Background

San Francisco Bay has long been recognized as a nutrient-enriched estuary. Nonetheless, dissolved oxygen concentrations found in the Bay's subtidal habitats are much higher and phytoplankton biomass and productivity are substantially lower than would be expected in an estuary with such high nutrient enrichment, implying that eutrophication is controlled by processes other than straightforward nutrient-limitation of primary production. The published literature suggests that phytoplankton growth and accumulation are largely controlled by a combination of factors, including strong tidal mixing, light limitation due to high turbidity, and grazing pressure by clams.

There is a growing body of evidence that suggests the historic resilience of San Francisco Bay to the harmful effects of nutrient enrichment is weakening. Since the late 1990's, regions of the Bay have experienced significant increases in phytoplankton biomass (30- 105% from Suisun to South Bay) and significant declines in DO concentrations (2% and 4% in Suisun Bay and South Bay, respectively; J. Cloern, unpublished data). In addition, an unprecedented autumn phytoplankton bloom in October of 1999, and increased frequency of cyanobacteria and dinoflagellate (2004 red tide event) blooms occurring in the North Bay, further signal changes in the Estuary.

The indications of decreased Bay resilience have come to the fore at a time when the availability of resources to continue assessing the Bay's condition is uncertain. Since 1969, a USGS research program has supported water-quality sampling in the San Francisco Bay. This USGS program collects monthly samples between the South Bay and the lower Sacramento River to measure salinity, temperature, turbidity, suspended sediments, nutrients, dissolved oxygen and chlorophyll a. The USGS data, along with sampling conducted by the Interagency Ecological Program, provide coverage for the entire San Francisco Bay –Delta system. The San Francisco Bay Regional Monitoring Program (RMP) has no independent nutrient-related monitoring program, but instead contributes approximately 20% of the USGS data collection cost. Thus, there is currently an urgent need to lay the groundwork for a locally-supported, long-term monitoring program to provide information that is most needed to support nutrient-related management decisions in the Bay.

The timing also coincides with a major state-wide initiative, led by the California State Water Resources Control Board (State Board), for developing nutrient water quality objectives for the State's surface waters, using an approach known as the Nutrient Numeric Endpoint (NNE) framework. The NNE establishes a suite of numeric endpoints based on the ecological response of a waterbody to nutrient over-enrichment and eutrophication (e.g. excessive algal blooms, decreased dissolved oxygen). In addition to numeric endpoints for response indicators, the NNE framework must include models that link the response indicators to nutrient loads and other management controls. The NNE framework is intended to serve as numeric guidance to translate narrative water quality objectives.

Since San Francisco Bay is the State's largest estuary, and one for which there is currently a relative wealth of data, it is a primary focus of a state-wide effort to develop NNEs for estuaries. As part of the state-wide effort, the Water Board is working with State Board to develop an NNE framework specific to the Bay. This effort was initiated by a literature review and data gaps analysis to recommend indicators to assess eutrophication and other adverse effects of anthropogenic nutrient loading in San Francisco Bay and summarize existing literature in the Bay using these indicators and identify data gaps (McKee et al., 2011). The review made five major recommendations: 1) develop an NNE assessment framework for the Bay, 2) quantify external nutrients loads, 3) develop a suite of models that link NNE response indicators to nutrient loads and other co-factors, 4) implement a monitoring program, and 5) coordinate development of the Bay NNE workplan with nutrient management activities in Sacramento and San Joaquin Delta.

At an RMP-sponsored workshop on nutrient management in the Bay (June 29-30, 2011), participants engaged in monitoring activities in the Bay-Delta were convened on day two to discuss elements of a monitoring strategy. They agreed that developing a NNE assessment framework and funding of a monitoring program were priorities, but that these efforts must begin with spatially–explicit conceptual models of the linkages between nutrient loads, ecological response indicators and Bay beneficial uses.

Another issue of importance to the Water Board and stakeholders is that of the potential impact of ammonia/ammonium on Bay beneficial uses. While the USGS has documented a loss of resiliency throughout San Francisco Bay, additional factors may influence productivity in Suisun Bay compared with South Bay. Recent studies argue that elevated levels of ammonium actually limit primary productivity in Suisun Bay (Dugdale et al., 2007, 2012; Parker et al., 2012a), and perhaps elsewhere in the Estuary (Parker et al., 2012b). There is currently disagreement within the scientific community about the potential role ammonium plays in limiting primary productivity, and this issue needs to be resolved. To help resolve the issue, the Water Board supported studies in Suisun Bay in 2010 that explored the relationship between ammonium concentrations, nitrogen uptake, and phytoplankton biomass; in the spring of 2011 the Water Board initiated a two-year follow-up study. Additional follow-up studies include toxicity tests and TIE method development to identify the cause of inhibition of diatom growth in Suisun, studies to evaluate copepod toxicity due to ammonium, investigations into the potential influence of nutrient ratios on system response, and the importance of nutrient fluxes from sediments. These data and information from additional studies being conducted in the Delta should be reviewed, synthesized and a process should be developed to resolve these outstanding questions and concerns about ammonium.

In addition, given that several factors (light-limitation/turbidity; grazing pressure by clams; tidal mixing) contribute to maintaining phytoplankton biomass at relatively low levels in this otherwise nutrient-rich estuary, improved understanding is needed with regards to the relative importance of these factors, including temporal and spatial considerations, and regarding susceptibility to future changes in the level of control they exert (e.g., decreases in suspended sediment loads).

Considering the compelling evidence of changing conditions in San Francisco Bay, uncertainty about future monitoring programs, and new nutrient policies on the horizon, there is a strong need for a coherent nutrient science and management strategy for the Bay. Section 3 identifies upcoming management decisions related to nutrient overenrichment and eutrophication. Section 4 lays out the goals of the nutrient strategy and a plan, developed collaboratively by the Water Board and Bay stakeholders, for the technical studies required to support decisions regarding nutrient management. The current version of the strategy focuses on priority work elements within a five-year planning horizon, with the recognition that this work will extend beyond that time period and will build upon these foundational early efforts. Some commitments have already been made by various groups to fund or undertake priority tasks. These are summarized in Appendix 1.

There is considerable ongoing research on the role of nutrients in a changing San Francisco Bay ecosystem. Given that this is the case, this nutrient science and management strategy will likely require modification as new information becomes available. While the strategy has a five-year planning horizon, it will remain flexible and adapt to new information.

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