NMS Science Program Update

1. Biogeochemical studies in Lower South Bay

2. HABs/toxins and Phytoplankton community

3. Water Quality Model development

4. NMS Work Products

D Senn, E Novick, P Bresnahan, R Holleman, and Zephyr Sylvester

San Francisco Estuary Institute

and MANY regional collaborators

sfbaynutrients.sfei.org
Key Science Collaborators

**SFEI**
- E Novick
- P Bresnahan
- R Holleman
- Z Sylvester
- D Senn

**SCCWRP**
- M Sutula

**USGS-Menlo Park**
- J Cloern
- L Lucas
- T Schraga

**USGS-Sacramento**
- M Downing-Kunz
- G Shellenbarger
- D Schoellhamer
- B Downing
- B Bergamaschi

**UC Santa Cruz**
- R Kudela
- M Peacock

**UC Berkeley**
- M Stacey
4 basic components

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?

4. Science Plan: With limited resources and time, what is the best approach for 1, 2, and 3?
Nutrient Science Program

- 10-Year Science Plan
- Monitoring Special Studies
- Modeling
- Assessment Framework
- Loads, Management Options

November 2012
San Francisco Bay Nutrient Management Strategy
Potential Adverse Impacts of Nutrients in SFB

Anthropogenic Nutrient Loads N, P

Increased phytoplankton biomass

Low DO in Margins: sloughs, creeks, wetlands

Low DO Deep Subtidal

Low Production

Harmful algal blooms and toxins

Poor food resource

Altered phytoplankton communities

Aesthetics

Recreation

Habitat

Fisheries
Lower South Bay

- Complex system, slow flushing
- Highest **Nitrogen** and **Phosphorous** concentrations in the Bay
- 3 WWTPs
- Parameters of interest: algal biomass (chl-a), dissolved oxygen (DO), algal community, toxins, **N** and **P**

**Key Questions**

- Condition?: Open Bay and sloughs/creeks. Adverse impacts?
- Spatial variability: production, biomass, nutrient cycling?
- Restoration efforts effect on DO, algae?
**Dissolved Oxygen – Deep subtidal**

USGS Polaris (1993 – present)

- Dumbarton near-surface continuous sensor

![Graph showing dissolved oxygen levels over time with low tide highlights.](image_url)
Conceptualization of water quality/source in LSB as a function of tide

Hypotheses:

- Waters in sloughs/creeks have low(er) DO and higher algal biomass
- Exchange with restored salt ponds is one of several contributing factors
Need to measure...
- The right things
- In the right places
- At the right times

Long-term USGS *Polaris*
(1970s – present)

Moored sensors: SFEI / USGS-Sac / UC Berkeley  
(2013 – present)

High-resolution biogeochemical mapping – USGS-Sac / SFEI / UCSC  
(2015)
Low DO is a common feature in sloughs and creeks.

- Complex.

What regulates the condition?

- Evidence for salt pond influence?

Is it causing problems?
Need to measure...
- The right things
- In the right places
- At the right times

High-resolution biogeochemical mapping – USGS-Sac / SFEI / UCSC

Bergamaschi, Downing et al.
On-going work

• Data Analysis and interpretation

• Two major directions
  – Mechanistic interpretation....why?
  – What does it mean? Habitat quality
Photosynthesis/respiration only – 1 month

Diel Cycle...

Oxygen production and consumption.

What we would expect to see if DO was primarily influenced by respiration and the diel production of DO
What causes observed tidal signal in dissolved oxygen in sloughs?

Tidal advection of water with different properties past a fixed-location sensor

--- OR ---

Vertical mixing due to tidal energy:
Spring vs. Neap
Ebb vs. Flood

--- OR ---

BOTH or OTHER
Interannual variability

Data: M Downing-Kunz (USGS)
Salt Pond
- Algae Production
- DO production/consumption
- Net flux to sloughs

Open Bay
WWTP Nutrients
Mixing vs. stratification
- Periodic low DO
- Periodic high chl-a

Flushing
- spring/neap
Mixing vs. stratification
- Freshwater
- Ebb vs. flood
- Spring vs. neap
- Channel geometry
Habitat-driven data analysis ↔ Protective DO

