

C.1 Ship-based sampling and sample analysis

FY19 Estimated NMS Cost = \$180,042

Collaborators: USGS, UCSC, SFEI

Ship-based samples will be collected and analyzed for multiple nutrient-related parameters. Discrete samples and in-situ sensor-based measurements will be collected during USGS cruises aboard the R/V Peterson on ~12 full-bay cruises and ~12 South Bay cruises (Figure 1), with SFEI staff participating as a field technician(s) during cruises. The overall program is jointly funded by USGS, the RMP, and the NMS, with field program design a continuation of the USGS' long-term research program in San Francisco bay, and the NMS funds supporting several nutrient-specific measurements (Table 1). Data from the ship-based program play critical roles in nearly all of NMS' activities, including condition assessment, hydrodynamic and biogeochemical model calibration and validation (Figure 2), and improved understanding of nutrient behavior and nutrient-related effects within SFB.

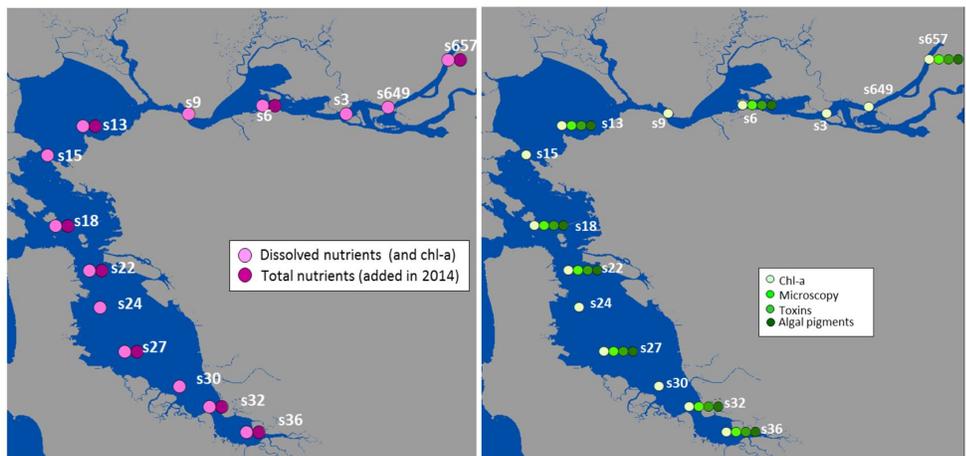


Figure 1 Station locations for discrete sample collection for nutrient-related parameters during biweekly and monthly USGS cruises

Table 1 Overall Ship-Based Program Funding Distribution: USGS, NMS

NMS	USGS core program*
<ul style="list-style-type: none"> - 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) 	<ul style="list-style-type: none"> - 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.

*USGS core program funding includes USGS in-kind funding and funding from the Regional Monitoring Program

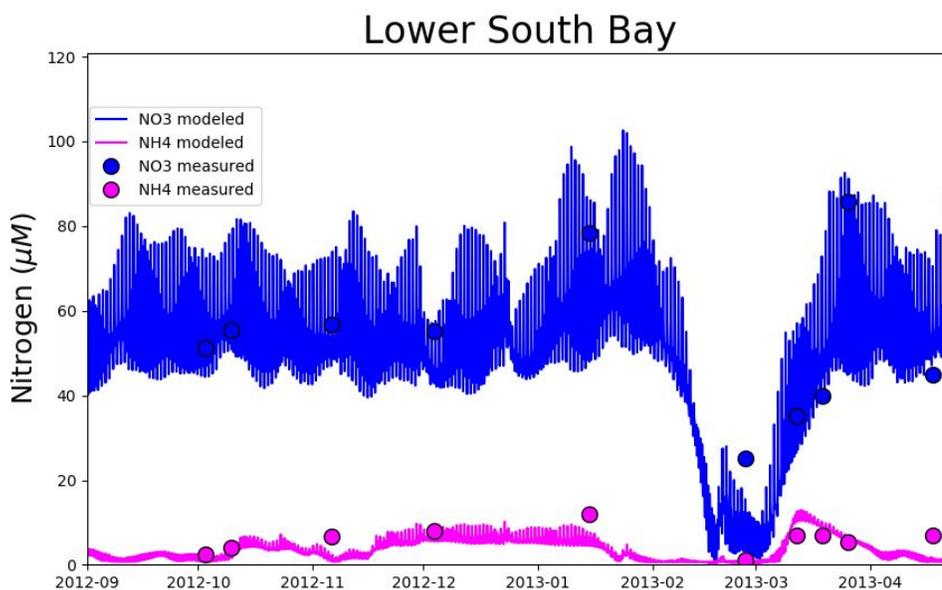


Figure 2 Measured and modeled concentrations of nitrate (NO₃) and ammonium (NH₄) in Lower South Bay (LSB), September 2012-April 2013. Measured data is from samples collected during USGS cruises in Lower South Bay (combining s34 and s36). Modeled values are hourly data, predicted using the current version of the NMS' coupled hydrodynamic/biogeochemical model (see C.3). The modeled concentrations are predictions for a fixed location in LSB (s36, Figure 1), and the large, high-frequency variations result from a combination of LSB's strong tides and spatial heterogeneity in water quality. Model output and observations suggest that the substantial DIN decrease beginning mid-February resulted from a major phytoplankton bloom (see Figure X)

Deliverables

Nutrient and chl-a data will be made publicly available through USGS's website. Datasets for toxins, phytoplankton microscopy, and pigments will also be made publicly available through the NMS. Results will be summarized in the [NMS Annual Report](#) (funded through other projects). Similar to past years, data will be used within numerous other NMS activities (e.g., model calibration [see C.3], condition assessment, assessment framework development).

