Kickoff: The Science of Puget Sound Water Quality

July 26, 2022

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Agenda

8:00 AM	Intro
8:10 AM	Role of the University of Washington Puget Sound Institute
8:20 AM	Dr. Martha Sutula's Keynote
8:50 AM	Q&A
9:10 AM	Breakout Discussions
9:55 AM	Next Steps

Navigating the Workshop

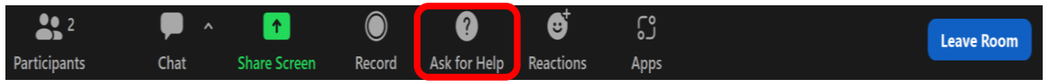
Welcome! While we wait, please:

- Update your name to include your pronouns and organization
- Message Marielle with any access needs
- Introduce yourself in the chat. We've muted participants and turned off your videos to minimize technical issues, so we encourage you to use the chat to say hello instead

Questions or Comments?

- Add them to the chat
- Raise your hand and we'll unmute you

- During the breakout sessions, you can also *Ask for Help* to call the host to your breakout room



The slides, recording, and synthesis will be available on [Puget Sound Institute's website]

Land Acknowledgement

Introduction

University of Washington's Puget Sound Institute provides analysis, research, and communication to inform and connect the science of ecosystem protection.

Implementation Strategy Analyses

- Shoreline Armoring
- Benthic Index of Biotic Integrity (B-IBI)
- Land Development and Cover
- Toxics in Fish
- Marine Water Quality (in progress)

https://www.pugetsoundinstitute.org/about/document-library/

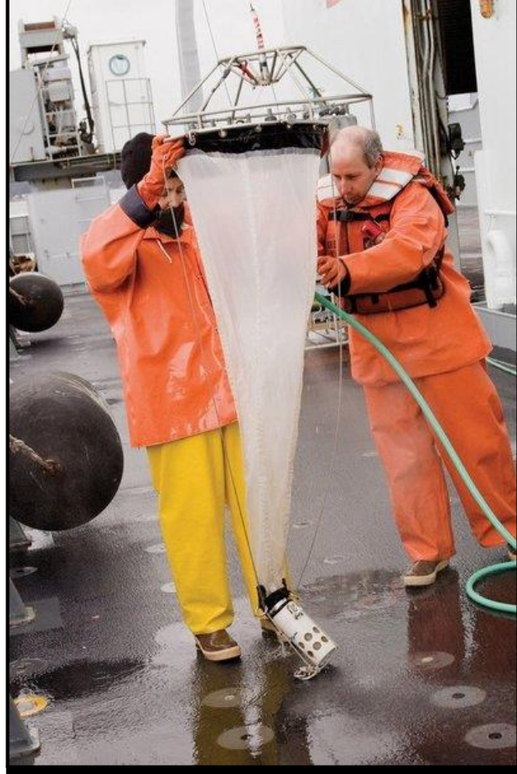
Topics We'll Cover in this Section

- Driving scientific questions and the role of iterative modeling and monitoring
- Marine Water Quality Implementation Strategy and this work
- Additional activities: addressing targeted uncertainties
- Purpose of this particular workshop and breakout groups

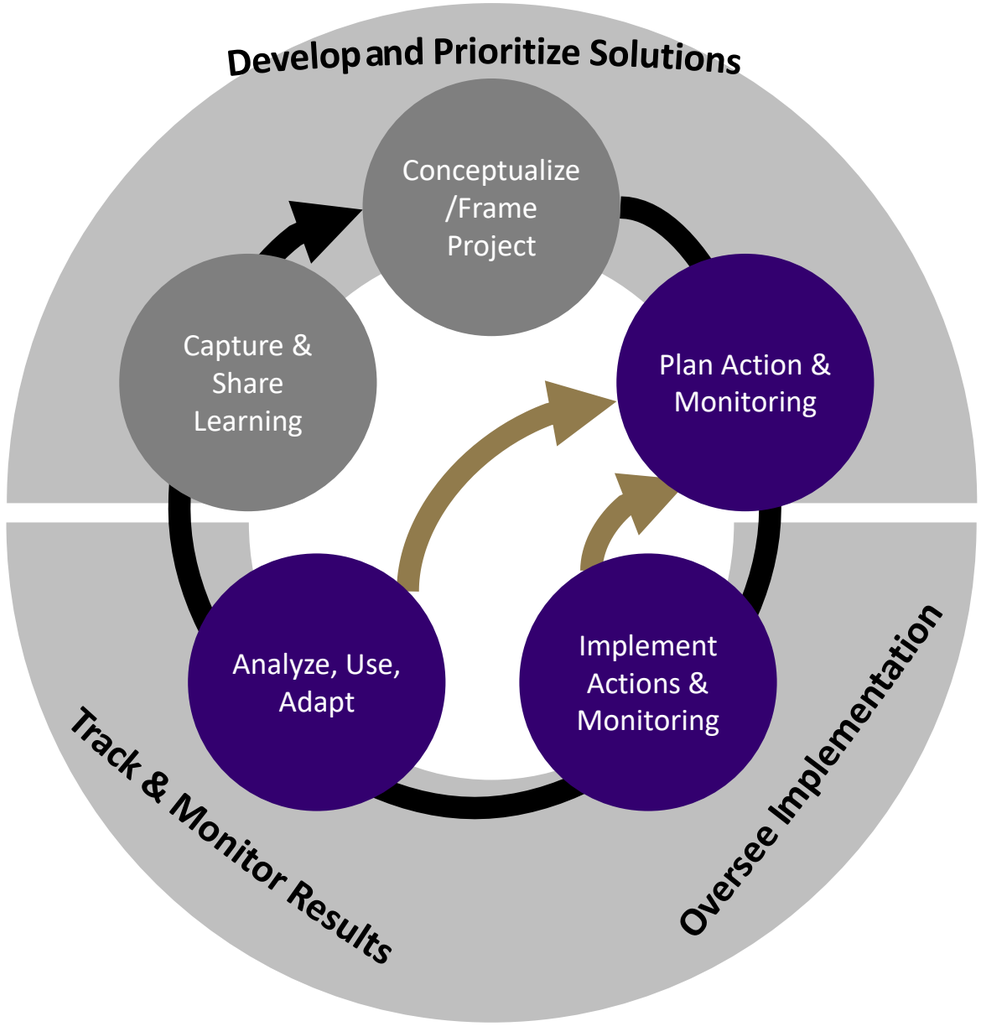
Background: Driving Scientific Questions

- What are the natural and anthropogenic nutrient loadings to Puget Sound?
- What are the ecosystem impacts of the current nutrient loads?
- How confident are we in modeling the consequences of changing these nutrient loads?

Instead of getting stuck on these technical uncertainties, we can move forward to reduce uncertainties that can support action now, and inform future modeling and monitoring

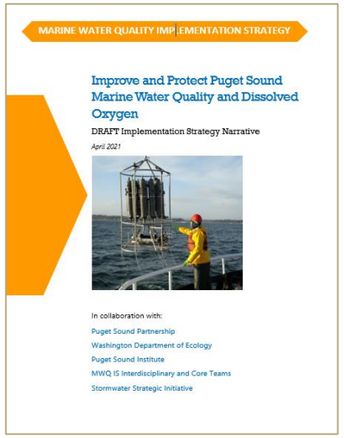


Approach: Adaptive Science Management

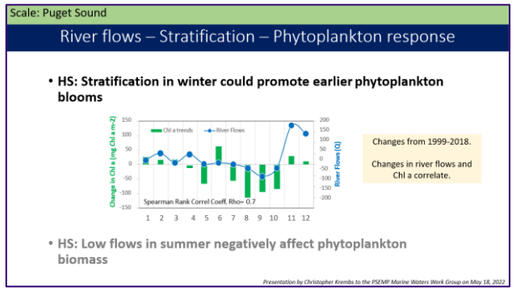


Adapted from *Puget Sound Partnership Adaptive Management Framework*

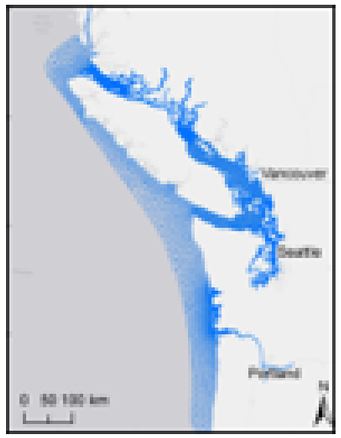
Adaptive Science Management: Modeling/Monitoring



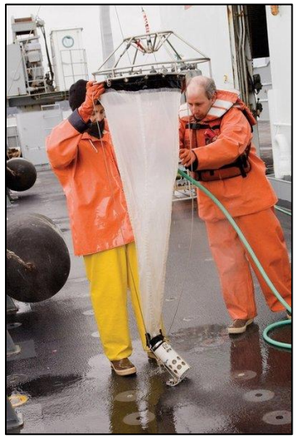
Identification of the problem and uncertainties