1. Sensitivity to low DO differs by
   • Species
   • Life stage
   • Motility
   • Habitat utilization

2. Both intensity (deficit) and duration may be important

3. Effects related to 1 - 2 will also differ depending on organisms
   1. Acute
   2. Chronic effects / Stress
   3. Avoidance
   4. Individual vs. population effects...e.g. decreased reproductive success
Habitat-driven data analysis ↔ Protective DO

1. Start by analyzing data quantitatively but flexibly, without fixed values of what is “good” vs. “ok” vs. “bad”

2. Sensitivity-analysis-type approach...
   - Work backward to identify data gaps
     • We frequently see condition A, B, and C but seldom see conditions X, Y, Z
     • What types of effects could occur
   - What has been shown to be important in other systems?
What do aquatic organisms experience in LSB habitats? Exposure and Duration

![Graph showing the effects of dissolved oxygen (DO) concentration and duration on aquatic organisms in LSB habitats. The graph indicates areas where better, worse, or even worse outcomes are expected based on the DO concentration and duration.]
Guadalupe

Exceeds EPA 2000 <24 hr exposure criteria

Draft

Suisun Marsh
Acute threshold

Suisun Marsh
Chronic criteria
- Relevant species for Lower South Bay?
- DO chronic data for those species?
Key Messages

• Lower South Bay is a complex and heterogeneous biogeochemical reactor: N transformations / Dissolved Oxygen / Blooms

• Low(er) DO in sloughs
  – Strong tidal variability
  – Variability: within sloughs, among sloughs, multiple time scales (tidal, seasonal, event
  – Influenced by multiple factors

• Continuing work...
  – Field investigations ...physical/biogeochemical processes in sloughs, ponds
  – Modeling
  – Is the low DO adversely impacting biota?
  – Importance of Nutrient ↔ Salt Pond restoration
  – Algal toxins and HAB-forming organisms??

• Opportunities for co-management of Nutrients and Salt Ponds?
Potential Adverse Impacts of Nutrients in SFB

Anthropogenic Nutrient Loads N, P

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Habitat

Recreation

Fisheries

Aesthetics
West Coast Summer 2015 *Pseudo-nitzchia* bloom

Domoic Acid

(Amnesic Shellfish Poisoning)

![Pseudo-nitzchia spp](image)

Domoic acid detected in marine wildlife from the Pacific Northwest to Southern California during a record-setting bloom of toxic algae in the North Pacific in the summer of 2015.

**Footnote:** Domoic acid is rapidly eliminated from the body on short time scales detected in stranded or sick animals may not accurately represent the magnitude of the initial exposure. Samples were collected from dead and stranded marine mammals by the West Coast Marine Mammal Stranding Network.
Harmful Algal Blooms (HABs)

Example Toxin Producing Organisms

Domoic Acid
(Amnesic Shellfish Poisoning)

Microcystin toxins
(hepatotoxin)

Saxitoxin
(Paralytic Shellfish Poisoning)

When are toxins produced?

When they are stressed...e.g.,

- Salinity, Temperature
- Nutrients (-P, -Si; +N, +metals)
- Light conditions
Are HABs and toxins problems in SFB? SFB nutrients cause or contribute?

Complex issue, multiple components

HAB-forming species?
Toxins in water?
Toxins in biota?
External Sources?
Internal production, role of nutrients?
Acceptable risk, protective nutrient inputs?

Collaborators: UCSC: Peacock, Kudela; USGS: Cloern, Schraga
Are HABs and toxins problems in SFB? SFB nutrients cause or contribute?
For example...

Do we see *Pseudo-nitzchia*?

Data: USGS
Pseudo-nitzchia spp.

- Detected in Central / South / Lower South Bay with non-trivial frequency and non-trivial abundance
- Scientific community considers 10 cells/mL (10,000 cells/L) threshold for a ‘bloom’ (e.g., http://www.cencoos.org/data/models/habs)

Data: USGS
Alexandrium spp. (saxitoxin, Paralytic Shellfish Poisoning)

Data: USGS
Multiple HAB-forming species are commonly detected in SFB

- **Pseudo-nitzchia spp.**
- **Alexandrium spp.**
- **Dinophysis spp.**

- **Karenia spp.**
- **Karlodinium spp.**
- **Heterosigma spp.**
Harmful algal blooms and toxins?

- **YES**

  HAB-forming species?

- Yes

  Toxins in water?

- Yes

  Toxins in biota?

