Marine Pollution Bulletin 103 (2016) 294–300

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Near-coastal water quality at reference sites following storm events

Kenneth Schiff [a,*], Jeff Brown [a], Steen Trump [b], Dane Hardin [c]

[a] Southern California Coastal Water Research Project, Costa Mesa, CA, United States
[b] ADH Environmental, Arcata, CA, United States
[c] Applied Marine Sciences, Santa Cruz, CA, United States

ARTICLE INFO

Article history:
Received 19 May 2015
Received in revised form 13 November 2015
Accepted 5 December 2015
Available online 21 December 2015

Keywords:
Natural
Trace metals
Nutrients
California
Marine protected area
Stormwater

ABSTRACT

Stormwater is a challenging source of coastal pollution to abate because stormwater also involves complex natural processes, and differentiating these processes from anthropogenic excesses is difficult. The goal of this study was to identify the natural concentrations of stormwater constituents along the 1377 km coastline of California, USA. Twenty-eight ocean reference sites, *a priori* defined by lack of human disturbance in its adjacent watershed, were collected following 78 site-events and measured for 57 constituents and toxicity. Results indicated a complete lack of toxicity and undetectable levels of anthropogenic constituents (i.e., pesticides). The range of concentrations in ocean receiving waters for naturally-occurring constituents (i.e., total suspended solids, nutrients, trace metals) typically ranged three orders of magnitude. Regional differences and storm characteristics did not explain much of the variations in concentration. The reference site information is now being used to establish targets for marine protected areas subject to runoff from developed watersheds.

1. Introduction

Stormwater has been the focus of management actions, particularly in the last two decades, because of its potential for environmental impact (National Research Council, 2009). Stormwater flushes contaminants deposited in coastal watersheds, transporting them to downstream waterbodies, sometimes to the detriment of coastal ecosystems. Stormwater runoff from developed watersheds with urban and agricultural land uses is known to contain pesticides, trace metals, nutrients, and eroded sediment (Tiefenthaler et al., 2008; Stein et al., 2006; Schiff and Sutula, 2004). Watershed development often exacerbates potential environmental risk by increasing peak flow, reducing time to peak flow, and changing total runoff volume associated with increased imperviousness (Leopold, 1968; Hawley et al., 2012). Ultimately, impacts to downstream receiving waters can occur, including aquatic toxicity and alterations to resident biological communities (Walsh et al., 2005; Bay et al., 2003).

Despite the increased regulatory focus on stormwater, making progress to reduce these pollutants can sometimes be slow. Part of the challenge associated with remediating stormwater inputs has been establishing appropriate clean-up targets. Some constituents in stormwater are clearly anthropogenic in origin, such as man-made pesticides. However, some of the constituents in stormwater are naturally-occurring, and would be present regardless of human intervention. Examples include suspended sediments, trace metals, and nutrients (Schiff and Weisberg, 1999). In fact, complete absence of these constituents would result in equally detrimental impacts such as beach erosion and insufficient nutrient and organic enrichment for ocean processes (Ryther and Dunstan, 1971).

The problem of identifying naturally-occurring levels of stormwater constituents in ocean receiving waters is especially problematic in areas like California, USA. California has extensive urban development along its coastline, including three of the top eight most populous cities in the USA (Los Angeles, San Francisco, and San Diego). California also has extensive agricultural development along its coastline, including the Salinas Valley, which produces the majority of the lettuce consumed within the USA. Juxtaposed against California's extensive urban and agricultural development is the promulgation of 580 km coastline miles for Areas of Special Biological Significance (ASBS), which are water quality marine protected areas where the regulatory mandate is "maintenance of natural water quality" and "no discharge of waste" (SWRCB, 2012).

Little work has been targeted at determining the appropriate, naturally occurring level of stormwater constituents in coastal receiving waters. The literature is flush with measurements of runoff samples from the mouths of rivers and creeks or in adjacent estuaries (Carpenter et al., 1998; Brezonik and Stadelmann, 2002), especially in California (Ackerman and Schiff, 2003). Conversely, few studies have measured background concentrations of trace metals and nutrients along the coast of California, and these studies were all-too-often distant from shore and frequently conducted during dry weather (Sañudo Wilhelmy and Flegal, 1991, Smail et al., 2012). Rarely have very near-coastal water column samples been collected following storm events

* Corresponding author at: Southern California Coastal Water Research Project, 3535 Harbor Blvd., Suite 110, Costa Mesa, CA 92626, United States.
E-mail address: kens@sccwrp.org (K. Schiff).

http://dx.doi.org/10.1016/j.marpolbul.2015.12.001
0025-326X/

specifically to assess issues of background conditions (Schiff et al., 2011), and never has there been a survey extending the length of the California coastline. As a result, most attempts to identify targets for coastal water quality rely on regulatory standards developed by state or federal agencies. These regulatory standards are most often developed using toxicity benchmarks, which identify how much pollutant is allowable before adverse effects may occur, as opposed to the "natural" level at which marine habitats (including ASBS) thrive.

