Science of the Total Environment 408 (2010) 1154–1165

Contents lists available at ScienceDirect

Science of the Total Environment

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

Temporal and spatial distributions of sediment mercury at salt pond wetland restoration sites, San Francisco Bay, CA, USA

A. Keith Miles *, Mark A. Ricca

U.S. Geological Survey, Western Ecological Research Center, 1 Shields Avenue, University of California, Davis, California 95616, United States

ARTICLE INFO

Article history:
Received 22 July 2009
Received in revised form 10 October 2009
Accepted 14 October 2009
Available online 17 November 2009

Keywords:
Methylmercury
Sediment
Salt pond
Restoration
San Francisco Bay
Total mercury

ABSTRACT

Decommissioned agricultural salt ponds within south San Francisco Bay, California, are in the process of being converted to habitat for the benefit of wildlife as well as water management needs and recreation. Little is known of baseline levels of contaminants in these ponds, particularly mercury (Hg), which has a well established legacy in the Bay. In this study we described spatial and short-term temporal variations in sediment Hg species concentrations within and among the Alviso and Eden Landing salt ponds in the southern region of San Francisco Bay. We determined total Hg (Hg_t) and methylmercury (MeHg) in the top 5 cm of sediment of most ponds in order to establish baseline conditions prior to restoration, sediment Hg_t concentrations in a subset of these ponds after commencement of restoration, and variation in MeHg concentrations relative to sediment Hg_t, pH, and total Fe concentrations and water depth and salinity in the subset of Alviso ponds. Inter-pond differences were greatest within the Alviso pond complex, where sediment Hg_t concentrations averaged (arithmetic mean) 0.74 µg/g pre and 1.03 µg/g post-restoration activity compared to 0.11 µg/g pre and post at Eden Landing ponds. Sediment Hg_t levels at Alviso were fairly stable temporally and spatially, whereas MeHg levels were variable relative to restoration activities across time and space. Mean (arithmetic) sediment MeHg concentrations increased (2.58 to 3.03 ng/g) in Alviso and decreased (2.20 to 1.03 ng/g) in Eden Landing restoration ponds during the study. Differences in MeHg levels were related to water depth and pH, but these relationships were not consistent between years or among ponds and were viewed with caution. Factors affecting MeHg levels in these ponds (and in general) are highly complex and require in-depth study to understand.

Published by Elsevier B.V.

1. Introduction

Restoration of human altered landscapes to historical habitat has been a major goal of resource and conservation agencies over the past several decades. Two of the largest wetland restoration projects in the United States are progressing in the Florida Everglades and more recently in the San Francisco Bay (Bay), California. More than 10,000 ha of decommissioned commercial salt ponds throughout the Bay have been identified for conversion from salt production to habitat that not only benefits wildlife but also water quality, flood control, and recreation (Takekawa et al., 2006). Natural resources associated with the pond complex in the southernmost Bay (hereafter, the Alviso ponds) are managed largely by the U.S. Fish & Wildlife Service (USFWS) while those located in south central Bay (hereafter, the Eden Landing ponds) are managed by the California Department of Fish and Game (CDFG) (Fig. 1). These agencies must address habitat and water quality issues that include reduction of salinity in these ponds, accomplished by direct or indirect dilution with waters from the Bay or its tributaries.

Sediment can sequester contaminants and therefore serves as a pathway for exposure to food webs. The Bay estuary in general is renowned for mercury (Hg) contamination particularly from historic Sierra Nevada gold mining in the North Bay and specifically Hg mining in the Guadalupe River watershed in the South Bay (Hornberger et al., 1999; Thomas et al., 2002; Conaway et al., 2004). The restoration of salt ponds to tidal marsh or seasonal mud flat habitat may result in mobilization of Hg due to, for example, wetting and drying or slough scour and sediment disturbance, and thus increase its availability and methylation (Marvin-DiPasquale and Cox, 2007).

Initial restoration activities at the Alviso and Eden Landing salt ponds involved increased water exchange to certain ponds via control gates or breached levees that opened directly to adjacent tidal tributaries or increased water flow between ponds; hereafter, restoration. Obvious changes in water or sediment qualities (e.g. salinity, pH) will result from water management changes. Changes in these or other qualities (e.g., sediment iron [Fe]) and Hg could influence MeHg production, fueled by effects on sulfur or iron-reducing bacteria (Compeau and Bartha, 1985; Fleming et al., 2006; Liu et al., 2009). The potential long-term effect of restoration actions

* Corresponding author. USGS Davis Field Station, 1 Shields Avenue, UC Davis, Davis, CA 95616, United States. Tel.: +1 916 752 5365; fax: +1 916 752 9680.
E-mail addresses: keith_miles@usgs.gov (A.K. Miles), mark_ricca@usgs.gov (M.A. Ricca).

0048-9697/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.scitotenv.2009.10.042