Hypothesis from monitoring



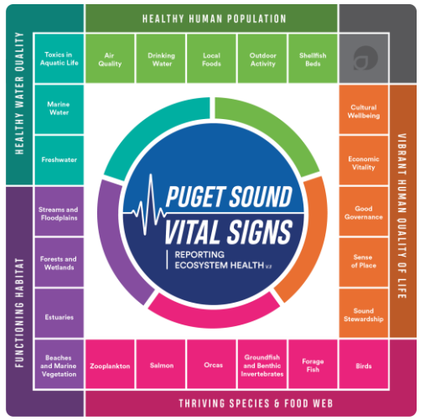
Modeling to test hypothesis

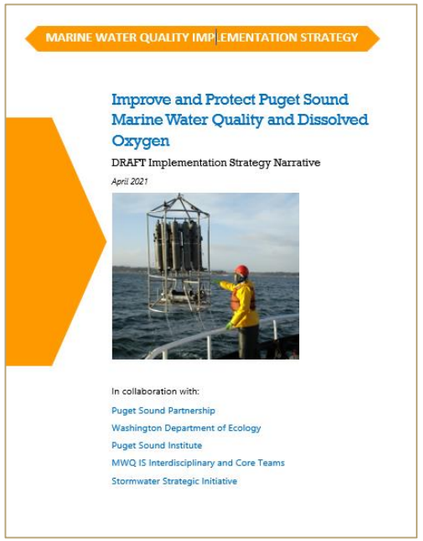


Address further monitoring & knowledge gaps

Marine Water Quality Technical Uncertainties

Puget Sound Partnerships' Marine Water Quality Implementation Strategy





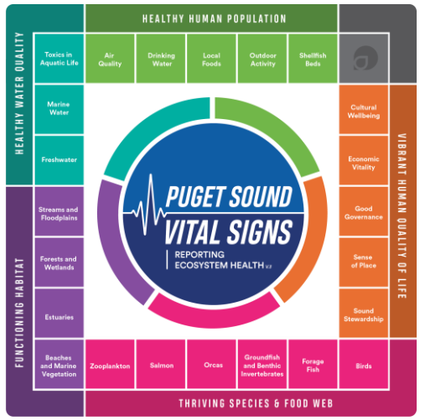
Technical Uncertainties

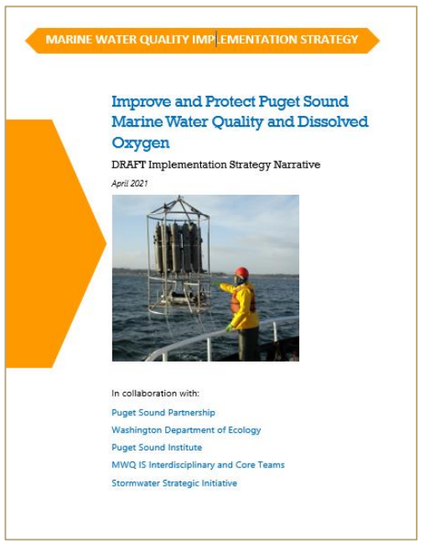
Expectations/outcomes- consensus on uncertainties to move forward with:

- Improved level of confidence in model application
- System science: gaps and priorities for longer-term modeling & monitoring
- Transparent and available access to models and analysis

Marine Water Quality Technical Uncertainties

Puget Sound Partnerships' Marine Water Quality Implementation Strategy





Technical Uncertainties

Research, Modeling, and Monitoring to Reduce Uncertainties

Nutrient Science Community in Puget Sound

PUGET SOUND INSTITUTE
UNIVERSITY of WASHINGTON | TACOMA

SALISH SEA MODELING CENTER
UNIVERSITY of WASHINGTON

Help address technical uncertainties and advance modeling tools to assist decision-making.

- Facilitate scientific workshops and regional collaboration
- Convene Model Evaluation Group
- Lead complementary model runs
- Expand access to models, outputs, tools, and scientific knowledge

Refine Research Actions

Targeted Technical Uncertainties

- Improve confidence in modeling of the Salish Sea and communicate findings

Fall Workshops

- **Dissolved oxygen impacts on the biological integrity of key habitats and species** *(week of 9/26)*
- **Change in interannual variability of rivers and ocean impact** *(week of 10/17)*
- **Phytoplankton and primary production** *(week of 10/24)*
- **Sediment exchange** *(week of 11/14)*
- **Improve watershed modeling to evaluate source reduction strategies to adaptively manage strategies** *(week of 12/12)*

Improved Confidence in Actions

Additional Activities: Addressing Targeted Uncertainties

Convene Model Evaluation Group

- Advise Puget Sound Institute and independently evaluate the application of the Salish Sea Model to support Puget Sound recovery goals on water quality
- **Not in initial scope:**
  - Evaluate regulatory standards
  - A full audit of the Salish Sea Model
- **For transparency:** Collaborate at fall workshop and share recommendations in technical memo and presentation

Lead Complementary Model Runs

- Targeted runs to increase our confidence in the application of the Salish Sea Model for nutrient reduction strategies
- Expand access to the model and modeling outputs

Expand Access to Scientific Knowledge

Articles, infographics, videos, webinars, and more to expand access to models, outputs, tools, and scientific knowledge

Meet the Members


Bill Dennison

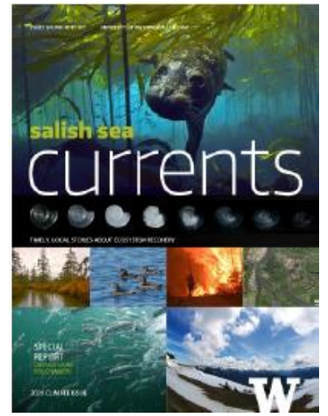

Jacob Carstensen

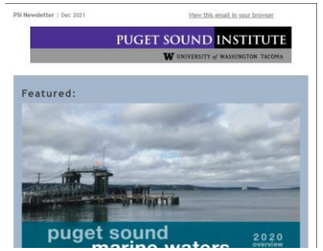

Jeremy Testa


Kevin Farley


Peter Vanrolleghem

Feel free to share!






Dr. Martha Sutula

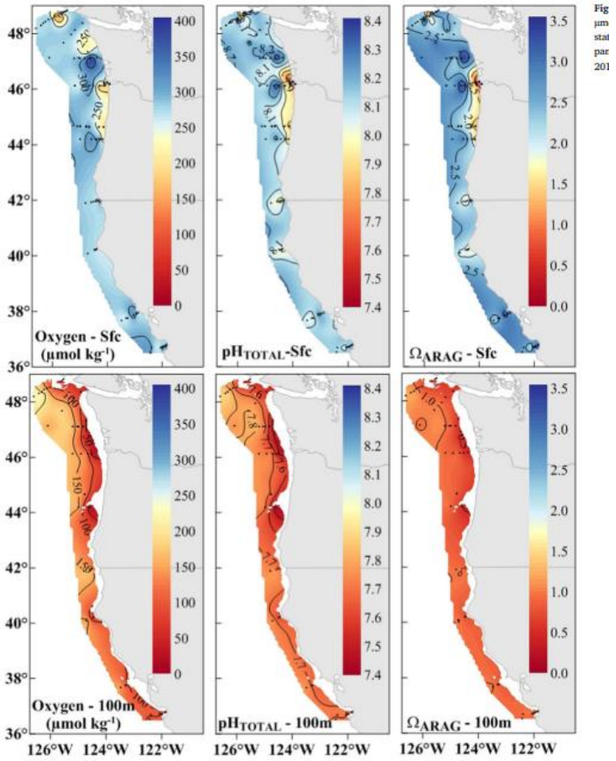
Ingredients to a Solution: Addressing Climate Change and Coastal Eutrophication Stress on Nearshore Ecosystems in the Southern California Bight

Martha Sutula
Biogeochemistry Department Head
Southern California Coastal Water Research Project Authority (SCCWRP)

Puget Sound Institute
Workshop on "Science Supporting Nutrient Management"
Keynote Address
July 26, 2022