Budget Justification

Over the course of the year, 300 station-date samples will be analyzed for a suite of nutrients (ammonium, nitrate + nitrite, reactive phosphorus, dissolved silicate; total N and total P will be measured at 75% of the sites) at the USGS national laboratory at a total cost of \$40,000. A portion of FY19 nutrient analyses were covered by the FY18 NMS budget, leading to lower nutrient analysis costs in FY19 (\$24,000). Phytoplankton taxonomy will be performed by microscopy on ~250 samples for phytoplankton community composition (225 grab samples, 25 net tows) and biovolume (\$45k); additional phytoplankton or harmful-algae (HA) related measurements (molecular/sequencing techniques, phycotoxins, algal pigments, etc.; total of \$50k) for cross-validation with microscopy data and imaging flow cytobot output, and to inform monitoring program refinement and to support investigation of HA-related mechanistic science and management questions. The SFEI staff labor budget covers the following effort (0.3 FTE distributed across two staff; \$43,542): participating as field technicians on all USGS cruises; and overall project management, including coordinating laboratory analyses (with UCSC and other non-USGS labs), cruise and sample collection planning, and data management.

C.2 Moored Sensor High-Frequency Observation Network: data analysis, interpretation, and maintenance

FY19 Estimated NMS Cost = \$360,810

Collaborators: SFEI, UC Berkeley (Stacey), USGS-Sacramento (Bergamaschi, Downing, et al)

San Francisco Bay is a dynamic and heterogeneous system. Data collected during [USGS](#) cruises over the past 40 years (see C.1) have played critically-important roles in shaping both our current understanding of the major factors regulating water quality in SFB, and in documenting water quality changes over that time. We also know, from other research in SFB, including along South Bay’s broad shoals, that important water quality indicators - e.g., salinity, temperature, chl-a, nutrients, dissolved oxygen, suspended sediments, etc. - have strong spatial gradients (Cloern et al., 1985; Huzzey et al., 1990; Lucas et al., 2008; Thompson et al., 2008), and can change substantially over fairly short time scales (e.g., hours to days), shaped by tidal forcings, wind, day-night variations in biological cycles, and other factors.

Therefore, in order to collect the necessary data to inform nutrient management decisions, the NMS prioritized developing an moored sensor network for high-frequency *in situ* measurements, focused initially in South Bay and Lower South Bay (Figure 3). Analysis of limited existing data for sloughs and creeks, along with early mooring network data, indicated that DO levels in sloughs frequently fell below the Bay’s 5 mg/L DO standard (SFEI 2015), and further highlighted the complex spatial and temporal variations in key water quality parameters (Figure 4). Two key aims for the mooring network were to allow for more comprehensive condition assessment, and to foster data collection that will allow us to better characterize and quantify ecosystem response to SFB’s high nutrient loads, including by aiding the calibration of numerical models (SFEI 2014). This project description briefly highlights major moored-sensor activities during FY18, and describes the major focus of proposed work in FY19.

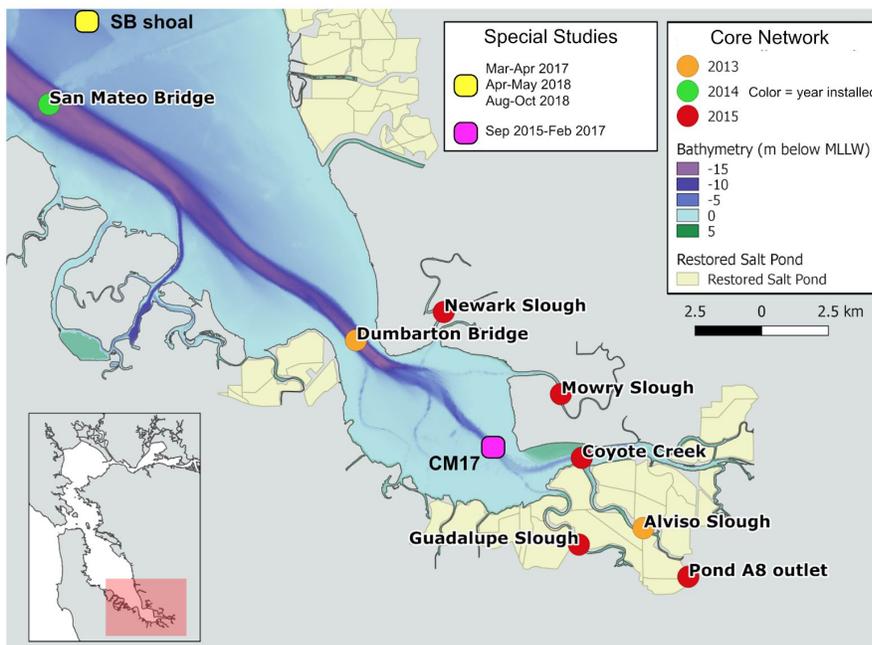


Figure 3 NMS Moored Sensor Network in Lower South Bay and South Bay. The network has been in its current configuration since May 2015. Sensors at each site take readings every 15 minutes for multiple parameters (salinity, temperature, depth, dissolved oxygen, turbidity, chlorophyll-a, and fluorescent dissolved organic matter (fDOM)). Sites are visited every ~3 weeks for servicing, calibration, and downloading data.