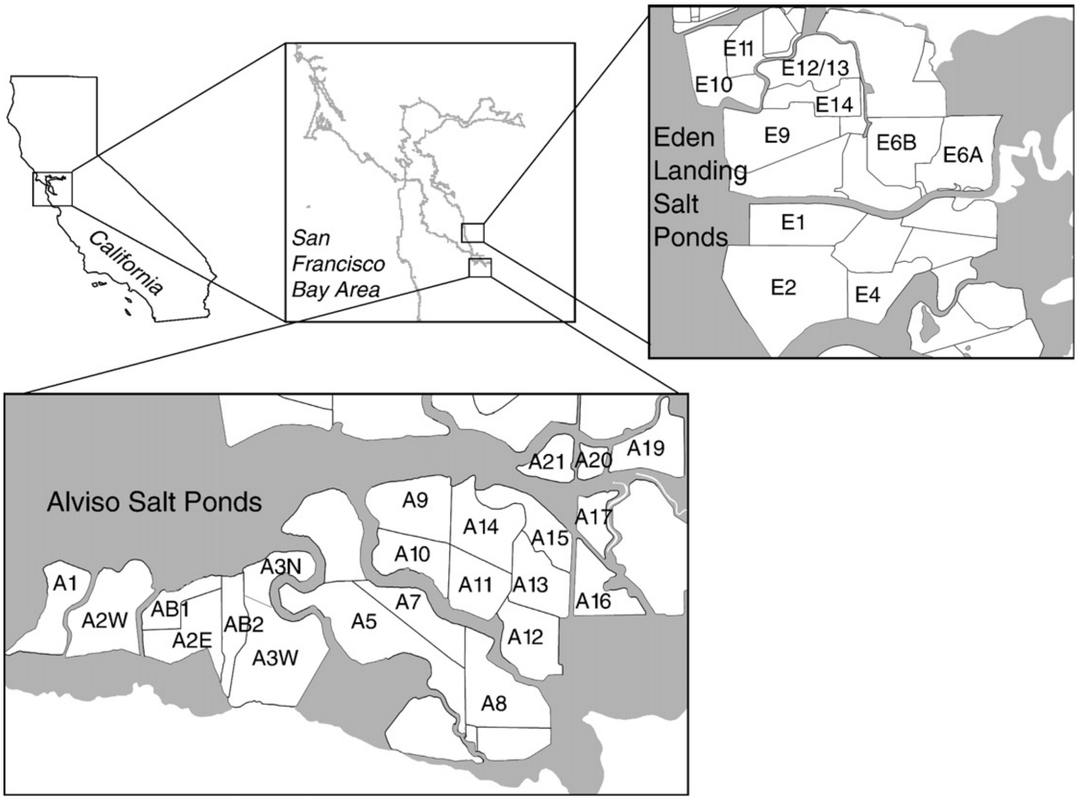

Fig. 1. Location of former commercial salt ponds at San Francisco (Bay), California, identified for restoration to natural or semi-natural conditions. Sediment samples were collected for mercury analyses from numbered ponds (note that in text, Eden Landing pond identification numbers are preceded by an "E" and Alviso ponds are preceded by an "A") periodically from summer or winter 2003–2007. Gray shading indicates Bay or tributaries.

such as lowering salinity in high salinity ponds, agitation of sediment, or tidal wetting and drying of sediment may be increased MeHg production (Compeau and Bartha, 1987; Gilmour et al., 2004; Gustin et al., 2006). Monitoring is important to understand changes in water and sediment chemistry that ensue from proposed or enacted water management plans and subsequent effects on Hg.

Levels of Hg in sediment and related concentrations in biota are not well understood but modeling of empirical data has been used to assess this relationship (Chapman, 1989; Long et al., 1995). When compared to other media (e.g., tissue concentrations), sediment can be a relatively stable medium for understanding differences in ambient, elemental contamination over space and time and can also provide a means of assessing remediation for improving environmental quality (Miles and Tome, 1997; Chapman, 1989). In a review of San Francisco Bay data from the 1970s and 1980s, Long et al. (1988) suggested a grand (arithmetic) mean of 0.50 μg/g dry weight (dw) Hg in sediment, in which 93% of these samples had concentrations ≤1.0 μg/g.

In this study we describe spatial and short-term temporal variations in sediment Hg species concentrations within and among the Alviso and the Eden Landing salt ponds. Our objectives were to determine: a) total Hg (Hg_t) and methylmercury (MeHg) in surficial (top 5 cm) sediment in order to establish baseline conditions prior to restoration, b) sediment Hg_t concentrations in a subset of Alviso and Eden Landing ponds after commencement of restoration, and c) variation in Hg species concentrations relative to discrete measures of sediment pH and total Fe (Fe_t) concentrations and water depth and salinity in a subset of ponds. Monitoring is important to understand how changes in water and sediment chemistry that ensue from any salt pond restoration activities subsequently affect Hg cycling. The information derived from this study is important to resource agencies that adaptively manage restoration at the ponds to water quality and natural resource goals.

2. Methods

2.1. Sediment sample collection

We collected sediment samples using a 2.0 cm diameter × 1.5 m corer made of PVC. The surficial layer of the sediment cores was used for all Hg analyses. We established in pilot work at the salt ponds that MeHg concentrations were higher in surficial sediment compared to deeper interval (15–20 cm) sediment, but Hg_t did not differ between surface and deeper sediment (unpublished data); Marvin-DiPasquale et al. (2003) and Hammerschmidt et al. (2004) reported similar findings. Sediment samples were placed in acid-rinsed glass jars, stored on ice, and transferred to a −20 °C freezer within several hours of collection. The corer was scrubbed with pond water and rinsed with deionized water between each point. At each site within a pond, 3 sub-samples of sediment were collected within a 10 m radius and composited as one sample per site (Elder et al., 1980). All sites were georeferenced with a Global Positioning System.

2.2. Sampling design

We conducted large-scale sampling in ponds that comprised the Alviso and Eden Landing salt pond complexes (Fig. 1) during August–October (summer) or January–February (winter) 2003–2007 to provide baseline Hg concentrations during initial restoration activities. All ponds were sampled at least once before and after restoration, which occurred approximately between summer 2004 and winter 2006 depending on the pond. Alviso ponds A3N, A8, A10, A15, and A2E were not subjected to restoration during the study (Table 1). Depending on funding constraints, samples collected within ponds were either composited as 1 sample per pond (Gilbert, 1987) or analyzed individually. A minimum of 3 sites located in proximity of inflow and outflow structures and mid-pond were sampled in each pond.