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Eutrophication and Nutrient Cycling in Buena Vista Lagoon, Carlsbad, California

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Executive Summary

The purpose of this report is to summarize the findings of a SCCWRP study conducted to support the development of a eutrophication water quality model in Buena Vista Lagoon. The study included measurement of primary producer biomass, sediment and particulate nitrogen and phosphorus deposition, benthic dissolved oxygen and nitrogen (N) and phosphorus (P) fluxes, and sediment bulk and pore water N and P.

The purpose of this report is two-fold:

- Provide a summary of SCCWRP study data that will be used to develop and calibrate the water quality model for Buena Vista Lagoon (the Lagoon).
- Synthesize study data to inform management actions to address eutrophication and improve the efficiency of nutrient cycling in Lagoon.

Following are the major findings of this study:

- The Lagoon is exhibiting symptoms of eutrophication, as documented by episodes of low dissolved oxygen in both the East and Central Basins and high biomass of phytoplankton in the East and macroalgae in the Central Basins. Symptoms of eutrophication were most severe in the Central Basin.

    a. Dissolved oxygen concentrations found to be below 5 mg L^{-1} about 0.6-16% of the wintertime and 20 and 30% of the summertime at East and Central Basins respectively during the 2008 TMDL field studies. On average, estuary benthic metabolism tends to be net heterotrophic (net uptake of oxygen by sediments) year round, with peak net rates of -227 mmol O2 m^{-2} d^{-1} occurring in the Central Basin during July 2008 relative to the East Basin (peak net rate of -35 mmol m^{-2} d^{-1}).

    b. Estimates of biomass of macroalgae in the Central Basin were extremely high with transect means of 3591 to 6384 g wet wt m^{-2} over the summer and fall 2008 index periods and 100% cover. No established framework exists to assess adverse effects from by macroalgae, though a recent review (Fong et al. 2011) found studies documenting adverse effects of

macroalgae on benthic infauna as low as 700 g wet wt m-^{2} and with cover greater than 30-70%.

c. Mean phytoplankton biomass concentrations in the East Basin peaked in the spring (360 mg chl a L^{-1}), but was generally high throughout summer and fall index periods as well (36 – 102 mg chl a L^{-1}). The California freshwater lakes Nutrient Numeric Endpoint framework provide 2 thresholds that can be considered for brackish water lagoons dominated by phytoplankton: 20 mg chl a L^{-1} is considered to be sustaining aquatic life use, while 50 mg chl a L^{-1} is considered to indicate a clear impairment of aquatic life use (Tetra Tech 2006). While these thresholds have not been yet to coastal lagoons, measured concentrations of 102 to 360 mg chl a L^{-1} are likely to be considered eutrophic to hypereutrophic.

d. The two basins have a vast difference in the amount of carbon and nutrients stored in the sediments and aquatic primary producer communities: in the East Basin, sediments are grade from high sand content proximal to the Creek mouth toward finer grain sizes at the I-5 bridge; suspended sediment concentrations in the surface waters of the East Basin are higher. As a result, the APP community is dominated by phytoplankton with, relative to Central Basin, low APP biomass. Central Basin sediments range from 80 - 100% fines, with a > 1 m layer of unconsolidated floc at the surface. The primary producer community is dominated by macroalgae and to a lesser extent, SAV. As a result, the Central Basin supports three orders of magnitude higher primary producer biomass than East Basin and is much more prone to problems with dissolved oxygen.