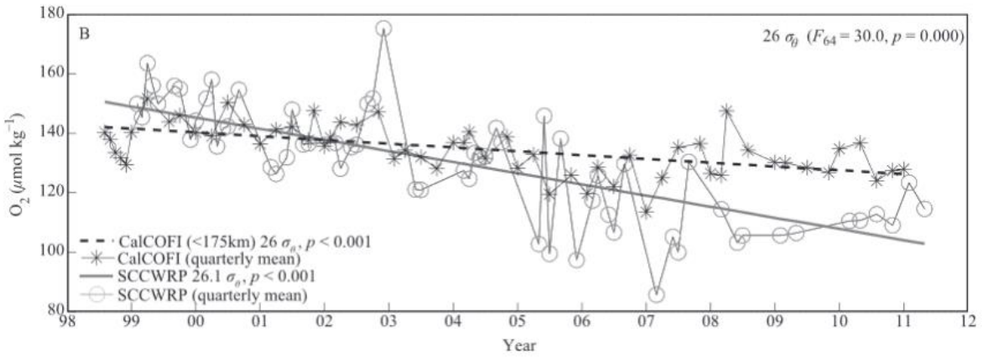
Pacific West Coast Is Stressed Out by Climate Change

Acidification & Deoxygenation (OAH), Warming and Harmful *algal Blooms (HABs) are having Significant Biological Impacts*



Feely et al. (2018) doi.org/10.1016/j.csr.2017.11.002

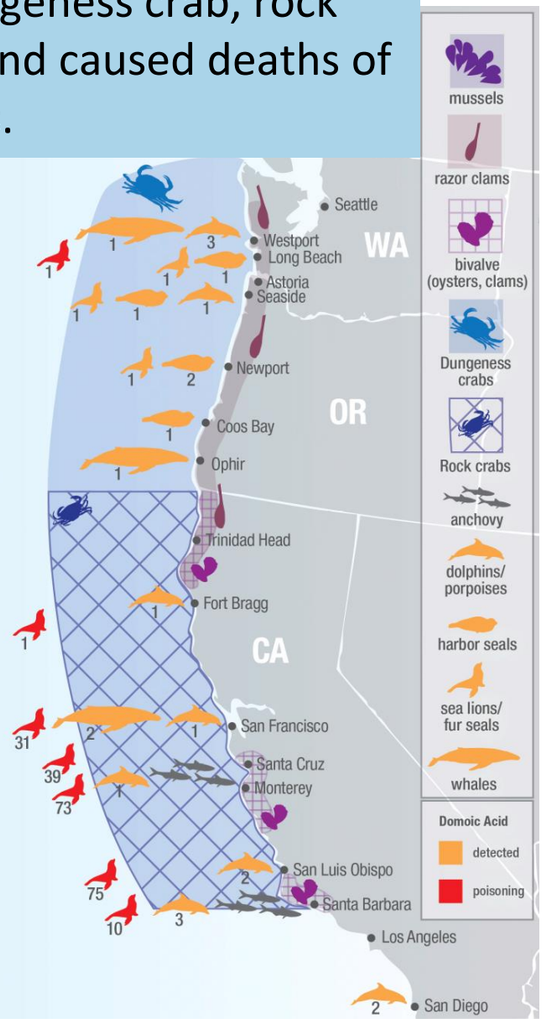
California Current: Corrosive water and hypoxic waters already being seen in shallow water close to shore



Why we are concerned: Declining DO (and pH) in the SCB, e.g. Booth et al. (2014)

Coastwide 2015 Pseudo-Nitschzia bloom caused $125 million coastwide in losses to Dungeness crab, rock crab, and razor clam harvesters, and caused deaths of many species of marine mammals.

2015	Shellfish Harvest and Fishery Closures with Maximum Domoic Acid Values
7-May	Quinault tribe razor clam harvest closure (WA)
8-May	Commercial, tribal & recreational razor clam harvest closure (WA)
9-May	Razor clam harvest closure (northern OR)
14-May	State wide razor clam harvest closure (OR)
15-May	Shellfish harvest closure (BC Canada)
29-May	Anchovy viscera maximum 1671 ppm (CA)
1-Jun	Anchovy, sardine fishery closure (CA)
3-Jun	Dungeness crab maximum 65 ppm (WA)
5-Jun	Dungeness crab fishery closure (WA)
3-Jul	Anchovy, sardine, mussel, & clam closures expanded to southern CA
11-Sep	Dungeness crab maximum 140 ppm (northern CA)
27-Oct	Razor clam maximum 170 ppm (southern OR)
3-Nov	Dungeness crab & rock crab warning for recreational harvest (CA)
6-Nov	Commercial rock crab fishery closed (CA)
8-Nov	Dungeness crab maximum 70 ppm (southern OR)
11-Nov	Dungeness crab & rock crab recreational & commercial fishery closure (CA)
22-Nov	Dungeness crab maximum 270 ppm (northern CA)
23-Nov	Rock crab maximum 1000 ppm (southern CA)
23-Nov	Delayed opening of commercial Dungeness crab fishery (WA, OR, CA)
9-Feb-2016	CA seeks federal disaster declaration for commercial crab fishery



Water Quality Managers On our Coast Share Many of the Same Challenges in Addressing This Problem

- Tremendous variability in pollution inputs, circulation, climate, biological communities
  - One size fits all solution will not work
- Limited long-term support for monitoring and modeling to inform management actions
- Limited knowledge about exact nature of biological impacts (where and when do you see the impacts?)
- Dated water quality goals that do not relate to biological effects
- Urgency to act quickly (short response time)
- Multiple jurisdictions (federal agencies, states, counties and/or municipalities)
- Lack of buy-in on vision for “solutions” and way forward

Ingredients to a Solution to Increase Coastal Resilience to Global and Local Stressors

#1 Willing partners to invest in solutions

#2 Sustained investment in coastal numerical models

#3 Identify solutions worth chasing

#4 Modeling uncertainties are understood

- stakeholder community engagement
- coastal monitoring/research to validate model and investigate causal mechanisms

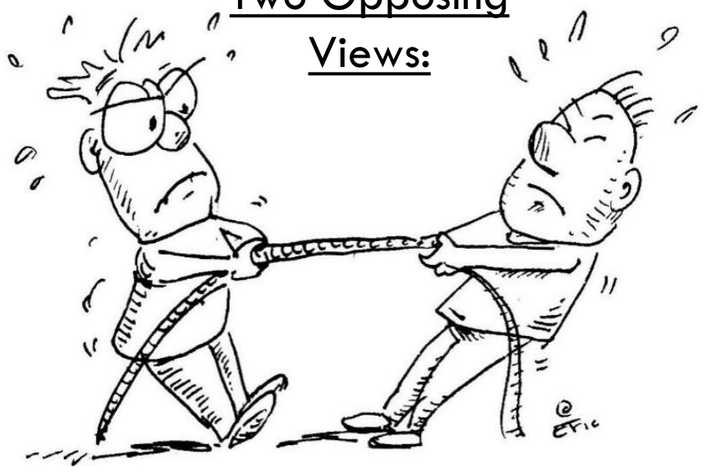
#5 Scientific basis for thresholds of algal biomass, pH and DO impact marine biological resources, as the basis for new water quality goals

#6 Flexibility on what a solution could look like

Southern California Bight (SCB) is A Test Case To Investigate the Effects of Anthropogenic Inputs on HABS, OAD and Consider POTENTIAL SOLUTIONS

California coastal waters are dominated by upwelling, therefore anthropogenic nutrients are not a primary driver

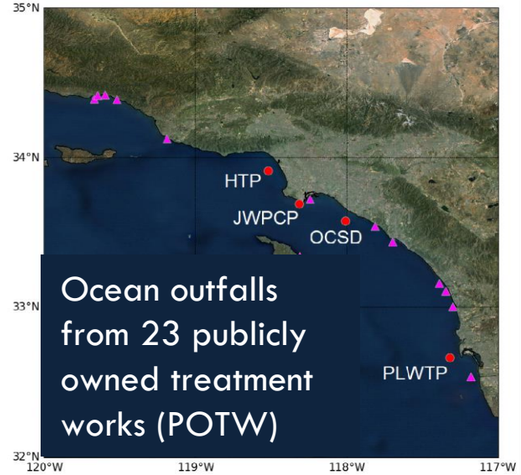
Two Opposing Views:

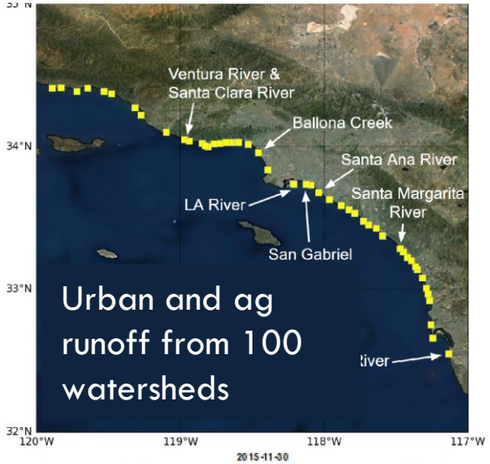


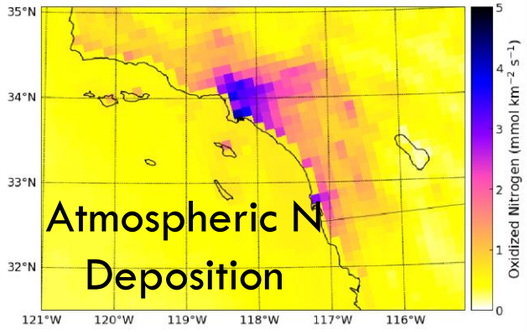
Local anthropogenic inputs can exacerbate global drivers, potentially pushing HABs, DO and pH to ecological tipping-points

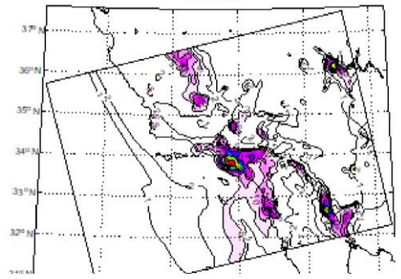
Anthropogenic Inputs from a Coastal Population of 20 Million Has Doubled N In the SCB Nearshore

THE SOLUTION: Nutrient Management Will Cost Tens of Billions of Dollars—is This Really Needed?







