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Eutrophication and Nutrient Cycling in Santa Margarita River Estuary: A Summary of Baseline Studies for Monitoring Order R9-2006-0076

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EXECUTIVE SUMMARY

The purpose of this report is to summarize the findings of the Southern California Coastal Water Research Project (SCCWRP) study conducted in the Santa Margarita River Estuary (SMRE) in support of the San Diego Regional Water Quality Control Board (SDRWQCB) Monitoring Order (R9-2006-0076), which requires stakeholders to collect data necessary to develop models to establish total maximum daily loads (TMDLs) for nutrients and other contaminants (e.g. bacteria). SCCWRP, Louisiana State University (LSU) and University of California Los Angeles (UCLA), supported by a Proposition 50 grant from the State Water Resources Control Board (SWRCB), conducted studies in support of model development including monitoring of primary producer biomass, measurement of sediment and particulate nitrogen (N) and phosphorus (P) deposition, measurement of benthic dissolved oxygen (DO) and N and P fluxes, and sediment bulk and porewater 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 the SMRE.
- Synthesize study data to inform management actions to address eutrophication and improve the efficiency of nutrient cycling in the SMRE.

Following are the major findings of this study:

1. The SMRE is exhibiting symptoms of eutrophication, as documented by high biomass and percent cover of macroalgae, as well as episodes of low DO.
   a. Biomass and percent cover of macroalgae were high with a mean averages of 1465 to 1714 g wet wt m^{-2} over the fall 2008 and 2009 TMDL and Bight '08 field studies, and cover up to 100%. 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 to 70%.
   b. Dissolved oxygen concentrations measured at Segment 1 showed surface waters to be below 5 mg L^{-1} approximately 19% of the wintertime and 23% of the summertime.
2. High dry season concentrations of dissolved inorganic nutrients indicate anthropogenicallyenriched nutrient sources. Four types of data provide evidence for this finding:
   a. During the summer and fall, little freshwater was delivered to the estuary, yet estuarine ambient dry season soluble reactive phosphorus (SRP) and ammonium (NH_4) were especially high in Segment 2 (16.1 ±10.1 µM SRP and 29.8 ±19.3 µM NH_4) and nitrate (NO_3) was high in Segment 1 (69.4 ±29.2) relative to the other San Diego Lagoons in this study.

   b. Mixing diagrams (plots of salinity relative to nutrient concentrations) of transect data indicate dry season sources of NO_3, phosphate (PO_4) and NH_4, not associated with direct freshwater input. Lateral inputs of groundwater or, at Segment 2, runoff from holding ponds, may be contributing an unquantified source of nutrients to the estuary.
   c. Comparison of mass emission sources of NO_3 versus benthic influxes of NO_3during the summer and fall show that SMRE surface waters has more NO_3 than can be predicted by inputs from the Mass Emission site (ME). These data indicate that there are additional sources, such as lateral groundwater inputs of NO_3. This is a reasonable assumption, given the proximity of intensive, irrigated agriculture that was occurring at the time of sampling and permeable, sandy substrates which dominate the estuary.
   d. The quantities of N and P required to grow macroalgae during the fall sampling period is not met by measured sources of terrestrial loads nor benthic flux. These data indicate that there are additional sources, such as lateral groundwater inputs of PO_4 that are occurring.
3. During the wet season (Nov- Apr), terrestrial total nitrogen (TN) and total phosphorus (TP) loads were the dominant source of nutrients to surface waters, but during the dry season benthic $NH_4$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:
   a. Terrestrial wet and dry weather TN loads were generally balanced, while wet weather dominated annual TP loads (65%). Winter dry weather runoff (Nov-Jan, 41,627 kg TN) represents 36% of the total annual export and 65% of the total dry weather runoff. With respect to TP, 88% of the total annual dry weather runoff (2,882 kg) occurred over the winter and spring index periods. Terrestrial runoff of N and P were during summer and fall were low (535 to 0 kg TN and 328 to 0 kg TP respectively).
   b. With respect to relative sources, terrestrial TN and TP input overwhelmed all other sources[1] during the wet season (Nov-Apr), but during the summer and fall estimated terrestrial input only represented 0 to 25% of TN and TP loads to the surface waters and direct atmospheric deposition is a negligible source. In contrast, benthic flux ranged acted as a sink for about 10% of the terrestrial N and P during the winter index period but then became a dominant source during the summer and fall (>75%), the periods of peak primary producer biomass.
   c. During peak periods of macroalgal blooms, benthic fluxes of NH_4 and SRP are 1.5 to 19X the N and 0.2 to 4X the P required to grow the abundance of macroalgae observed. Macroalgae is an efficient trap for dissolved inorganic nitrogen (DIN) and has been shown to intercept benthic nutrient effluxes 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 nutirent retention and recycling within the estuary.
4. The patterns of NH_4 and NO_3 fluxes suggest that denitrification (loss of NO_3 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 NO_3 to NH_4 under anoxic sediment conditions, is clearly a dominant pathway during the summer

