

Below is a summary table of the projects proposed for FY17 funding, broken into Core Program and Projects, followed by project descriptions. Projects are arranged in order of relative priority. The relative ranks are based on both the science needs and timing (i.e., lower priority activities could come in subsequent years with less impact on program).

Total NMS funding for FY17 will be in the range of \$1.4-1.7mill (new FY17 funds + reserves). We are also actively fundraising to identify funding for projects further down on the list.

The three modeling projects (P.7, P.8, P.9) are considered to be of comparable priority. Our goal is to secure funding for at least two of them, but not necessarily all of them, especially if that would prevent us from pursuing P.10.

Activities are classified into three categories relative to funding

- Must-Dos Within Budget: Core + Projects that can be carried out with current anticipated budget (will require some reserves and some reallocating)
- Must-Dos Exceeding Budget: The next highest priority projects that, if funds became available, would move forward in FY17.
- High-Priority Exceeding Budget: Additional projects that we need to be moving forward with this year if funding can be identified, but not realistic with current budget.

CORE PROGRAM		Cost	Cumulative Total		
C.1	Channel Monitoring	146800	146800		
C.2	Basic Modeling	286500	433300		
C.3	Moored sensor / DO / biogeochemistry data interpretation	342460	775760		
C.4	Data Analysis / Synthesis	99563	875323		
C.5	Science Program Coordination	258125	1133448		
C.6	Program management	66735	1200183		
Core Program subtotal		1200183			
PROJECTS					
P.1	Monitoring Program Development	107702	1307884		
P.2	Vertical DO profiles in sloughs/creeks	91640	1399524		
P.3	DO in margins: approach for characterizing habitat/condition	135438	1534962		
P.4	Toxins in mussels	76300	1611262		
P.5	Workshop, lit review: Characterizing current HAB risk	50000	1661262		
P.6	Data Management	71243	1732504		
P.7	Modeling A: slough/creeks/ponds	97600	1830104		
P.8	Modeling B: Scenarios..Risk-based considerations	97600	1927704		
P.9	Modeling C: Suisun biogeochemical model development, application	97600	2025304		
P.10	HABs/Phytos: characterize community, IFCB, experiments	172100	2197404		
P.11	Biota Surveys: field investigations for DO, LSB focus (multi-year)	200000	2397404		
P.12	High-res biogeochemical mapping: light field, nutrients, chl-a, etc.	100000	2497404		
P.13	Intensive field investigations, rates, processes: e.g., denitrification, nitrification, SOD, water column BOD (annual budget, multi-year, ~5 yrs)	250000	2747404		
P.14	Benthos, grazer surveys (annual cost, multi-year, 3-5 years)	100000	2847404		Must-Dos Within Budget
P.15	HABs/toxin intensive investigations (multi-year)	200000	3047404		Must-Dos Exceeding Budget
P.16	Program review	40000	3087404		High-Priority Exceeding Budget
Projects subtotal		1887222			
Total (Core + Projects)		3087404			

Table of Contents

[C.1 Ship-based sampling and sample analysis](#)

[C.2 Biogeochemical model development and application](#)

[C.3 Open-Bay and slough moored sensors: data analysis/interpretation and maintenance](#)

[C.4 Data Analysis / Synthesis / Technical Project Management](#)

[C.5 and C.6 Science Program Coordination and Program Management](#)

[P.1 Monitoring Program Development](#)

[P.2 Characterizing DO spatial \(vertical, longitudinal\) variability in LSB sloughs/creeks](#)

[P.3 Characterizing DO-related habitat quality in LSB sloughs and open Bay](#)

[P.4 Algal toxin monitoring in bivalves from Central, South, and Lower South Bay.](#)

[P.5 Implications of current HAB toxin levels in SFB: expert workshop and white paper](#)

[P.6 Develop and begin implementing a NMS data management plan](#)

[P.7 Modeling linkages between Open-Bay, Sloughs and Salt Ponds](#)

[P.8 Risk-based framework: quantitatively exploring plausible future scenarios for ecosystem response](#)

[P.9 Suisun Bay biogeochemical modeling: model development and application](#)

[P.10 Mechanistic Harmful algae bloom investigation](#)

[P.11 Fish and/or benthos surveys in LSB sloughs and open Bay](#)

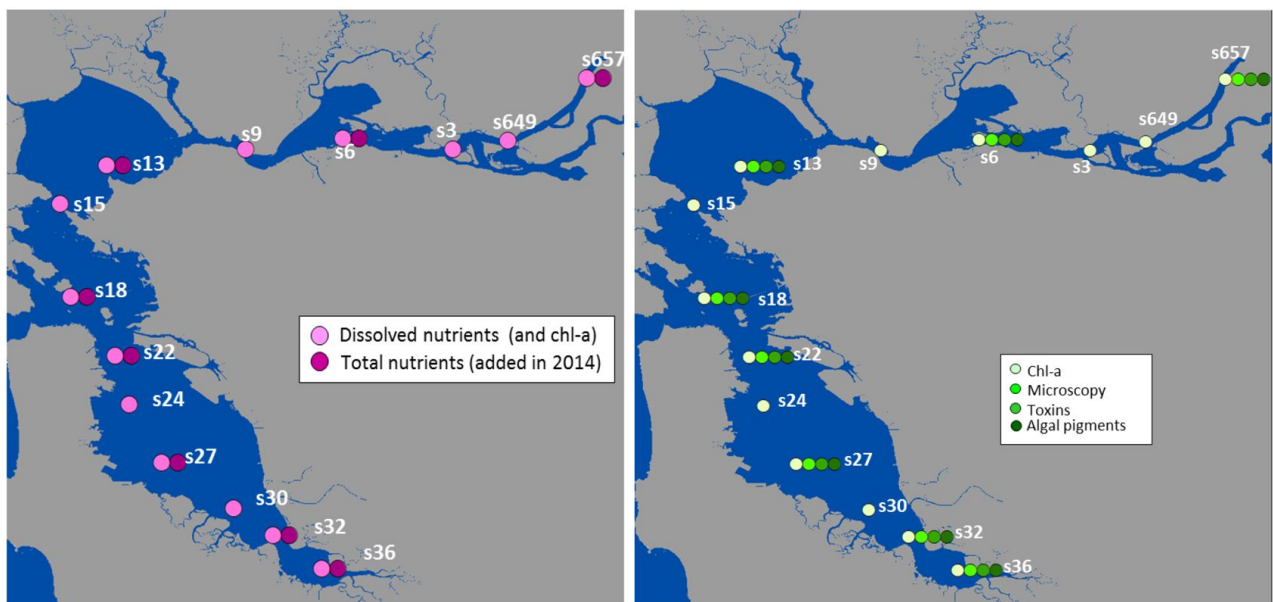
CORE PROGRAM (C)

C.1 Ship-based sampling and sample analysis

FY17 Estimated NMS Cost = \$153,000

Collaborators: USGS, UCSC, SFEI

Ship-based samples will be collected and analyzed for a range of nutrient-related parameters. This data is essential for basic condition assessment, model calibration, and improved understanding of nutrient behavior and nutrient-related effects in the Bay. Ship-based discrete samples will be collected by USGS aboard the R/V Peterson on ~12 full-bay cruises and an additional ~12 South Bay cruises.



Costs covered by NMS

- Nutrient analyses (USGS national lab)
- Analysis of integrated toxin samples (SPATT), discrete toxin samples, and algal pigments (at UCSC)
- Basic data QA/QC and basic reporting
- Additional staff support on cruises to support the collection of NMS-related samples: inorganic nutrients, total nutrients, microscopy, algal pigments, and particulate algal toxins; spatially integrated toxin samples (SPATT)

Costs covered by USGS as part of their core program

- Collection of samples for chlorophyll and ancillary data (e.g., suspended particulate matter, dissolved oxygen, salinity)
- Vertical profiles for multiple parameters
- Underway flowthrough data collection (salinity, T, chl-a fluorescence, turbidity/optical backscatter)
- Program management, scientific oversight
- Data management for USGS parameters plus inorganic nutrients

- Ship maintenance, fuel, crew, etc.

Deliverables

Nutrient and chl-a data will be made publicly available through USGS’s website. Results will also be summarized in the [NMS Annual Report](#). Data will be used for many NMS aspects (model calibration, condition assessment, assessment framework development).

Budget Justification

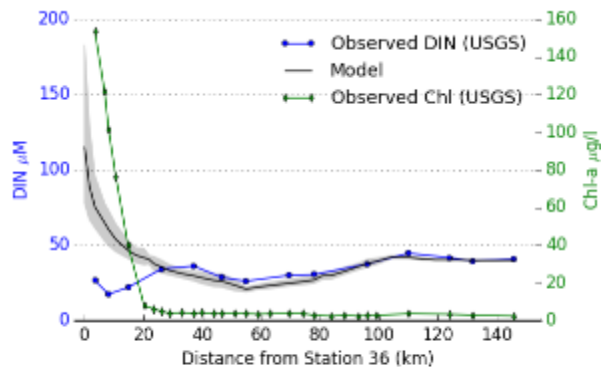
Nutrient analyses for 300 station-date samples (\$40,000; ammonium, nitrate + nitrite, reactive phosphorous, dissolved silicate; total N and P measured at a subset of sites samples); Taxonomy on ~200 samples for phytoplankton community composition and biovolume (\$45k); toxin and algal pigment measurements (\$55k); Additional staff support for field work (\$20k).