- No

  External Sources?

- No

  Internal production, role of nutrients?

- No

  Acceptable risk, protective nutrient inputs?

- No
Are toxins present?  Domoic Acid...spatial average

Suisun
San Pablo
Central
South + Lower South

2012  2013  2014  2015

Kudela et al, in prep.
Harmful algal blooms and toxins?

- YES HAB-forming species?
- YES Toxins in water?
- Yes Toxins in biota?
- 
  Sources?
- 
  Internal production, role of nutrients?
- 
  Acceptable risk, protective nutrient inputs?
Are toxins entering the food web?

Mussel Watch (RMP)

- Deployed mussels Bay-wide
- Time-integrated “sampler”

*Peacock et al. in prep*
DA detected in all samples
- DA << 20 ppm regulatory limit for shellfish

Deployment period: 90 days.

Peacock et al. *in prep*
Harmful algal blooms and toxins?

- **YES** HAB-forming species?
- **YES** Toxins in water?
- **YES** Toxins in biota?
- **GG Delta LSB** Sources?
- Internal production, role of nutrients?
- Acceptable risk, protective nutrient inputs?
Sources from the coastal ocean?

Domoic Acid
(Amnesic Shellfish Poisoning)

Pseudo-nitzchia spp

Test with naturally-occurring mussels

Peacock et al. *in prep*
Sources from the coastal ocean?

Domoic Acid
(Amnesic Shellfish Poisoning)

- Apparently no "big" internal event in Central Bay in Summer/early-Fall 2015
- What about rest of Fall?
- What about elsewhere inside the Bay?
Best approach for toxin monitoring?

- Spatially-integrated water (SPATT)
- Discrete water samples.... “grab samples”
- Biota

- All approaches have pros and cons...
  - Spatial averaging
  - Time-averaging
  - Translate to actual concentrations
  - Effort/cost
Bay-wide mussel survey (FY2016)

- Naturally occurring mussels
- Accessible from land, floating docks.
- Found throughout South, Lower South, Central, and western San Pablo

Approach:
- Bi-weekly sampling
- ~10 sites Bay-wide, in 2-3 days.
- Oversample, analyze subset.
Domoic Acid concentration in mussels

Sep-Oct 2015

100 ppb

1 ppb

Nondetect

No Sample
Harmful algal blooms and toxins?

- YES
- HAB-forming species?
  - YES
- Toxins in water?
  - YES
- Toxins in biota?
  - YES
- Sources?
  - Internal production, role of nutrients?
    - N, P, T physics
  - Acceptable risk, protective nutrient inputs?
**Mussel Watch Samples**

Domoic Acid *(Pseudo-nitzchia)*

DA detected in all samples

- DA << 20 ppm regulatory limit for shellfish

Microcystin *(Microcystis)*

Microcystin detected in most mussel samples

- Some samples with MC > 10 ppb OEHHA limit
- Commonly considered a freshwater toxin
- Source?

Saxitoxin *(Alexandrium)*

Deployment period: 90 days.

Peacock et al. *in prep*

All units wet w
Archived *Potamocorbula* to explore Microcystin inputs from the Delta?

- Substantial *Microcystis* blooms in the Delta have been reported in the past several years
- To date, no systematic monitoring of toxin levels.
- Limited information about *Microcystis* or microcystin in Delta prior to ~2005
- Can we use a multi-year archive of monthly *Potamocorbula* samples to assess past toxin levels?

Proof of concept, initial data...additional sample analysis underway
Key Messages

• Algal toxins and HAB-forming organisms commonly detected Bay-wide
  – ✔ Water ✔ Biota ...at low/moderate levels, nonetheless concerning
  – Multiple species, multiple toxins
  – Exploring: Sources, Mechanisms, Monitoring
  – Linkage to Nutrients? Adverse Impacts?

• Observations to date appear to reflect ‘typical conditions’ in SFB. Nutrient concentrations are sufficient in SFB to support HAB ‘events’

• Should SFB nutrient management considerations focus on ‘typical conditions’, or on ‘events’?