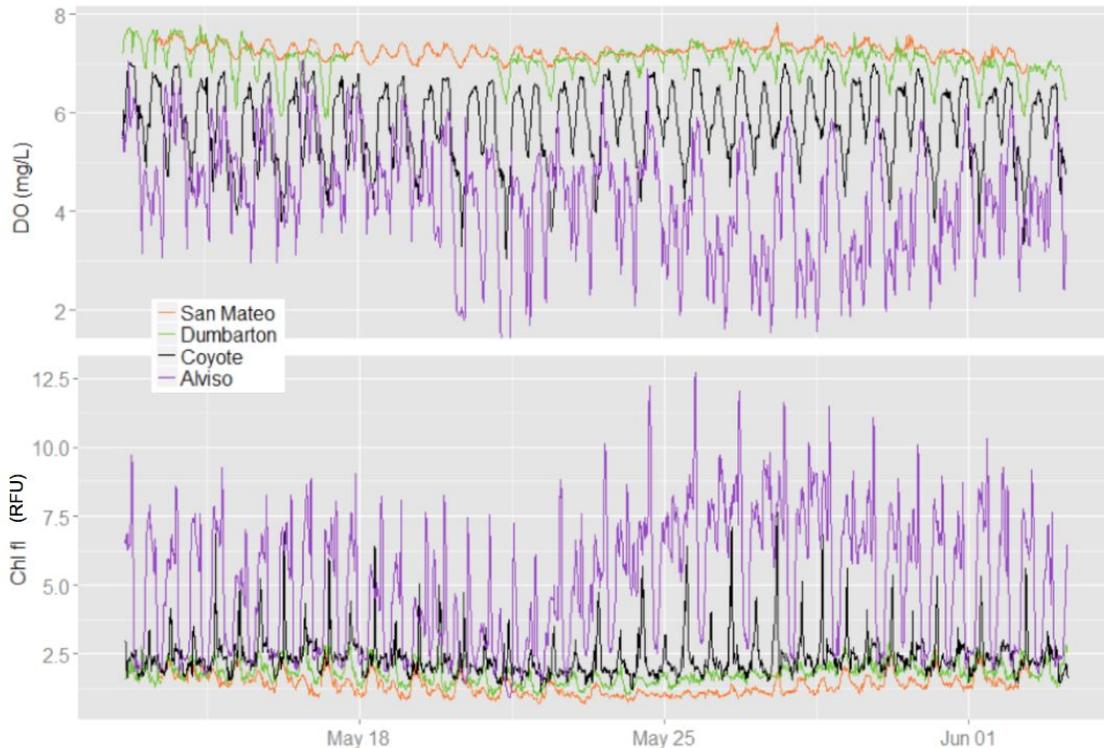


Figure 3 Dissolved oxygen (mg/L) and chl-a fluorescence (relative fluorescence units, RFU) along a northwest-southeast transect from the San Mateo Bridge to Alviso Slough, early-May to mid-June 2015.

Major FY18 activities

- Sensor network maintenance (maintenance at 3 week intervals, 2 field days per interval + 1-2 days field set-up / break-down).
- Developed codes for automated data cleaning, with a primary focus on DO%sat, DO_mgL, T, and S. Reprocessed all data since 2013, documented, and data is now publicly available. Viewable at www.enviz.org, or obtained by request from SFEI-NMS staff. The QA/QC protocols are described within an upcoming moored sensor program update (draft July 2018)
- Applied DO data from Lower South Bay stations within a DO-related condition assessment project (see Figure 4; draft technical report, June 2018)
- Mechanistic interpretation of DO and other data for elucidating mechanisms contributing to DO decreases and for quantifying transformation rates. (see Figure 5; progress report or draft technical report, Q1 2018)
- South Bay shoal deployment (4/3/2018-5/23/2018; same parameters as other sites, plus *in situ* nitrate sensor, additional chl-a fluorometer, and acoustic velocity measurements). Data is still being processed, but early indications are that 2-3 modest to sizable phytoplankton blooms were captured (Figure 6).
- Field-testing new instrument package and biofouling controls to maximize data quality during deployments. For the program's first several years the NMS relied on YSI EXO instruments. After assessing other suitable field instruments, we piloted a comparably-priced instrument from SeaBird, and now have two instruments in service.

As part of field-testing, we have conducted multiple side-by-side deployments with the YSI EXO. Results from a recent deployment are shown in Figure 7.

- Application of high frequency mooring data for model calibration (see Figures 8-10). As the NMS hydrodynamic and biogeochemical models undergo further refinements, we have begun relying heavily on high frequency data from the NMS network and other research groups. Salinity and elevation data have proven valuable for calibrating hydrodynamic model runs for Core Modeling work and for LSB model development. We have also begin using long-term turbidity records from high-frequency sensors from around SFB to develop time-space varying turbidity and light attenuation estimates.