C.2 Biogeochemical model development and application
FY17 Estimated NMS Cost = \$265,000
Collaborators: SFEI, Deltares, USGS, UC Berkeley

Biogeochemical modeling work for San Francisco Bay has progressed significantly in the first year of the modeling effort. While Year 1 activities focused on building modeling capacity and proof-of-concept studies, Year 2 will shift the focus towards improving model fidelity, evaluating uncertainty, and the addition of phytoplankton.

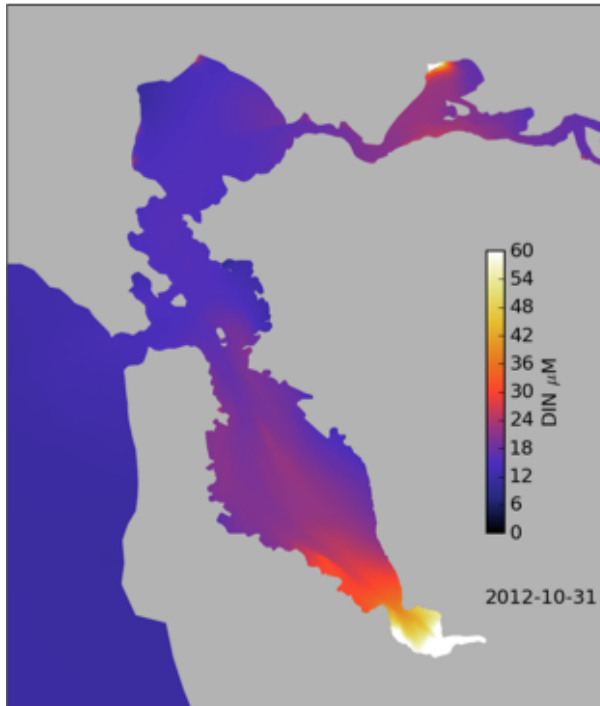
Hydrodynamic data have so far been taken from previously developed SUNTANS models that have fidelity in South Bay but incomplete representations upstream of Carquinez Strait. Long-term modeling needs point to the use of Deltares tools for hydrodynamics, and the status of D-Flow FM (Deltares’ unstructured hydrodynamic model) in San Francisco Bay is likely to reach a mature and usable level during Year 2. The USGS CASCaDE project, in collaboration with Deltares, has developed a hydrodynamic model calibrated for the northern portion of the Bay/Delta system. SFEI will be augmenting that effort in South Bay through in-house model development and collaboration with Deltares and RMA.

The present water quality model includes a minimal set of reaction terms: nitrification, denitrification, an imposed sediment oxygen demand, and reaeration. Year 2 will greatly expand the range of transformations and nutrient forms, as well as introduce phytoplankton into the model. The concomitant increase in tunable parameters will necessitate simplified modeling



Model-observation comparison of DIN, from LSB to Suisun on 2013-02-26, demonstrating good agreement except for LSB phytoplankton drawdown.

to better understand the implications of the many parameterizations. With the increase in model complexity and the incorporation of a newer hydrodynamic platform in FY17 we will put significant effort towards evaluating model skill, both of hydrodynamics and biogeochemistry.



Snapshot (Oct 31 2012) of simulated Bay-wide DIN concentrations. The simulation reproduced the expected longitudinal gradients in DIN, and predicted concentrations are within $\pm 20\%$ of observations. The nutrient cycling model was run atop a high-resolution calibrated hydrodynamic model that included multiple point sources (36 POTWs, 5 refineries, 73 rivers & creeks). Nitrification and denitrification were included in this early simulation. Phytoplankton processes (nutrient uptake, release) and sediment fluxes were not, and will be added to runs in FY17. Given low primary production rates during mid-Fall in SFB, simulating with no phytoplankton may be a reasonable simplification for these early test runs for some seasons

Focus in FY17

- Adding phytoplankton growth and grazing to the South Bay and LSB model, in simplified-domain and fully-resolved model runs.
- Testing the model's ability to reproduce major features in the observational data record, e.g.: seasonal nutrient and chl-a trends; tidal variation at high-frequency moorings; large blooms observed during some years; trend of increasing fall chl-a.
- Integration of Delft Flexible Mesh hydrodynamics with the water quality models, with improved resolution and forcing data for the South Bay portion of the model.
- Initial calibration of the full-Bay water quality and phytoplankton model.
- Evaluating the sensitivity/uncertainty in parameters for the biogeochemical model, including the identification of further highest priority data collection to reduce uncertainty.
- Bay-wide nutrient loads and transport, including tracing loads from individual nutrient inputs, including initial reactive-transport (v.1.0: no phytoplankton; v.1.5: initial phytoplankton)

Deliverables:

- Overview of modeling progress presented in the FY17 Annual Progress report, along with a technical appendix that goes into greater depth on FY17 results.
- Output from 1 year full-Bay simulation of nutrient loads/transport/transformation (v1.0 and v.1.5), including seasonally-varying concentrations and source attribution;
- Comparison of hydrodynamic model skill;

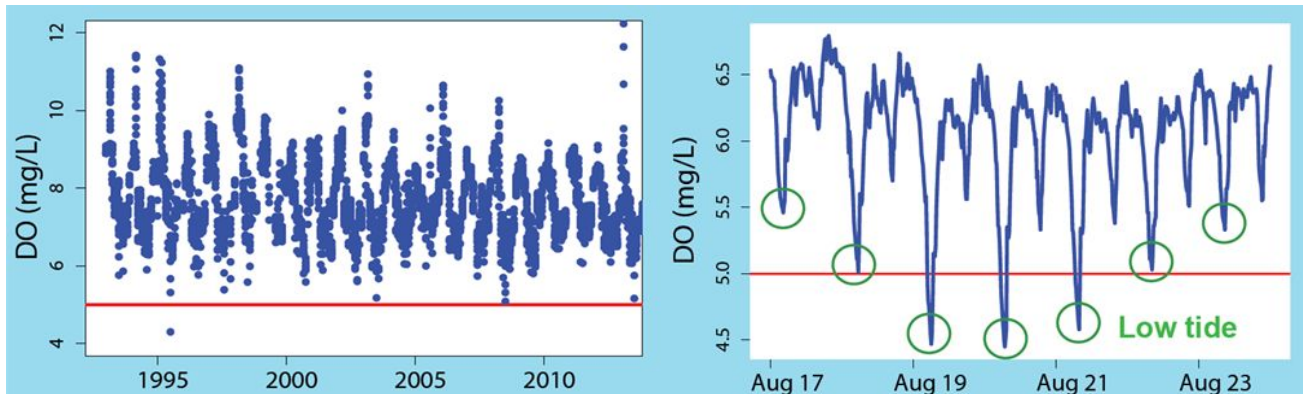
Budget Justification: 0.85 FTE modeler (\$200k; remaining modeler time allocated to other projects below); Deltares, technical assistance and model development (\$50k); regional collaborators and technical advisors (\$50k)

C.3 Open-Bay and slough moored sensors: data analysis/interpretation and maintenance

FY17 Estimated NMS Cost = \$342,000

Collaborators: SFEI, USGS-Sac, UC Berkeley

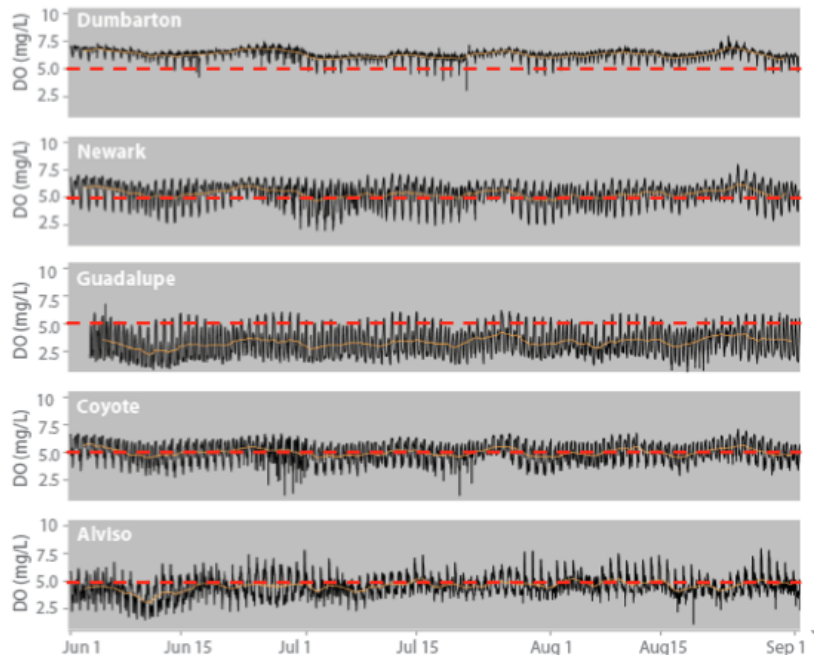
While San Francisco Bay is generally not known to be either eutrophic (primary production > 300 g C m⁻² y⁻¹) or hypoxic (dissolved oxygen < 2 mg L⁻¹), a substantial portion of our knowledge of SFB biogeochemistry comes from a long-term dataset collected in the Bay’s main channel. Over the past ~2 decades, dissolved oxygen rarely dipped below 5 mg L⁻¹ during biweekly to monthly surveys at stations in South and Lower South Bay (below left). More recently, though, high-frequency moored *in situ* sensors at the Dumbarton Bridge have shown that dissolved oxygen concentrations frequently drop to levels not typically observed in the long time series. For example, dissolved oxygen repeatedly dipped near or below 5 mg L⁻¹ in August 2013 during the lower low tide several days in a row (below, right). The DO signal was strongly coupled to the tides at multiple frequencies (semidiurnal: two highs and two lows per day; fortnightly: two spring tides and two neap tides per lunar month), with lowest DO observed around the spring tide on August 20, 2013. Since dissolved oxygen decreases on ebbing tides, we hypothesized that lower dissolved oxygen waters were being advected from margin habitats, including the extensive network of sloughs and creeks in Lower South Bay ([SFEI 2015a](#)).



