

Southern California Bight 2008 Regional Monitoring Program: Volume VII. Water Quality

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EXECUTIVE SUMMARY

Introduction and Key Questions, and Study Design

Algal blooms occur in coastal waters in response to a variety of environmental conditions (temperature, light availability, currents etc.). Nutrients, in particular, are critical to the development and/or maintenance of algal blooms. Most algal blooms are harmless, necessary, and beneficial to the function of aquatic ecosystems. However, some blooms can have negative impacts to the environment, human health, and the economy and are thus referred to as “harmful algal blooms” (HABs). Globally, HAB events are increasing in frequency and intensity in coastal waters. Nutrient pollution from anthropogenic activities has been shown to be the most significant environmental factors contributing to the global expansion of HABs. Nutrient inputs associated with anthropogenic activities such as agricultural land use, contaminated groundwater, and discharge of treated and untreated wastewater provide significant sources of nitrogen (the primary limiting macronutrient for algae in coastal waters) that have been linked to increased HAB events.

In the coastal waters of the Southern California Bight (SCB), there is a generally held perception that algal blooms and HAB events appear to have been increasing in recent years. The SCB is subject to input from one of the most populated U.S. metropolitan areas via both point (municipal effluent) and nonpoint (urban runoff and atmospheric deposition) discharge sources. The SCB also receives large amounts of natural nutrients, primarily from upwelling (the process by which nutrient-rich oceanic deep water is brought to the surface). There is a generally held perception that the quantity of anthropogenic nutrients is negligible relative to natural nutrient sources. However, no previous regional scale studies have been conducted to quantify the relative magnitude of natural and anthropogenic nutrient sources to the SCB, nor have any studies documented the increase in algal blooms to test the accuracy of these commonly held perceptions.

Key Questions

The Bight 2008 Offshore Water Quality study provided an opportunity to conduct the first large scale characterization of algal bloom patterns and estimation of the relative magnitude of anthropogenic versus natural nutrient sources to the SCB. Environmental managers and scientists from 76 organizations, including sanitation and stormwater agencies, municipalities, State and Federal regulatory agencies, and universities collaborated to answer three questions:

1. Are algal blooms increasing in frequency and are there areas where chronic blooms ('hotspots') are evident in the SCB?
2. What are the relative nutrient contributions of natural and anthropogenic sources to the SCB on bightwide and local spatial scales?
3. What are the mechanisms behind how algal blooms develop? Do blooms develop offshore or inshore, in the subsurface or surface depths?

Study Approach

The water quality study design for Bight'08 was divided into three main components: 1) Historical Analysis of Remotely Sensed Algal Blooms, 2) Comparison of Anthropogenic and Natural Nutrient Inputs, and 3) Algal Bloom Characterization. A special study was also conducted to determine whether nutrient sources (atmospheric deposition, wastewater, stormwater, and upwelling) could be identified from their stable isotope signatures in a common form of nitrogen (nitrate) in coastal waters.

1) Historical Analysis of Remotely Sensed Algal Blooms. Historic patterns in algal bloom occurrence and spatial extent were assessed using remote sensing to determine how frequently algal blooms occur and if this frequency has increased over the last decade. An analysis of surface algal blooms was conducted using remotely-sensed surface chlorophyll concentration and sea surface temperature from 1997-2007.

2) Comparison of Anthropogenic and Natural Nutrient Inputs. The relative magnitude of major nitrogen (N) and phosphorus (P) sources to the SCB (upwelling, wastewater discharge, riverine runoff and atmospheric deposition) were quantified using a combination of modeling and field studies over a one-year period. Estimates of upwelling include the novel use of the Regional Ocean Model System (ROMS) hydrodynamic model coupled with a biogeochemical model to provide a spatially- and a temporally-integrated estimate of this important nutrient source. As part of the nutrient source comparison, a special study was conducted to determine whether nutrient sources could be identified from their stable isotope signatures. The special study involved two parts: 1) determination of nutrient specific isotope ratios in nutrient sources such as wastewater effluent, river discharge and upwelled water; and 2) field measurements of seawater to determine if source signatures were maintained in the SCB or if they were over-written by biological transformations. The intent was to determine if isotopic signatures could be used to provide an additional line of evidence to identify nutrient sources that support algal blooms.

3) Algal Bloom Characterization. The purpose of this component was to characterize the spatial and temporal patterns of a spring algal bloom and determine the origin of bloom development. The physical, chemical, and biological oceanographic features of the development, evolution and dissipation of a

spring algal bloom were characterized. This aspect of the study utilized remote sensing and gliders in combination with pier-based and ship-based sampling between February and May 2010 to provide a multi-disciplinary dataset capable of covering a wide range of temporal and spatial scales.

Study Findings

Question 1: Are algal blooms increasing and are there areas in which chronic blooms ('hotspots') are evident in the SCB? The results of the historical analysis using satellite imagery (1997-2007) showed that the extent of algal blooms have increased significantly over the past 10 years in the SCB. Seasonally, blooms occurred consistently during the spring and early summer during upwelling periods. However, chronic algal bloom 'hotspots,' regions with year round high chlorophyll signatures, were identified in several areas in the SCB including the Santa Barbara Channel, the San Pedro Shelf, Santa Monica Bay, South San Diego, and the Ensenada coast. These algal bloom hotspots were co-located with anthropogenic nutrient inputs such as wastewater discharge outfalls and major river mouths, as well as with geographic areas that had longer residence times of coastal waters.