Work in FY19 will focus on the following:

1. Continued field maintenance of mooring network, as described above, and continued refinement of automated data cleaning protocols, moving attention to chl-a.
2. Data synthesis, analysis and interpretation, including one or more of the following:
 - a. Exploring chl-a data and estimating gross primary production rates using sensor data, including comparisons between shoal and channel observations.
 - b. Assessing the importance vertical variations in DO concentration, including influence on to mechanistic interpretations.
 - c. Continued work on sediment and light field analyses, and wrap up version of these analyses.
 - d. Finalize technical report DO mechanistic interpretations from mooring data.
3. Critically evaluating the current mooring network structure, and, if warranted, moving resources to other locations in SFB, as proposed in the NMS Observation Program description (Figure 11, SFEI 2016).
4. Related to the reallocation of effort, two pilot efforts will move forward in FY2018
 - a. Deploy and interpret data from the South Bay shoal mooring again in Summer/Fall 2018.
 - b. Work with USGS-Sac collaborators to deploy additional sensors on existing mooring infrastructure in Suisun Bay. USGS-Sac maintains 3 moorings in Suisun Bay and the western Delta. Extensive field work is planned for late summer / early-fall related to changes in Suisun Marsh gate operations. NMS funds will be pooled with resources from other agencies.

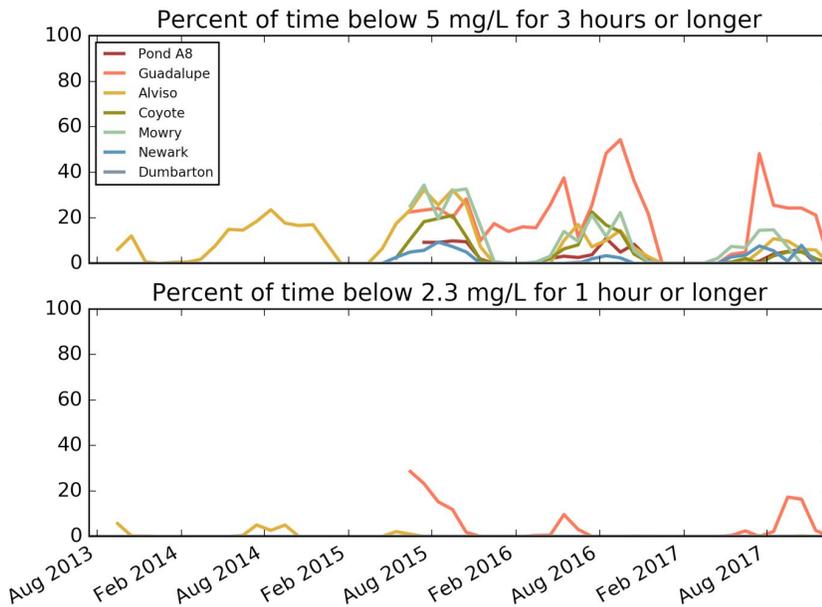
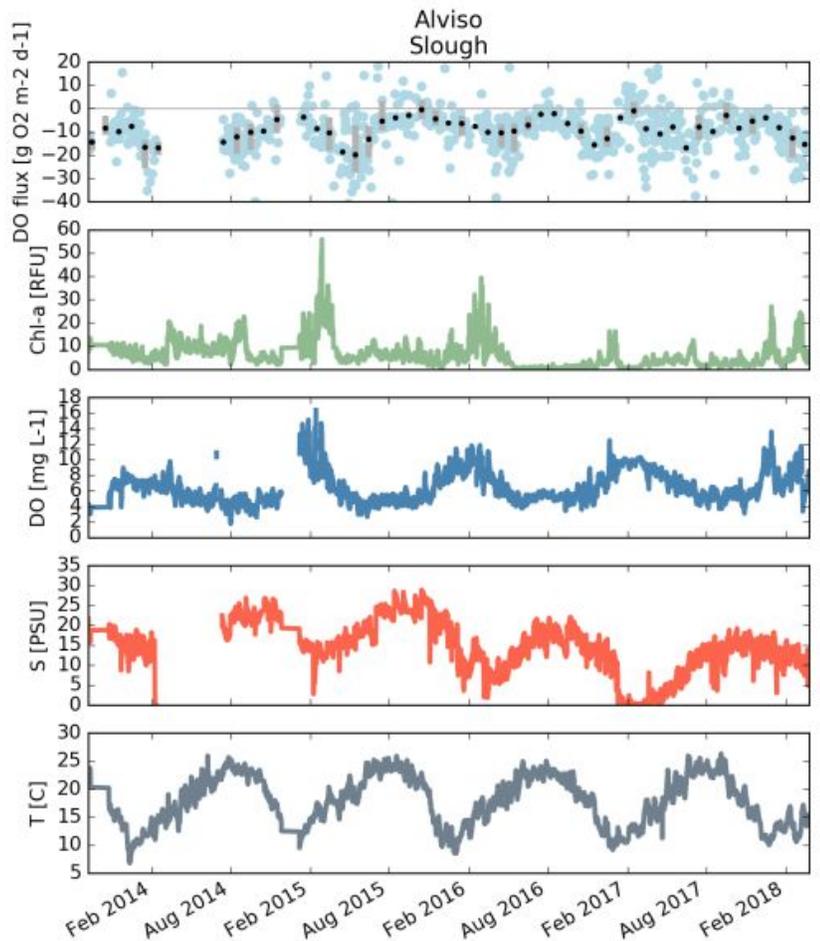


Figure 4 Percent of time each month in which DO is 5 mg L^{-1} or below for 3 hr or longer (top) and 2.3 mg L^{-1} or below for 1 hr or longer (bottom). Fish and benthos can be affected by both the DO deficit and a deficit's duration. Since low DO often occurred within fairly narrow windows in SFB's dynamic sloughs, considering both deficit and duration offers a potential path toward characterizing severity.

