NMS Science Program Update

1. Program Overview

2. Update on Major Activities
   1. Numerical Modeling
   2. Harmful Algae Blooms
   3. Dissolved oxygen in margin habitats

3. Work Ahead

D Senn, R Holleman, Zephyr Sylvester, L MacVean, M McKibben

San Francisco Estuary Institute

and MANY regional collaborators

Source: C. Benton
Key Collaborators

**SFEI**
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- L MacVean
- M McKibben
- Z Sylvester
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- D Schoellhamer
- B Downing
- B Bergamaschi

**UC Santa Cruz**
- R Kudela

**UC Berkeley**
- M Stacey
Reports and Work Products

Nutrient Strategy work products are available below, organized by Work Element. This list is regularly updated as new reports become available in draft and final versions.

Annual Reports
- 2015 NMS FY2015 Annual Report
- 2016 NMS FY2016 Annual Report

Work Element 1: Nutrient Program Administration
- 2012 Nutrient Strategy Nov 2012
- 2016 NMS Science Plan Report Sep 2016

Work Element 2: Define the problem
- 2014 Nutrient Conceptual Model Draft Final
- 2014 Status Synthesis I
- 2014 External Nutrient Loads to SF Bay
- 2016 Nutrient sources, sinks and transformations in the Delta (Main Report Jan 2016)
- 2016 Summary and Evaluation of Delta Subregions for Monitoring and Assessment
  - Link to technical appendices (Summary and Evaluation of Delta Subregions for Monitoring and Assessment)

Work Element 4: Establish Guidelines
- 2011 SF Bay NNE Development Lit Review
- SF Bay AF Meeting Summary Feb 2014
- Proposed Workplan for Assessment Framework Development

Work Element 5: Monitoring Program Development and Implementation
- 2014 Monitoring Program Development Plan Aug 2014
- 2014 Algal Pigment Final Report
- 2014 Moored Sensor Yr 1 Progress Report

Work Element 6: Modeling Strategy
- 2014 Detailed Modeling Workplan.pdf
- FY2016 Modeling Plan

www.sfbaynutrients.sfei.org
NMS FY2016 Annual Report

NMS 10-year Science Plan

San Francisco Bay Nutrient Management Strategy Science Plan

San Francisco Bay Nutrient Management Strategy Observation Program

December 2016

March 15 2016
Does SFB have nutrient problems?
- now?
- future?

How can impacts be mitigated or prevented?
- $5-10$ billion question

- Large algae blooms
- Low DO
- Harmful algae, toxins

- Largest CA estuary
- Drains 40% of CA

- WWTPs
- Bay 37 7.4 mill
- Delta 4 2.0 mill
Does SFB have nutrient problems?
- now?
- future?

How can impacts be mitigated or prevented?
- $5-10\text{ billion question}

\begin{itemize}
\item Large algae blooms
\item Low DO
\item Harmful algae, toxins
\end{itemize}

\textbf{SFB doesn’t use most of its nutrients}

\begin{itemize}
\item 1. High turbidity
\item 2. Strong tidal mixing
\item 3. Filter-feeding clams
\end{itemize}

Historically: Resistant to classic eutrophication symptoms

Recently: Evidence of changing response to nutrients
What would a problem look like?

Problems Now

Problems in the Future

- Large algae blooms: Several weeks/months, 20+ µg/L
- Low DO: DO < 5 mg/L, extended periods of time
- Harmful algae, toxins: HAB-species $\rightarrow$ toxins $\rightarrow$ biota $\rightarrow$ adverse effects
“So, how is the Bay doing?”

Still changing...

- South Bay and Lower South Bay appear to have reached a new ‘state’
  - 2-3x-higher Fall biomass, with unknown cause
- Causes poorly understood...
  - Climate Oscillations (changes in upwelling, coastal currents)
  - Decreased grazing by benthos
  - Decreased suspended sediments

Data: USGS
SFEI 2016

Cloern et al. 2007
Major Focus

1. Nutrient sources, movement, transformations

2. Ecosystem response to nutrients
   – Causing problems?
   – Develop best-possible understanding of dose:response
   – What are protective nutrient levels? (now, future)

3. What management actions will maintain nutrients at protective levels?
   – Which would be most efficacious and cost-effective?
What data and tools do we need to inform management decisions?
NMS Observation and Forecasting Program

Ship-based monitoring, with USGS

Mussels

Numerical Modeling

High-frequency observations

DO, chl, OBS, fDOM, salinity, T
Understanding nutrient loads, transport, cycling and effects

Modeling → Quantitatively integrate complex information

• Quantify important mechanisms

• Quantify effects of anthropogenic nutrients

• Conditions look like under future scenarios

• Analysis of management alternatives

But...

