ARTICLE IN PRESS

MPB-08024; No of Pages 12

Marine Pollution Bulletin xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

# Long-term perspective on the relationship between phytoplankton and nutrient concentrations in a southeastern Australian estuary

Michaela E. Larsson [a,*], Penelope A. Ajani [a], Ana M. Rubio [b], Kristy Guise [b], Ross G. McPherson [b], Steven J. Brett [c], Kevin P. Davies [a], Martina A. Doblin [a]

[a] Climate Change Cluster ($C_3$), Faculty of Science, University of Technology Sydney, PO Box 123, Broadway, NSW 2007, Australia
[b] Environment and Human Services, Hornsby Shire Council, 296 Peats Ferry Rd, Hornsby, NSW 2077, Australia
[c] Microalgal Services, 308 Tucker Rd, Ormond, Victoria 3204, Australia

A R T I C L E   I N F O

*Article history:*
Received 23 July 2016
Received in revised form 4 September 2016
Accepted 6 September 2016
Available online xxxx

*Keywords:*
Chlorophyll-a
Harmful Algal Bloom (HAB)
Sewage Treatment Plant (STP)
Nitrogen
Phosphorous
Eutrophication

A B S T R A C T

Sixteen years (1997–2013) of physicochemical, nutrient and phytoplankton biomass (Chlorophyll-a (Chl-a)) data and a decade (2003-2013) of phytoplankton composition and abundance data were analyzed to assess how the algal community in a temperate southeastern Australian estuary has responded to decreased chronic point source nitrogen loading following effluent treatment upgrade works in 2003. Nitrogen concentrations were significantly lower ($P < 0.05$) following enhanced effluent treatment and Chl-a levels decreased ($P < 0.05$) during the warmer months. Temperature and nutrient concentrations significantly influenced temporal changes of Chl-a (explaining 55% of variability), while salinity, temperature, pH and nutrient concentrations influenced phytoplankton abundance and composition (25% explained). Harmful Algal Bloom (HAB) dynamics differed between sites likely influenced by physical attributes of the estuary. This study demonstrates that enhanced effluent treatment can significantly decrease chronic point source nitrogen loading and that Chl-a concentrations can be lowered during the warmer months when the risk of blooms and HABs is greatest.


## 1. Introduction

Coastal development has caused extensive modifications to catchments worldwide, degrading estuarine water quality through nutrient pollution and increasing the occurrence of harmful algal blooms (HABs) (Hallegraeff, 1993; Hallegraeff, 2003; Glibert and Burkholder, 2006; Anderson et al., 2008; Heisler et al., 2008). Persistent and recurrent phytoplankton blooms are a common occurrence in highly disturbed eutrophic estuaries globally (Nixon, 1995; Ajani et al. 2011; Ajani et al., 2013). While the accumulation of phytoplankton biomass may lead to greater provision of carbon to the food web, excessive phytoplankton growth or harmful algal blooms (HABs) can cause significant ecological disturbance (Smayda, 1997) and lead to economic loss and public health concerns (Cloern, 1996; Anderson et al., 2002).

Studies have found point source nutrient delivery from Sewage Treatment Plants (STP) can be the primary factor influencing the phytoplankton community and HAB taxa dynamics at both a local (e.g. Swan River Valley, Western Australia, Chan et al., 2002) and global level (e.g. Tolo Harbour, Hong Kong, Lam, 1989). As such, reducing continuous point source nutrient delivery to estuarine systems through upgrading STP facilities is one mechanism often adopted to manage this issue. Application of this management strategy has been successful in reducing phytoplankton growth and the occurrence of blooms in some freshwater (Edmondson, 1970) and estuarine systems (Okaichi, 1997; Nuzzi and Waters, 2004), while no response has been found in others (Glibert et al., 2005).

Despite our advanced understanding of the physicochemical factors facilitating phytoplankton blooms, predicting when, where and what type of bloom will occur is still a significant challenge (Cloern, 2001; Smayda, 2008; Phlips et al., 2015). Continuous long term (>5 years) water quality monitoring programs are rare for coastal systems (Hays et al., 2005; Davidson et al., 2014) and programs which additionally monitor phytoplankton composition and abundance exist only in a handful of locations globally (see compilation by Carstensen et al., 2015). Water quality data has been collected as part of local government monitoring at Berowra Creek, New South Wales, Australia since 1997 (HSC, 2013). Water quality modeling in the 1990s identified nitrogen-rich discharges from two STPs as the primary influence driving phytoplankton blooms in this system (MHL, 1998; Qin and Fisher, 2004). As a result, between 2001 and 2003, two sewage treatment facilities discharging a total of ~20 M liters of tertiary treated effluent per day (SWC, 2016) into this estuary underwent biological nutrient upgrades in an attempt to reduce nitrogen loading (SWC, 2006). Since this management intervention, Chl-a and physico-chemical monitoring has been supplemented with phytoplankton taxa composition and

* Corresponding author.
*E-mail address:* Michaela.E.Larsson@student.uts.edu.au (M.E. Larsson).

http://dx.doi.org/10.1016/j.marpolbul.2016.09.011
0025-326X/© 2016 Publisher by Elsevier Ltd.

abundance analyses in an attempt to understand the lower trophic level response to this decrease in nutrient loading (HSC, 2013). This dataset represents the longest continuous water quality and phytoplankton composition data series in Australia and as such presents a rare opportunity to assess the link between nutrients and phytoplankton dynamics over a decade. Here we use this long term data series and a multivariate statistical approach to evaluate the relationship between phytoplankton and nutrients in a system that has undergone management action to decrease nitrogen loading. Specifically we assess (1) if nitrogen concentrations and in turn Chl-a concentrations have decreased in response to upgrade works of the two STPs discharging into the estuary and (2) in the decade following the upgrades, how much of the variation in phytoplankton abundance and composition (including HABs) is explained by changes in nutrient concentrations and other physicochemical variables.