Question 2: What are the relative nutrient contributions of natural and anthropogenic sources to the SCB on bightwide and local spatial scales? At a regional, bightwide scale, the Bight '08 Water Quality study found that natural sources dominate anthropogenic sources of nutrients by 1 order of magnitude for nitrogen and 2 orders of magnitude for phosphorus. At smaller sub-regional scales, that are ecologically relevant to understanding algal blooms, the anthropogenic sources of nitrogen were comparable in magnitude to natural sources in Santa Barbara, Ventura, Santa Monica Bay, San Pedro Bay, and San Diego nearshore regions. While this study provided estimates of nutrient sources within an order of magnitude, the results suggest that anthropogenic nutrients are important at spatial scales relevant to algal blooms. Because algal productivity in SCB coastal waters is limited by the amount of nitrogen, anthropogenic inputs have doubled the amount of nitrogen available to support algal blooms. Among anthropogenic sources, POTW effluent typically exceeded riverine loads and atmospheric deposition by 1-2 orders of magnitude.

Recent studies have shown that the form of nitrogen, not just the quantity, is important for HABs and algal blooms. The sources of nitrogen to the SCB are comprised of different forms of nitrogen, mainly nitrate (plus nitrite), ammonia, and organic nitrogen (including urea). Dissolved inorganic nitrogen (DIN), the most biologically available form, was the dominant form in most natural and anthropogenic sources. As expected, upwelling was mostly comprised of nitrate, effluent was mostly comprised of ammonia and riverine runoff was dominated by nitrate and organic nitrogen forms. Despite the large ammonia component of effluent, this source contributed a significant nitrate (plus nitrite) load to the SCB, larger than the entire nitrogen contribution from riverine runoff.

Findings of Special Study. As part of the investigation into the relative contributions of natural and anthropogenic sources, a pilot study was employed to determine if isotopes could be used to identify different sources of nutrients in seawater samples taken in proximity to bloom events. The special study documented that the nitrogen and oxygen isotopic signatures of nitrate in the different sources

(wastewater effluent, riverine discharge and upwelled water) had distinct isotopic signatures, or fingerprints. The isotopic signatures from SCB nearshore samples were somewhat unique, but not enough to trace different nutrient sources in the SCB. Although nutrient input from atmospheric deposition was found to be less significant than input from other sources, the signature of atmospheric deposition sources was clearly identified in some surface samples in nearshore waters. However, it is possible that atmospheric deposition at the ocean surface may be more significant, but when integrated over increased water depth, it diminishes in importance relative to other nutrient sources.

Question 3: What are the mechanisms behind how algal blooms develop? Do blooms develop offshore, inshore, in the subsurface, or at surface depths? This study component provided new insights into algal bloom development and evolution in the SCB. Prior to this study, upwelling was perceived to support algal bloom development by providing nutrients to surface waters for existing surface algal populations. The Bight'08 Water Quality findings showed that algal bloom development was observed in both the surface and subsurface depths and in both the offshore and inshore locations within the SCB. The subsurface algal bloom was observed in most regions but was not detectable via remote sensing. This study documented that upwelling can be a physical mechanism that transports existing subsurface algal blooms into surface waters, provides direct connectivity between the two populations, and results in bloom intensification in surface waters due to higher light and nutrient conditions.

Recommended Next Steps

Evaluate if there is a trend of increased frequency of algal blooms and refine the temporal and spatial trends and patterns of algal blooms in the SCB. The results of the remote sensing study determined that the spatial extent of algal blooms has increased over the last decade in the SCB. However, this is a relatively short time scale in which to evaluate an oceanographic trend. Additionally, the presence of a subsurface algal feature was consistently identified which is not visible via remote sensing. Two types of research are recommended:

(1)

(2) Utilize sediment cores to investigate trends in phytoplankton productivity and HAB prevalence on decade to century timescales. Similar studies have been conducted in the past to deconstruct the relative influence of climate and oceanographic variability from anthropogenic influence.

Refine and validate models to assess various anthropogenic and natural nutrient source scenarios and provide a multi-year nutrient source analysis. Models are needed to evaluate the effect of anthropogenic nutrients on phytoplankton productivity and related effects such as coastal hypoxia. Models can determine the net change in these parameters on different temporal and spatial scales under different management scenarios. The types of models used in this study, with additional calibration and validation, can be used to simulate scenarios of altered magnitude and forms of nutrients to coastal waters. The modeled nutrient loads reported in this study were limited to annual time scales because of uncertainties in upwelling predictions on shorter (daily-seasonal) time scales. However, effects of nutrient delivery to the coastal ocean are more ecologically relevant for primary

productivity and algal bloom development if considered on these shorter time scales. The timing of nutrient sources may be as important as their magnitude because some sources are chronic, (daily wastewater effluent discharge into oceans and into rivers), whereas other sources are seasonal (riverine runoff and upwelling). Therefore, the relative importance of different nutrient sources on the development and maintenance of algal blooms may vary seasonally. To capture these higher-frequency timescales, existing models need to be refined and validated for smaller spatial scales and shorter (daily to weekly), timescales. In addition, these models can be used to conduct a multi-year comparative source analysis to determine interannual variability for each source. There is existing data that would allow for a multi-year analysis of effluent and riverine sources. The upwelling component could be estimated by hindcasting the models over several years.

Investigate subsurface algal blooms. Subsurface algal blooms and high chlorophyll were observed in most regions in this study. While these results provided a new view of algal bloom development, they also raised several questions. Future Bight studies need to:

1. Identify the nutrient source(s) associated with these subsurface algal blooms
2. Determine how often and in what seasons subsurface algal blooms develop
3. Determine the pervasiveness of the subsurface algal blooms
4. Investigate how far offshore subsurface algal blooms are located using the existing datasets discussed above
5. Determine the light levels and algal community composition associated with these features

Full Text ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/710_B08WQ.pdf