• Substantial development time, then application

• Data needs for model calibration and validation

• Weak link...humans
Coupled Hydrodynamic and Water Quality Modeling

- Management Scenarios
- Environmental Scenarios

Phyto: community
Phyto: growth
Dissolved oxygen
Nitrif. Denitrif. Sediment Flux

Conservative Tracers
Transport/Mixing/Dilution

Hydrodynamics

Today
Conservative Tracers

A snapshot of conservative tracer distributions is displayed in this series of maps. The layer selector in the upper right corner of the map can be used to select a single POTW or refinery source. The colors displayed correspond to the dilution of that source throughout the bay. These simulations show a snapshot in time, corresponding to the start of July, 2013, from a simulation starting in October, 2012. The color scale is logarithmic, with each tick representing a factor of 2 dilution.

Reactive Nutrients

Here the results of a reactive nutrient water quality simulation is shown. The model run includes estimated NO3 and NH4 loads from the POTWs and refineries. In addition to transport by the underlying hydrodynamic model, the water quality model includes nitrification and denitrification with stock formulations for the rate constants. Hot-spots of NH4 are associated with non-nitrifying POTW flows, but disperse and nitrify over relatively short periods. The result is a NO3 field which is relatively diffuse with the exception of several significant nitrifying POTW flows.
Forcings

- 36 POTWs + 5 refineries
- 73 rivers & creeks
- Est. flows, NO3, NH4, PO4
- Wind, tides, evaporation

SUNTANS Domain

- 31 z-layers, (0.5m+)
- 25k 2D cells
- 200k 3D cells
- 70x real-time on 1 core
- 4km to 200m resolution

Hydrodynamics

Sources
- Discharge
- Creeks and Rivers

Model grid / bathymetry
- 0m NAVD88
- -2
- -5
- -10
- -15
- -25 and deeper

Actual shoreline
Phased Model Development and Implementation

- **Management Scenarios**
  - Phyto: community
  - Phyto: growth

- **Environmental Scenarios**
  - Conservative Tracers
  - Transport/Mixing/Dilution
  - Hydrodynamics

- **Complex**: Phytoplankton, sediment, ...

- **Dissolved oxygen**
  - Phyto: community
  - Phyto: growth

- **Sediment**
  - Sediment flux

- **Phytoplankton**
  - Phytoplankton growth

- **Nutrients**
  - Dissolved oxygen
  - Nitrification
  - Denitrification
  - Simple transport, de/nitrification, reaeration
  - Complex: Phytoplankton, sediment, ...
How “good” is the model?? Model calibration and validation

Hydrodynamics: Salinity

Nutrient Concentrations

Velocities
Simulated Nutrients: Spatial View

DIN (µM) July 2013

NH4 (µM) July 2013
What are the fates of N loads to SFB?

Mass = Load + Transp$_{\text{IN}}$ + Transp$_{\text{OUT}}$ - Loss

DIN (µM)  
WY2013

Oct 2012
Monthly-Average Mass Balances (based on 30 min accounting)

September 2013

WY2013

10,000 kg N/day, DIN
- Load
- Loss
- Transport
What are the fates and effects of Bay nutrients along the coast?

Collaboration with UCLA-SCCWRP project
Current Focus...Next ~1 year

**Complex:** Phytoplankton, sediment, ...

High-res...
- 5-10 days to simulate 1 year of water quality
- 100+ GB per run

Low-res...
- 5–20 minutes to simulate 1 year
- Practical for sensitivity analysis, exploration
April

Time=263 days since 2012-08-07

Chl-a ug/L
Max: 26
Min: -26

DIN uM
Max: 114.8
Min: -0.0

P uM
Max: 2.6
Min: 0.2

Si uM
Max: 201.9
Min: 33.13
Modeling Focus 2017-2018

Core Modeling

Risk-based, scenarios

LSB sloughs, creeks

Suisun/Delta

Sources
- Discharge
- Creeks and Rivers

Model grid / bathymetry
- 0m NAVD88
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Actual shoreline
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3. Work Ahead
Domoic Acid
(Amnesic Shellfish Poisoning)

Photo: Eric Risberg, Associated Press
Contra Costa County health officials are warning Discovery Bay residents to avoid coming into contact with the water in the area as field tests showed it contains blue-green algae. The bacteria can cause a variety of ailments, including rashes and other allergic reactions, skin and eye irritation, and an upset stomach. Exposure to high levels can lead to serious illnesses and even death, according to the California Department of Public Health.
Background: HABs

• Increasingly important water quality issue worldwide

• Indications that SFB needs to be on the lookout
  – in general, or as far as we know, noteworthy resistance, in general, to severe HAB events
  – But HAB-organisms and toxins commonly detected

• HABs among the NMS’ higher priorities (SFEI 2016)
  – Substantial increase in observations to evaluate system
  – Sufficient time to answer management questions with sufficient confidence?
Are HABs and toxins problems in SFB? SFB nutrients cause or contribute?