## 2. Materials and methods

### 2.1. Study area

Berowra Creek (33.5770°S, 151.1280°E), New South Wales Australia, is a tidally influenced waterway that joins the Hawkesbury River estuary ~24 km from the ocean (Rissik et al., 2006). It has a water area of ~13 km$^2$ that drains a catchment area of ~310 km$^2$ (MHL, 1998) (Fig. 1). The Hawkesbury-Nepean estuary is an example of a highly modified drowned river valley (Roy et al., 2001) that sustains a significant commercial fishing and aquaculture industry, worth $6 million and services over 43,000 recreational fishers (HNCMA, 2007). The catchment is highly developed in the south with residential, industrial and commercial occupancy, while the north of the catchment is predominantly forested. Phytoplankton blooms persist in Berowra Creek, occasionally affecting

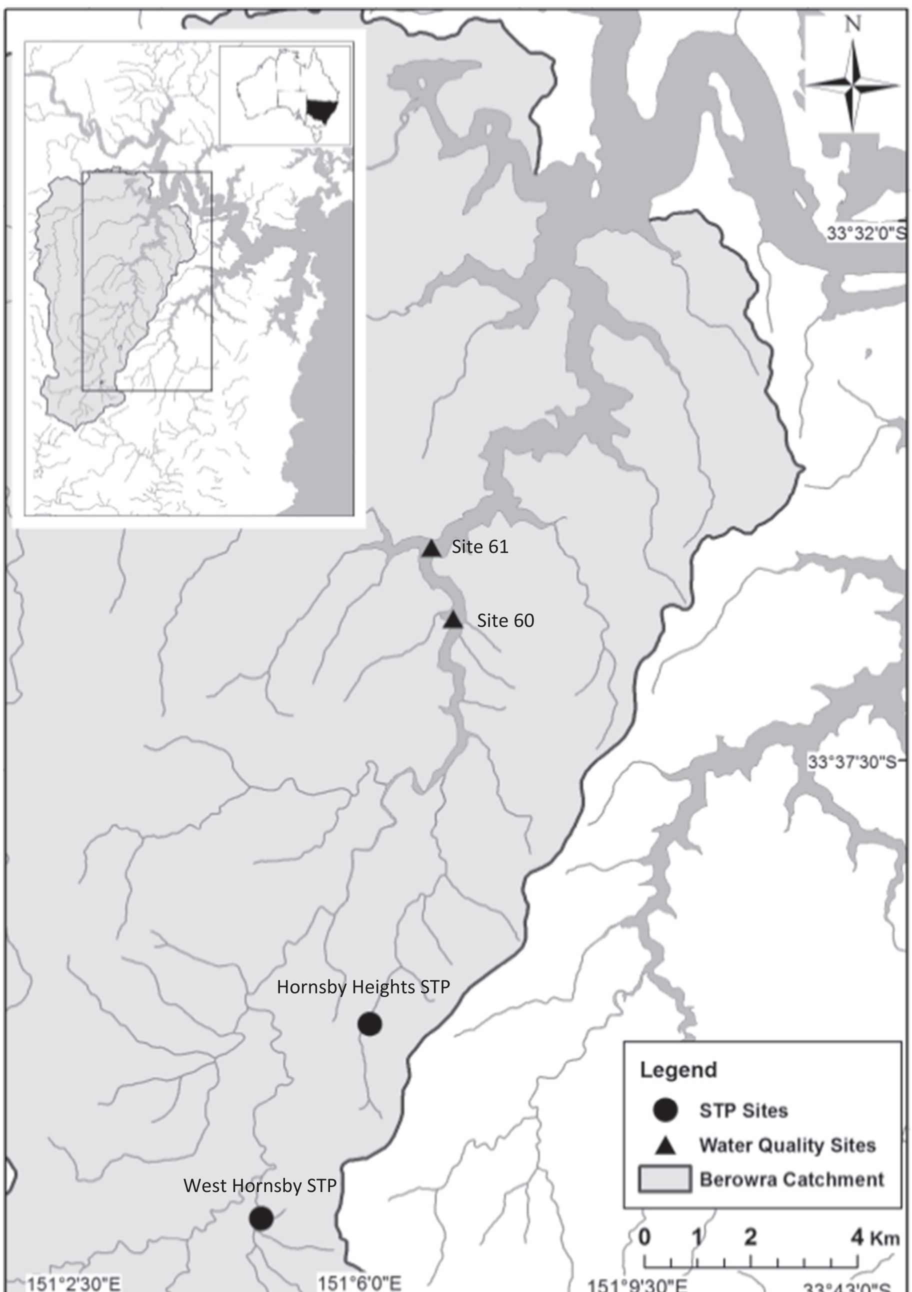


**Fig. 1.** Map of Berowra Creek estuary located within the Lower Hawkesbury Nepean estuary in New South Wales, Australia. Large map shows locations of two sewage treatment plants Hornsby Heights and West Hornsby (dark circles) and sampling sites 60 and 61 (dark triangles) downstream of the facilities.

Please cite this article as: Larsson, M.E., et al., Long-term perspective on the relationship between phytoplankton and nutrient concentrations in a southeastern Australian estuary, Marine Pollution Bulletin (2016), http://dx.doi.org/10.1016/j.marpolbul.2016.09.011