Marine Pollution Bulletin 71 (2013) 159–167

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

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

Changes to chronic nitrogen loading from sewage discharges modify standing stocks of coastal phytoplankton

Emily A. Saeck [a,*], Katherine R. O'Brien [b], Tony R. Weber [c], Michele A. Burford [a]

[a] Australian Rivers Institute, Griffith University, 170 Kessels Road, Nathan, Queensland 4111, Australia
[b] School of Chemical Engineering, The University of Queensland, Brisbane, Queensland 4072, Australia
[c] BMT-WBM, Water and Environment Group, PO Box 203, Spring Hill, Brisbane, Queensland 4004, Australia

ARTICLE INFO

Keywords:
Microalgae
Chlorophyll
Subtropical
Australia
Moreton Bay
Wastewater

ABSTRACT

Nutrient delivery in subtropical coastal systems is predominantly via acute episodic high flow events. However, continuous nutrient discharges from point sources alter these natural fluctuations in nutrient delivery, and are therefore likely to lead to different ecosystem responses. The aim of this study was to assess how a reduction in chronic sewage nutrient inputs affected chlorophyll *a* (chl *a*) concentrations in a subtropical bay, in the context of seasonal fluctuations in riverine nutrient inflows. Reduced nutrient inputs from a large sewage treatment plant (STP) resulted in lower mean dissolved inorganic nitrogen and phytoplankton chl *a* concentrations during both the austral summer wet and winter dry season. This was measurable within 10 y of nutrient reductions and despite the confounding effects of nutrient inflow events. Our study demonstrates that reductions in STP inputs can have significant effects on phytoplankton biomass despite confounding factors over relatively short time frames.

1. Introduction

Nutrient load reduction is a key goal of coastal waterways management, however evaluating the impact of nutrient load reduction strategies on waterways is notoriously difficult (Duarte et al., 2009). Within developed watersheds, nutrient inputs come from multiple sources, including point source discharges and rainfall related land runoff. Managers seeking to reduce nutrient inputs to waterways often tackle point source nutrient loads, such as sewage treatment plants (STPs). This is because technology for advanced nutrient removal from point sources is well established and the success of nutrient removal can be readily quantified. However, predicting the effect of a nutrient management strategy on coastal eutrophication can be challenging because ecosystems differ in their response to a reduction in nutrient loads (Duarte et al., 2009). For example, reducing the chronic input of nutrients from STPs successfully reduced symptoms of eutrophication in Tampa Bay, Florida (Greening and Janicki, 2006), and in tributaries of Chesapeake Bay, USA (Kemp et al., 2005). In contrast, phytoplankton biomass in San Francisco Bay increased as STP nutrient loadings decreased (Cloern et al., 2007).

The variation between systems in response to decreasing nutrient loads (i.e. *oligotrophication*) can be attributed to the confounding effects of other new or persistent pressures and nutrient inputs that are controlling phytoplankton growth and accumulation (Duarte et al., 2009). For example in San Francisco Bay, STP nutrient load reductions coincided with a decline in the abundance of bivalve molluscs, the key consumer of phytoplankton in the estuary. This lead to an increase in phytoplankton accumulation within the estuary (Cloern et al., 2007). Other coincidental changes within the system could be, for example, an increase in diffuse nutrient inputs caused by land clearing within the drainage basin, or a decline in freshwater flow caused by the construction of a dam. System response to oligotrophication may also vary due to system-specific differences in eutrophication resistant mechanisms, such as water residence times (National Research Council, 2000), nutrient processing efficiency and 'top down' food web controls on phytoplankton accumulation (Cloern et al., 2007). Additionally, if the nutrient prioritised for management—i.e. nitrogen or phosphorus—is not the primary limiting nutrient for the system, little to no change may follow (Carpenter, 2008; Conley et al., 2009).

