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Southern California Bight 2008 Regional Monitoring Program: Volume VIII. Estuarine Eutrophication

K. McLaughlin[1], M. Sutula[1], L. Busse[2], S. Anderson[3], J. Crooks[4], R. Dagit[5], D. Gibson[6], K. Johnston[7], N. Nezlin[1] and L. Stratton[8]

[1] *Southern California Coastal Water Research Project*

[2] *San Diego Regional Water Quality Control Board*

[3] *California State University, Channel Islands*

[4] *Tijuana River National Estuarine Research Reserve*

[5] *Resource Conservation District of the Santa Monica Mountains*

[6] *San Elijo Lagoon Conservancy*

[7] *Santa Monica Bay Restoration Commission*

[8] *Cheadle Center for Biodiversity and Ecological Restoration*

EXECUTIVE SUMMARY

Introduction and Key Questions, and Study Design

The estuaries of the southern California, found in a distinct region that extends from Point Conception to Punta Banda, Baja Mexico, are an important resource for biodiversity, support of commercial and recreational fisheries, migratory birds, endangered species, as well as ecotourism. These estuaries are at risk, due to habitat loss, fragmentation, and increased loading of contaminants from urbanized watersheds. Nutrients are a major form of contaminant loading, particularly from points sources such as industrial and municipal effluent and non-point sources such runoff from agricultural and residential land uses and atmospheric deposition.

While nitrogen (N) and phosphorus (P) are required to support all life forms, too much of a good thing causes problems. Nutrient pollution causes an over-growth of algae and aquatic plants, leading to reduced dissolved oxygen (DO) concentrations, reduced biodiversity and changes in food webs. This collection of symptoms is referred to as "eutrophication." Eutrophication is recognized as one of the leading impairments of water quality in the United States, yet, despite the large number of estuaries in the Southern California Bight (SCB), little data are available on extent of eutrophication and the relationship with watershed nutrient loads. Only three of the SCB's 76 estuaries had sufficient data to be included in the 2007 National Oceanographic and Atmospheric Administration (NOAA) National Estuary Eutrophication Assessment. As the State Water Resources Control Board (SWRCB) prepares to develop estuarine nutrient objectives, a heightened need exists to identify appropriate indicators, standard protocols and methods to interpret data, and establish linkages between nutrient inputs and symptoms of eutrophication to support improved nutrient management.

The Bight 2008 Estuarine Eutrophication Assessment provided an opportunity to conduct the first large scale assessment of estuarine eutrophication in the region, in addition to getting early agreement on indicators and standard protocols, and informing the development of estuarine nutrient objectives.

Working together, environmental managers from twenty-one organizations, including stormwater agencies, municipalities, State and Federal regulatory agencies, and scientists joined forces to answer three basic questions:

1) What is the extent and magnitude of eutrophication in SCB estuaries?
2) Is there a difference in eutrophication between different classes of estuaries or by the degree of tidal flushing?
3) Is there a relationship between the symptoms of eutrophication and nutrient inputs?

Study Approach, Design, and Framework Used to Interpret Data

Magnitude of eutrophication was assessed using macroalgal abundance, phytoplankton biomass, and dissolved oxygen (DO), indicators that have scientifically well-vetted linkages to the ecosystem functions and beneficial uses of estuaries. Total N and P loading from the watershed, as well as 19 other water column and sediment physical and chemical parameters were also measured to determine how site-specific factors affect magnitude and extent of eutrophication.

Because eutrophication is highly spatially variable within an estuary, and because this was a regional assessment, we chose to report on targeted index area (segment) within many estuaries to get a broad estimate of extent of eutrophication across the region. A total of 27 segments in 23 estuaries were randomly selected from a comprehensive list of 76 estuaries. For the majority of systems, the segment represents 50 - 100 % of the estuarine area, but for a subset of systems (7 estuaries) the segment represents less than 25% of the total area). Segments were proportionally selected from the list to be able to investigate differences by estuarine classes (enclosed bay, lagoon, river mouth, estuaries) and degree of tidal restriction within the estuary, which relates to tidal inlet status: open, restricted, or closed. Each segment was located in a region of the estuary that is likely to have a longer residence time in order to capture where symptoms of eutrophication would likely be most severe. DO and phytoplankton biomass were assessed continuously while macroalgal biomass and other parameters assessed every other month from November 2008-October 2009.