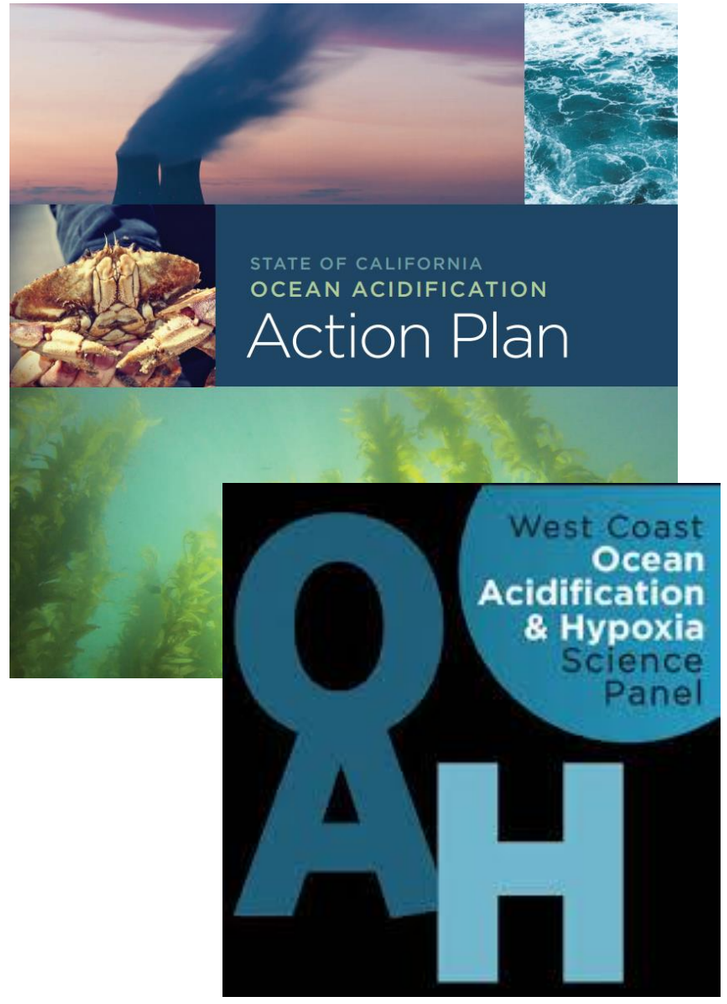


Local Urban Atm. CO2 Dome

Howard et al., 2014 Anthropogenic nutrient sources rival natural sources on small scales in the coastal waters of the SCB 2014, 59 (1):285 L&O 10.4319/lo.2014.59.1.0285

Willing Partners at Federal, State and Regional Level to Invest in Science and Management Conversations to explore Solutions

- California State policy and strategies to invest in SOLUTIONS
  - **Manage local pollution sources**
  - Sequester C through habitat restoration
  - **Create biologically relevant OA and DO water quality criteria**
- Clear directives on science and research from West Coast OAH Panel:
  - Invest in **numerical ocean modeling** to disentangle the contributions of climate change, natural variability and local pollution
- Sustained federal-state-local investments in science and management conversations
  - NOAA and OPC made strategic investments in coastal numerical models



In Southern California, We have 50-year partnership of regulated water agencies, regulators (US EPA, Cal-EPA), CA Ocean Protection Council

- Identify key regional science questions
- Cooperatively fund modeling, research and monitoring
- Get consensus on interpretation of that science
  - What is driving the problem
  - Agree on interpretation framework (a.k.a. water quality goals)
  - Solutions
- Managers use this science to support policy decisions
  - Informal mechanism to build trust and engage in policy discussions

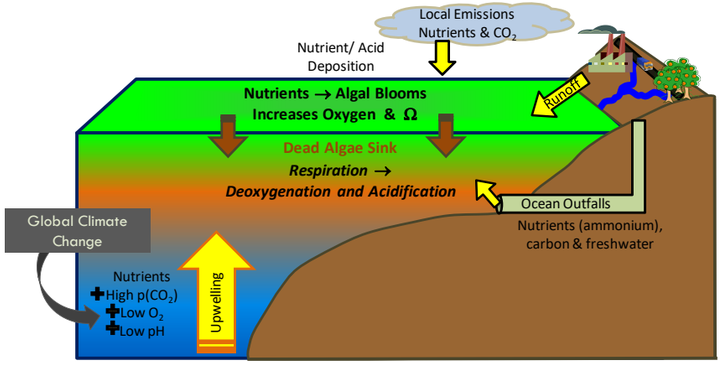
OCEAN NUMERICAL MODEL: MECHANISTIC 3-D REGIONAL OCEAN MODELING SYSTEM (ROMS), PLUS BIOGEOCHEMICAL ELEMENTAL CYCLING (BEC)

Atmospheric forcing
- **W**eather **R**esearch **F**orecast -

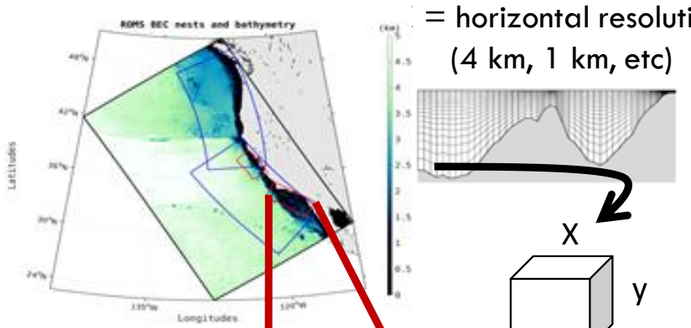
Ocean circulations
- **R**egional **O**ceanic **M**odeling **S**ystem -

Biogeochemical Elemental Cycling

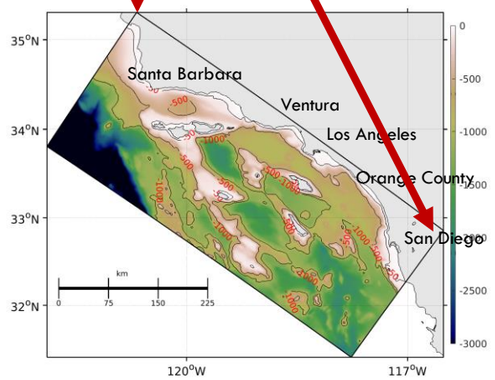
- Zooplankton
- Phytoplankton
- Nutrients
  - Iron
  - Silicate
  - Phosphate
  - Nitrate
  - Nitrite
  - Ammonium
- Dissolved Oxygen
- pH
- Organic matter



Nested Grid: 4km resolution at California Current Scale; 2 subdomains at 1 km resolution for CA, OR and WA



Spatial resolution ~300m

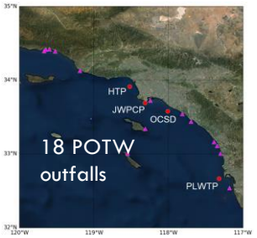


2 smaller subdomains at 300 m resolution within the SCB an and SF/ Monterey Coast

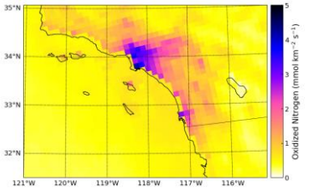
We force land & atmospheric inputs to simulate effects of at 300-m within SCB

