Development of a Ammonia/Ammonium Research Framework for the Delta and Suisun Bay

Al Vargas
CALFED

F. Parchaso

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- CALFED Science Program Mission:
  - To provide the best possible, unbiased scientific information for water and environmental decision-making in the Bay-Delta system.

Strategy:

- Facilitate independent peer review

To that end CALFED volunteered to coordinate the development of a Research Framework to assess the role of ammonia(um) in the Delta and Suisun Bay

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Process

- Research framework to be developed by independent panel of national experts
- Open and transparent
- Panel to review the best available scientific information with input from local experts, stakeholders, and interested public in a workshop setting
- Workshop organized by planning committee of stakeholders and agencies

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Pre-Workshop

- Background paper
- List of key references on local studies provided to Panel and workshop participants
- Solicited discussion questions from workshop participants

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Workshop

- Day 1:
  - Introductory/Background presentations by the IEP and CALFED Lead Scientists
  - Brief presentations by the panelists
  - Facilitated discussion based on questions submitted by participants
    1. Sources, fate and transport of ammonia(um)
    2. Food web dynamics
    3. Ecotoxicology
  - Public comment

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Workshop

- Day 2:
  - Panel deliberations in private to develop draft Research Framework Outline
  - Continued facilitated discussions including impromptu presentations by stakeholders and local experts
  - Presentation of draft Research Framework Outline
  - Facilitated discussion and public comment

Role of CALFED Science

- Host, facilitator, coordination, depository and distribution of information (comments and products)

- http://www.science.calwater.ca.gov/events/workshops/workshop_ammonia.html

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Workshop Highlights – Sources Fate and Transport

The discussion focused on a system modeling approach

- integrating the biogeochemistry, biological processes, and hydrodynamics in the Delta and Suisun Bay.
- Explains interactions of components & makes predictions on how changes in nutrient loading & transport will impact ecosystem

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Workshop Highlights – Food Web Interactions

- Discussion focused on the observed low primary productivity in Suisun Bay and the role of ammonia(um) vs grazing by *Corbula amurensis*

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Workshop Highlights – Food Web Interactions – Ammonia(um) Inhibition

- Low primary productivity in Suisun Bay corresponds with increasing discharges of ammonia(um)
- Dugdale – [NH_4] >4uM (56 ug/L) inhibits uptake of NO_3 in Suisun Bay
- Theoretical 75% reduction in primary productivity from reduced NO_3 uptake and lower C productivity with ammonia(um)
- Ammonia(um) responsible for depressed diatom blooms

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Workshop Highlights – Food Web Interactions - Corbula

- Proliferation of Corbula is in “lock step” with the decreased primary productivity
- Salinity of Suisun Bay is increasing and becoming hospitable to Corbula
- Trend to increasing primary productivity in the Delta despite ammonia(um) levels 2X those in Suisun Bay
- Diatom blooms occur in wet years due to short residence times

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Workshop Highlights – Ecotoxicology

- Data and science gaps identified with regard to toxicity assessment include:
  - Toxicity monitoring of POD sensitive life stages and habitats
  - Monitor toxicity and ammonia(um) near sources
  - Monitor diurnal variations in pH, T^{o}, ammonia(um)
  - Study chronic and sub-lethal effects
  - Study mixture of contaminants to assess potential synergism

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Workshop Highlights – Outline for Draft Research Framework

- Outline of the Draft Research Framework
  - Perceptions of the major concerns
  - Conceptual framework
  - Research recommendations

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Workshop Highlights – Outline for Draft Research Framework

- Central to the Panel's recommendations is a conceptual framework of drivers and responses in the Delta ecosystem
- The conceptual framework ties the variable factors of hydrology and climate to the factors and processes that drive primary production