We began testing this hypothesis in Spring/Summer 2015 by installing a network of moored sensors in margin areas of Lower South Bay, measuring dissolved oxygen and a range of other parameters (e.g., salinity, T, turbidity, chl-a fluorescence). Observations over Summer 2015 confirmed that DO frequently fell below 5 mg L⁻¹ at multiple sites. The data also indicated that condition varied substantially among the sites, and that DO concentration was strongly influenced by the tides. In addition, DO-related condition at individual sites appears prone to large differences between years, based on comparisons of summer 2012 and 2015 data in Alviso Slough ([SFEI 2015a](#)).



Dissolved oxygen concentrations at a subset high-frequency moored sensors sites in Lower South Bay.



FY17 work will focus on the following:

- Complete Year 3 of open bay stations (San Mateo, Dumbarton Bridges) and Alviso Slough.
- Complete Year 1 of slough/creek deployments, and extend through a second summer/fall/winter.
- Data analysis, and quantitative mechanistic interpretations to identify factors contributing to observed conditions.
- Sensor network maintenance.
- Data management and QA/QC.

Deliverables:

- Mid-fiscal year (Dec 2016) update to inform FY18 priorities;
- Summary of major observations in the NMS FY17 Annual Report (e.g., [SFEI 2015b](#)), and technical report(s) included as appendices to the annual report describing:
 - Spatial/temporal variability in LSB/South Bay/open Bay and slough water quality (DO, chl, etc.)
 - Mechanistic interpretations, including physical forcings (including exchange between pond ← → sloughs ← → Bay)
 - Initial inferences related to the potential influence of anthropogenic nutrients on DO conditions at specific sites or in LSB margins more broadly, and the potential role of exchange with salt ponds on DO, phytoplankton biomass, and nutrient budgets in LSB.

Budget Justification: 2 staff (0.8 FTE, 0.65 FTE; \$233,000) for field work, data management, data analysis, interpretation, and report preparation. Field support and additional technical support (including boat, fuel, field technicians; USGS, \$80k); equipment/supplies (\$30k, replacement sensors, maintenance).

C.4 Data Analysis / Synthesis / Technical Project Management
FY17 Estimated NMS Cost = \$99,600
Collaborators: SFEI

The NMS has numerous projects that are generating large amounts of data that need on-going analysis and interpretation, and need to be presented to technical and non-technical audiences in the form of technical documents, progress reports, and graphics for presentations. In addition to analyzing the data, these projects need management at the technical level (i.e., beyond budgets and deliverables), including engaging with collaborators, and fielding requests for data and interacting with stakeholders.

This core funding supports staff effort to carry out these activities.

Deliverables:

- NMS Annual Report
- Contributions to technical reports and technical appendices that accompany the Annual Report
- Data analysis and data visualization for the above reports, and to support public presentations to the NMS SC, NTW, and stakeholders, and at regional conferences

Budget Justification:

0.6 FTE of mid-level scientist. This funding will an important gap with recent changes in staffing.

C.5 and C.6 Science Program Coordination and Program Management
FY17 Estimated NMS Cost = \$259,000 + \$67,000
Collaborators: SFEI

Science Program Coordination accounts for lead scientists effort across all scientific activities of the NMS and for overall Program coordination. The distribution of work is estimated to be 60% hands-on science and/or managing directing projects and 40% program coordination (fundraising, stakeholder engagement, NMS and PS process). Program Management includes project and financial management (\$44,000), honoraria for advisors (\$20k), and travel (\$7.5k)

PROJECTS

P.1 Monitoring Program Development
FY17 Estimated NMS Cost = \$110,000 (Estimated to be a 3 yr Project, cost for Year 1)
Collaborators: USGS, SFEI, UC Berkeley, others

Goals:

- Develop a strawman NMS monitoring program design to address the key data needs for NMS status and trends; assess condition with respect to DO and chl-a; and inform mechanistic interpretations and modeling.
- Test the program's spatial and temporal sampling design through a combination of model simulations and historic data analysis, and develop recommendations for refinements needed to meet monitoring goals
- Work with key stakeholders and partners to identify options for long-term institutional structure, coordination, and funding for a sustained monitoring program

A robust and consistent monitoring program is essential for assessing nutrient-related condition in SFB and evaluating changes in condition over time. The vast majority of our understanding of nutrient cycling and ecosystem response has developed through long-term ship-based monitoring. Ship-based monitoring will continue to be a central component of NMS-related monitoring. Ship-based monitoring will be augmented by moored sensors, and possibly other emerging technologies, in the future.

This multi-year project includes three main components: i. Developing a strawman program design; ii. Quantitatively testing and refining that design to maximize its efficacy and efficiency relative to NMS goals; and iii. Building the institutional framework to manage and sustain the program.

FY17 activities

- Develop a draft/pilot monitoring program design, including: basic components and analytes; estimated requirements for spatial and temporal resolution based on best professional judgement; and cost estimates. Initial work on this activity began in FY16 and will be continued into FY17.
- Solicit and incorporate input from technical advisors and stakeholders on program priorities and design. Electronic review of documents or an in-person meeting.
- Quantitative tests to guide program design and refinement, including:
 - Model simulations to identify the necessary spatial and temporal sampling frequency (e.g., characterize 'events' with sufficient accuracy, e.g., phytoplankton blooms).
 - Analysis of historic and contemporary monitoring program data to inform decisions about the utility of certain analytes, ability to detect trends over time, etc.
- Meet with national and state agencies to identify opportunities for sustained management and funding of the monitoring program.

Deliverables:

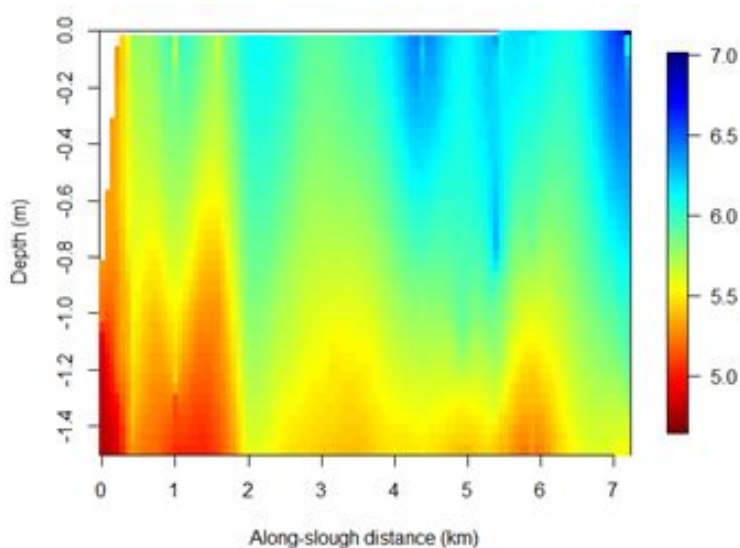
- A high-level description of monitoring program design (~5 page) and estimated costs that can be used for fundraising purposes and institutional planning (Fall 2016)
- Progress report (May 2017) describing results from modeling and data analysis, and proposed refinements to program design.
- An “institutional program building” work plan (December 2016), and progress report on year 1 steps implementing the work plan (May 2017).

Budget Justification: 0.3 FTE staff time for data analysis of model output (biogeochemist, statistician: \$90k; modeling covered under C.2); external experts/collaborators (\$20k honoraria plus travel); Developing sustained monitoring program institutional framework (\$25k staff, \$15k external advisor/facilitator)

P.2 Characterizing DO spatial (vertical, longitudinal) variability in LSB sloughs/creeks
FY17 Estimated NMS Cost = \$91,640
Collaborators: SFEI, USGS

Goals:

- Characterize how dissolved oxygen concentrations vary spatially (x, y, z) and temporally in sloughs and creeks of Lower South Bay
- Develop improved understanding of DO-related habitat condition and improved mechanistic interpretations of factors contributing to periodic low DO at slough and creek sites.



In addition to the x/y (or latitudinal/longitudinal) variability described in C.3 Moored Sensors, evidence from field work in 2014 and 2015 found that intense vertical gradients could also develop in water quality. For example, profiles of dissolved oxygen roughly every 500 m along Alviso Slough show that DO can vary vertically by > 1 mg L⁻¹ m⁻¹. See figure above illustrating profile data from September 2015 (DO in mg L⁻¹); dissolved oxygen ranges from < 5 mg L⁻¹ in the upstream portion of the slough toward the bottom to just over 5 mg L⁻¹ near the downstream (open bay side) surface. All data shown here were collected in ~ 45 minutes, representing as close as possible to a snapshot of Alviso Slough.

Accurate information about slough DO, and the factors leading to lower DO, are essential for

- Characterizing habitat condition - Does the entire water column experience low DO or just a bottom slice?
- Developing mechanistic interpretations, - e.g., Is physical stratification or intense sediment oxygen demand the primary driver of vertical variability?
- Accurately predicting condition under future scenarios, including management scenarios.