River runoff

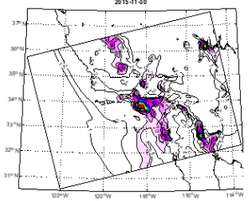
POTW ocean outfalls



Modeled wet and dry deposition



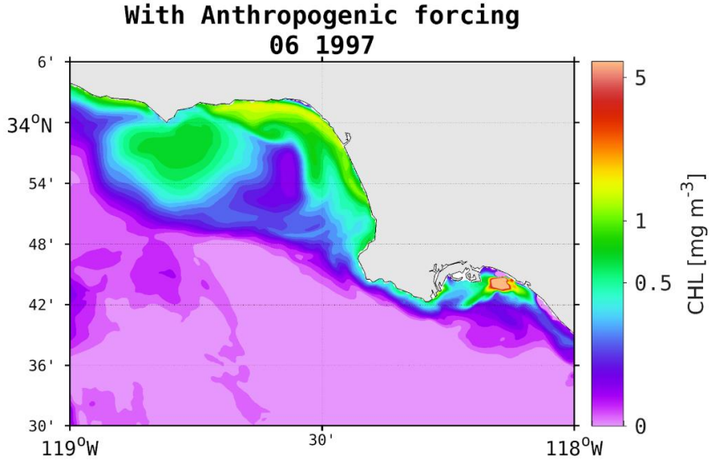
Modeled atm. CO_2 exchange

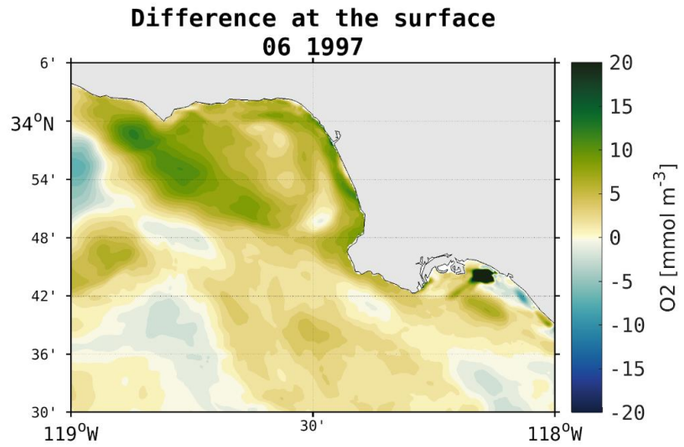


KESSOURI ET AL. (2021) DEMONSTRATED THAT ANTHROPOGENIC NUTRIENTS ARE AMPLIFYING PRIMARY PRODUCTION, ACIDIFICATION AND DEOXYGENATION IN THE SCB

Modeled surface chlorophyll concentration in June 1997

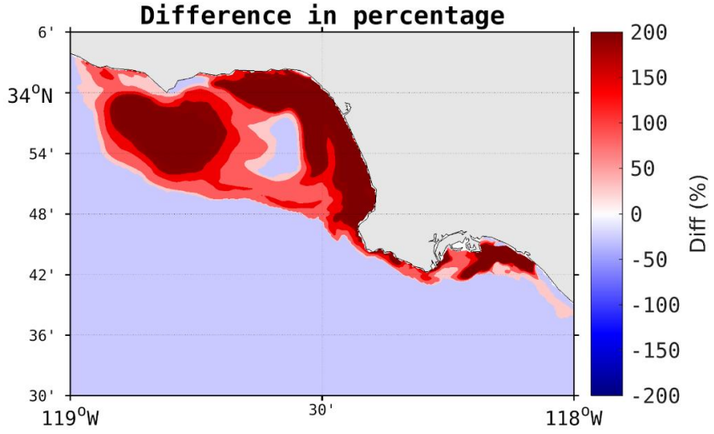
Chlorophyll concentration is increased by anthropogenic inputs

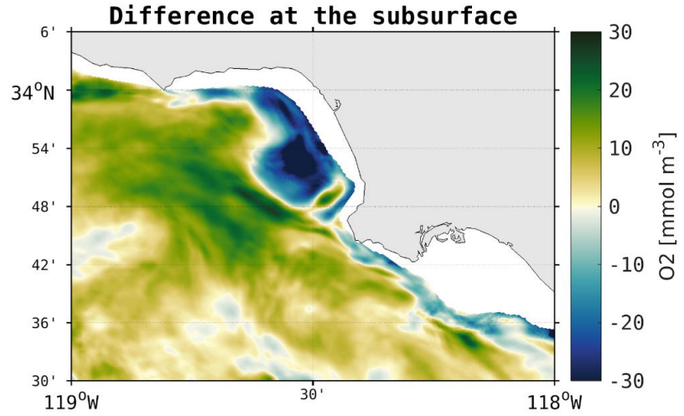




Surface DO increases considerably driven by increased photosynthesis

Percentage increase of surface chlorophyll-a



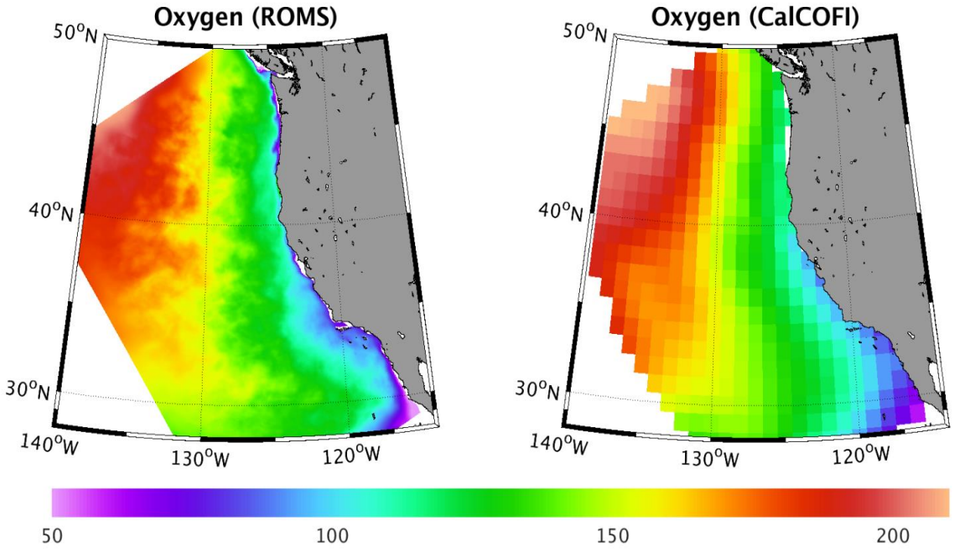


subsurface DO decreases, caused by increases respiration

FROM BIGHTWIDE TO PLUME SCALE WITHIN THE SCB, WE'VE DEMONSTRATED THAT MODEL IS REPRODUCING KEY SEASONAL, VERTICAL AND HORIZONTAL GRADIENTS AND CLIMATE EVENTS FOR MODEL PREDICTIONS

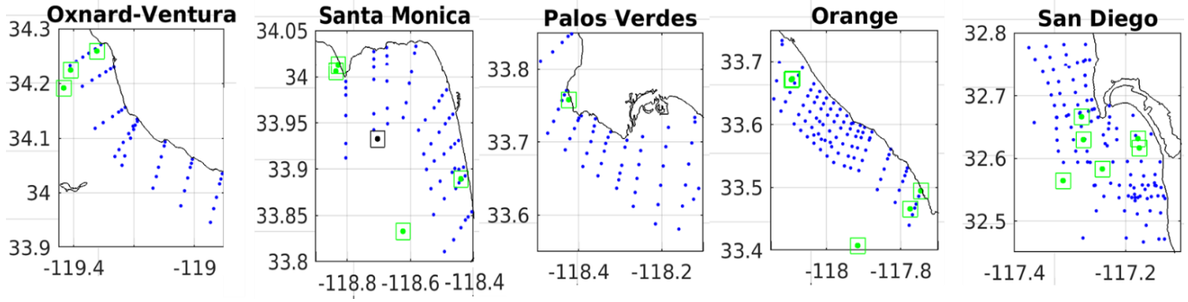
……at CCS-Wide Scale (Renault et al., 2021, Deutsch et al. 2021)

Depth averaged O2 concentrations in ROMS BEC (a) versus measured (CalCOFI (b) O2 in mM

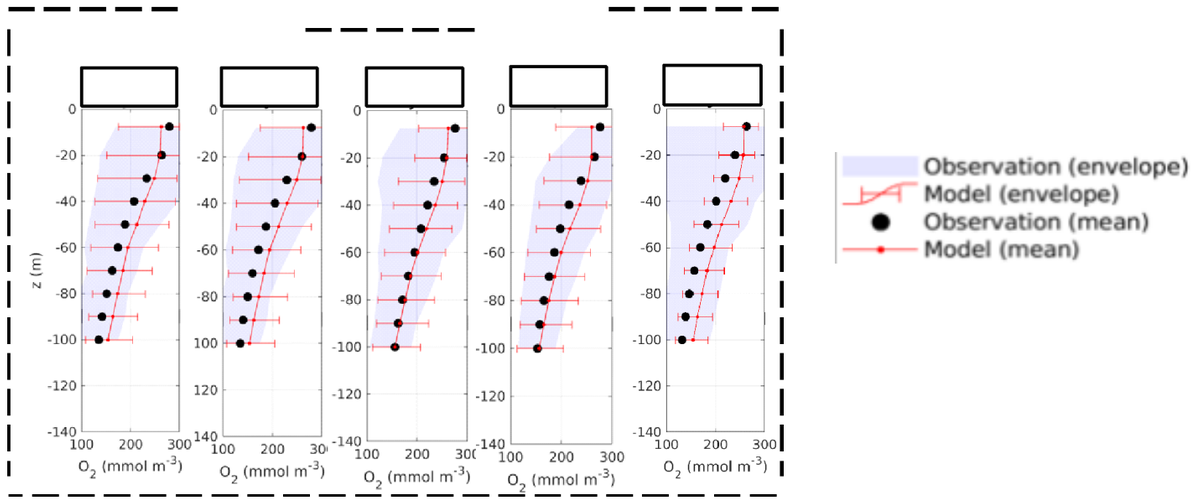


Surface averaged O2 concentrations in ROMS BEC (red line mean and variance) versus measured (CalCOFI) in grey