Reporting on the extent of eutrophication requires a framework to interpret data. Dissolved oxygen, macroalgae, and phytoplankton assessment frameworks for European Union Water Framework Directive (EU-WFD) were applied to the monitoring data set to assess extent of eutrophication. Ecological condition in each segment was classified into one of five categories from very high (minimally disturbed conditions), high, moderate, low, to very low (severely degraded condition) for each indicator.

Study Findings

Question 1: What Is The Extent and Magnitude of Eutrophication in SCB Estuaries?

According to the EU-WFD framework, this study found that eutrophication is pervasive in the SCB segments monitored during the Bight’08 survey. The EU-WFD suggests management action if ecological condition is listed as "moderate" or worse. In SCB estuaries, 78% of segments using macroalgal abundance, 39% using phytoplankton biomass, and 63% using dissolved oxygen were categorized in "moderate" ecological condition or below. Applying a conservative "one out, all out" approach in determining ecological status, wherein the lowest score for any single indicator becomes the overall score the waterbody, all but one of the segments (96%) assessed would require management action. Utilizing a multiple lines of evidence approach that combines the worst of the primary symptoms (phytoplankton or macroalgal biomass) and a secondary symptom (low DO) would result in 53% of segments requiring management action. These findings should be interpreted with caution because segments do not represent the entire estuary and segments from larger estuaries were located within the part of the estuary where we would be most likely to find a problem, if it exists. Thus, these study results cannot be used to infer that the same percentage of estuarine habitat within the SCB is eutrophied. These results represent a preliminary regional estimate of the extent and magnitude of eutrophication in susceptible segments of SCB estuaries, and do not address the spatial extent of eutrophication in any single estuary.

Another use of the eutrophication data set is to provide the ranks of the estuarine segments relative to one another individually for each of the indicators, or overall by integrating across all indicators. Use of the data in this fashion provides context for the severity of eutrophication in the segment relative to other estuaries in our region. The three response indicators did not necessarily score the segment the same, reflecting a difference in dominant algal group (phytoplankton versus macroalgae) or relative importance of direct versus indirect effect of eutrophication (algae versus dissolved oxygen). Generally, macroalgae was the dominant primary producer, though several exceptions were found.

Question 2: Is There a Difference in Eutrophication between Different Classes of Estuaries or by the Degree of Tidal Flushing?

Environmental managers were interested in testing the effect of estuarine class and degree of tidal restriction (i.e., inlet status) on extent of eutrophication. Enclosed bays are the largest, deepest estuaries, and have well-flushed, permanent connections to the ocean. In comparison, the smaller lagoons and river mouth estuaries, which have sand bars that form across their mouths, have intermittent restriction or complete closure of their tidal inlets. Although we hypothesized that the magnitude of eutrophication would be higher in estuaries with more restricted hydrology (longer residence times), we found that class had no effect on extent of eutrophication in the segments studied; nutrient or organic matter loading was more important than inlet status in terms of nutrient impairment. However, macroalgal biomass decreased significantly where tidal variation in water level increased. In addition, the relationship between algal biomass and N and P loads became more significant when the volume and residence time of water in the estuary were both taken into account. Water residence time is largely driven by the status of the ocean inlet and volume is a function of the morphology of the estuary. Furthermore, extent of low DO was significantly related to sediment organic matter, which is typically preserved in habitats that tend to deposit fine-grained sediment in areas of restricted flow. Among paired restricted and unrestricted segments, restricted segments were ranked lower compared to unrestricted segments in the same estuary for nutrient impairment. Thus, inlet status likely influences extent of eutrophication, but is not necessarily more important than gradients in nutrient and organic matter loading.

Question 3: Is There a Relationship between the Symptoms of Eutrophication and Nutrient Inputs?

