Charge to White Paper Author and Panel

Role of Nutrients in Shifts in Phytoplankton Abundance and Species Composition in the Sacramento-San Joaquin Delta

Charge for the White Paper

The objectives of the white paper are to: 1) describe what is known about the importance of nutrient loads, forms, and ratios to primary productivity and shifts in algal species composition in the Delta and Suisun Bay; 2) identify significant unresolved science questions; and 3) provide recommendations for future research and monitoring.

A two-day workshop is planned to provide input to the white paper. The workshop will highlight research pertinent to two hypotheses of nutrients' role in phytoplankton growth. An independent white paper author in coordination with a panel of experts will summarize results of the workshop and then use the summary, additional literature and professional expertise to create a white paper. Ultimately, the white paper will be used to design studies and monitoring activities pertinent to the resolution of management questions in the Delta and Suisun Bay and potentially the San Francisco Bay.

Background and Project Scope

The Sacramento-San Joaquin Delta defines the freshwater portion of the San Francisco Estuary. The watershed that drains to the Estuary covers about 40% of California. Suisun Bay is the transition zone between fresh and salt water at the eastern end of San Francisco Bay. In the early 2000s, scientists' recognized a sharp decrease in populations of pelagic fish species in the Delta and Suisun Bay. Among the factors being investigated as contributing to the pelagic organism decline are a decrease in primary productivity and changes in phytoplankton community composition. The role of nutrients (forms, ratios, concentrations, and loads) and nutrients' relative importance in promoting changes in phytoplankton abundance and species composition will be the subject of a white paper that will guide future research and monitoring.

The San Francisco Bay and Central Valley Regional Water Quality Boards, which are State agencies responsible for protecting water quality in the Estuary, are organizing the workshop and white paper preparation.

The mission of the Delta Stewardship Council is to implement the coequal goals adopted by the California Legislature: to provide a more reliable water supply for California and to protect, restore, and enhance the Delta ecosystem. The Council

adopted a Delta Plan in 2013 to implement these goals. The Delta Plan Chapter 6 Recommendation # 8 states, in part,

> "…the State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards should prepare and begin implementation of a study plan for the development of water quality objectives for nutrients in the Delta …."

Potential nutrient related problems identified in the Delta Plan for evaluation are:

1. Decreases in algal abundance and shifts in algal species composition, resulting in potential food web impacts
2. Increases in the abundance and distribution of macrophytes, including water hyacinth and Brazilian waterweed
3. Increases in the magnitude and frequency of cyanobacteria blooms

This charge is to develop a white paper that addresses the first issue, assessing whether the observed decrease in algal abundance and shift in algal species composition in the Delta and Suisun Bay are the result of long term changes in nutrients and whether nutrient management might measurably remedy the food web impacts.

White papers for cyanobacteria, macrophytes and modeling are complete and approved by the Delta Nutrient Stakeholder and Technical Advisory Group (STAG). The knowledge gap document has been completed and approved for cyanobacteria and the knowledge gap document for macrophytes should be approved by the STAG soon. The cyanobacteria, macrophyte, modeling, drinking water, and this white paper collectively along with the data gap documents will be used to inform the development of a Nutrient Research Plan for the Delta and Suisun Bay. The information developed may also help inform the Bay Area Science Plan developed for nutrient management in the San Francisco Bay.

The State Water Resources Control Board's independent Science Panel for nutrient objectives will provide peer review of the Delta Nutrient Research Plan. A final Nutrient Research Plan addressing all review comments will be presented to the Central Valley Regional Water Board and the Delta Stewardship Council in 2017. Results from the research conducted under the Nutrient Research Plan may be utilized by the Water Board to direct staff to develop nutrient water quality objectives (narrative and/or numeric) as warranted.

