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Eutrophication and Nutrient Cycling in San Elijo Lagoon, Encinitas, 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 San Elijo 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 San Elijo Lagoon (the Lagoon).
- Synthesize study data to inform management actions to address eutrophication and improve the efficiency of nutrient cycling in Lagoon.

Major Findings of This Study

The Lagoon is exhibiting symptoms of eutrophication, as documented by episodes of low dissolved oxygen. Macroalgae, a key indicator for eutrophication, was present in moderate amounts. Episodes of low DO and macroalgal biomass were that were highest the year of the 2008 TMDL field study relative to the Bight ’08 Eutrophication Assessment (2008-2009).

- Dissolved oxygen concentrations found to be below 5 mg L^{-1} about 1 - 18% of the wintertime and 62 - 42% of the summertime at Segments 1 and 2 respectively during the 2008 TMDL field studies. This trend was repeated at Segment 1 the following year during the Bight study (5% winter versus 44% summer), but at a lower percentage than the previous year. Hypoxia (<2 mg L^{-1}) was more prevalent annually at Segment 2 (15%) versus Segment 1 (1%).

- Estimates of biomass and percent cover of macroalgae were moderate with averages of 251 g wet wt m^{-2} over the fall 2008 field studies and cover up to 67%. 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%. Dissolved oxygen concentrations measured during the

Bight '08 study at Segment 1 site showed surface waters to be below 5 mg^{-1} about 19% of the wintertime and 23% of the summertime.

During the wet season (Nov-April), terrestrial TN and TP loads were the dominant source of nutrients to surface waters, but during the dry season benthic ammonium and SRP flux dominated measured sources to surface waters and provide nutrients in excess of that required to grow the abundance of macroalgae measured in the estuary. Three types of data are used to support this finding:

- With respect to relative sources, terrestrial TN and TP input overwhelmed all other sources[1] during the wet season (Nov-April), but during the summer and fall estimated terrestrial input only represented 25 and 6% of TN and TP loads to the surface waters respectively. Direct atmospheric deposition is a negligible source. In contrast, benthic flux ranged acted as a sink for about a large percentage of the terrestrial N during the winter index period but then became a dominant source of N and P during the summer and fall (>75%), the periods of peak primary producer biomass.
- Mixing diagrams show a source of dry season SRP and ammonium sources to the estuary which is not accounted for by measured terrestrial input from the mass emission station. Lateral inputs of groundwater or runoff from Orilla Creek are contributing an unquantified source of nutrients to the estuary.
- During peak periods of macroalgal blooms, benthic fluxes of ammonium and SRP are 10X the N and 5X the P required to grow the abundance of macroalgae observed. Macroalgae is an efficient trap for dissolved inorganic nutrients and can even increase the net flux by increasing the concentration gradient between sediments and surface. 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.

The patterns of ammonium and nitrate fluxes suggest that denitrification (loss of nitrate to N 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 (DNR), 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 nitrogen (DIN) 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 San Elijo Lagoon illustrate that internal recycling of N and P has 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

[1] The net exchange of groundwater is unknown.

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 N 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/636_SanElijo.pdf