Eutrophication is assessed based on ecological response indicators, but impairment is managed largely by reducing nutrient inputs. This question sought to determine if relationships exist between nutrient availability and the magnitude of eutrophication symptoms in SCB estuaries, and whether these relationships were stronger for estuarine nutrient concentrations or nutrient loads delivered to the estuary. This question is important for two reasons. First, management strategies differ by whether the ultimate endpoint is defined by nutrient loads to the estuary (weight per unit time) or estuarine water column nutrient concentrations; strategies to control wet weather inputs, representing most of the load, are different from strategies to reduce concentrations, which are more applicable during dry weather. Second, the current USEPA approach to nutrient objectives is driven by the assumption that estuarine nutrient concentrations are a good predictor of eutrophication. We used statistical models to determine the strength of the relationships between extent of eutrophication and nutrient concentrations or nutrient loads.

Watershed nutrient loads and estuarine water-column nutrient concentrations were both significantly, positively correlated with aquatic primary producer (aquatic primary producers) biomass (i.e., macroalgae and phytoplankton), Several important points emerge from the analyses: 1) the relationship between nutrient inputs (water column concentrations and loads) and aquatic primary producer biomass was generally weak, though better for phytoplankton than macroalgae; 2) estuarine water column concentrations had a higher correlation with aquatic primary producer biomass than nutrient loads; 3) selecting the appropriate timescales over which to average the data is important to the strength of the relationship; 4) total nutrients were better correlated with biomass than dissolved inorganic nutrients; and 5) watershed nutrient loads and ambient nutrient concentrations at the segment site were significantly correlated with one another on annual timescales. The relationship between nutrient loads and aquatic primary producer biomass was only significant when estuarine volume and residence time are taken into account. While, these positive relationships build confidence in the use macroalgae and phytoplankton biomass as indicators of eutrophication in SCB estuaries, these models are more indicative of the expression of eutrophication symptoms along a disturbance gradient. Much needs to be done before the models can be used to set site-specific water quality goals to prevent or mitigate eutrophication.

In contrast to algae, extent of low DO events had no significant correlation with N and P loads; instead, it was strongly related to sediment organic matter (OM) content (Section IV). Macroalgae was also significantly correlated with sediment OM. Sediment OM generally increases along a gradient of increasing eutrophication, with increased amounts of OM due to long-term accumulation of external OM loading and/or within-estuary production and accumulation of algae over decadal time-scales (i.e., evidence of past nutrient loading). Thus, DO and algae indicators integrate the effects of increased nutrient loading over very different time-scales. Aquatic primary producer biomass reflects a more immediate response to nutrient loads entering on that particular year, while low DO is largely driven by the combination of OM loading and aquatic primary producer biomass which has accumulated over time. These findings have important implications for how different response indicators can be used for management of eutrophication in estuaries. If nutrient loads are reduced, one may expect to see a response in algal blooms relatively quickly, while hypoxia may decrease over a much longer time.

Recommended Next Steps

Create An Assessment Framework Appropriate For California Estuaries. The State Water Resources Control Board (SWRCB) is in the process of developing nutrient objectives based on ecological response indicators, which will require assessment frameworks specific to the local ecology of our estuaries. Results from this study can be utilized to inform this process by highlighting which indicators are relevant and how sensitive the results are to threshold selection, spatial and temporal sampling, as well as spatial and temporal integration of the data. Furthermore, the experience of our Bight planning committee can be used to refine protocols to optimize monitoring for eutrophication by identifying trade-offs between more data and a better assessment. However, there are still a number of issues that must be addressed to create a scientifically defensible assessment framework for the state of California. These issues include protocol refinement, science supporting the selection of thresholds, determination of how to incorporate inter-annual and spatial variability, how to incorporate duration (length and frequency) of blooms and hypoxia, and recognition that eutrophication may occur naturally in some of the smaller seasonally closed estuaries.

Refine Predictive Load - Response Models. Analysis of the relationships between nutrient loading and ecological response in this study was limited to simple statistical models. While a relationship between algae and nutrient loads was significant, these models lacked precision and are not yet appropriate for management use. The predictive capability of these models can be improved through: 1) development of, at minimum, improved data and models of estuarine hydrology, shown to be critical in improving load-response relationships, and 2) mechanistic studies of processes known to mitigate the effects of eutrophication (e.g., denitrification, etc.). This information can be incorporated into a regional model for scenario analysis of various nutrient loading rates and expected estuarine response.

Full Text

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