Science to Support Nutrient Management in San Francisco Bay

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Outline

- Background: nutrients in SFB
- SFEI Nutrient Initiatives
  - Science synthesis to inform management decisions
  - Monitoring
  - Quantifying nutrient loads
  - Load-response modeling
- SFEI and SCCWRP collaboration
San Francisco Bay - Large nutrient loads...
San Francisco Bay Paradox

Resilience of San Francisco Bay

1) High turbidity
2) Strong tidal mixing
3) Filter-feeding clams

Subject to change?

National Estuarine Experts Workgroup (2010)
Past 20 years → +105%
- decreased clam abundance,
lower grazing rates

Cloern et al (2007)
- low Chl-a → food limitation
- Past 20 yrs → +32%
  
  Source: J. Cloern, USGS

- NH$_4^+$ impacts
  - impairing primary production?
  - toxicity to copepods?

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South Bay

Past 20 years → +105%

- decreased clam abundance, lower grazing rates

Cloern et al (2007)

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Suisun Bay

Corbula clam invasion

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Source: J. Cloern, USGS
Need for a Bay-Wide Nutrient Strategy

- Nutrient objectives on the horizon: Nutrient Numeric Endpoint (NNE)

- Consensus among scientific community: Bay conditions are changing
  - increasing chl-a, harmful algal blooms, other roles of NH$_4^+$ (?)

- No regionally-administered water quality monitoring program
  - uncertain future for USGS research program (40 yr record)

- Lot of nutrient-related work being done with limited coordination
SFEI Nutrients - Science to Support Management Decisions

- *Synthesis to inform management decisions*

- *Monitoring Program Development*

- *Quantifying loads*

- *Load-response modeling*
- **Synthesis to inform management decisions**
  - Bay nutrient strategy
  - Conceptual models, problem definition
  - Objectives and assessment framework: phytoplankton, D.O., NH$_4^+$

- **Monitoring Program Development**

- **Quantifying loads**

- **Load-response modeling**
Key Management Questions

Is there a nutrient problem, and how is it defined?
- *In which Bay segments/habitats?*

Most important sources, pathways, and processes?

What loads can be assimilated without impairing beneficial uses?

What are appropriate guidelines for identifying a problem?
GOAL: Beneficial Use Protection

Draft Nutrient Strategy

Define the Problem

Assessment Framework, WQ objectives

Monitoring Program

Modeling

Control Strategies

Regulatory Approaches

GOAL: Beneficial Use Protection
Bloom formation: South Bay

*Physics and Benthos*

- light limitation

- lateral exchange
  - light-rich shoals
  - light-poor deep subtidal

- seasonal/interannual variations in clam abundance
Evidence of NH4 inhibiting NO3 uptake

\[ \ln(Y) = -1.28 \ln(X) - 4.26 \]

\( r^2 = 0.5 \)

Dugdale et al., 2007
Objectives:

- Determine if NH4, copper and/or pesticides cause inhibition of primary production (laboratory study – TIE)

- Determine if NH4 conc, specific nutrient ratios, or nitrogen uptake rates are related to a lower rate of primary production (field study)

Researchers/Funding: Region 2, SFSU-RTC, SWAMP, Water Contractors, Central Contra Costa Sanitation District
Interagency Ecological Program – Delta and Suisun Bay

- Emphasis on underlying causes of Pelagic Organism Decline (POD)
  - ~$25 mill/yr

- Highly altered ecosystem: withdrawals, altered habitat, contaminants
  - *multiple factors likely contribute to POD*

- Major changes in lower food web of Delta and Suisun Bay
  - *phytoplankton biomass*
  - *zooplankton: biomass, community composition, size*

- *Microcystis* blooms with increasing frequency in the Delta

  Baxter et al. 2010
  Jassby 2008
  Winder and Jassby 2011
  Lehman et al. 2005, 2008
Other Suisun/Delta Nutrient Studies

Microcystis in the Delta (2011-2014; Parker et al., SFSU-RTC)

Goal: Determine environmental conditions leading to Microcystis blooms, their toxicity, and their impact on the pelagic food web

Effect of nutrient forms/ratios and light availability on Delta lower food web (2011-2014; Glibert et al. U-Maryland)

Goal: Test the relationship between phytoplankton community composition/production and N and P ratios and chemical form, and light availability

Sediment flux study (2011-2014; Glibert and Cornwell, U-Maryland)
Strong Bay/Delta Research Community

UC Berkeley, Stanford
- hydrodynamic modeling

UC-Davis
- toxicology

USGS
- phytoplankton, nutrients
- sediment transport
- benthos

SFSU Romberg Tiburon Center
- phytoplankton, nutrients
- zooplankton and fish ecology
- aquatic macrophytes

SFEI
- synthesize past/current work
- identify relevant science gaps
- coordinate/conduct/align future work to address management questions

Regional Board(s)
- State Board

Stakeholders

Interagency Ecological Program (IEP)
- fisheries, ecology, flows
Problem Definition: Conceptual Models, Scenarios

(2012) RMP

What current problems, or future scenarios, are most concerning?