Figure 5 Net DO consumption rate ($\text{g O}_2 \text{ m}^{-2} \text{ d}^{-1}$) in Alviso Slough, calculated using the tidal symmetry method, an ecosystem-scale approach that is under development through this project. In the top plot, light blue circles are DO consumption estimates for individual tidal cycles, black dots are monthly median values, and vertical gray bars are monthly interquartile range. Values in the bottom four plots are daily averaged values.

This version of the net DO consumption rate does not include terms such as reaeration or DO production during primary production. In that sense it can be thought of as a conservative estimate of oxygen demand (benthic + water column). Loss rates in Alviso Slough were consistently the highest (most negative) of all sites. In several instances, rates were most negative in the days-weeks after large pulses of phytoplankton biomass (as measured by chl-a) entered the slough due to exchange with salt ponds.



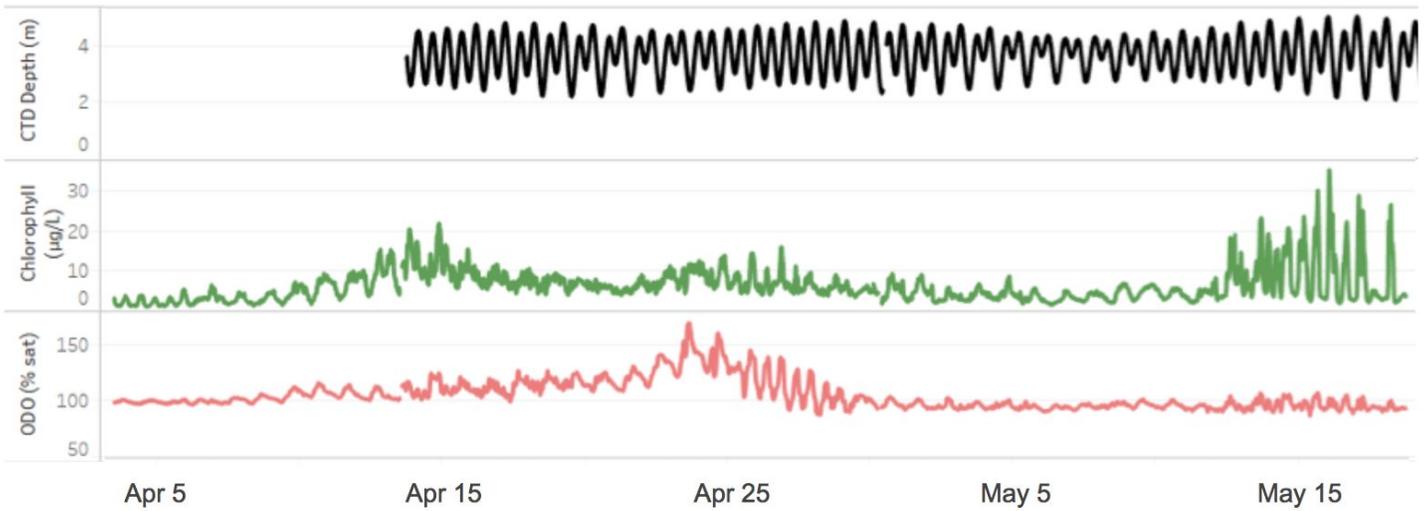


Figure 6 South Bay shoal mooring deployment, Spring 2018: depth (top), chl-a (middle), DO saturation (bottom). Elevated chl-a fluorescence along with supersaturated DO (>100%) are consistent with substantial phytoplankton production.