time and is likely responsible for the large fluxes of NH_4 observed during these periods. Thus in the winter and spring, the SMRE is better able to assimilate external DIN inputs through denitrification, but will be more likely to retain N inputs during the summer and fall as DNR-derived NH_4 is incorporated into algal biomass and to some degree retained within the estuary.

5. As a fluvially-dominanted river mouth estuary, the SMRE has an inherent capacity to scour finegrained sediments, thus making it less susceptible to eutrophication because particulate sources of nutrients such as watershed sediments and decaying organic matter tend to be more quickly exported. Two types of data support this finding:

   a. Meaurement of benthic oxygen (O_2)fluxes indicated that, on average, estuary net positive flux of O_2 to surface waters in spring to net uptake of $O_2$by sediments in the fall. These rates of O_2 uptake were moderate relative to other eutrophic estuaries. High net total carbon dioxide (TCO_2) effluxes are typically driven by respiration of accumulated dead or decaying biomass (organic matter accumulation) in the sediments rather than respiration of live biomass.

   b. While the SMRE had among the highest peak biomass of macroalgae documented, this biomass does not appear to accumulate in SMRE sediments from season to season. Surficial sediments were primary sandy, had surface C:N values <10, indicative of algal carbon sources, but these values increased dramatically with depth and with often non-detect with respect to N, indicating that organic matter is not accumulating with depth. In fluviallydominated river mouth estuaries such as the SMRE, this lack of interannual organic matter accumulation would make them less susceptible to eutrophication and is a factor responsible for the lower sediment O_2 demand, given the high abundances of algal biomass.

Management Options to Reduce Eutrophication

The SMRE has the advantage, as a river mouth estuary, that sediments do not appear to have accumulated excessive organic matter with depth. Hypoxia was present in the estuary, but not chronic. Interestingly, both N and P appear to be seasonally limiting in the SMRE. Therefore, options for management of eutrophication in the SMRE are aimed at reducing the availability of nutrients for primary production during the growing season and increasing tidal exchange in order to increase availability of DO and enhance denitrfication. Surface water nutrients were P limited during the winter, and N limited during the summer and fall. Thus management of both N and P sources and the ratios available for primary productivity is critical for managing eutrophication.

Three types of options could be considered:

1) Reduce terrestrial loads in order to limit primary productivity. Emphasis should be placed on reducing both P as well as N from the watershed and lateral inputs. **Because sources during the growing season appear to be lateral inputs rather than those estimated by the ME site, minimizing these loads will be a critical and effective management strategy.**

2) Increase flushing during peak periods of primary productivity, particularly when SMRE has reduced tidal exchange to surface water exchange with ocean during summer. Clearly this is a trade off with the need preserve available tidewater goby habitat during summer. Improved circulation during closed condition could help to limit stratification and therefore ameliorate, to a minor extent, problems with hypoxia.

3) Restoration to improve exchange with expansive area of wetland habitat west of Interstate Highway 5 (I-5). Denitrification rates are typically highest in wetland habitats (Day *et al.* 1989). Restoration to increase connectivity and exchange of surface waters with the large expanse of intertidal habitat south of the main channel would help to divert excessive NO_3 available during dry season from DNR towards denitrification and permanent loss. This could be accomplished through grading of portions of the natural levee with separates this central channel from the wetland area.

Future Studies

Quantification of additional sources of nutrients such as groundwater to the estuary during dry season is a critical research need, as it will effect TMDL allocations.

Full Text

Http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/635_SantaMargaritaSlough.pdf