Nutrients (e.g., forms, ratios, concentrations and loads) are only one of many drivers of phytoplankton production in the Delta and Suisun Bay, others of which include Delta

inflows, contaminants, optical properties, water residence time, and food web interactions. It is not the objective of this white paper to develop a quantitative analysis of the various drivers of phytoplankton in the Delta and Suisun Bay, although the white paper should address the relative importance of nutrients compared to other drivers. References that address other drivers will be available to the white paper author and workshop panel to provide context for their focus on nutrients. This white paper will provide an additional piece that will help the Regional Water Boards and STAG to understand when nutrient-related factors are most important and what other physical, chemical, and biological conditions must exist in order for nutrient-related factors to be critical.

As available, information on the relative importance of nutrients and other drivers will be incorporated into the Delta Nutrient Research Plan; however, it is anticipated that additional information will be needed and possibly mathematically modeled to fully understand the relative importance of nutrients and other factors in controlling phytoplankton abundance, rates of primary production, and community structure.

Current Nutrient Hypotheses and Research Tracks Related to Decreased Algal Abundance and Species Shifts

In the Bay-Delta Estuary, and in particular Suisun Bay, there has been significant reduction of phytoplankton biomass and primary production. A number of researchers have attributed this change to grazing by clam species which invaded San Francisco Bay and established a significant presence in 1987 and in subsequent years.

Two nutrient-focused hypotheses have been proposed to help explain shifts in the food web in Suisun Bay and the Delta. One hypothesis concerns the effect of elevated concentrations of ammonium on phytoplankton biomass and community composition. This hypothesis is referred to as the "ammonia paradox" (Dugdale *et al*. 2012)[1]. The hypothesis states that elevated concentrations of ammonium (NH_4) suppress nitrate (NO_3) uptake in some algal groups commonly present in the Delta. The resulting lack of access to NO_3 results in a decrease in primary production rates and, if some algal functional groups are differentially sensitive to NH_4, to shifts in community composition from more to less NH_4 sensitive algal forms.

The second hypothesis concerns the influence of nutrients on algal community composition and algal nutritional quality to herbivores and is referred to as the ecological stoichiometry hypothesis as applied to the Delta (Glibert 2011)[2]. The hypothesis states

[1] Dugdale, R.C., F.P. Wilkerson, A.E. Parker, A. Marchi and K. Taberski. 2012. River flow and ammonium discharge determine spring phytoplankton blooms in an urbanized estuary. Estuarine and Coastal Shelf Science 115: 187-199.

[2] Glibert, P.M., D. Fullerton, J.M. Burkholder, J.C. Cornwell, and T.M. Kana. 2011. Ecological stoichiometry, biogeochemical cycling, invasive species, and aquatic food webs: San Francisco Estuary and

that changes in the forms and ratios of nutrients (NH_4:NO_3, N:P, dissolved inorganic N:soluble reactive P) cause “shifts” in algal community composition, and that these effects occur even when nutrient concentrations are in surplus and not limiting algal growth rates. Increasing N:P and increasing NH_4 in relation to NO_3 are hypothesized to reduce the competitive advantage of larger, faster growing algal forms, like diatoms, and to select for smaller, slower growing groups like flagellates, green algae and cyanobacteria. The latter algal forms have been characterized by some researchers as being of a lower nutritional value for some high-quality zooplankton herbivores, resulting in a reduction in secondary production and “bottom up” ecological effects further up the food chain, including potential decreases in fishery production.

Studies conducted in the lab and field by numerous local researchers to examine these hypotheses have conflicting results, and uncertainties regarding whether changes in phytoplankton composition are correct interpretations of monitoring data have entered the discussion.

One or both of these hypotheses may explain past changes in algal abundance and species composition and may help predict future changes based on an anticipated state change (i.e., a unidirectional, reduction in nitrogen and phosphorus loads, including a reduction in total ammonia concentrations in the system. Decreases in total nitrogen loadings within the Delta are expected to occur due to planned upgrades to meet wastewater system permit requirements and implementation of best management practices by other non-point sources. This projected change in the loads of nutrients and current similar types of control measures for nutrients that have already been made presents a potential opportunity to test the ammonia paradox and ecological stoichiometry hypotheses in the field. The workshop allows for a panel of technical experts to review the scientific literature, discuss with researchers directly and subsequently develop a white paper that identifies recommended research strategies to evaluate the effects of this state change, along with additional studies that would help resolve conflicting results.