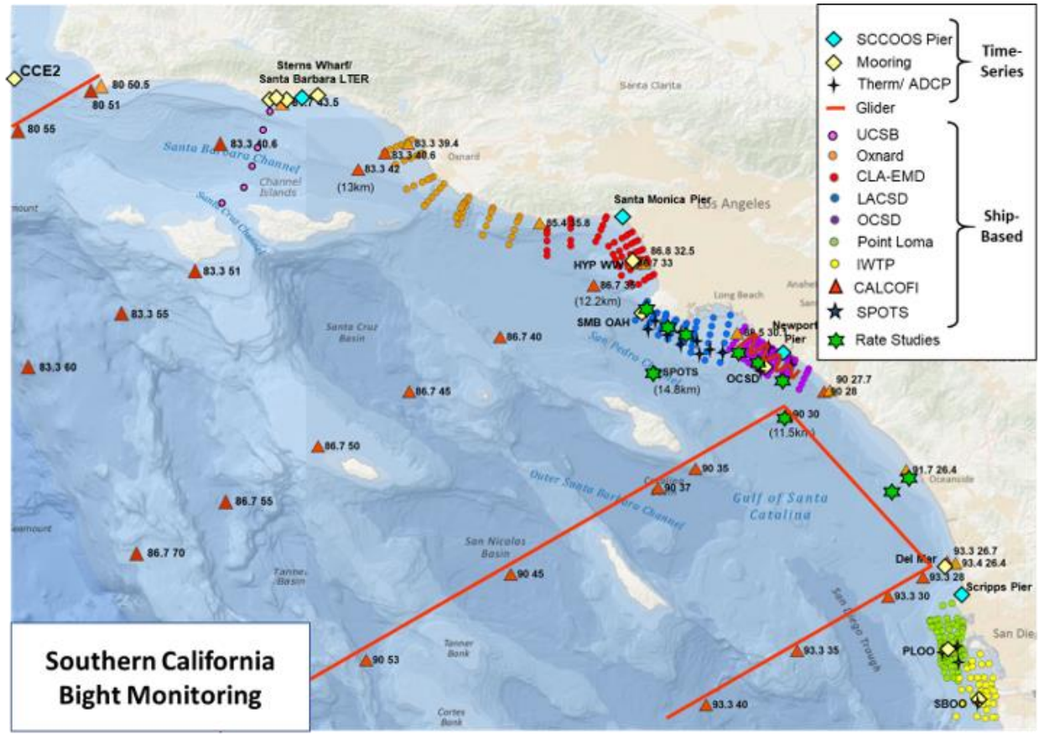
….Within SCB, From Plume to Subregional Scale, Focusing on Anthropogenic Gradients (Kessouri et al., 2021)



ROMS-BEC reproduces seasonal (winter, summer) and annual mean and variability of chl-a, oxygen and pH and biogeochemical rates (McLaughlin et al., in prep)



WE WORKED WITH SCB STAKEHOLDERS TO COMPILE ANTHROPOGENIC INPUTS AND ON MODEL VALIDATION TO INCREASE MODEL CREDIBILITY FOR POLLUTION APPLICATIONS



- With SCB stakeholders (utilities, regulators, environmental NGOs) and scientists, we agreed on a relevant list of anthropogenic gradients, indicators and metrics for validation
- We got consensus on interpretation
- Invested in stakeholder education: Summer 2021workshop on modeling uncertainty

Regional monitoring partnership provided wealth of data

- 50 years of wastewater and 20 years of stormwater data
- 22 years of quarterly data on ocean state and rates
- Multiple temporal and spatial scales

RECOMMENDATIONS FROM 2021 UNCERTAINTY WORKSHOP: HOW TO INCREASE MANAGEMENT CONFIDENCE IN MODELS

1. **Invest in and maintain an open dialogue**
2. **Invest in and maintain long-term chemical and biological monitoring**
3. **Assess the skill of the model, on an ongoing basis**
4. Make transparent the rational for model selection and parameterization
5. **Managers should provide guidance on the interpretation framework**
6. Utilize observations, experiments, and model simulations to synthesize and update conceptual model of coastal eutrophication drivers
7. Make model output, skill assessment metrics, and model code freely available
8. Develop ways to communicate uncertainty in scientific findings
9. Provide sustained funding for modeling program over the long term

EXISTING CALIFORNIA OCEAN WATER QUALITY OBJECTIVES (WQO) ARE NOT "PLUG AND PLAY" FOR THIS APPLICATION

Biological integrity WQO are narrative

- Nutrient materials* shall not cause objectionable aquatic growths or degrade* indigenous biota.

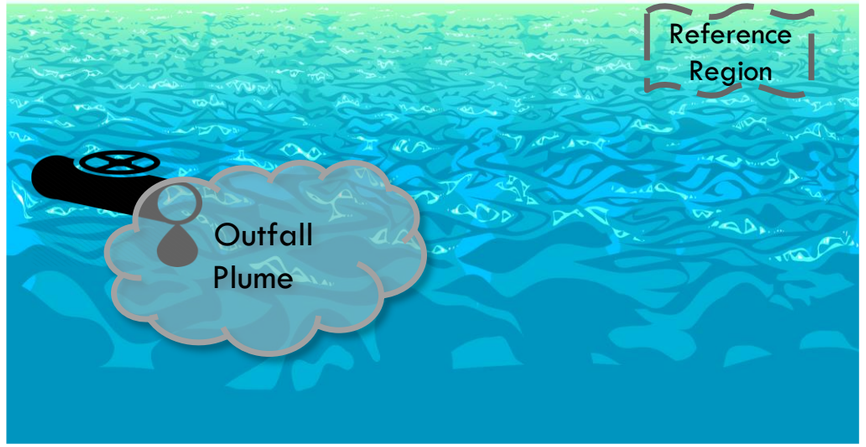
- Biological characteristics: Marine communities…shall not be degraded.*

CALEPA: "I'd like to see us use biological effects (rather than existing numeric WQO)

Numeric pH and Dissolved oxygen (DO) WQO intended to be an "end of pipe" criteria

Can't apply as intended- since nutrients are dispersed regionally and "reference" doesn't exist

- DO WQO ± 10% difference
- pH WQO ± 0.2 pH unit difference)