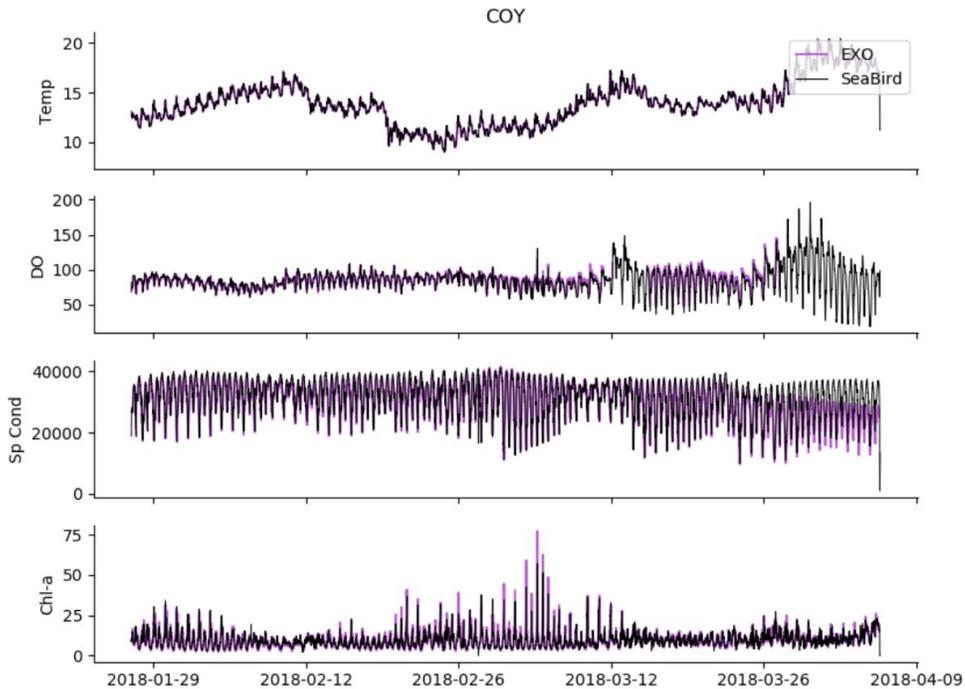


Figure 7 Data comparison from side-by-side deployments of EXO and SeaBird sensor packages. Note SpCond deviations around mid-March, likely due to fouling of EXO SpCond sensor. Although the SeaBird instrument has other advantages, its longer SpCond (i.e., salinity) field life is one major improvement.

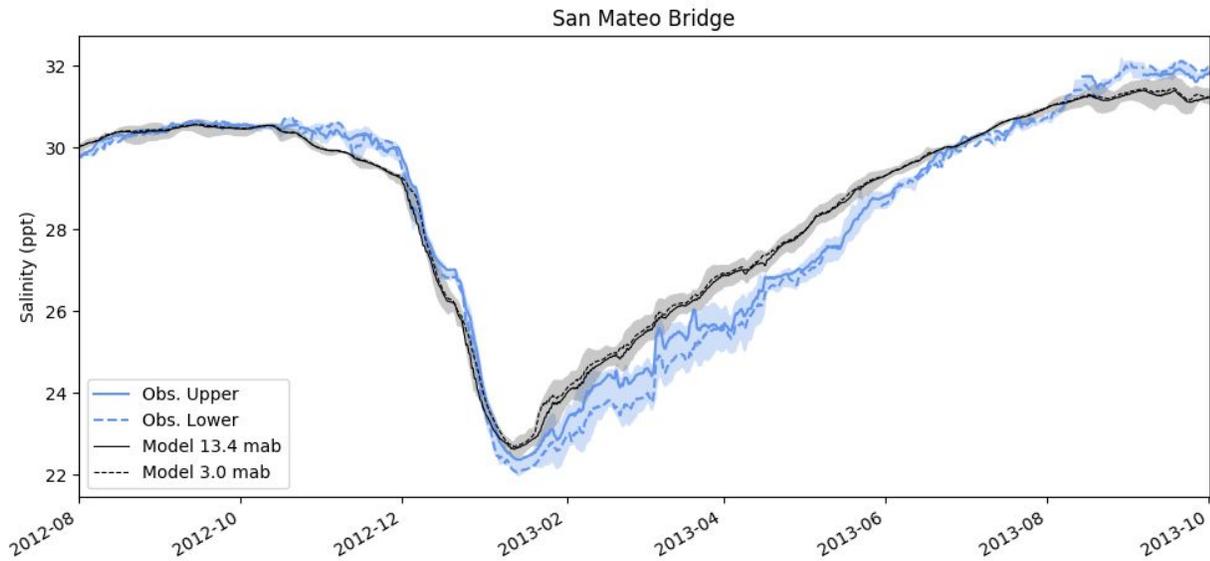


Figure 8. Application of high-frequency salinity data from moorings for updated NMS hydrodynamic runs completed in FY18. Blue and black curves depict daily average observed and modeled salinities, respectively, at two vertical locations in the water column at San Mateo Bridge (13.4 meters above bottom, and 3 meters above bottom); shaded areas show daily ranges of 15-min data. The model captures the major salinity patterns at San Mateo Bridge. However, the model over-represents salinity during late-winter and early-Spring, perhaps due to underestimating freshwater inputs to South Bay from local creeks. In addition, also the model predicts small but extended periods of vertical salinity differences (i.e., stratification), the modeled salinity differences are smaller than those observed.