- These preliminary nutrient budgets for Buena Vista Lagoon illustrate that terrestrial loads dominate nutrient cycling in the East Basin, while aquatic primary productivity and internal recycling of N and P control nutrient cycling in the Central Basin. Nitrogen assimilation is more efficient in the East Basin, as evidence by high nitrate influxes (presumably through denitrification) during the spring. Internal recycling of Central Basin nutrient stores through a cycle of benthic release, uptake and overgrowth by primary producers, then senescence and release of organic nutrients to the sediments perpetuates hypereutrophication in the Central Basin. This concept is supported by the following findings:

a. Benthic efflux of ammonium and SRP was the high in the Central Basin during summer and fall (4.8 mmol NH_4 m^{-2} d^{-1} and 1.1 mmol SRP m^{-2} d^{-1}) during peak periods of primary productivity. In contrast, East Basin ammonium and SRP fluxes were low during peak primary production (0.3 mmol NH_4 m^{-2} d^{-1} and -0.1 mmol SRP m^{-2} d^{-1}); thus internal recycling of nutrients is particularly important in the Central Basin and is likely providing a major source of nutrients to support primary productivity. These fluxes in the Central Basin meet or exceed required N and P to support the amount of observed primary producer biomass observed. The storage of large quantities of N and P as algal biomass thus diverts loss from denitrification and burial and providing a mechanism for nutrient retention and recycling within the estuary.

b. Patterns of nitrate versus ammonium fluxes indicate that denitrification (conversion of nitrate to nitrogen gas that is permanently lost from the estuary) is a more important mechanism in the East Basin while dissimilatory nitrate reduction (reduction of nitrate to ammonium) is more dominant in the Central Basin. Mean annual influx of nitrate was high (-3.5 mmol m^{-2} d^{-1}). East Basin, the most proximate to high sources of nitrate (Buena Vista Creek), had the highest rates of nitrate influx during the winter and spring (-8.8 to -13.6 mmol m^{-2} d^{-1}), relative to the Central Basin (-4.2 to -0.4 mmol m^{-2} d^{-1}). High ammonium fluxes, coupled with very high ammonium, SRP and sulfide porewater concentrations, signal that Central Basin sediments in an anoxic state and thus would favor DNR over denitrification. Thus in the winter and spring, the Lagoon is better able to assimilate external nitrate inputs through denitrification in the East Basin, but as the estuary becomes more eutrophic during summer and fall, the efficiency of nitrogen loss may be reduced in the Central Basin, retaining N in primary producer biomass that is returned to the sediments during the fall and available again for primary production the following year.

c. The patterns of ammonium and nitrate fluxes suggest that denitrification (loss of nitrate to nitrogen gas) may be playing a large role during the winter and spring time when sediments are better flushed and oxygenated but that dissimilatory nitrate reduction, the conversion of nitrate to ammonium under anoxic sediment conditions, is clearly a dominant pathway during the summer time and is likely responsible for some portion of the large fluxes of ammonium observed during these periods. Thus in the winter and spring, the Lagoon is better able to assimilate external dissolved inorganic nutrient inputs through denitrification, but will be more likely to retain N inputs during the summer and fall as DNR-derived ammonium is incorporated into algal biomass and to some degree retained within the estuary.

Management Options to Reduce Eutrophication

Preliminary nutrient budgets for Buena Vista Lagoon illustrate that internal recycling of N and P have a more important role than terrestrial runoff during peak periods of productivity. While exchange with the ocean is not well quantified and a great deal of uncertainty in these budgets exists, the relative magnitude of these inputs is not likely to change this conclusion. Sediment data indicate that the Lagoon has accumulated a large amount of organic matter in the sediments. Because benthic flux is the major source of nitrogen to the Lagoon, recycling of this organic matter to biologically available forms of nutrients will likely continue to cause problems with algal blooms and hypoxia, even with nutrient reductions, unless restoration is undertaken to flush the Lagoon of the fine-grained sediments and improve circulation.

Given the findings of this study, the following options for management of eutrophication in the Lagoon should be considered:

- Increase flushing and circulation within the Lagoon to decrease detention of fine-grain sediments and decrease water residence time. Restoration options which favor intertidal habitats over subtidal habitats will be an advantage over subtidal habitat, which will tend to plagued by hypoxia.

- Reduce terrestrial loads from the watershed, with emphasis on detention of fine-grained particles before it reaches the Slough. Emphasis should be placed on reducing both phosphorus as well as nitrogen from the watershed.

Full Text

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/638_BuenaVista.pdf