What information do we need to evaluate these problems/scenarios?

How do we detect current problems or the onset of future problems?
Problem Definition: Conceptual Models, Scenarios

Example Scenarios
- 1% per year decrease in sediment load
- decreased clam abundance
- changing nutrient loads, NH4:NO3, N:P:Si
- drought conditions
- climate change effects

Outcomes
- ‘Consensus’ statement on nutrient outlook for the Bay
- Critical knowledge gaps and science plan
- Feedback to assessment framework
- Monitoring/Modeling recommendations
What are the precise measures of phytoplankton that we need to assess? Biomass? Assemblage? Harmful algal species?

What are the appropriate thresholds for regulatory action?

What kind of monitoring data are needed to make an assessment?
Phytoplankton: leading candidate indicator for assessment of Bay eutrophication

Outcomes
- Transparent decision framework to determine whether regulatory action is required
- Numeric targets that can be used to inform decisions on load allocations
Suisun Bay: evaluating potential impacts of nutrients and NH$_4^+$

Complex management questions

- Pelagic Organism Decline (POD)
- Phytoplankton and zooplankton
  - Decreased abundance
  - Different community composition
- Potential links to nutrients, with specific focus on NH$_4^+$

(2012-2015)
Suisun Bay: evaluating potential impacts of nutrients and NH$_4^+$

(2012-2015)

**Outcomes**

- **Synthesis** – Nutrient/NH$_4^+$ role in...
  - *altered phytoplankton community composition?*
  - *low primary production rates?*
  - *copepod toxicity*
- **Data gaps and future studies**
SFEI Nutrients - Science to Support Management Decisions

- Synthesis to inform management decisions

- Monitoring Program Development
  - Nutrient/water quality monitoring program development
  - Special Studies

- Quantifying loads

- Load-response modeling
1969-present

- monthly sampling
- research studies
- RMP support

1993-present

- USGS
- IEP
Next Generation...

“Regular” Monitoring

- identify optimal spacing along spine
- complement with moored sensors
Next Generation...

“Regular” Monitoring
- identify optimal spacing along spine
- complement with moored sensors
- lateral transects

Special studies
- processes, internal cycling
- focus sites/habitats
- exchange across Golden Gate
40% shallow subtidal
20% deep subtidal
7% tidal flat
10% tidal marsh
15% diked wetland

Parameters

- **Chemical/biological**
  - salinity, T, PAR, nutrients, DO
  - chl-a, phytotoxins
  - phytoplankton composition
  - zooplankton abundance/composition
  - benthos

- **Processes**
  - growth/uptake kinetics
  - denitr., nitrif., oxygen demand

- **Physical**
  - velocities/exchange (ADVs)
Continuous monitoring

Suspended sediment
- 15 minute interval
- 1991-present
- Funding: RMP & USACE

Salinity/T:
- 15 minute interval
- 1989-present
- Funding: IEP & DWR, USGS
Continuous monitoring

Dissolved Oxygen
- on the horizon...

What else??
- chl-a ?
- nutrients ?
- flow cytometry ?
SFEI Nutrients - Science to Support Management Decisions

- *Synthesis to inform management decisions*

- *Monitoring Program Development*

- *Quantifying loads*
  - On-going watershed loading studies
  - Effluent characterization and Bay segment load estimates

- *Load-response modeling*
Contaminant export from urban watersheds

- 10 year SFEI history of characterizing contaminant export from Bay-area watersheds
  - Stormwater sampling program
  - 20+ watersheds characterized to different degrees
  - Focus: Hg, PCBs, dioxin, other organics, suspended sediments
  - Limited focus thus far on nutrients
Current Studies: nutrients

- 4 watersheds in 2012, 4 storms
- 4-6 watersheds in 2013-2014
- contaminants, flow, turbidity
- Added:
  - NO3, NO2, NH4, PO4, TN, TP

Developing GIS-based “spreadsheet”
Regional model

Funding: RMP and BASMAA

Lent and McKee (2011)
Assess Nutrient Loads to the Bay (2012-2013) RMP

- Assess major nutrient loads (and composition)
- Characterize variations in space and time
- Identify major uncertainties and data gaps, future work
Assess Nutrient Loads to the Bay

- Space/time will be important (Bay segments)
- POTW effluent characterization
- Urban runoff contribution, and Delta inflow