SCIENCE TO ASSESS BIOLOGICAL EFFECTS

THIS WORK HAS THREE MAJOR COMPONENTS

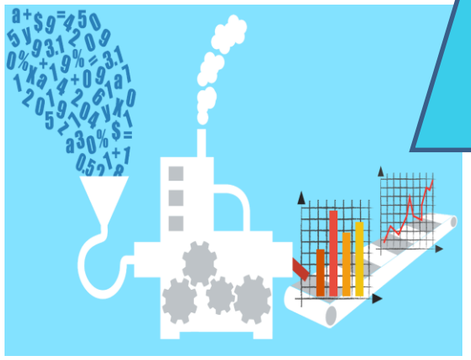
Threshold and/or Index Development

Laboratory Experiments

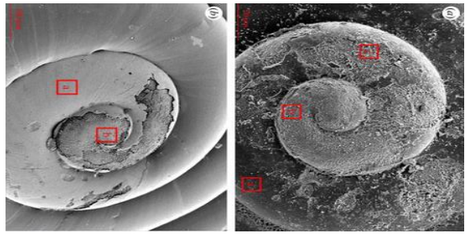
Field Observations

Data Synthesis & Expert Consensus

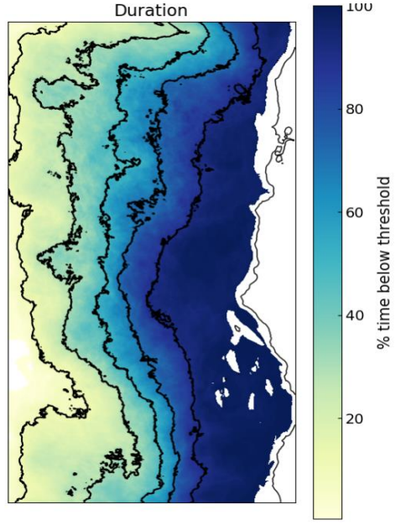
Multi-stressor Index Development



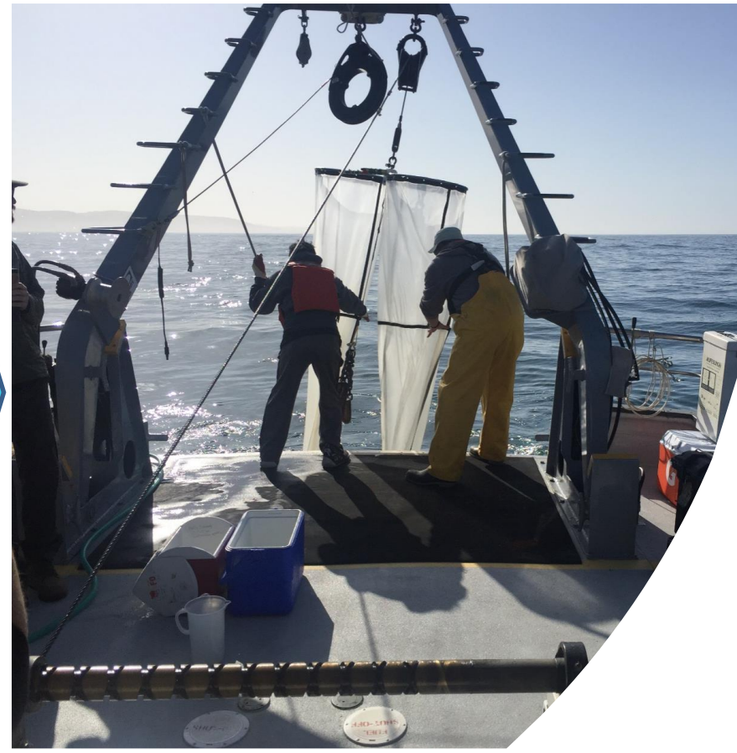
Protocols to Apply Thresholds to Model Output or Observations



Interpretation of Modeled Effects on Biology: e.g. Pteropods



Validation of Thresholds with Chemical-Biological Effects Observations



ESTABLISH PROCESS AND CLEAR SET OF SCIENCE AND POLICY QUESTIONS TO GUIDE TARGET SETTING

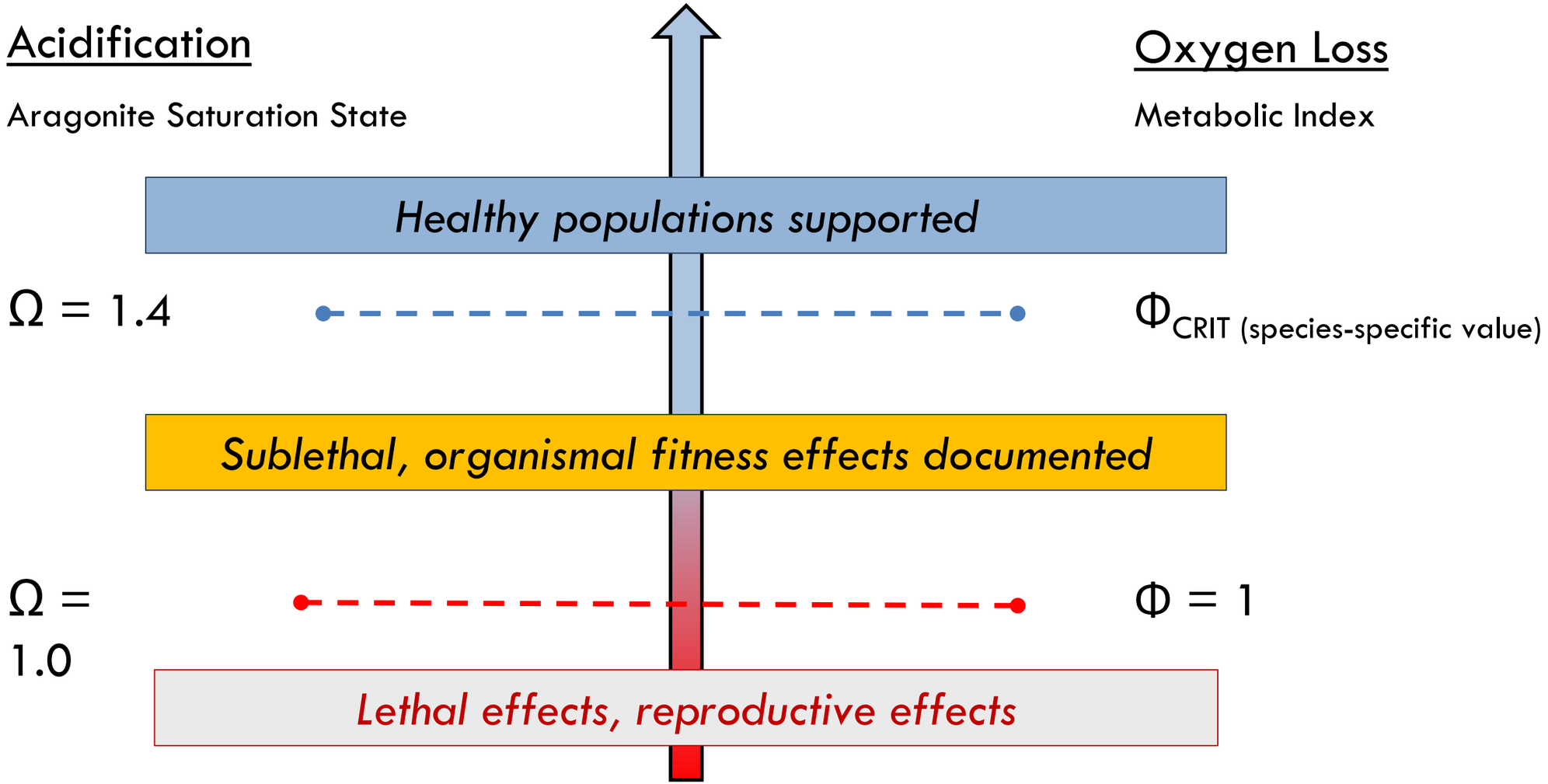
To choose Biologically-relevant Oxygen and pH Targets:

- What metric?
  - E.g. pH, pCo2, aragonite saturation state
- What about multiple stressors?
- What threshold?
  - Level of severity
  - Habitat, taxa, and data used to derive thresholds
- Duration required and spatial and temporal scales used to apply thresholds
- Acceptable frequency of deviation from thresholds