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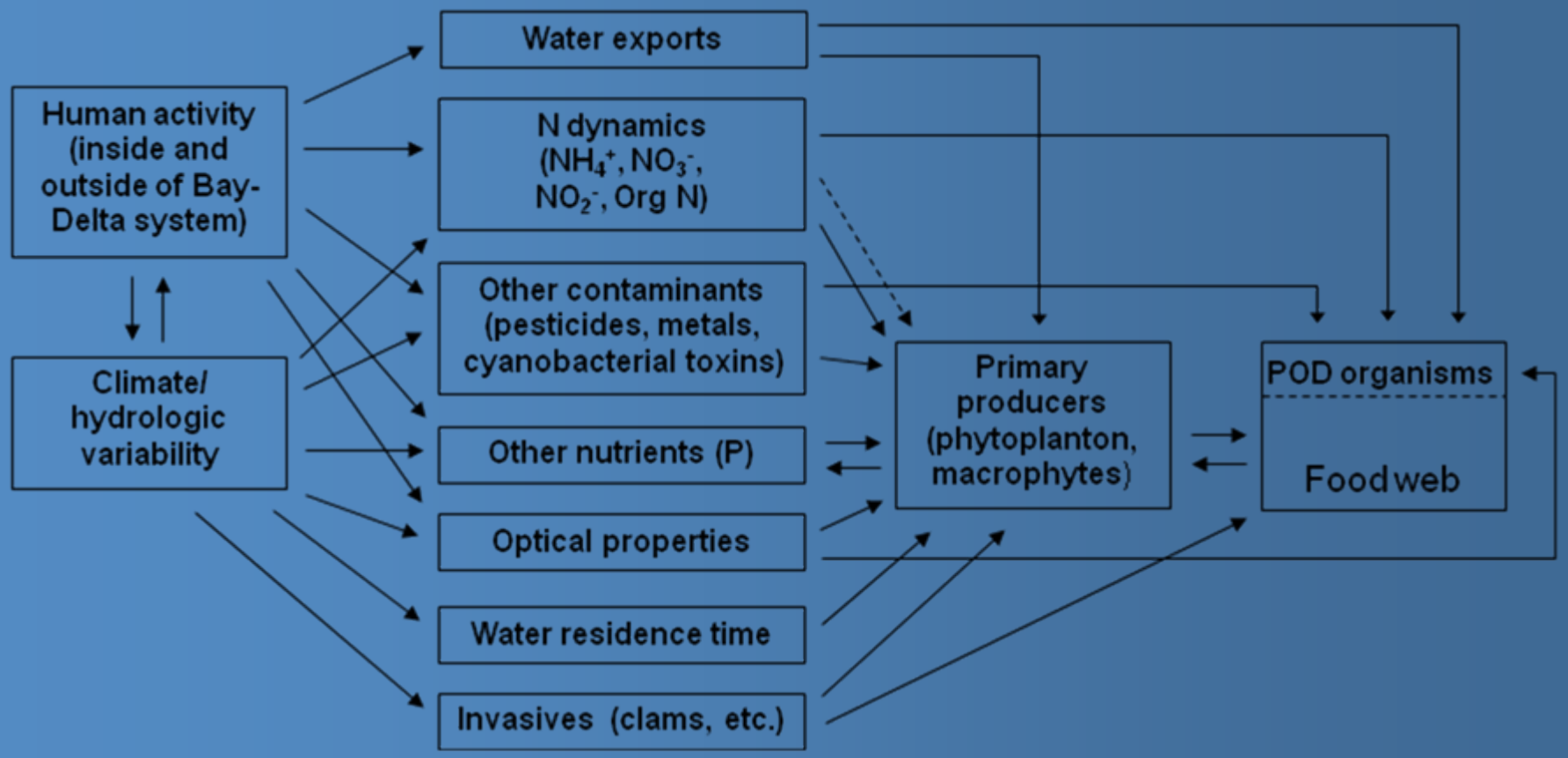
Final Research Framework – Conceptual Framework



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Final Research Framework – Major Research Needs

- Twelve research topics recommended
  1. Modeling – 1 research topic
  2. Sources, fate & transport – 2 research topics
  3. Food web effects – 6 research topics
  4. Toxicity – 3 research topics

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Final Research Framework – Priority Research

- Research Topic 1 – Modeling analysis of historical controls on phytoplankton populations
- Research Topic 2 – Sources and fates of N and P
- Research Topic 4 – Links between nutrient processing and phytoplankton populations
- Research Topic 11 – Cyanobacterial toxins

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Final Research Framework – Priority Research

- Most important research gap - development of an integrative model of the major drivers controlling the Bay-Delta ecosystem.

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Final Research Framework – Major Research Needs

- Purpose of model:
  - Guide and prioritize current and future research
  - Integrate information
  - Predict outcomes of potential management actions

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Final Research Framework – Integrative Model

- Major model components
  - Hydrology
  - Biochemistry of N & P
    - Sources (internal and external)
    - Sinks
    - Transformations – nitrification, denitrification, mineralization
  - Trophic structure and function
    - Rate constants for transformations and trophic transfer processes

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Final Research Framework – Research Topic 1

Modeling should distinguish the influences of changes from:

- nutrient loading
- freshwater flow (residence time)
- grazing

on cyanobacteria blooms in the Delta and downstream phytoplanktom blooms in Suisun Bay

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Final Research Framework – 4 Questions to be addressed in Topic 1

1. Delivery of ammonia(um) vs residence time as controlling factors in phytoplankton dynamics
2. Nutrient threshold responses vs invasive filter feeders in primary productivity in Suisun Bay

Evaluation of phytoplankton production and consumption to assess the role of grazing in controlling spring blooms

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Final Research Framework Priority Research

Topic 2 Sources & Fate of N & P

Central question to be addressed:

- What is the role of WWTP effluents vs other sources (internal & external) in controlling ammonia(um) concentrations and N dynamics in the Delta and in Suisun Bay?