In FY17, we propose to measure dissolved oxygen at multiple depths in the vicinity of mooring sites, and at multiple locations along the longitudinal axis of sloughs and creeks and in the open Bay under a range of tidal stages and phases to obtain better-resolved estimates of DO concentrations in space (x, y, z) and time.

FY17 activities will include:

- Add sets of DO and conductivity sensors (e.g., 3 depths) at 2 stations along slough channels to collect data on vertical and longitudinal variability in DO concentrations at high frequency (e.g., 15 min intervals, similar to other sensors being used). Deploy these sensors for 2-4 week periods within 2-3 sloughs over Summer 2016 to study along-slough and inter-slough differences.
- Conduct several along-slough and along-creek surveys, measuring vertical profiles (lower a CTD + DO and other parameters) at multiple stations, at a range of tidal stage (high, average, low) and phase (spring, neap).
- If possible (time and budget) collect velocity data during the along slough surveys, to inform data interpretation (turbulent mixing energy that can break down stratification, model calibration). Control volume experiments will be set up such that we know a cross-slough surface's biogeochemistry at upstream and downstream locations and have velocity measurements as well. Any change from upstream to downstream on an ebb or vice versa on a flood will have been generated in the volume between upstream and downstream control surfaces.

Deliverables: Analysis of this data will be incorporated into the technical report described in C.3, and data will be summarized in the FY17 annual report.

Budget Justification: study design and field work (0.2 FTE biogeochemist, \$33k; 0.2 FTE field support); field work (technician, boat, etc., \$20k), and equipment (DO sensor array; conductivity sensors, \$15k).

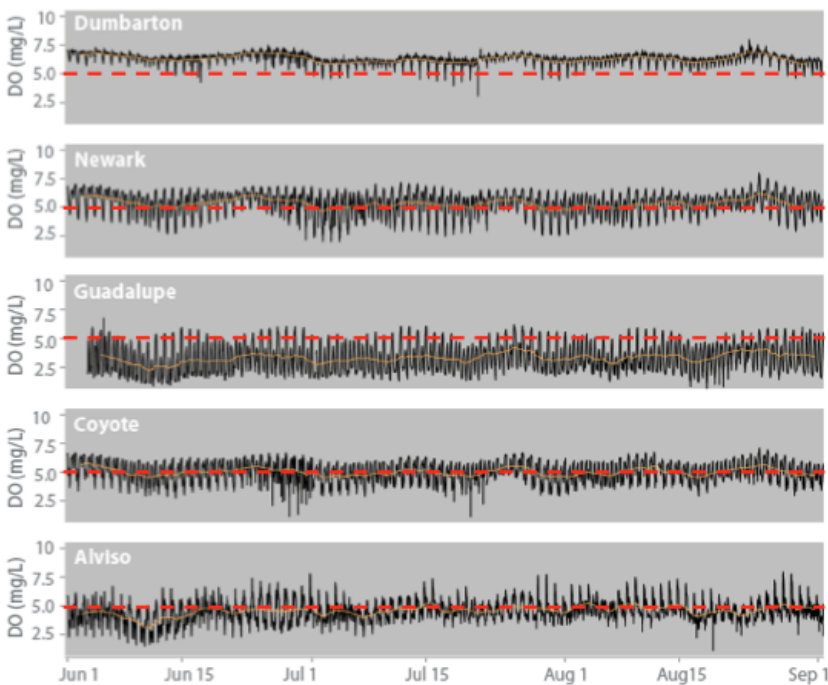
P.3 Characterizing DO-related habitat quality in LSB sloughs and open Bay

FY17 Estimated NMS Cost = \$140,000 (Year 1 cost of a multi-year project)

Collaborators: SFEI, SCCWRP, expert advisors

Goal:

- Develop and begin implementing a work plan that will build the NMS' scientific basis for assessing DO-related habitat quality in sloughs, creeks, and open areas of SFB, with an initial focus on Lower South Bay.



The San Francisco Bay Basin Plan established dissolved oxygen criteria of 5 mg/L and a 3-month median of 80% saturation in all tidal regions. Historical monthly sampling in the SFB's deep channel indicates that conditions are generally well above this threshold (see C.3). However high-frequency data collected over the past few years in sloughs and some open-Bay areas of Lower South Bay indicate that that DO frequently falls below the basin plan standard of 5 mg/L (see left). In some cases, these departures below 5 mg/L are modest ($DO > 4.5$ mg/L), infrequent, and/or short-lived (minutes to a couple hours). In other cases, concentrations commonly reach 2-3 mg/L for several hours per day.

Although the Basin Plan's DO guidance is specific in its numeric threshold, it does not provide further guidance with regard to frequency, duration, or magnitude of excursions below 5 mg L⁻¹. As noted in C.3 and P.2, large uncertainties remain about DO spatiotemporal patterns, and about the relative importance of naturally-occurring low DO versus the effects of anthropogenic nutrients, which those projects aim to address. Beyond those questions, there has been very little work in SFB related to identifying organisms utilizing these habitats and DO conditions that would be considered protective.

This project will develop a multi-year work plan, and begin implementing Year 1 activities, for address the following questions:

1. What are the key biota (e.g., fish, benthic invertebrates, microbial community) or ecosystem functions requiring protection related to DO excursions?
2. What is the severity, extent (space), duration, and frequency of low DO in this region?

3. What is known about how biota and ecosystem functions will these DO conditions?
4. Based on 2-3 above, what are acceptable conditions for SF Bay habitats?

The first activity of this project is to identify and convene an expert panel to develop and begin implementing a work plan. Expertise on the panel should include: the ecology of SF Bay fishes and benthos; fish physiology, in particular with respect to DO; microbial ecology; and the development of DO-related habitat criteria in estuarine systems. The work plan will also receive input from stakeholders, regulators, and the NMS Steering Committee. We expect the work plan will call for the some or all of following activities, some of which will be undertaken in FY2017, and others that will be pursued in subsequent years.

1. Background technical report and conceptual model:
 - a. Description of LSB habitat characteristics, and qualitative review of fish and benthos community data from LSB habitats, including historical accounts;
 - b. State of the science related to aquatic biota DO requirements, including: physiological and behavioral factors that determine organisms' DO requirements; acute and chronic effects of low DO at both the individual and population levels; and existing data on DO requirements for individual taxa noted in 1a or relevant surrogate species;
 - c. Conceptual model of LSB habitat utilization by fish and benthos, and the role played by the microbial community in shaping ecosystem services;
 - d. Priority data gaps.
2. Quantitative analysis of existing biota survey data to characterize community structure and changes in structure over time (e.g., DFW, mid-1980s to present, monthly South Bay Dischargers Authority 1980s; recent LSB fish surveys; USGS benthos surveys).
3. Based on 1 and 2, develop a plan for monitoring and addressing data gaps
 - a. Ambient DO conditions: spatial and temporal resolution of data collection to appropriately characterize habitat.
 - b. Biota surveys: approach for surveying fish, benthos, and microbial communities based on the concepts and data in 1-2.
 - c. Special studies or controlled experiments to address priority data gaps.
4. DO reference site margin/slough identification: conceptual model, approach for identifying reference site for DO condition (i.e., 'natural') in margin/slough habitats, and initial identification of potential sites.

Deliverables: Year 1 progress report or technical report at the conclusion of FY 2017.

Budget Justification: 0.5 FTE staff time for leading workgroup, writing work plan, and undertaking initial work (biogeochemist; \$90k); Technical advisory team, including expertise in: DO-related fish physiology and the ecology local fish populations (\$35k, honoraria and travel); Technical collaborator (M Sutula, SCCWRP, \$30k).

P.4 Algal toxin monitoring in bivalves from Central, South, and Lower South Bay.

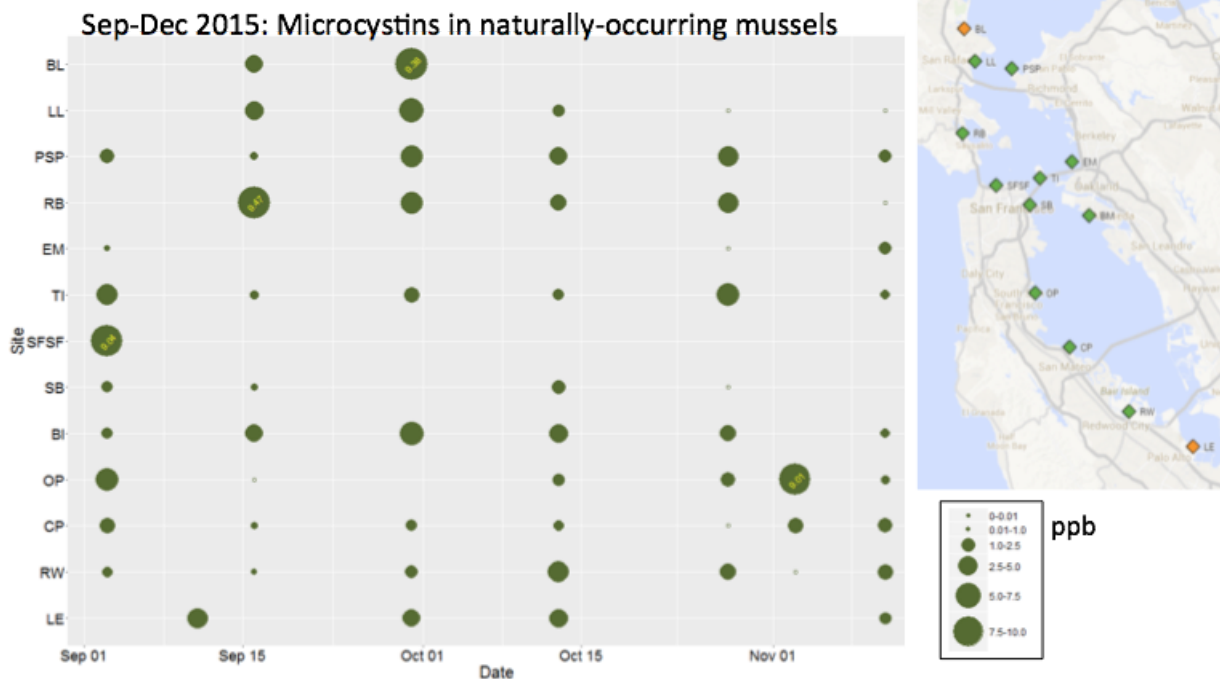
FY17 Estimated NMS Cost = \$77,000

Collaborators: SFEI, UCSC

Goals:

