Marine Pollution Bulletin 64 (2012) 627–635

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

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

Rapid increase in copper concentrations in a new marina, San Diego Bay

Trent W. Biggs *, Heather D'Anna

San Diego State University, Department of Geography, San Diego, CA 92182, USA

ARTICLE INFO

Keywords:
Copper
San Diego Bay
Box model
Anti-fouling paint
Marina
Mass balance

ABSTRACT

Concentrations of copper in water rose rapidly following the introduction of boats to a new marina in San Diego Bay. Two months after the marina reached half its capacity, a majority of water samples exceeded chronic and acute criteria for dissolved copper, and copper concentrations in several samples exceeded the highest concentrations observed in another marina that has been listed as an impaired water body. A box model suggested that a small fraction of the leached copper was sequestered in sediment. Copper concentrations in water entering the marina from the bay was more than half the chronic concentration limit, so only 50% of marina boat capacity could be accommodated without exceeding the chronic criterion more than 50% of the time. Copper concentrations in water may increase rapidly following boat introduction in small marinas, but could return to pre-introduction levels by controlling boat numbers or reducing use of copper-based paints.

1. Introduction

Copper is an essential nutrient for marine organisms, but can be toxic at low concentrations (Hall and Anderson, 1999), and is a common contaminant in coastal waters due to its use in anti-fouling paint for boat hulls. Enclosed water bodies, such as bays and marinas, may be particularly susceptible to contamination due to low flushing rates (Schiff et al., 2007). Copper contamination from anti-fouling paints has been documented in Europe (Hall and Anderson, 1999) and the United States, including San Diego Bay (Schiff et al., 2007), San Francisco Bay (Flegal and Sanudo-Wilhelmy, 1993), and Florida (Srinivasan and Swain, 2007). Several studies have documented that copper concentrations in marinas in San Diego Bay often exceed water quality standards (Blake et al., 2004; Neira et al., 2009; Schiff et al., 2007), and concentrations in sediment in one marina of the bay were sufficiently high to have adverse effects on benthic fauna (Neira et al., 2009). Due to the high concentrations of copper in its water, the bay is a net source of copper to adjacent ocean waters (Esser and Volpe, 2002). Despite the importance of copper to aquatic organisms and a history of high concentrations in marinas, there is little documentation of how rapidly copper concentrations rise in new marinas. A close correlation between the number of boats and the copper concentrations in water has been observed for a marina in Queensland, Australia, suggesting that boat numbers are a primary control on copper in marina waters (Warnken et al., 2004). To our knowledge, no studies have documented copper concentrations before and after introduction of boats to new, uncontaminated waters.

This study quantifies the impact of boat introduction on copper concentrations in a newly opened marina in San Diego Bay. A simple model of the copper budget is used to estimate the importance of loading from boat paint and watershed runoff, and losses due to flushing and sedimentation. The model is then used to simulate copper concentrations under different scenarios that substitute copper-based paint with other paints, in order to determine how many boats could continue to use copper-based paints while maintaining water quality criteria. The copper concentrations in the new marina are compared with concentrations in another nearby marina (Shelter Island Yacht Basin) that has been identified as impaired by dissolved copper. The implications of the observations and model results for management of copper are discussed.

2. Study area

Pier 32 Marina (P32M) is located in southeastern San Diego Bay off the Sweetwater Channel and adjacent to the Sweetwater National Wildlife Refuge (Fig. 1). Construction of the docks in the marina began in March 2006 and boats were introduced starting in June 2008. The marina is approximately 275 m by 200 m and can accommodate 250 boats (Table 1). During construction, three pipes were installed in the east end of the jetty to aid in water circulation. Parking lots bordering the marina cover a total of 10,000 m^2 and drain to the marina during storms (Fig. 1). The volume of the marina at mean lower low water (MLLW) is 313,000 m^3 (Table 1) (RWQCB, 2005). The Sweetwater River drains a watershed of 596 km^2 and discharges into the Sweetwater Channel to the east of P32M. The runoff is dominated by a few storms in the wet season, which starts in October or November

* Corresponding author. Tel.: +1 619 594 0902; fax: +1 619 594 4938.
E-mail address: tbiggs@mail.sdsu.edu (T.W. Biggs).

