INVESTIGATIONS OF EFFECTS OF LOCAL ANTHROPOGENIC NUTRIENT INPUTS ON ACIDIFICATION AND HYPOXIA IN THE SOUTHERN CALIFORNIA BIGHT

WEBINAR: September 03, 2019
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With James McWilliams, Martha Sutula, Daniele Bianchi, Curtis Deutsch, Richard Feely, Karen McLaughlin, Lionel Renault, Steve Weisberg and many science partners

Sponsored by:

SCCWRP
University of California, Los Angeles
University of Washington
PMEL
NOAA
Are Local Anthropogenic Sources of Nutrients Exacerbating Acidification and Hypoxia?

Local anthropogenic inputs can exacerbate global drivers, potentially pushing Dissolved O$_2$ and pH to ecological tipping-points.

Two Opposing Views:

- California coastal waters are dominated by upwelling, therefore anthropogenic nutrients are not a primary driver.
- Nutrients Produce Algal Blooms, Which Increase DO and pH in the Surface
- Dead Algae Sink
- Nutrients/ Acid Deposition
- Upwelling
- Acidification & deoxygenation
- Outfall Pipe

Nutrients
High p(CO$_2$)
Low O$_2$, Low pH

We need validated mechanistic numerical ocean models to disentangle

- Natural variability (upwelling)
- Global climate change
- [local] anthropogenic nutrient and organic matter inputs
Key Attributes of ROM-BEC Allow Us to Investigate the Effects of Natural Versus Anthropogenic Nutrients on Ocean Biogeochemistry and Lower Ecosystem
In collaboration with Partners
We Compiled Daily Data on Land-based And Atmospheric Sources of Nutrients, Organic Matter and Freshwater to Used in Model Simulations (Anthropogenic And Natural)

River runoff
(natural + anthropogenic)

POTW ocean outfalls
(only anthropogenic)

Modeled wet and dry deposition (natural and anthropogenic; EPA community multiscale air quality model)

Modeled local atmospheric CO₂ air sea exchange (anthropogenic) (Feng et al)

100 watersheds ~ 40 rivers

18 POTW outfalls
SCB Stakeholders previously agreed on set of two scenarios to assess effects of local anthropogenic inputs

a) Ocean with no atmospheric or land-based inputs
   We call this “no forcing”

b) Ocean with atmospheric deposition and land-based input
   We call this “anthropogenic forcing”

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Howard et al., 2014

Early Modeling Studies (Bight ’08) Showed Us that Outfall N Contributes Over 70% of All Land-based and Atmospheric Sources
This Spring, A Set of Scenarios Were Completed (1997-2000) to Validate ROMS-BEC for This Application and Conduct An Initial Assessment of Effects

- We made a preliminary estimate of “effect” of anthropogenic nutrients on chlorophyll-a, O\textsubscript{2} & pH

- We validated the model against available observations, focusing on “anthropogenic” gradients

- We discussed these findings at a recent SCB Stakeholders Advisory Group meeting and identified next steps
Nitrogen is widely dispersed by ocean currents far from sources.

Ocean with *NO* atmospheric or land-based inputs

Ocean *INCLUDING* atmospheric deposition and land-based input

01 02 1997

Vertical Maximum [nmol m$^{-3}$]
Model Predict Substantial Increase In Algal Blooms

AMJ = Spring: April, May, June --- (Average 1998-2000)
Increased Productivity Increases \( O_2 \) And pH At The Surface But Reduces \( O_2 \) and pH At Depth

0 m  Chl-a at the surface

Oxygen and pH at 50m

Bottom
Model Validation
Model Faithfully Reproduces Anthropogenically-Enhanced Gradients in Chl-a, O₂ and pH Found In Ocean Observations At Appropriate Scales

Temporal Scales
✓ Seasonal
  • Model is capturing a well mixed water column in winter, and stratification in summer

Spatial Scales
✓ Vertical scale (with depth or density)
  • Appropriate change with depth relative to “mixed layer”
✓ Alongshore and Cross-shelf
  • E.g. Model captures intensification of anthropogenic gradients closer to shore
✓ Plume scale
  • Effects are intensified near outfalls and rivers mouths

Oxygen profiles

Summer
Winter
Are These Differences Significant Enough To Warrant Management Attention? 
To Initiate Discussions Among stakeholders:
We Applied Thresholds From Two Approaches Reflected in the California Ocean Plan 
Water Quality Standards

1) Numeric O₂ and pH Objectives
Dissolved O₂ shall not be depressed >10 % from 
that which occurs naturally, as a result of 
discharge of oxygen demanding waste.

pH shall not be changed > than 0.2 units from 
that which occurs naturally.

