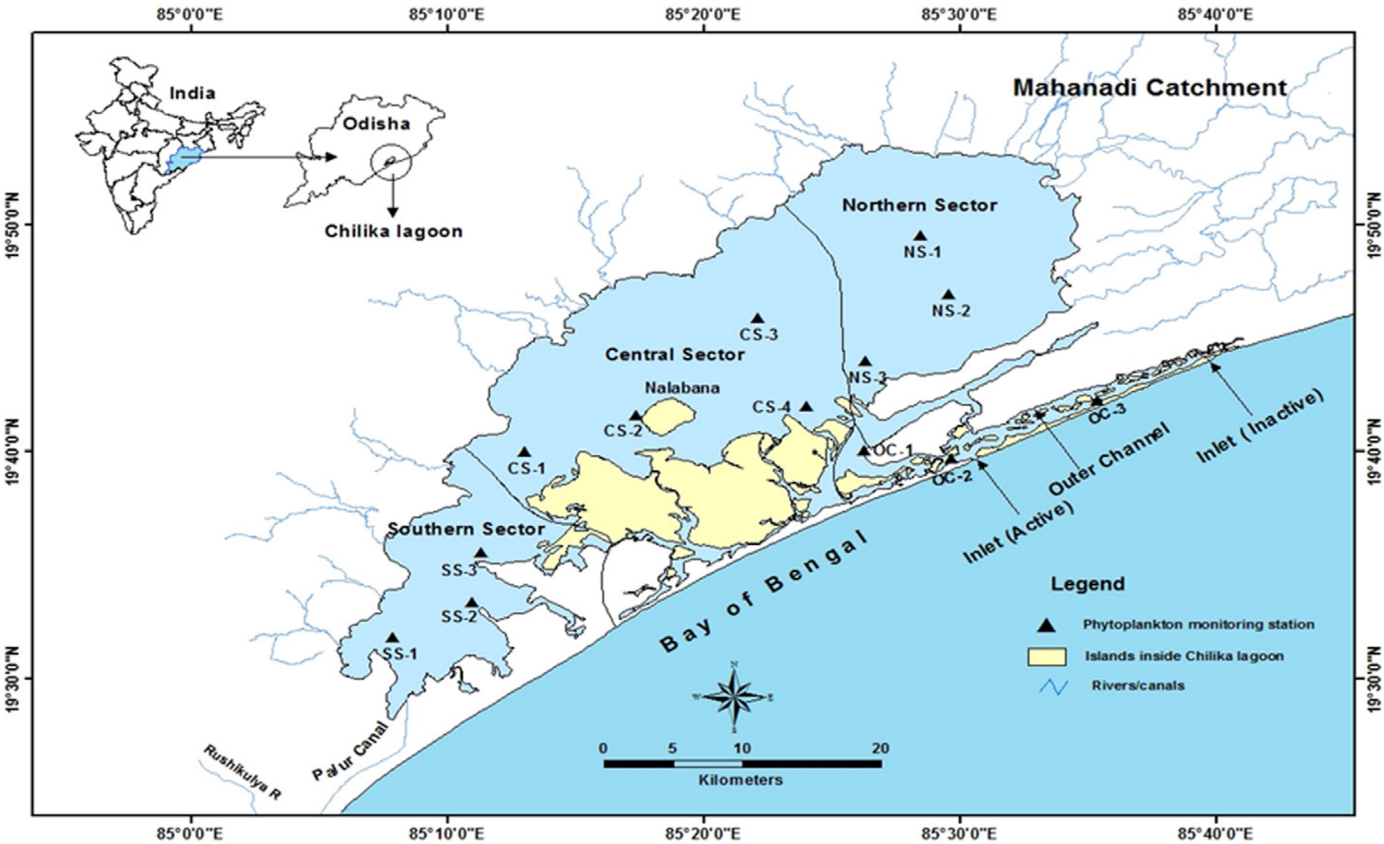

Fig. 1. Map of Chilika lagoon showing sampling stations. Physical boundaries delineating four sectors of the lagoon are hypothetical. NS; northern sector, CS; central sector, SS; southern sector, OC; outer channel.

Based on the salinity gradient, Chilika lagoon has been spatially delineated into four sub regions; northern sector, central sector, southern sector, and outer channel (Fig. 1). Northern sector being in direct contact with Mahanadi River distributaries receives ~78% river discharge and primarily experiences freshwater salinity (<5). Central sector with inter-mixing of freshwater and seawater exhibits a high variability in salinity (6–15). While, southern sector due to its connectivity with the Bay of Bengal through 'Palur Canal' experiences higher but fairly stable salinity regime (>15). Outer channel due to its direct connectivity with the Bay of Bengal experiences the highest salinity regime (>30) typical to a marine ecosystem (Ansari et al., 2015). Major, seawater exchange with lagoon occurs through inlets located in the outer channel (Fig. 1). The mixing of freshwater and seawater due to strong winds and tidal forcing results in a pronounce shift in the physicochemical characteristics and phytoplankton communities in Chilika lagoon (Panigrahi et al., 2009; Srichandan et al., 2015).

Literature suggests that in many coastal environments much effort has been devoted to describe seasonal variability in phytoplankton assemblages at an annual scale. However, variability at an interannual scale remains mostly unexplored. Much less is known about the influence of episodic weather disturbances such as cyclones on the phytoplankton communities. In last 10 years, seasonal variability in phytoplankton communities of Chilika lagoon has been broadly described by many investigators over an annual scale (Panigrahi et al., 2009; Mohanty and Adhikary, 2013). These studies have employed a seasonal sampling approach (i.e., samples were collected only once during a particular season) which might not capture the true extent of the phytoplankton diversity due to dynamic nature of coastal lagoons. Furthermore, considering the high spatio-temporal variability, seasonal sampling would not offer sufficient granularity to capture the intrinsic variability in phytoplankton assemblages.

In order to bridge these knowledge gaps, we used Chilika lagoon as a model coastal estuarine ecosystem and conceived this study with following key objectives (i) examine the spatial and interannual variability in phytoplankton communities, (ii) investigate the impact of a tropical category-5 VSCS *Phailin*, on the phytoplankton communities and their biomass, and (iii) assess the variation in physicochemical factors and identify key ecological drivers determining the phytoplankton composition. This study has used a classical taxonomic approach coupled with satellite-remote sensing imagery to decipher the cyclone-induced changes in phytoplankton biomass and composition. We demonstrate variabilities in phytoplankton communities and discuss the major underlying processes and mechanisms that control them.

2. Materials and methods

2.1. Sampling procedure and study period

Sampling was conducted at 13 long-term monitoring stations located across the four sectors of the lagoon (Fig. 1). Water samples were collected on a monthly basis over a two year period from July 2012 to June 2014 for physicochemical measurements and phytoplankton identification. The first year (July 2012–June 2013) and second year (July 2013–June 2014) of study period would be subsequently referred as year 1 and year 2 throughout the manuscript. Based on the annual rainfall pattern, each year has been further classified into three seasons; pre-monsoon (March–June), monsoon (July–October), and post-monsoon (November–February). During monsoon, freshwater inflow from rivers, land run-off, and precipitation are added into the lagoon resulting a drastic change in the hydrology and physicochemical characteristic. After monsoon, the lagoon goes through a process of recovery followed by a stable period of pre-monsoon.