Process

A significant source of information for the white paper will be a 2-day workshop during which scientists will present original research related to nutrients and phytoplankton in the Delta and Suisun Bay. The white paper author and expert panel will actively participate in the workshop and will summarize: the main observations of the workshop presentations and reports; the discussions between panel members and presenters; and areas of certainties and uncertainties based upon the presentations and reports submitted for the workshop. Using the

workshop summary, additional literature, and the best professional judgment of the panel, the lead author will develop a white paper that: 1) describes what is known about the importance of nutrients (forms, ratios, concentrations, and loads) to the primary productivity and shifts in algal species composition in the Delta and Suisun Bay; 2) identifies significant unresolved science questions; and 3) provides recommendations for future research and monitoring.

Charge for the Workshop

The purposes of the workshop is to review nutrient-related research and syntheses in the Delta and Suisun Bay, determine areas of agreement and disagreement, identify the types of follow-up studies needed to resolve differences; and provide recommendations for future research and monitoring.

The white paper author and panel, working together, will examine observations and evidence related to primary production and phytoplankton community composition (including physical, chemical, biological, and phytoplankton-physiological factors), both from field observations and controlled experiments, and report on the following:

1. Articulate the areas/topics of certainty and uncertainty (observations, causal factors, specific mechanisms) within the scientific community regarding the relationships and relative importance of nutrient forms, ratios, concentrations, and loads and the following in the Delta and Suisun Bay:
    a. Low production rates and low phytoplankton biomass
    b. Shifts in phytoplankton community composition

2. Identify the types of studies (e.g., field investigations, controlled experiments, statistical analysis of data, and modeling) that would test the areas of uncertainty and outstanding science questions related to the following in the Delta and Suisun Bay:
    a. Low production rates or low phytoplankton biomass
    b. Shifts in phytoplankton community composition

3. Identify additional studies and monitoring needed to fill knowledge gaps and understand changes in phytoplankton species composition and biomass in the Delta and Suisun Bay, particularly in light of anticipated changes in nitrogen loads

Table 1 contains questions for the white paper author and panel members to consider as they participate in the workshop and develop the white paper. These questions have received extensive review by stakeholders and agency staff in

order to reach a consensus. The goal of the joint workshop is to advance our understanding of the science on which to base management decisions, so the following questions have been developed to facilitate that goal rather than focus on the differing results between studies. It is anticipated that the white paper author, with input from panel and STAG members, will help structure the overall workshop. Should the white paper author and panel members think that a question in Table 1 requires clarification, or that an important question has been omitted, the clarified question or new questions may be added to the current list.

Table 1. Detailed Questions for the White Paper:

1. Can differences in experimental conditions (for example, light levels, temperature, duration of experiment, pH, salinity, grazing, initial experimental conditions, phytoplankton species and genetics, and others) explain differing results from different researchers for the ammonia paradox and ecological stoichiometry hypotheses?

2. What bench-scale/mesocosm/field experiments would test the ammonia paradox and ecological stoichiometry hypothesis in the Delta and in Suisun Bay? In controlled tests, what are the appropriate and ecologically relevant nutrient concentrations and ratios to use as experimental variables?

3. What factors should be considered in the experimental designs:
    a. What are the appropriate and ecologically relevant temporal scales (hours, days, weeks) at which to evaluate the ammonia paradox and ecological stoichiometry hypotheses in the Delta?
    b. What are characteristics of times and locations, including duration and frequency, when the ammonia paradox is believed to be important?
    c. What are the appropriate and ecologically relevant nutrient concentrations and ratios to use as experimental variables?
    d. What modeling or other work should inform the experiments to identify the nutrient concentrations and ratios that will result in situ from management actions underway?

4. What nutrient monitoring, special studies, and modeling are recommended to track changes in nutrient levels and phytoplankton responses in the Delta? Note that presenters will be asked to make predictions in their oral presentations based on their understanding of the mechanisms affecting phytoplankton abundance and species composition and about how the Delta and Suisun Bay will respond to the expected nutrient state change and to describe experiments to test the predictions. The panel will review and comment on the appropriateness of both the predictions and experimental design.