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Final Research Framework – Research Topic 2 Sources & Fate of N & P

Three approaches suggested:

1. Longitudinal transects of N and other parameters, stable isotope composition of ammonia(um), N_2.Ar
2. High frequency measurements of N species and other parameters
3. Direct measurement of important processes – uptake of NH4, NO3, nitrification, mineralization, N-fixation

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Final Research Framework
Research Priorities

Topic 4 – Nutrient processing and Phytoplankton Populations

- Purpose is to develop model parameters linking nutrients to phytoplankton production
  - Phytoplankton community composition analyzed in relation to nutrient inputs and physical drivers
  - Use fluoroprobe and diagnostic pigments to provide indices of community composition

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Final Research Framework Priority Research

Topic 11 – Cyanobacteria Toxins

- Why is this important? Climate change and human induced changes may increase the intensity and extent of cyanobacterial blooms in the future
- Little is known about the distribution and concentration and duration of exposure to cyanobacterial toxins and their trophic ramifications

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Final Research Framework Macrophytes

1. Research Topic 3 – Nutrient dynamics in stands of aquatic macrophytes
2. Research Topic 5 – Bottom up controls of higher trophic levels and POD organisms
3. Research Topic 9 – POD habitat in stands of aquatic macrophytes

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Final Research Framework
Research Topics - Macrophytes

- Research Topic 3 – Nutrient dynamics in stands of aquatic macrophytes
- What are the effects of macrophytes stands on nutrient transport and transformation?
- Approach:
  - low altitude photography and GIS analysis
  - nutrient changes upstream and downstream vs control

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Final Research Framework
Research Topics - Macrophytes

Research Topic 5 – Bottom up controls of higher trophic levels and POD organisms

- Do cyanobacteria blooms and macrophyte stands act as nutrient filter/transformers?
- How have these changes affected higher trophic levels and POD organisms?

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Final Research Framework Research Topics - Macrophytes

- Research Topic 9 – POD habitat in stands of aquatic macrophyte
- How do changes in extent of and distribution of submerged aquatic vegetation affect POD species?

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Final Research Framework
Inhibition by Ammonia(um)

1. Research Topic 7 – lag times in NO_3 uptake in phytoplankton bioassays
2. Research Topic 8 – Inhibition vs preferential uptake of ammonium

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Final Research Framework – Other Research Topics – Food Web Effects

Research Topic 7 – lag times in NO_3 uptake and growth in phytoplankton bioassays

- Is the delay growth response in phytoplankton bioassays caused by the "container effects" or by NH_4 inhibition of NO_3, other nutrient limitations and/or inhibition by metals or xenobiotic compounds?

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Final Research Framework – Other Research Topics – Food Web Effects

- Research Topic 8 – Inhibition vs preferential uptake of ammonium
- Per amount of N assimilated, is there a change in productivity, C:N uptake ratios, and growth per unit N uptake when phytoplankton are grown on NH_4 vs NO_3?

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Final Research Framework POD

1. Research Topic 10 – Sensitivity of POD organisms to ammonia(um)
2. Research Topic 12 – Field observations of POD organisms

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Final Research Framework – Other Research Topics -POD

Research Topic 10 – Sensitivity of POD organisms to ammonia(um)

- Assess the sensitivity of POD fishes to acute toxicity
- Use most sensitive POD fishes to further assess chronic toxicity sensitivity under stressed and standard conditions
- If POD spp not sensitive than assess prey species sensitivity to ammoni(um)

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Final Research Framework – Other Research Topics -POD

Research Topic 12 – Field observations of POD organisms

- No historical fish-health data are available for POD fishes. Baseline is needed from which to compare future fish health.
- Recommend initiating fish-health monitoring program per protocols of Adams et al. 1993
- Include genomic response to ammonia(um), metals and potential pesticide exposures, and micro-toxins.

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Final Research Framework Climate Change

Research Topic 6 – Effects of climate change on phytoplankton

- How will anticipated changes (increased spring flows and decreased fall flows) impact the expansion of cyanobacteria blooms in the Delta and phytoplankton blooms in Suisun Bay?

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Conclusions

- The external Panel of experts recommended 12 research topics in four topic areas: 1) modeling, 2) sources, fate and transport, 3) food web dynamics, and 4) toxicity.
- Four research topics were identified as priority.

Conclusions

- The primary recommendation was the development of an integrative model of the majors drivers controlling the Delta ecosystem.
- The model is intended to allow for evaluating of competing hypothesis (NH_4 inhibition, invasive spp, residence time) related to the phytoplankton production dynamics in the Delta and Suisun Bay

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Conclusions

- Three of the priority research topics relate to the development of the model and model inputs (parameters)
- The remaining priority research topic is directed in exploring the toxicity of cyanobacteria toxins to the Delta food web.

- http://www.science.calwater.ca.gov/events/workshops/workshop_ammonia.html

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