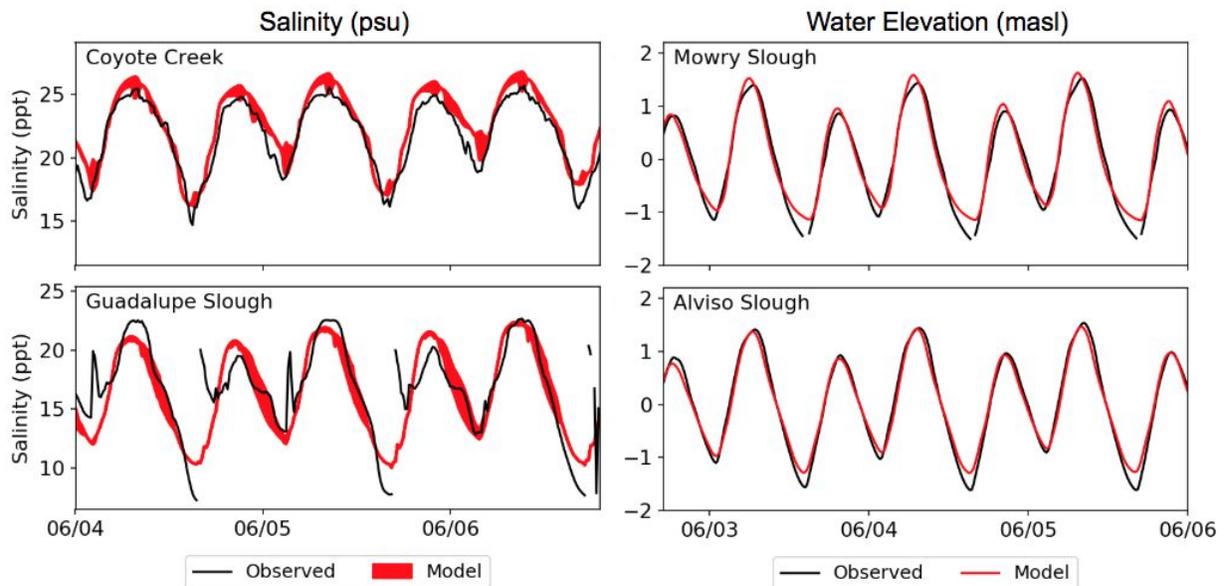


Figure 9 Mooring data (depth, salinity) is playing an important role in calibrating the NMS Lower South Bay hydrodynamic model, which was a major focus of the NMS modeling team during FY18. After further hydrodynamic refinements in the first half of FY19, it will be possible to begin running biogeochemical simulations for examining factors regulating DO and other parameters.

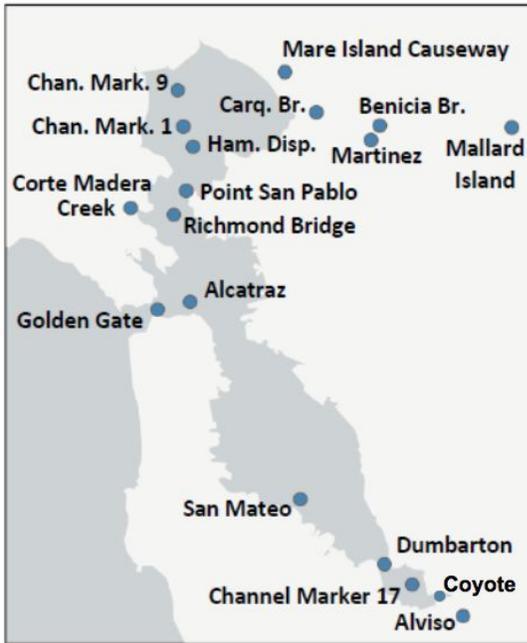
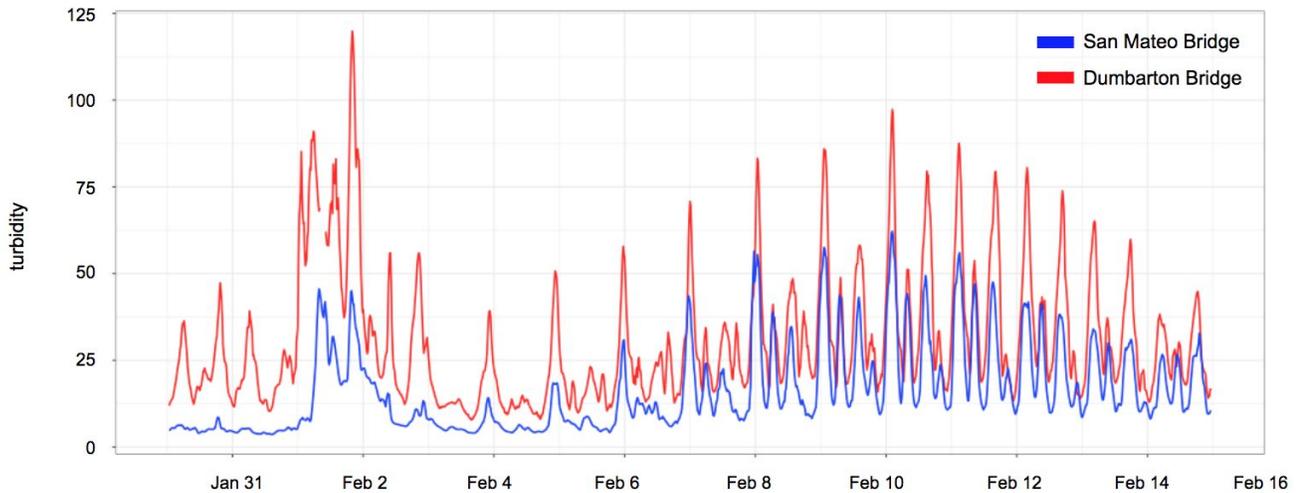


Figure 10 Left: Using high-frequency turbidity data at multiple stations throughout SFB to generate time- and space-varying estimates of light attenuation. Data are available for ~20 stations (subset shown to the left), with overall data availability extending from 1992-present. Although some sites have very little data (e.g., Golden Gate, <1 yr), most of the sites have >5 years of data and several have records extending 20+ years. In many cases, pairwise comparisons indicate that turbidity signals (daily-average) at neighboring stations are highly correlated (e.g., CM17:Dumbarton, $r=0.78$; Dumbarton:San Mateo, $r=0.57$; Mallard:Benicia, $r=0.69$; Point San Pablo:Benicia, $r=0.77$; Point_San_Pablo:Richmond_Bridge, $r=0.63$).