0025-326X/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpolbul.2011.12.006

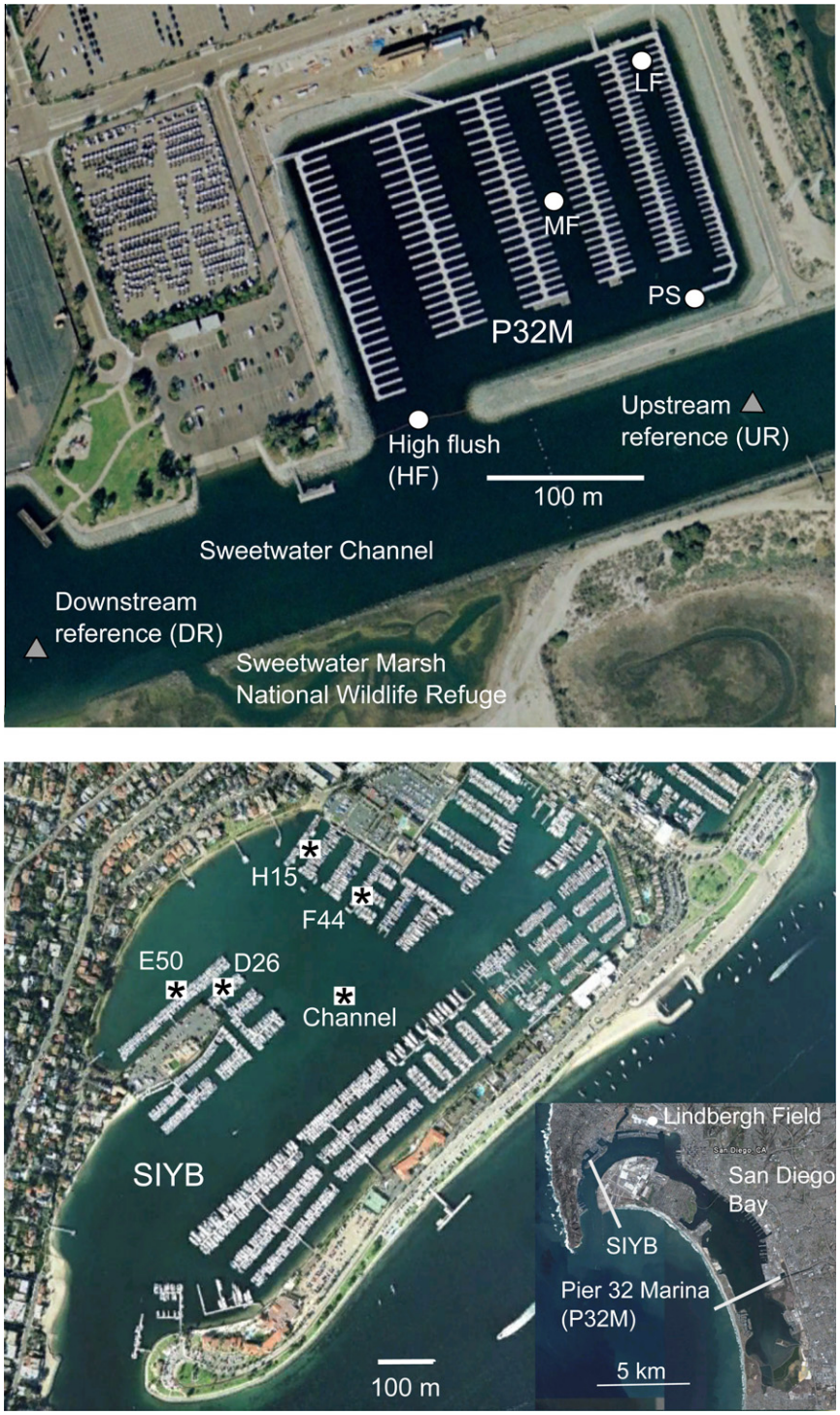

Fig. 1. Map of the study area with sampling locations in Pier 32 Marina (P32M, top), and Shelter Island Yacht Basin (SIYB, bottom). Lindbergh Field is the location of the meteorological station.

Table 1
Characteristics of Pier 32 Marina (P32M) and Shelter Island Yacht Basin (SIYB).

	P32M	SIYB
Planimetric surface area[a] (m^2)	61,400	740,000
Volume[a] (m^3)	313,000	31,00,000
Mean depth[a] (m)	5.1	4.2
Capacity (boats)	250	2363

[a] Determined at mean lower low water (MLLW).

and ends in April. The watershed of the Sweetwater River was approximately 37% urbanized as of 2008, the rest in open space and undeveloped lands (San Diego Bay WURMP, 2008).

The Shelter Island Yacht Basin (SIYB) is also in the San Diego Bay, approximately 13.5 km northwest of Pier 32 Marina (Fig. 1). SIYB is approximately 10 times the size of P32M in volume and number of boats (Table 1). In 1996, Shelter Island Yacht Basin (SIYB) was placed on the section 303(d) list of the Clean Water Act as an impaired water body for dissolved copper, and a total