- Quantify toxin concentrations entering biota in Central, South, and Lower South Bay through measurements in naturally occurring mussels.
- Collect samples with sufficient frequency that concentrations in mussels serve as semi-quantitative bioindicators of ambient toxin concentrations in the water column as a function of space and time, to address monitoring goals and inform mechanistic understanding of where and under what conditions toxins are being produced.

In September 2015 the NMS launched a pilot study to measure toxin concentrations in naturally-occurring mussels (see microcystins below, and domoic acid under project P.4). Mussels can serve as valuable time-integrating measures of toxin levels that are entering aquatic biota. Because toxins enter mussels through the process of them actively pumping and assimilating material from the surrounding water, mussels also have the potential to serve as semi-quantitative bioindicators of ambient toxin concentrations. However, toxin concentrations in mussel tissue can respond quickly to changes in ambient toxins concentrations, because mussels excrete some toxins at fast rates (e.g., excretion half-life is on the order of days for domoic acid). Thus, mussels need to be sampled at high enough frequency in order for them to provide sufficiently-precise data that about changes in ambient condition over time.



Over the past 9 months, the sampling of naturally-occurring mussels every ~2 weeks from floating docks around the Bay has proven to be an efficient and cost-effective approach to

monitoring ambient condition with respect to toxins over approximately 60% of San Francisco Bay (salinity tolerance generally limits these mussels to Central, South and Lower South Bays, as well as along the coast). Collecting samples from the 10-15 stations can be accomplished by just one person, traveling by car and accessing from land, with just 1-2 days of effort.

FY17 activities

- Continue collecting naturally occurring mussels from 10-15 stations on a biweekly basis, depending on season. Collections will be timed relative to spring-neap, and possibly collecting samples weekly at one site..
- Analyze mussels for domoic acid, microcystin, saxitoxin, and potentially other toxins.
- The following may be carried out, depending on time and budget: controlled experiments to estimate depuration rates of native mussels under varying conditions (e.g., temperature, salinity), which will allow water column concentrations to be more accurately back-calculated; deployment of “standard” mussel-watch mussel species or passive samples alongside native mussels, for comparison between techniques.
- Data analysis and interpretation.



Deliverables: Data will be incorporated into the FY17 annual report. A more detailed technical report will also be prepared (May 2017), reporting on ~18 months of data.

Budget Justification: 0.35 FTE staff time (\$42k); sample analysis (\$15k); sampling/travel (\$5k); technical support from collaborator(s) (\$15k).

P.5 Implications of current HAB toxin levels in SFB: expert workshop and white paper

FY17 Estimated NMS Cost = \$63,000

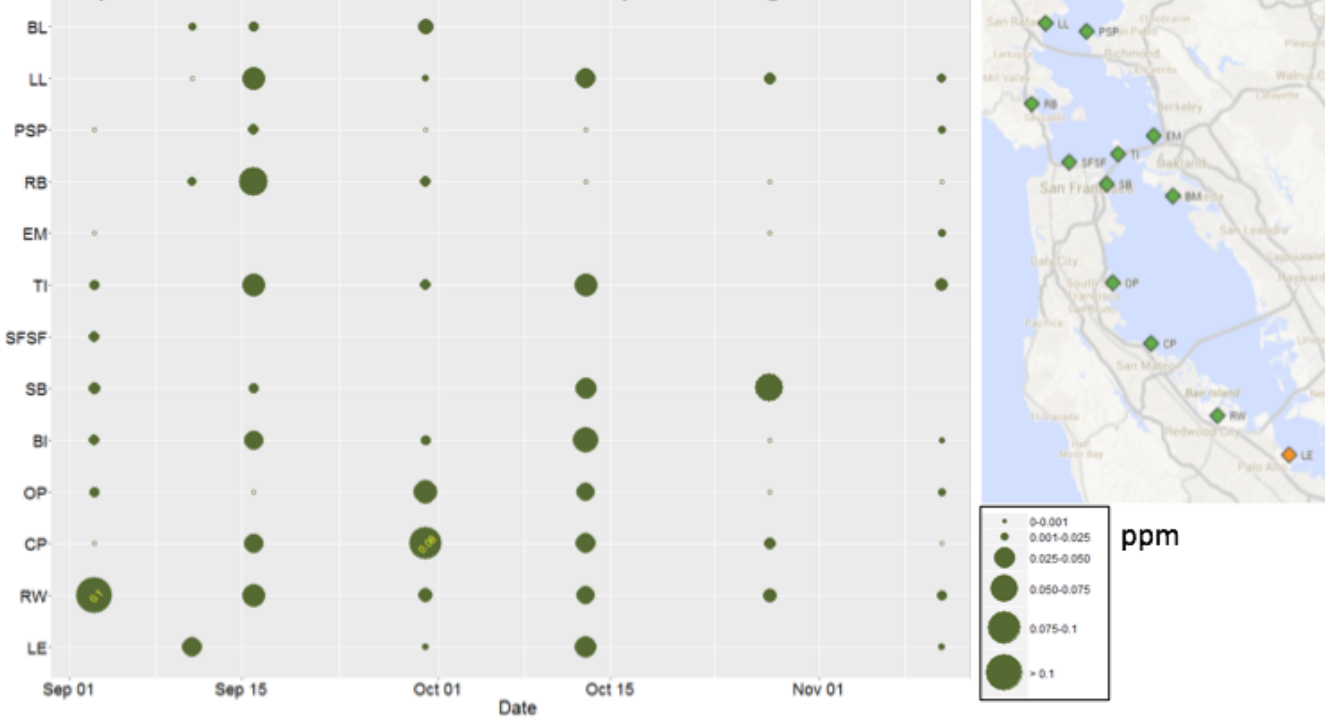
Collaborators: SFEI, UCSC, USGS, SCCWRP, expert advisors

Goals:

- Obtain expert input on interpreting HAB toxins detected in the water column and biota of San Francisco Bay in terms of risks for ecological health and human health
- Identify follow-up studies that should be conducted to further inform understanding of toxin occurrences, potential impacts, and causal factors

NMS-supported studies conducted over the past two years have found that multiple toxins produced by HAB-forming phytoplankton are regularly found in the water column of SFB and are incorporated into primary consumers such as bivalves. Toxins detected in biota include: domoic acid (DA; amnesic shellfish poisoning); microcystin (MCY; a hepatotoxin); saxitoxin (SAX; paralytic shellfish poisoning), and okadaic acid (OKA). To date, most of our toxin-analysis effort has been directed toward measuring DA and MCY. DA, the toxin that

Sep-Dec 2015: Domoic Acid in naturally-occurring mussels



impacted wildlife and closed fisheries along the Pacific coast in 2015, is commonly detected in SFB bivalves (above), but at concentrations well below those considered acutely toxic to humans consuming shellfish (20 ppm). Nonetheless, we know little about the potential effects of

chronic exposure of aquatic biota to DA at these levels. MCY, which is thought to be produced primarily by freshwater cyanobacteria, was also widely detected in SFB bivalves, but at concentrations closer to OEHHA action levels for human consumption (10 ppb), which also coincide with concentrations that have been found to exert chronic and acute toxic effects on marine biota (OEHHA, 2009). Analyses have been less systematically performed for SAX, but SAX has nonetheless toxins been detected with some regularity at low levels in bivalve samples. OKA, tested in a few samples to date, has also been detected.

In FY17, we will convene a workshop to obtain expert input on the state of science on effects of chronic exposure of marine biota to algal toxins, with a particular focus on observed concentrations in SFB biota, and potential effect of simultaneous exposure to multiple toxins.

Deliverables

- Workshop goals and structure, and proposed list of experts
- Convene workshop, and workshop summary
- Technical report, including literature review, main findings from workshop, data gaps, and recommended next steps.

Budget Justification: Support for 4 expert participants, including chair/report senior author (\$27k); SFEI staff coordinating the workshop, literature review, and technical report writing (0.2 FTE; \$31k); travel, meeting costs (\$5k).