The goal of this study is to define the naturally occurring levels of stormwater constituents in the near-coastal environment of the Pacific Ocean along the coast of California, USA. Relationships among geography and storm characteristics will be used to explain the variability in these naturally-occurring concentrations. Finally, the naturally occurring concentrations will be used to establish benchmarks of acceptable constituent concentrations for marine water quality protected areas for the state.

2. Methods

There were three primary design elements for this study. The first design element was a focus on ocean receiving waters. All of the samples collected for this study were collected from the ocean, not from flowing rivers or creeks prior to entering the ocean. The second design element was the use of reference sites to define natural water quality. Reference sites are beaches adjacent to the mouths of rivers or creeks that drain undeveloped watersheds. Reference site selection followed five criteria: 1) the site must be an open beach with breaking waves (i.e., no enclosed bays); 2) the beach must have drainage from a watershed that produces flowing surface waters during storm events; 3) the reference watershed should be similar in size to the watersheds that discharge to ASBS; 4) the watershed must be comprised of primarily (>90%) open space; and 5) neither the shoreline nor any segment within the contributing watershed can be on the State's 2006 list of impaired waterbodies (e.g., §303d list). The third design element was a focus on wet weather. This assumes that no discharge of waste occurred during dry weather.

A total of 28 sites were sampled, split roughly evenly between the three regions of the state (Fig. 1, Table 1). The North Region extended from Oregon to Bodega Head. The Central Region extended from Bodega Head to Point Conception. The South Region extended from Point Conception to Mexico. Up to 6 storm events were sampled per site. A

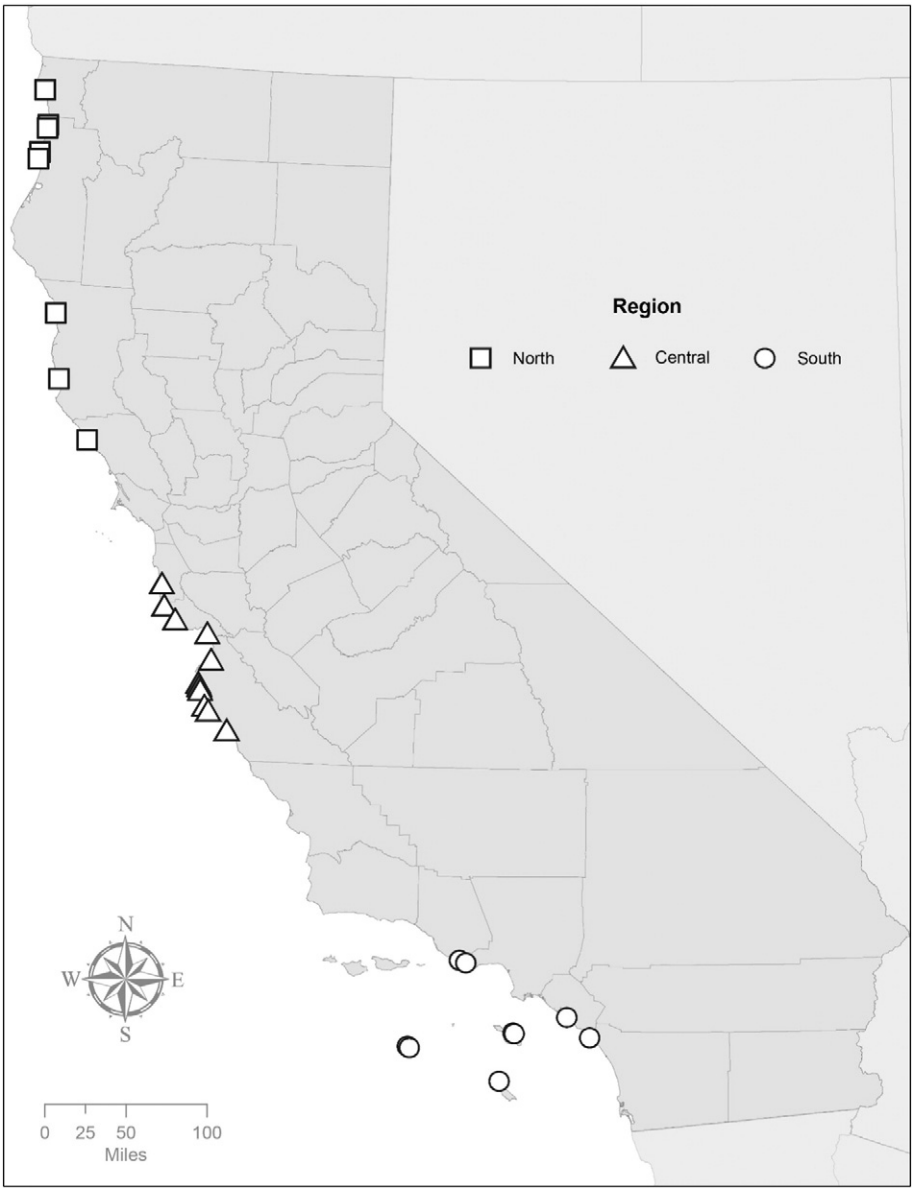

Fig. 1. Map of ASBS and reference site locations.