2) Narrative Biological Integrity Objectives
Nutrient materials shall not cause objectionable aquatic 
growths or degrade indigenous biota

Here we use recent science on biologically relevant 
thresholds for DO₂ and pH to estimate potential habitat compression for selected marine taxa
We Found Excursions Of Thresholds For Both Approaches: $O_2$ % change and biological effects

e.g. Santa Monica Bay Subregion, Anchovy Aerobic Habitat Change

Northern Anchovy (0-200 m)

Deutsch et al. 2015, Howard et al. In review

Santa Barbara Subregion, Pteropod Reproductive Endpoint

Pteropods (0-200 m)

Bednarsek et al. (2019)
While Excursions of Thresholds Are Found, The Management Significance is Still Under Discussion

The Devil is in the Details: Lots of Decisions are Required that Can Affect the "Significance" of Effect

**Interpreting Ocean Plan Numeric Objectives**

- Scale of assessment — what depth range? What horizontal spatial scale? What time period?
- Decisions on how to aggregate data
- Individual effect of a single source or cumulative impact?
- Effect of freshwater only versus nutrients and organic matter?
While Excursions of Thresholds Are Found, The Management Significance is Still Under Discussion

The Devil is in the Details: Lots of Decisions are Required that Can Affect the "Significance" of Effect

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<th>Interpreting Ocean Plan Numeric Objectives</th>
<th>Interpreting Narrative Biological Objectives</th>
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<tbody>
<tr>
<td>• Scale of assessment – what depth range? What horizontal spatial scale? What time period?</td>
<td>Same issues of ocean plan standards, plus</td>
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<tr>
<td>• Decisions on how to aggregate data</td>
<td>• Which species/habitats to choose</td>
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<td>• Individual effect or cumulative impact?</td>
<td>• How to apply thresholds and what is considered significant?</td>
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<tr>
<td>• Effect of freshwater only versus nutrients and organic matter?</td>
<td>- Best metric of change? Absolute depth change, percent change?</td>
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<td>- Extent and severity of effect requires additional interpretation and consensus among biologists</td>
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We need consensus on the interpretation approach
Two subcommittees were created to shape the future work plan

1) Interpretation Approach, led by Katherine Walsh, State Water Board
   • Develop an approach to interpret “impacts” for the existing (and new) model runs

2) Validation and new model scenarios, led by George Robertson Orange County Sanitation District
   • Complete validation to the stakeholders’ satisfaction
   • Run additional model scenarios that address the most prominent management questions (e.g. attribution of individual sources, climate change impacts, etc.)
Investigations of Impacts of Wastewater Recycling on Plume Buoyancy and Environmental Effects is Among the Leading Management Scenarios of Interest

Leveraged by an OC Sanitation District-sponsored Modeling Project to Investigate the Environmental Impact of Wastewater Recycling

Investigating Plume Dispersion After Water Recycling
Huntington Beach (Orange County)

Sponsored by Orange County Sanitation District - Animation by: Minna Ho
We've Formed New Collaborations with Scientists and Stakeholders to Conduct Similar Investigations in Central Coast

**Modeling anthropogenic inputs from San Francisco Bay and Monterey coast**

Collaborative Project with SF Bay Nutrient Management Strategy and SFEI (Senn et al.)
UC Santa Cruz (Edwards et al.,)

And other Regional Partners
Elkhorn Slough NERR
Central Coast Water Board
Questions, discussions, suggestions, collaboration?

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Additional slides
Outfall nitrogen mixes with upwelling with strong seasonality.

E.g. At Huntington Beach (Orange County)

Summer

Nutrients trapped below thermocline and dispersed horizontally.

This situation is recurrent in winter.
Intensity Of Mixing Varies Between Regions

E.g. At Santa Monica Bay (Los Angeles)

E.g. At Point Loma (San Diego)
HABS in Southern California
UCLA (Bianchi et al) – SCRIPPS (Anderson et al) – UCI (Kudela et al) – SCCWRP (Sutula et al) – UW (Deutsch et al)

Nutrients
- Iron
- Silicate
- Phosphate
- Nitrate
- Nitrite
- Ammonium

Phytoplankton
- Small (C, Chl-a)
- Diatom (C, Chl-a)
- Diazotrophs (C, Chl-a)
- *Pseudo-Nitzschia* (Domoic Acids)
- Dinoflagellates
- Coccolithophores

Zooplankton
(multiple groups and improve parametrization)

DOM (C N P Fe)

Dissolved Oxygen

Air-sea exchange

Sediments

POM (C)

pH

Air-sea exchange
Nutrients disperse horizontally far from the sources
Algal Photosynthesis Produces Oxygen In The Euphotic Zone. Respiration Consumes Oxygen And Produces CO$_2$ At Depth.
Difference in dissolved O$_2$ and pH caused by the anthropogenic nutrients loads ---

e.g. Santa Monica Bay at 50m depth

Metric: Which one matters?
BEC simulate acidification

BEC : Comprehensive model of coastal biogeochemistry

WRF (Atmospheric model)

ROMS (Physics)

Land-based Atmospheric-based loads

DOM (C N P Fe)

Air-sea exchange

Nutrients
Iron
Silicate
Phosphate
Nitrate
Nitrite
Ammonium

Dissolved Oxygen

Phytoplankton
Small (C , Chl-a)
Diatom (C , Chl-a)
Diazotrophs (C, Chl-a)

Zooplankton (C)

pH

POM (C)

Air-sea exchange

Sediments

BEC simulate blooms / eutrophication
BEC simulate deoxygenation or hypoxia
BEC simulate acidification

DOM (C N P Fe)

BEC : Comprehensive model of coastal biogeochemistry