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Nutrient Fluxes from Sediments in the San Francisco Bay Delta

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Abstract In September 2011 and March 2012, benthic nutrient fluxes were measured in the San Francisco Bay Delta, across a gradient from above the confluence of the Sacramento and San Joaquin Rivers to Suisun Bay. Dark and illuminated core incubation techniques were used to measure rates of denitrification, nutrient fluxes (phosphate, ammonium, nitrate), and oxygen fluxes. While benthic nutrient fluxes have been assessed at several sites in northern San Francisco Bay, such data across a Delta–Bay transect have not previously been determined. Average September rates of DIN (nitrate, nitrite, ammonium) flux were net positive across all sites, while March DIN flux indicated net uptake of DIN at some sites. Denitrification rates based on the N_2/Ar ratio approach were between 0.6 and 1.0 mmol m^{-2} day^{-1}, similar to other mesotrophic estuarine sediments. Coupled nitrification–denitrification was the dominant denitrification pathway in September, with higher overlying water nitrate concentrations in March resulting in denitrification driven by nitrate flux into the sediments. Estimated benthic microalgal productivity was variable and surprisingly high in Delta sediments and may represent a major source of labile carbon to this ecosystem. Variable N/P stoichiometry was observed in these sediments, with deviations from Redfield driven by processes such as denitrification, variable light/dark uptake of nutrients by microalgae, and adsorption of soluble reactive phosphorus.

Keywords Benthic flux · Denitrification · Nutrient stoichiometry · N/P ratios · P efflux · Benthic microalgae

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Introduction

Management issues related to the San Francisco Bay Delta are complex. Many management questions and actions are directly affected by the extent to which the factors contributing to food web changes can be identified and managed. Several fish, including the delta smelt (*Hypomesus transpacificus*) and longfin smelt (*Spirinchus thaleichthys*), are on the federal endangered species list or are considered threatened (Wanger 2007a, b). Water exports have been restricted by court order in recent years in an attempt to restore these species; new habitat is being created with the hope that it will contribute positively to the restoration of the system; and proposed major re-engineering of the flow is also being debated (e.g., Bay Delta Conservation Plan, 2010, http://baydeltaconservationplan.com/BDCPPlanningProcess/ReadDraftPlan/ReadDraftPlan_copy1.aspx).

Nutrient cycling bears on these issues in multiple ways. The estuary has been considered to have chronically low rates of productivity (e.g., Jassby et al. 2002; Kimmerer et al. 2012). Nutrient loads, speciation, and stoichiometry affect productivity and phytoplankton composition and ultimately can alter trophodynamics (e.g., Berg et al. 2001; Kemp et al. 2005; Glibert 2010, 2012; Glibert et al. 2011; Parker et al. 2012). While impacts of nutrients have long been ignored in this system compared to other stressors such as invasive bivalves (Alpine and Cloern 1992; Greene et al. 2011), nutrients are now gaining attention as important ecosystem stressors (Dugdale et al. 2007; van Nieuwenhuyse 2007; Jassby 2008; Glibert 2010, 2012; Glibert et al. 2011; Parker et al. 2012). Nutrients loads have increased substantially over the past decades due to increased sewage effluent loads (Van Nieuwenhuyse 2007; Dugdale et al. 2007; Glibert et al. 2011). Yet, despite the increasing recognition of nutrients as a potential stressor for this system, an accurate accounting of nutrient sources and sinks in the Bay Delta is not available. Without consideration of the role of nutrient sources and fluxes, the