In subtropical coastal systems, assessing the impact of nutrient load reductions is further complicated by seasonal variability: subtropical systems are typically oligotrophic during the dry winter periods with nutrients delivered primarily during the wet summer periods via pulses associated with high rainfall events (Eyre, 2000; Eyre and Ferguson, 2006; Eyre and Pont, 2003; Junk et al., 1989). These events are an important driver of phytoplankton and higher order productivity in the coastal zone (Gillanders and Kingsford, 2002; Loneragan and Bunn, 1999; Mallin et al., 1993). This pattern of nutrient delivery may make subtropical coastal systems

* Corresponding author. Tel.: +61 7 3735 7711; fax: +61 7 3735 7459.
E-mail address: e.saeck@griffith.edu.au (E.A. Saeck).

0025-326X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2013.03.020

particularly vulnerable to chronic nutrient inputs from an STP, as the characteristic wet–dry season periodicity in nutrient inputs can be significantly modified (Gillanders and Kingsford, 2002).

In subtropical systems, where water temperature is less limiting, phytoplankton growth may be primarily regulated by nutrient availability (Eyre, 2000). During the winter dry periods water temperature regulates maximal phytoplankton productivity rates, however phytoplankton growth may still increase with nutrient inputs (Eyre, 2000; O'Donohue and Dennison, 1997). For systems from higher latitudes, which have sustained inflows of freshwater and nutrients and are temperature limited during the winter, a chronic STP nutrient source may be an insignificant contribution relative to the overall load and may have minimal impact on phytoplankton growth. In contrast, the nature of subtropical coastal systems suggests that chronic STP nutrient load would increase dry season phytoplankton productivity when nutrient concentrations are typically low, while the impact during the summer wet season would be minimal relative to the effect of nutrient loads associated with flow events. This suggests that in subtropical systems, reducing chronic nutrient inputs from point sources could lead to successful outcomes for the management of phytoplankton blooms, however the response may vary between seasons.

The aim of this study was to assess how reducing STP nutrient inputs affects coastal phytoplankton biomass, in the context of seasonal fluctuations in total nutrient inputs. The study used 16 y of historical water quality and modelled inflows to a subtropical coastal system to compare conditions prior to and following nitrogen load reductions associated with a major STP upgrade. We hypothesised that for subtropical systems, reducing STP nutrient inputs reduce phytoplankton biomass, with the largest impact observable during dry season months.

2. Materials and methods

2.1. Study area

Moreton Bay is a shallow subtropical embayment located on the southeast coast of Queensland, Australia (Fig. 1). Water temperature range is typically between 16 and 29 °C throughout the year. The bay covers 1523 km^2 and has a drainage basin area of 19,430 km^2 (Dennison and Abal, 1999). A human population of approx. 2.7 million resides within the drainage basin, which is one of the fastest growing regions within Australia (Skinner et al., 1998). Moreton Bay has a mean depth of 6.4 m, a tidal range of 1.7 m and is not vertically stratified, the result of wind driven mixing and minimal freshwater flow for the majority of the year. Moreton Bay water also has a relatively short average water residence time (approx. 45 d) (Eyre and Mckee, 2002; McAlister and Walden, 1999). Highest rainfall occurs in the wet season (September to April) and the pulsed river flows associated with monsoonal summer rains contribute significant sediment and nutrient inputs to the bay (Eyre et al., 1998).

The Brisbane River is one of the major rivers discharging into the western side of Moreton Bay, draining 62% of the total basin area (Dennison and Abal, 1999). Flow, nutrient and sediment loads from the upper watershed of the Brisbane River are mostly retained by two dams (Burford et al., 2012), limiting connectivity with the downstream coastal zone. Below the dams the Brisbane River drainage basin is dominated by agriculture, while the lower estuary flows through an urban floodplain. The Brisbane River discharges into middle Moreton Bay, at the southern end of Bramble Bay (Fig. 1). The river mouth and adjacent areas are muddy with mangrove cover. The nearshore zone of middle Moreton Bay is

Fig. 1. Map of Moreton Bay and the study stations. Luggage Point STP (LP STP), located at the mouth of the Brisbane River, is the region's major sewage treatment plant. Bramble Bay (BB) is a small embayment north of the mouth of the Brisbane River. Six Moreton Bay water quality monitoring stations were used in this study (▲), three (N-1, N-2, N-3) are located to the north of the Brisbane River mouth and three (S-1, S-2, S-3) to the south.