Very Rough Numbers

<table>
<thead>
<tr>
<th>Source</th>
<th>Tons DIN/yr</th>
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<tbody>
<tr>
<td>Bay POTWs</td>
<td>18,000</td>
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<tr>
<td>SacRegional</td>
<td>5,000</td>
</tr>
<tr>
<td>Sac+SJ Rivers (Agriculture*)</td>
<td>5,000</td>
</tr>
<tr>
<td>Urban runoff**</td>
<td>1,000</td>
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*Kratzer et al. (2011)
**Gluchowski and McKee (2011)
SFEI Nutrients - Science to Support Management Decisions

- Synthesis to inform management decisions

- Monitoring Program Development

- Quantifying loads

- Load-response modeling
  - Modeling program development (hydrodynamics, nutrients/contaminants)
Bay/Delta Modeling

- Engaged and top-notch Bay/Delta modeling community

- Multiple platforms, multiple actors, and multiple funders
  - 1D, 2D, 3D
  - Delft3D, UnTRIM, SUNTANS, EFDC
  - limited agreement on “the best model”

- **Strengths**: hydrodynamics and sediment transport

- **Weaknesses**: water quality (nutrients, phytoplankton, D.O.) and contaminant models
Modeling Needs for Nutrient Management

- Goldilocks hydrodynamic model
  - *sufficiently complex, but usable by non-developers*
  - *open-source*

- Development of a WQ/phytoplankton model

- Coupling with coastal ocean model (ROMS)
  - *upwelling and exchange across Golden Gate*

- Compatible (to extent possible) with needs for other contaminants
Staged Approach:

Conceptual Model ➔ Monitoring Program Development

Assessment Framework ➔ Basic Biogeochemical Models ➔ Nutrient Modeling Strategy, Model Development

WQ and bioaccumulative contaminants management model
Numeric Models: Suisun Bay, South Bay

- Quantitative data synthesis and nutrient budgets
- Assess relative importance of key processes/drivers
- Sensitivity analysis, identify critical uncertainties and data gaps
- Characterize system response (e.g., chl, O₂) under future scenarios
Numeric Models: Suisun Bay, South Bay

- flow, tidal exchange ($t_{res}$)
- light limitation
- benthic grazing
- potential inhibition of PP by $NH_4^+$
- budgets: transformations, sources, and sinks
Outcomes
- Key inputs to advanced modeling
- Relative importance of processes
- Uncertainty/sensitivity analysis
- Knowledge/data gaps
  → field studies, monitoring
- Narrowing scenarios of concern
SF Bay Regional Strengths/Resources for Nutrient Research

- Strong engagement of stakeholders and Regional Board

- Established university & agency nutrient research programs
  - Mechanistic understanding of controls on load-response
  - Understanding of how to use phytoplankton as an indicator

- Long-standing ambient water quality monitoring program
  - Key in development of models
  - Status and trends

- Significant data collection on some nutrient sources
  - Stormwater loading studies
  - POTW effluent characterization

- Considerable modeling work (hydrodynamic) to build upon
Overview of Joint SCCWRP-SFEI Presentation

• Comparative presentation on research on common program elements
  — SCCWRP
  — SFEI

• Opportunities for leveraging and enhancing collaboration
  — Roundtable discussion
Potential Areas of Collaboration

Strong collaboration already exists because of NNE

✓ Guidelines
  – Phytoplankton NNE Assessment Framework
  – Application of dissolved oxygen to habitats with “natural hypoxia”

• Load-response models:
  – Hydrodynamic and water quality
  – Watershed and airshed

• Drivers for cyanobacteria and other harmful algal blooms

• Monitoring
Load-Response Models

Hydrodynamic and water quality models:
• Collaboration in development of nearshore models (ROMS, SUNTANS) - biogeochemical & phytoplankton dynamics
• Simple box models
• Mechanistic studies (benthic flux, denitrification/nitrification)

Watershed and airshed loading models
• Applications of spreadsheet versus calibrated numeric models
• Additional investments in land-use specific runoff data
• Methods for direct estimates of atmospheric deposition
Guidelines

✓ Phytoplankton NNE Assessment Framework
  – Will be developed for SF Bay
  – Potentially adapted to other State enclosed bays (including ports and harbor)

• Dissolved oxygen objectives
  – Application of dissolved oxygen to habitats with “natural hypoxia”
  – Common issue to So Cal, SF Bay and Delta
Cyanobacteria et al. Harmful Algal Blooms

- Improved/standardized monitoring methods and networks
  - Passive sampling techniques
  - Development of rapid molecular methods-
  - Monitoring coordination through HABMAP

- Occurrence in different habitat types
  - Benthic
  - Pelagic
  - Streams, lakes, estuaries

- Understanding drivers controlling bloom frequency and toxin production, e.g.
  - Nutrient ratios
  - Hydrology
  - Geology: alkalinity
Monitoring Program

• Design

• Innovative Methods
  – Gliders et al. autonomous vehicles
  – Moored sensors
  – Remote sensing and hyperspectral methods

• Data integration and visualization