Example: Santa Cruz Wharf, weekly mussel sampling.
- Vast majority of samples had low Domoic Acid (<<20ppm)
- During short-lived ‘events’, DA was orders of magnitude higher than ‘typical conditions’
- Observing and distinguishing between ‘typical’ and ‘event’ required frequent monitoring

Deployed mussels, Santa Cruz Wharf: weekly, 2010-2016
Source: R Kudela
Key Messages

- Algal toxins and HAB-forming organisms commonly detected Bay-wide
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- Observations to date appear to reflect ‘typical conditions’ in SFB. Nutrient concentrations are sufficient in SFB to support HAB ‘events’

- How should future scenarios inform management considerations?

e.g.,

Substantial decreases in suspended sediments Bay-wide over the past 10-20 years.

Proportional increases in light levels to support phytoplankton growth, including HAB-forming species

SFEI (2015)
What shapes community phytoplankton community composition?
Are conditions in SFB adversely impacting phytoplankton composition?

- Light
- T
- Residence time
- Selective grazing
- Nutrients
What shapes community phytoplankton community composition?
Are conditions in SFB adversely impacting phytoplankton composition?

- Light
- T
- Residence time
- Size-selective grazing by clams
- Nutrients

SFEI 2014
Peacock et al. in prep.
Seasonal and spatial variability in class-level phytoplankton community: Insights for...
- Internal processes/forcings
- HABs
- Food Quality

All Data
How to identify patterns/cycles? One approach

- nMDS: nonmetric MultiDimensional Scaling
- Finding patterns in phyto. composition data
- Computes “distance” between samples, places optimally in 2D based on similarity of composition
- Similar samples clustered, disparate samples dispersed
Hypotheses:
- Coherent seasonal community shifts
- Subembayments exhibit distinct seasonal cycles, some overlap
Lower South Bay

Averaged by month, highlighting Lower South Bay stations

Note: Colors indicate month/season, shape indicates year
Suisun Bay

Note: Colors indicate month/season, shape indicates year

Averaged by month, highlighting Suisun Bay stations
Central Bay

Note: Colors indicate month/season, shape indicates year

Averaged by month, highlighting Central Bay stations
Central
Suisun
LSB

Forcings?
Key Messages

• Lower South Bay is a complex and heterogeneous biogeochemical reactor: N transformations / Dissolved Oxygen / Blooms
  – Frequent Low DO in sloughs
  – Large and complex biogeochemical gradients
  – Role of nutrients? Field investigations and modeling underway
  – Adverse effects? Condition assessment

• Algal toxins and HAB-forming organisms commonly detected Bay-wide
  – ✔ Water ✔ Biota …at low/moderate levels, nonetheless concerning
  – Multiple species, multiple toxins
  – Exploring: Sources, Mechanisms, Monitoring
  – Linkage to Nutrients? Adverse Impacts?

• Overall Science Plan and Science Program
  – Major progress on priority fronts, guided by Science Plan
  – Optimized team: internal/external…deep expertise + utility players
  – Effort is under-funded if timeline goals are to be met
Key Science Collaborators

**SFEI**
- E Novick
- P Bresnahan
- R Holleman
- Z Sylvester
- D Senn

**SCCWRP**
- M Sutula

**USGS-Menlo Park**
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- R Kudela
- M Peacock

**UC Berkeley**
- M Stacey
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NMS Steering Committee and Planning Subcommittee

SFEI: P Trowbridge, J Hunt, J Davis, A Malkasian, T Hale, G Shusterman, C Grosso, S Bezalel

Technical Team and Collaborators: M Sutula (SCCWRP), J Cloern (USGS), R Dugdale (SFSU), W Kimmerer (SFSU), R Kudela (UCSC), L Lucas (USGS), A Mueller-Solger (IEP), M Stacey (UC Berkeley), E Gross (RMA), J Fitzpatrick (HDR-Hydroqual), O Fringer (Stanford), M Berg (AMS), A Parker (CSMA), J Hobbs (UC-Davis), T Schraga (USGS), J Thompson (USGS), D Schoellhamer (USGS), M Downing-Kunz (USGS), G Shellenbarger (USGS), K Weidich (USGS), P Buchanan (USGS), F Parcheso (USGS), J Crauder (USGS), M Peacock (UCSC), A Chastain (SFPUC), Erica Spotswood (SFEI), P de Valpine (UC Berkeley)

Region 2: N Feger, T Mumley, K Taberski, B Baginska, R Looker

BACWA: D Williams, J Ervin, E Dunlavey, M Connor

USEPA: T Fleming

Source: C. Benton