- HAB-forming species?
- Toxins in water?
- Toxins in biota?
- External Sources vs. Internal production, role of nutrients?
- Increased events/frequency in future?
- Acceptable risk, present/future
- Protective nutrient inputs?

N, P, T physics

Cloern and Dufford 2005
Cloern and Jassby 2012
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Cloern and Dufford 2005
Cloern and Jassby 2012

N, P, T physics
HABs and Toxin-focused work

- Microscopy: 1992-present
- Spatially-integrated toxin sampling since 2012.
- Particulate toxins since 2013
- Mussels since Sep 2015
Are HAB-forming organisms present in SFB?

**Pseudo-nitzchia**

- **Rivers**
- **Suisun**
- **San Pablo**
- **Central**
- **South**
- **Lower South**

Density (cells mL⁻¹):
- ○ Non-detect
- ● 1
- ● 10
- ● 100
- ● 1000

Data: USGS SFEI 2016

**Other frequent visitors**

- **Dinophysis**
- **Karlodinium**
- **Alexandrium**
- **Microcystis**
Naturally occurring mussels floating docks, readily-accessible bi-weekly sampling. Domoic Acid in Mussels (ppm)
What do current ambient conditions tell us about HAB-related condition in SFB?

• Regularly detect multiple toxins at low/moderate levels in biota and in the water
  – Domoic Acid       Low
  – Microcystin       Moderate/Elevated
  – Saxitoxin         Low
  – Okadaic Acid      Moderate
  – DTX2              Low

• Workshop and Expert Panel Spring 2017
  – Broad range of expertise: physiologists/toxicologists, HAB specialists
  – Comparison of SFB conditions with other estuaries and thresholds
  – Major uncertainties and recommendations
Are HABs and toxins problems in SFB? SFB nutrients cause or contribute?

- HAB-forming species?
- Toxins in water?
- Toxins in biota?
- External Sources vs. Internal production, role of nutrients?
- Increased events/frequency in future?
- Acceptable risk, present/future
- Protective nutrient inputs?
  - Continue current effort
  - New or increased effort in FY17-18

Cloern and Dufford 2005
Cloern and Jassby 2012

N, P, T physics
What shapes community phytoplankton community composition?
Are conditions in SFB adversely impacting phytoplankton composition?

- Light
- T
- Residence time
- Size-selective grazing by clams
- Nutrients
PDO = Pacific Decadal Oscillation
ONI = Oceanic Niño Index

PDO and Central Bay T anomalies

PDO (bars) vs ONI (line)

Temperature (°C)

Pseudo-nitzschia spp. (cells/mL)

Central Bay

PDO = Pacific Decadal Oscillation
ONI = Oceanic Niño Index
Central Bay – October 18 2017

Red tide?

Akashiwa Sanguinea
Imaging Flow Cytobot (IFCB)

- 2 instruments
- NOAA-funded, PI: UC Santa Cruz, co-PIs: USGS, SFEI
- Genus level counts and ID
- Integration into the Bay monitoring program
  - Ship-board (USGS) beginning October 2016
  - Moored application, late 2017
In collaboration with UCSC and USGS

Thanks to D Schultz and R Kudela (UCSC)
In collaboration with UCSC and USGS

Pseudo-nitzchia
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3. Work Ahead
**Key Assumption for Science Plan:**

- Water Board’s goal of ‘Standards within 10 years’
- Work and timeline based on this goal, not current budget.

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<td>3. Role of anthropogenic nutrients? Protective nutrient loads?</td>
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*Initial evaluation, Secondary evaluation, Final evaluation*
Current Major Science Gaps (un- or underfunded)

- Biogeochemistry field studies
  
- HABs investigations: mechanisms, causes, effects
  
- Expanded monitoring
  
- Biological endpoints
  
- Quantifying nonpoint source nutrient loads
  
- Expanded modeling, including future scenarios
What is the necessary level of certainty to inform major management decisions?
- Depends on the cost
- Depends on the potential environmental risk

What are the relevant timelines?
- Which decisions?
- Environmental risk?

What science program can achieve the goals/certainty in the appropriate time?
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**NMS Steering Committee, NMS Planning Subcommittee, and Stakeholders**

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