P.6 Develop and begin implementing a NMS data management plan
FY17 Estimated NMS Cost = \$72,000
Collaborators: SFEI, possibly USGS

The NMS program’s activities are collecting and generating large amounts of data and new data types, including: relatively new discrete sample analytes (C.1, P.5); high frequency *in situ* water quality data (C.3, P.2); and amounts of model input/output. This project will develop and begin implementing a data management plan, with particular focus on: protocols for semi-automated QA/QC of high frequency data; efficient maintenance; searchability and accessibility to collaborators, stakeholders, and the external science community; and, in general, compatibility with other well-established data management protocols, including those of the Bay RMP. Data management is expected to become a more resource-intensive component of the core program in the future. The proposed FY17 activities identified here are intended to launch this effort in an efficient and sustainable direction, but not fully complete the accumulated data management needs.

Deliverables:

- Data management plan
- Database with appropriate structure for current and anticipated future needs
- Initial protocol testing and beginning to migrate data into the new database.

Budget justification: Database/data management staff (0.15 FTE) for designing data management plan and database structure, and biogeochemist/scientist (0.3 FTE) for both designing and implementing the plan.

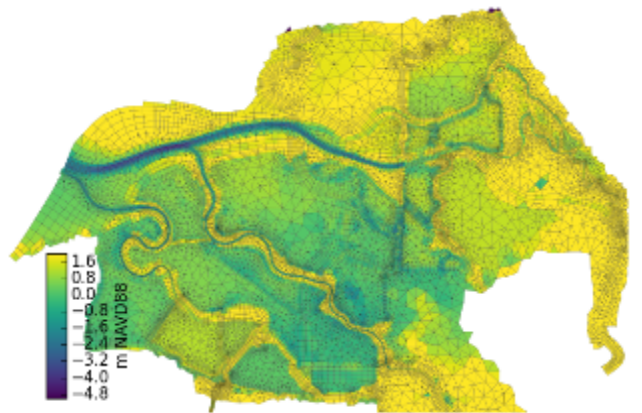
P.7 Modeling linkages between Open-Bay, Sloughs and Salt Ponds

FY17 Estimated NMS Cost = \$98,000 (FY17 cost)

This is a 2-yr project, with the FY17 cost estimate assuming work is distributed over a 2 yr period (FY17-18).

Collaborators: SFEI, USGS, and other collaborators

This project will extend development of the biogeochemical model into small-scale sloughs and ponds in the margins of Lower South Bay. This effort will complement Task C.2 (Biogeochemical model development and application), which focuses on development in the open bay but does not include explicit modeling of slough and salt pond connections and associated biogeochemistry.



Grid and bathymetry from a hydrodynamic / sediment model developed for Coyote-Aliviso-Guadalupe region, which would likely serve as a starting point for development of a LSB pond-slough model. Source: M. van der Wegen, F. Achete, and B. Jaffe

The margins of LSB represent the entry point for a large portion of the nutrient loads into South Bay. Observational data in LSB demonstrates the ubiquity of strong spatial gradients in water quality parameters and large temporal variability. In addition, observations bracketing changes in pond operations illustrate the significance of pond-slough connections (e.g., large spikes in chl-a when gates are opened). While the net effect of these interactions is difficult to quantify from observations alone, high-frequency data at the Dumbarton Bridge - which could be considered an ‘integrated signal’ of LSB processes - suggest that exchange with margin habitats substantially affects open-Bay water quality, especially during spring tides when net exchange is greatest. Extending the biogeochemical model into these areas will provide a powerful, and necessary, approach for synthesizing observations, and understanding local nutrient transformation processes.

Here we propose to augment the NMS biogeochemical modeling effort (C.2) by simulating exchange between open Bay ↔ sloughs/marshes ↔ salt ponds, and explore how these exchanges and salt pond operations influence water quality in the Bay. The model will also allow us to quantify the degree to which sloughs, marshes and salt ponds act as efficient nutrient sinks.

FY17 activities include:

- Extend and adapt existing hydrodynamic model grids in LSB, and evaluate the skill of the resulting hydrodynamic model
- Adapt the full bay biogeochemical model to the LSB margins, drawing on rate parameters from prior studies in the salt ponds.
- Quantify the influence of salt ponds-Bay exchange on water quality in each system

Deliverables: Year 1 progress report (June 2017); Final report (June 2018).

Budget Justification: 1 FTE modeler (\$165k/yr), distributed over 2 years; External collaborators / technical experts (\$30,000).

P.8 Risk-based framework: quantitatively exploring plausible future scenarios for ecosystem response

FY17 Estimated NMS Cost = \$98,000/yr

This estimate assumes work is distributed over a 2 yr period (FY17-18). Depending the results of this project, this line of inquiry is likely a multi-year undertaking, with additional funding needed beyond this initial effort to complete the effort.

Collaborators: SFEI, UC Berkeley, UCSC, USGS, other collaborators

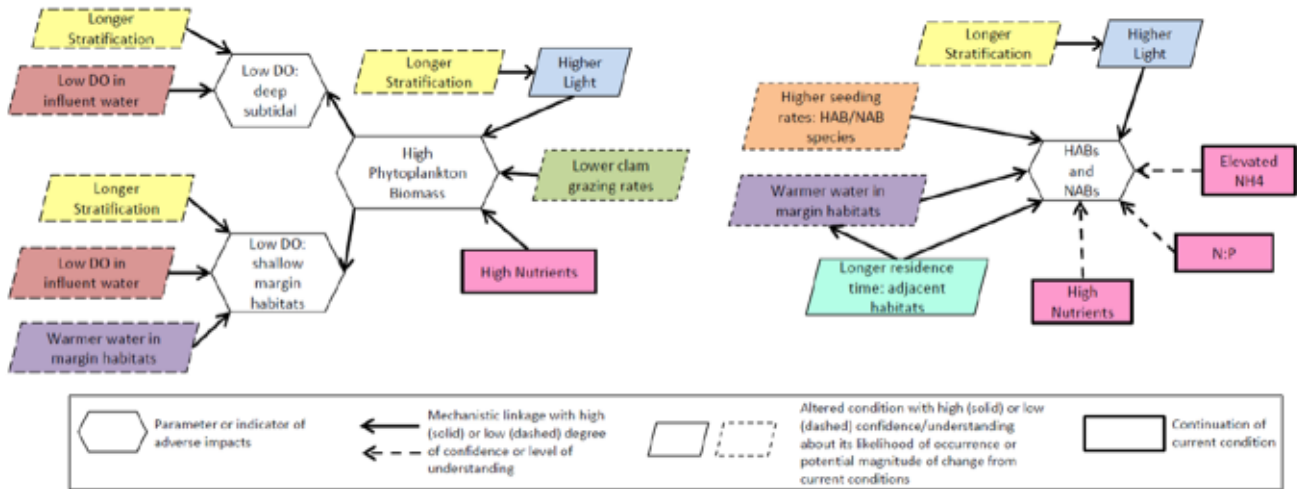
Goals:

- Identify a set of future scenarios under which Bay condition should be explored in a risk-based framework.
- Evaluate the likelihood of occurrence of these scenarios and the corresponding effects on water quality.
- Based on the above work, identify a subset of future scenarios that need to be considered alongside current conditions to inform nutrient management decisions.

Although nitrogen and phosphorous concentrations in SFB are elevated relative to those in many other US estuaries, those levels were thought to pose little ecological-health risk in SFB because of physical and biological factors that limit nutrient conversion into phytoplankton biomass (SFBRWQCB, 1975; others). However, multiple recent studies have documented how physical and biological drivers of ecosystem response have changed over the past ~20 years (Cloern et al., 2007, 2010; Schoellhamer 2011), leading some areas of the Bay to exhibit greater sensitivity, or responsiveness, to ambient nutrient concentrations, as evidenced by increasing chl-a concentrations in South Bay (Cloern et al., 2007) and other subembayments. Climate change predictions suggest that additional changes are ahead (Cloern et al., 2011). The magnitudes and combined influence of those changes on ecosystem responses to nutrients have not been quantitatively explored. In addition, the 2015 harmful algal bloom along the entire US west coast served as a stark reminder that “atypical” conditions, or events, can have widespread, unforeseen impacts and that nutrient-related responses may need to be evaluated in a risk-based framework.

Since any large-scale nutrient management actions in SFB will take years to decades to implement, NMS guidance documents call for exploring ecosystem response under both current conditions and plausible future conditions (Strategy document; NMS Science Plan; NMS Conceptual Model). Although characterizing likelihood, or risk of occurrence, of future scenarios and SFB response under these future scenarios is of paramount importance, so far the vast majority of NMS work has been focused on current conditions.

In this project, we will develop a risk-based framework for evaluating nutrient-related effects in SFB, and begin the work of quantitatively examining these scenarios within this framework. Future scenarios for detailed exploration will be identified and prioritized through input from experts and stakeholders. Scenarios will be explored through a combination of hydrodynamic and water quality models.



Physical, chemical, and biological drivers, and changes in those drivers, that could influence phytoplankton biomass or the occurrence of HABs or NABs. SFEI 2014

The major modeling phases of the project are:

- Simulate the physical response to changes in external forcings such as solar insolation, wind, precipitation and freshwater inputs, sea level rise, climate oscillations (e.g., NPDO), and suspended sediment concentrations in the water column. These simulations would quantify the range of future physical conditions within the Bay, in terms of parameters such as vertical mixing, duration and spatial extent of stratification, light levels, and temperature. This phase of the modeling would primarily use resolved, fully mechanistic models. To the extent possible these models will be validated against present-day conditions.
- Based on knowledge of the range of future conditions gleaned from the previous step, simplified biogeochemical models will be used to explore the corresponding ecosystem response in terms of phytoplankton and DO. At later stages of the project, HAB risk under future scenarios will also be examined.
- Additional biogeochemical simulations will quantify phytoplankton and DO responses to scenarios involving changes in nutrient loads and grazer population. Both load increases and decreases will be examined (e.g., Testa et al., 2014), driven by present-day physics and a subset of future-forcing scenarios

FY17 activities include:

- Work with stakeholders, regulators and collaborators to identify plausible forcing scenarios to consider
- Develop resolved and simplified simulations of the Bay to evaluate how those forcing scenarios affect the physical conditions within the Bay
- Employ simplified biogeochemical models to evaluate ecosystem response to the altered physical conditions

Deliverables: Year 1 progress report (June 2017); Final report (June 2018).