First, we developed a set of statistical models, using data from neighboring stations, to fill temporal data gaps at each stations, yielding a daily-average turbidity values for each station from 2000-2016. Current work is focused on spatially-interpolating these values to each grid cell of the NMS biogeochemical model. That dataset will be used for sensitivity analysis modeling work in FY19. It will also be used as a training or calibration dataset for a sediment transport model that is under development, through collaborations with Deltares, UNESCO-IHE, and USGS.

Below: Turbidity at San Mateo and Dumbarton Bridges, Jan 30 - Feb 15 2017. Curves depict 15 min data after applying a basic moving average smoother (75-min window), and illustrate the potential promise that this spatial-interpolation approach may hold.



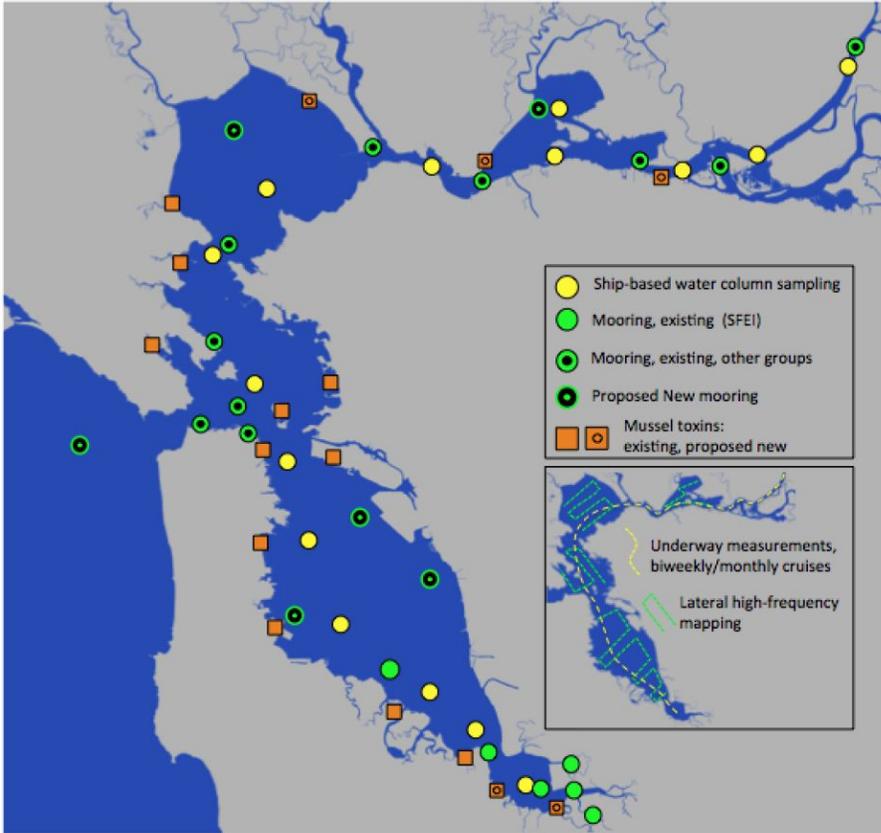


Figure 11. Proposed future NMS Observation Network v1.0 (NMSOPv1.0), including moored sensor network collecting high-frequency data from *in situ* measurements (see SFEI 2016). Details of the mooring network -- including exact locations and analytes -- are proposed as a strawman design, with the expectation that they will be tested and modified, working toward a robust and sustainable program design.

Deliverables during FY19:

1. Refined / cleaned dataset for additional year of data, and application of enhanced QAQC protocols to additional parameters (e.g., chl-a).
2. Several technical reports or progress reports, developed using C2 funding (FY19 or past years), or based on analysis using C2 data with analysis and write-up funded by other NMS projects:
 - a. Moored sensor program summary
[Draft and Final: Q1 FY19]
 - b. DO-related habitat characterization report (DO condition, fish abundance).
[Draft: Q1 FY19; Final: Q2 FY19]
 - c. Mechanistic interpretations of factors contributing to periodically low DO at slough sites and physical and biogeochemical factors.
[Progress report or Draft, Q1; Final, Q4 FY19]
 - d. Improved understanding of transport/lateral exchange in LSB using salinity and velocity data (in collaboration with UC Berkeley)
[Draft technical report/manuscript, Q2 FY19]
 - e. Turbidity, SSC, and light attenuation: evaluating the fe
[Progress report or draft technical report, Q3 FY19]
 - f. Chl-a sensor data: data synthesis, uncertainty analysis, and interpretations related to biomass sources, primary production rates, including summary of 2017 and 2018 results from the South Bay shoal mooring.
[Progress report or draft technical report, Q4 FY19]
3. Phase II of Mooring Program: proposed structure for next phase of mooring work (stations, analytes), and initial steps implementing that new structure (within time/budget constraints)
4. Summary of major observations in the NMS FY19 Annual Report (e.g., [NMS FY16 Annual Report](#))

Budget Justification: Partial support for 3 staff for field work, data management, data analysis and interpretation, and report preparation (0.75 FTE, 0.5 FTE, and 0.2 FTE for junior, masters, and PhD-level scientists; \$197,000); field support (including boat, fuel, and field technicians; \$70,000); equipment/supplies (\$30,000); support for USGS-Sac field campaigns and analysis in Suisun Bay (\$20,000), and analysis of discrete samples for instrument calibration (\$5,000)