5. What is the range of potential outcomes, regarding biological impacts, of future management of nutrients in the Delta? In other words, what can reasonably be expected, in terms of

phytoplankton abundance, biomass, species, composition, and what are the justifications for those predictions?

6. How does the Delta Estuary fit into the global spectrum of large, river-dominated estuarine ecosystems across multiple parameters? Based on its particular characteristics (e.g., habitat types, morphology, flow/tidal flux/retention time, light/turbidity, seasonal nutrient loads and forms and food web components), what can we surmise about the Bay-Delta's responses, in comparison with responses to changes in nutrient loads observed in other estuaries?

Roles and Responsibilities

White Paper Author: Responsibilities for the white paper author are to: provide advice on the organization and structure of the workshop including recommendations of panel members, refinement of questions to presenters, final selection of presenters; develop the white paper outline; write the draft white paper and present it to stakeholder and technical groups (could be as web-based presentations); provide written responses to comments on the draft white paper and prepare the final white paper. The white paper should represent the consensus of the panel to the degree possible, and, in areas where consensus is not reached, should reflect the diversity of opinions among panel members.

Panel: The panel will be comprised of four to six individuals with relevant scientific expertise. The role of the panel will be to question presenters, discuss and evaluate workshop presentations and written material, and to formulate a response to the charge questions under the leadership of the white paper author.

Stakeholder Involvement: Members of the Delta and San Francisco Bay nutrient stakeholder advisory groups will participate in planning the workshop. It is also anticipated that members of the groups will attend the workshop. Upon completion of the draft white paper, the stakeholders will be given an opportunity to review and provide comments. Stakeholders' comments will receive responses within the white paper or in an accompanying document, depending on the comment.

Products

The process of reviewing and evaluating the role of nutrients in determining phytoplankton species composition, productivity, and abundance will produce a set of products listed below.

- Workshop summary [exact format to be determined with white paper author prior to workshop. Possibilities include detailed notes of workshop appended to white paper and/or autonomous workshop report.]
- Draft white paper
- Comments and recommendations from Delta and San Francisco Bay nutrient

stakeholder advisory groups

- Final white paper

These products, in combination with previously completed white papers and knowledge gap documents, will be used by Central Valley Water Board staff and Delta stakeholders to develop a draft Delta Nutrient Research Plan. Once the Research Plan has been implemented, Delta stakeholders will also be asked to review study results and subsequent recommendations as to whether water quality objectives for nutrients are needed in the Delta.

Estimated Schedule

Nutrient Forms and Ratios Workshop: November 2016
Draft Nutrient Forms and Ratios White paper available for review – February 2017
Final Nutrient Forms and Ratios White Paper – estimated March 2017

Draft Nutrient Research Plan by Water Board staff available for review – summer 2017

This charge was approved by the Delta Nutrient Research Plan Stakeholder and Technical Advisory Group in March 2017. It may be considered "draft" until the scope and schedule are reviewed with the Nutrient Forms and Ratios White Paper author and panel. For more information about the Nutrient Forms and Ratios White Paper, please contact Janis Cooke (Central Valley Regional Water Quality Control Board; 916 464 4672 and Janis.Cooke@waterboards.ca.gov).

The nutrient forms and ratios workshop and white paper are jointly organized by the Central Valley and San Francisco Bay Regional Water Quality Control Boards. Financial support is also being provided by the Delta Stewardship Council and wastewater and water supply stakeholders.

The Central Valley and San Francisco Bay Water Boards are developing nutrient strategies that include addressing effects of nutrients on food webs, nuisance aquatic macrophytes, dissolved oxygen, and harmful algal blooms. Information about research supporting the development of the nutrient strategies is available on the project webpages.

Delta nutrient research plan effort – http://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/delta_nutrient_research_plan/index.shtml

San Francisco Bay research and management strategy effort – http://sfbaynutrients.sfei.org/ .