Budget Justification: 1 FTE modeler (\$165k/yr), distributed over 2 years; External collaborators / technical experts (\$30,000). NOTE:

P.9 Suisun Bay biogeochemical modeling: model development and application
FY17 Estimated NMS Cost = \$98,000 (FY17 cost) This is a 2-yr project, with the FY17 cost estimate assuming work is distributed over a 2 yr period (FY17-18).
Collaborators: SFEI, multiple collaborators

Goals:

- Develop, calibrate, and validate a coupled hydrodynamic and biogeochemical model for Suisun Bay and the western Delta, including nutrient cycling, phytoplankton growth, and benthic grazing, that serve as the foundation for subsequent work
- Apply the model to examine nutrient sources to Suisun Bay, accounting for upstream loads and transformations in the Delta, and quantify assimilative capacity of Suisun Bay and the Delta for nutrients.
- Conduct initial simulations of future scenarios under changing nitrogen speciation and total nitrogen loads, and how those changes influence predicted ambient nutrient concentrations and phytoplankton growth.

NMS modeling efforts in FY16, and the bulk of work continuing into FY17, are focusing on South Bay applications. Refining the model for applications in Suisun Bay is a high-priority task ([NMS FY16 work plan; Dec 2015](#)), with immediate and long-term benefits to the region, and would ideally be moving ahead in parallel with South Bay work. However, at current funding levels for core modeling work, a major push on Suisun Bay model refinement will not begin until FY18 or later. A coupled hydrodynamic-biogeochemical of major importance for numerous efforts in the northern Estuary. A 2009 CALFED-funded report stated that “the most important gap to be filled in the Bay-Delta research program is the development of an overarching, integrative model of the major drivers controlling the Bay-Delta ecosystem” ([Meyer et al 2009](#)). However, to date, little concerted effort has been directed to the development and application of such models.

With this project, we propose to launch a Suisun Bay and Delta focused component to the NMS biogeochemical modeling effort in FY17/FY18. Model development will make extensive use of the existing CASCaDE hydrodynamic model (USGS), which uses the same model platform as the NMS effort (Deltares suite of models) and has been partially supported by NMS funds. USGS researchers have invested extensively effort into the hydrodynamic calibration for Suisun Bay and the Delta, and CASCaDE model has been calibrated for salinity and temperature for the year 2010. Benthic grazers have also been integrated into the model, using data from DWR’s extensive benthos surveys in Suisun Bay and the Delta. The CASCaDE project, however, is not modeling nutrient loads and cycling. Thus we will build upon the CASCaDE model by including a broader set of freshwater and wastewater sources and their accompanying

nutrient loads, and focusing primarily on nutrient loads and transformations, phytoplankton growth testing, and application of a biogeochemical model.

FY17/FY18 activities include:

- Refine and calibrate the base NMS hydrodynamic model for the northern estuary, drawing largely from the CASCaDE hydrodynamic model.
- Establish a preliminary calibration of the water quality model for nutrient transformations and phytoplankton biomass, including areas of the Delta to ensure accurate estimates of nutrient loads from the Delta to Suisun Bay.
- Use model results for source attribution estimates and to quantify nutrient assimilative capacity of the Delta and Suisun.
- Sensitivity analysis to inform future data collection.
- Initial simulation of future scenarios, including anticipated changes in nitrogen speciation and total nitrogen loads.
- Depending on time and budget, we will also begin work on intermodel comparisons, comparing output from the Deltares biogeochemical model with other biogeochemical models (e.g., RCA, CoSINE), and possibly also use other hydrodynamic model output with the Deltares water quality model (e.g., SCHISM).

Deliverables: Year 1 progress report (June 2017); semiannual progress meetings with stakeholders; Final report (June 2018).

Budget Justification: 1 FTE modeler (\$165k/yr), distributed over 2 years; External collaborators / technical experts (\$30,000).

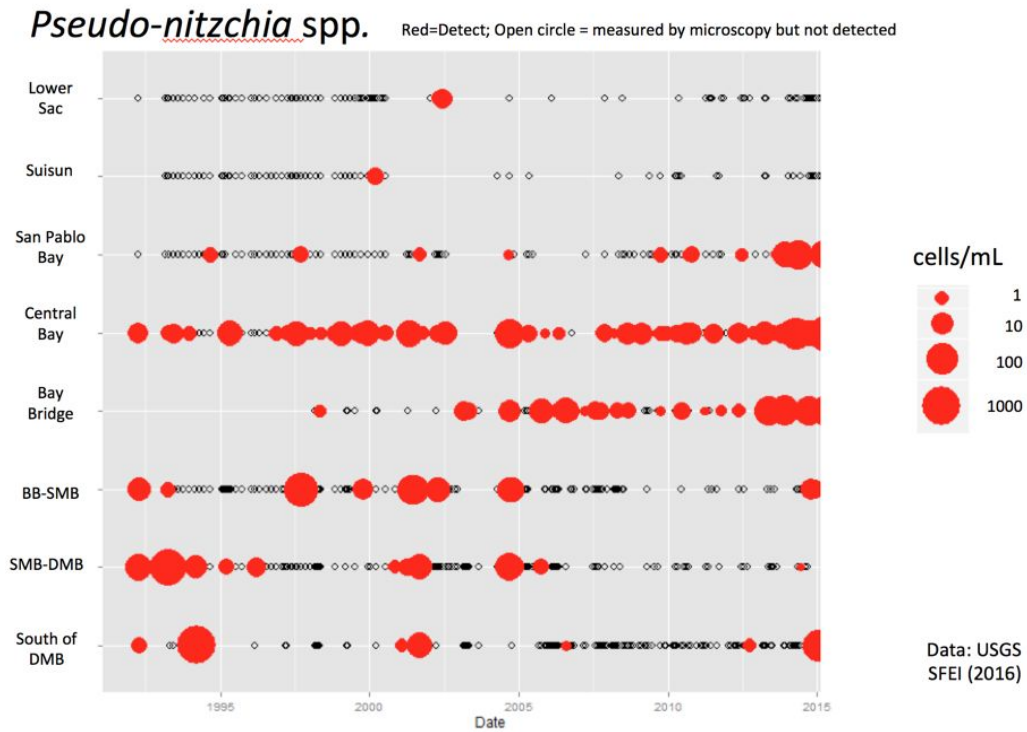
P.10 Mechanistic Harmful algae bloom investigation
FY17 Estimated NMS Cost = \$175,000 (Year 1 of a multi year study)
Collaborators: SFEI, UCSC, USGS

Goals:

- Continue building the NMS program’s capacity to reliably and efficiently monitor for phytoplankton assemblage and HAB-organisms specifically
- Develop improved understanding of the source(s) of HAB-forming organisms and toxins in SFB
- Through a combination of observational data or experiments, characterize the growth requirements and toxin production of priority HAB-forming organisms, and identify conditions that have inhibited large-scale blooms from developing in SFB

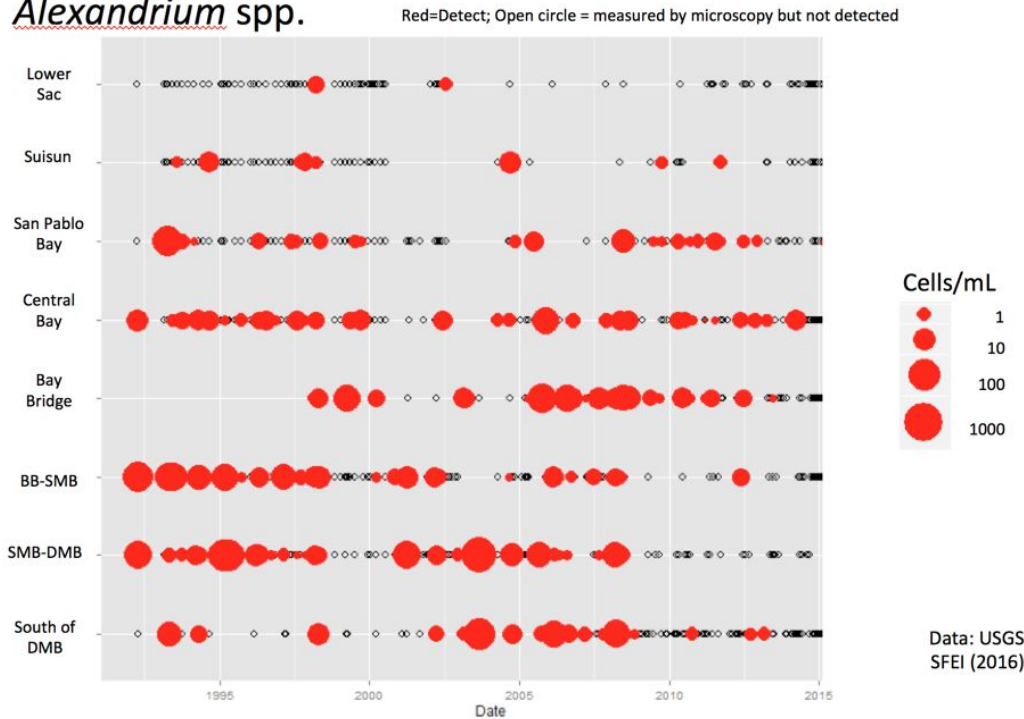
The record-setting and long-lived toxic algae bloom (*Pseudo-nitzschia spp.*; *P-N*) along the US west coast in Spring/Summer 2016 clearly illustrated the severe impacts of harmful algal blooms (HABs). It also illustrated how the factors that lead to HABs developing and persisting are complex and difficult to predict, and that they occur episodically. The fact that a major *P-N* bloom did not occur in the Bay in 2015 is noteworthy, given that: the coastal event created the opportunity for a sustained source of *P-N* cells to the Gulf of Farallones and SFB; Central and South Bay conditions (T, nutrients, salinity) are generally considered quite favorable for *P-N* (Cochlan et al., 2008); *P-N* are commonly detected in San Francisco Bay, as is the toxin they produce, domoic acid, albeit at lower concentrations than they were along the coast in 2015. In

addition, other harmful algae and their toxins (e.g., *Alexandrium spp.*, and saxitoxin) are also commonly detected in the Bay. For both *Pseudo-nitzschia spp.* and *Alexandrium spp.*, there is



limited information about factors that would stimulate rapid (or slow) growth and high (or low) toxin production. This type of information is essential for assessing the risk of major HAB events occurring, both now and under future conditions.

Alexandrium spp.



The possible focus in FY17 for this project has been discussed extensively with advisors and collaborators. The exact activities for FY17 will be identified and work plans developed once the project concept has been provisionally authorized by the NMS SC and funding has been secured. Projects under consideration for FY17 activities are described below.

A. Lab and field testing of the Imaging Flow CytoBot (IFCB) to help ensure near-term field-readiness for ship-based sampling.

- The IFCB is an automated flow cytometer and image-capture instrument for counting phytoplankton down to the species level, estimating biovolume, and characterizing phytoplankton community composition. Through a joint proposal funded by NOAA (UCSC, SFEI, USGS; PI: Kudela, UCSC), two IFCB's have been purchased for application in phytoplankton related studies in SFB, including the ship-based monitoring with USGS and at a mooring site. One instrument recently arrived at UCSC.
- Although the instrument has been successfully used in other estuaries, substantial effort needs to be directed toward testing the IFCB in SFB's high suspended sediment concentrations; training its image recognition algorithms for the SFB phytoplankton community; developing field and QA/QC protocols; and data interpretation.
- Funding would be used to support a postdoctoral researcher working jointly between UCSC, USGS, and SFEI, focused on
 - IFCB application in SFB
 - Testing and validating IFCB results, including by comparing IFCB results with those from other techniques, including: microscopy, pigments/CHEMTAX; and molecular techniques (e.g., qPCR)
- **NOTE:** UCSC has base funding to support a postdoctoral researcher through the NOAA grant. NMS funds could be used to augment NOAA funding and bring on additional (temporary) expert staff to speed the lab-to-field transition; support additional analyses

(microscopy, molecular techniques); or support one or more of the complementary studies below.

B. Conduct basic “grow-out” experiments in San Francisco Bay water to assess the extent of *Pseudo-nitzchia* and *Alexandrium* growth under *in situ* conditions.

- During regular USGS cruises, collect water from a subset of stations where these organisms have been most commonly detected
- Return samples to the laboratory, and measure $t = 0$ abundances of *Pseudo-nitzchia* and *Alexandrium* using the IFCB
- Incubate samples at *in situ* temperatures and light levels for 24-72 hours. Reanalyze samples using IFCB to determine whether counts increase, stay the same or decrease.
- For a subset of samples, also use molecular techniques (e.g. Amplicon sequencing) to test for *Pseudo-nitzchia* and *Alexandrium*, along with a broad semi-quantitative scan of entire eukaryote community (18s) and cyanobacterial (16s) communities. Compare results from molecular techniques with IFCB to determine
- Both the IFCB and Amplicon sequencing can also detect and quantify zooplankton, especially microzooplankton. Therefore, if already being conducted for phytoplankton, this combination of techniques could be used as a cost-effective approach to characterizing the zooplankton community (potentially important grazers on phytoplankton) in regions of the Bay where no zooplankton monitoring is occurring. On a subset of samples, microzooplankton grazing rates could also be measured to
- In addition to this serving a relatively low-cost / low-effort initial test of growth potential of *Pseudo-nitzchia* and *Alexandrium*, this work will contribute to testing of the IFCB and training its image recognition software.

C. Determine whether SFB harbors and supports internal sources of *Alexandrium* in the form of cysts in sediments.

- *Alexandrium* forms resting stages, or cysts, that can survive for long periods in sediments. In addition, *Alexandrium* occurs as both toxigenic and non-toxigenic strains.
- Collect surface sediment grab samples from a predetermined set of locations in Lower South and South Bay, and extract DNA.
- Test for and quantify gene copies of *Alexandrium* at the genus level (all strains, all species) using qPCR.
- In positive samples, use additional molecular techniques (e.g. Amplicon sequencing) to distinguish between toxigenic and nontoxigenic strains. If warranted, use additional techniques to explore whether there is significant variability in strains as a function of space, and in particular along a S-N transect, which may suggest the presence of distinct populations inside the Bay relative to the coast.
- Time and budget permitting, incubate *Alexandrium*-positive sediment samples under a range of conditions (temperature, light, nutrients) and identify factors that contribute to *Alexandrium* migrating from the sediments to the overlying water. Measure *Alexandrium* in overlying water using IFCB

D. Identify the species, and possibly strains, of *Pseudo-nitzchia*, *Alexandrium*, and possibly other HAB-forming organisms (*Karlodinium*, *Dinophysis*, etc.) that occur in SFB

- During routine monthly cruises, collect additional samples for analysis by molecular techniques for detecting these organisms down to species, and possibly strain, level.
- Test for toxigenic and non-toxigenic strains (for *Alexandrium*; probes not available for *Pseudo-nitzschia*)
- Determine if strains differ consistently as a function of space (or time), and whether there is evidence of strains endemic to SFB.
- Compare with species and strains identified in other systems, and, to the extent possible, develop first-order estimates of growth characteristics.

E. Determine the growth characteristics of *Pseudo-nitzschia* or *Alexandrium* strains, isolated from SFB, in controlled laboratory experiments

- Isolate one or more strains of HAB-forming organisms
- Identify species and strains using molecular techniques
- Conduct a series of experiments to determine growth rates and toxin production under varying light, T, and nutrient concentrations
- Compare growth characteristics with organisms isolated from other systems, in particular *Pseudo-nitzschia* isolated along the CA coast during the 2015 event.
- Based on the growth characteristics identify conditions in space and time when these organisms could, and could not, either sustain their populations at low levels or develop into harmful blooms. This work could, for example, be carried out at Romberg Tiburon Center, building upon 2015-2016 work with *Pseudo-nitzschia* isolates from the CA coast (W Cochlan), with toxins measured at UCSC.

Deliverables: Progress report (June 2017) describing findings to date, and recommendations for specific work to be continued in Years 2-3.

Budget Justification: The following approximate costs are based on the assumption that one major project moves forward: 1 FTE postdoctoral researcher (\$100k); collaborators/advisors (\$30k); lab/field/travel (\$45k). Depending on the project (alignment with IFCB work), a portion of the postdoc salary could be covered by NOAA funds to UCSC.

OTHER PROJECTS Not described in depth because unlikely to be funded in FY17

P.11 Fish and/or benthos surveys in LSB sloughs and open Bay
FY17 Estimated NMS Cost = \$200,000
Collaborators: UC Davis

Investigations into fish and/or benthos communities are needed to inform if and how water quality conditions, and in particular large fluctuations in DO, are influencing biota. Survey-type investigations need to be conducted over multiple years and various seasons throughout the year in order to capture trends over time. Targeted field studies are also possible and may be necessary to test biota response to specific events. Although these types of studies should arguably already be occurring (and some are), they also need to be thoughtfully designed and part of a comprehensive plan to address the NMS's science and management questions and data gaps. The goal of P.3 (above) is to develop such a plan, along with a conceptual model and data analysis to inform that plan's design. That plan will help identify the highest priority

data needs for biota surveys, and study designs to address those needs. Therefore, if work does not proceed on P.11 in FY17, we propose that its funding be preserved to potentially support more comprehensive investigations in FY18.

Deliverables: Analysis of this data will be incorporated into the technical report described in C.3, and data will be summarized in the FY17 annual report.

Budget Justification: Field work (UC Davis) and data interpretation (\$200,000)

P.12	High-res mapping: light field, nutrients, chl-a, etc. for model calibration, condition assessment	\$100,000/yr
P.13	Intensive field investigations, rates, processes: e.g., denitrification, nitrification, SOD, water column BOD (multi-year, ~5 yrs)	\$250,000/yr
P.14	Benthos, grazer surveys (annual cost, multi-year, 3-5 years)	\$100,000/yr
P.15	HABs/toxins intensive investigations (~5 years)	\$200,000/yr
P.16	The NMS Science Plan calls for periodic external program review to assess science priorities, This was initially proposed for FY16, but is unlikely to occur this year. FY17 will be year 3 of the program.	\$40,000/yr