Clarify what technical issues or questions the scientists should weigh in on

And what questions or issues are policy decisions

TO EVALUATE EFFECTS OF ANTHROPOGENIC INPUTS ON pH AND O_2, WE USED TWO THRESHOLDS TO BRACKET EFFECTS

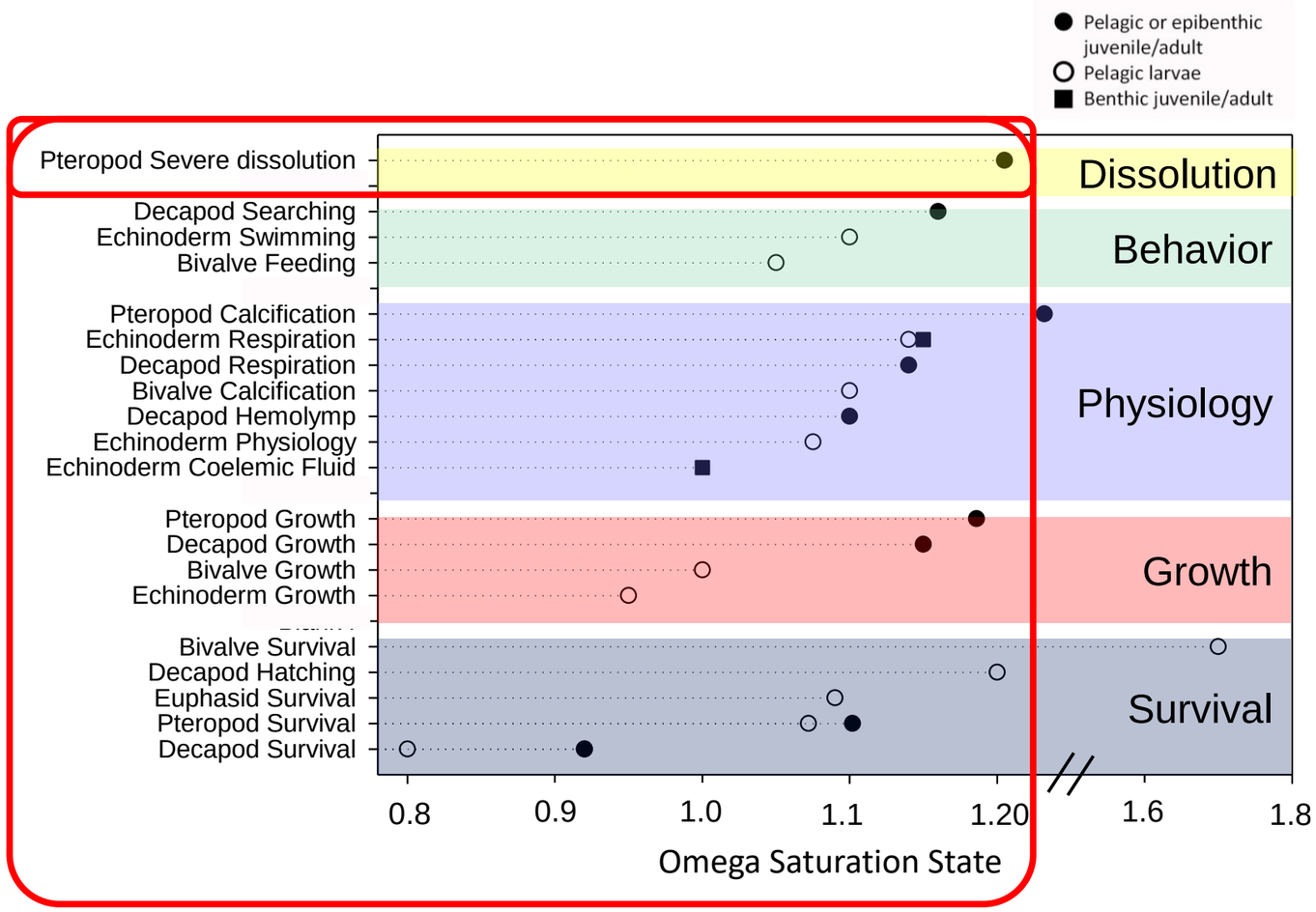


WHAT VALUE OF Ω?

OUR ANSWER IS $\Omega_{ARAG\text{-}TH} = 1.4$

<u>Why?</u>

1. Sensitive taxa approach:
   - For pteropods, severe dissolution occurs at Ω = 1.2
   - Thresholds with highest confidence
2. Multi-taxa approach:
   - Ω = 1.2 protects against physiological and growth threshold responses for multiple taxa: decapods (crabs + krill), echinoderms, urchins, bivalves
3. Protect with measurement error of ±0.2; Therefore, $\Omega_{Arag\text{-}Th} = 1.4$



Oxygen loss and biological effects: Why the Metabolic Index?

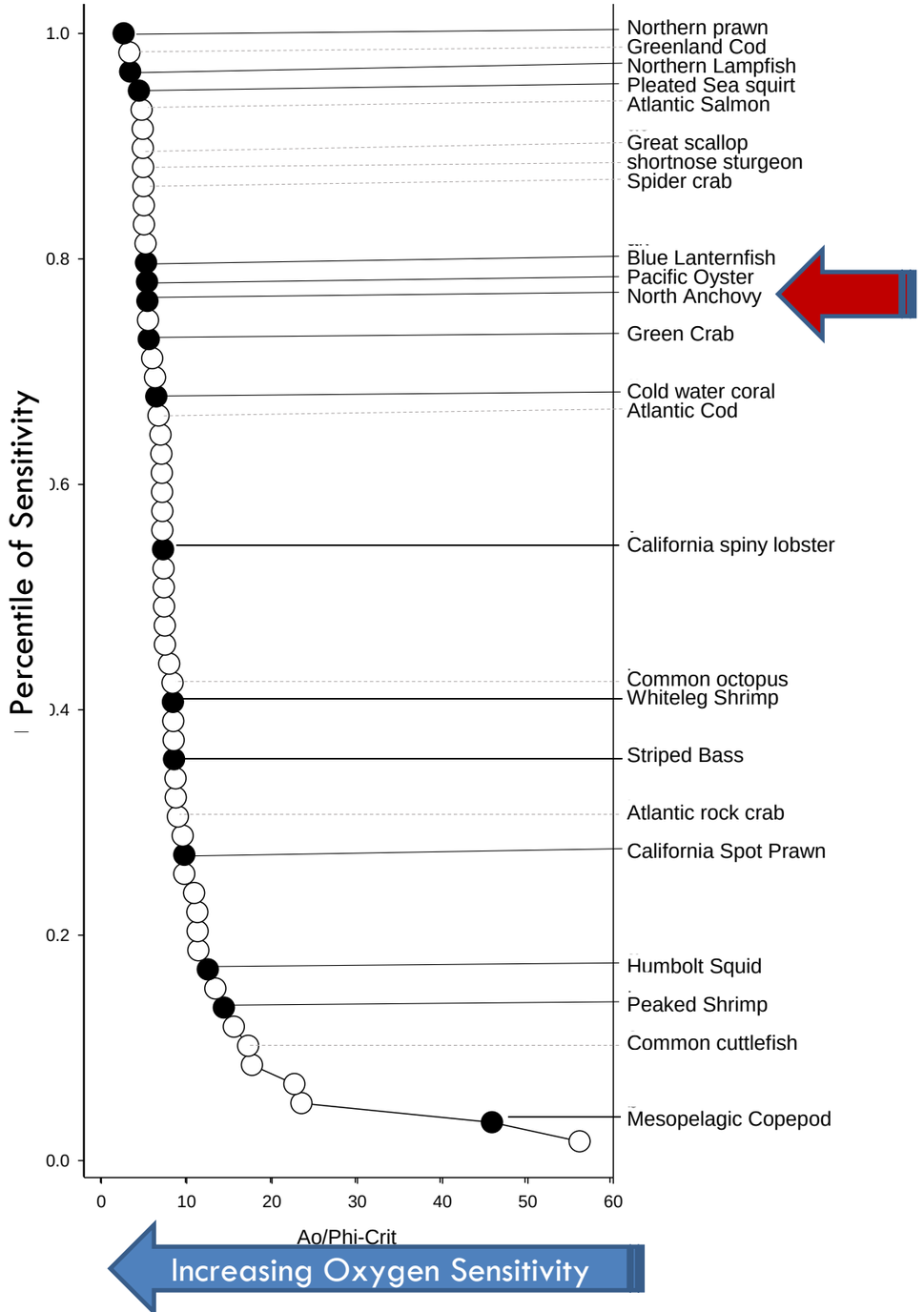
- Historical precedence is to use oxygen concentration (mg/L) to set biologically relevant thresholds
- However, the partial pressure of O_2, pO_2, is what is sensed by biology (drives gas exchange)
- Further, biological sensitivity to oxygen is temperature-dependent
  - Oxygen thresholds can vary 2-fold across temperature range

The Metabolic Index combines pO_2 with temperature-dependent biological responses to oxygen in order to define "aerobically available habitat"

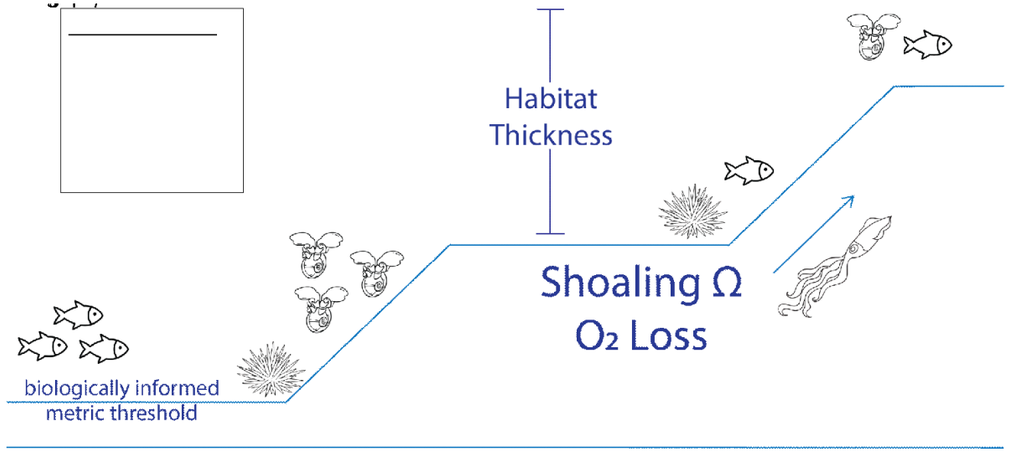
Metabolic Index –Which Value to Choose

<u>Chose oxygen sensitivity representative of northern anchovy</u>

- Epipelagic
- Represents 75th percentile of aerobic sensitivity across all taxa
  - Median of epipelagic taxa
- Commercially and ecologically important
- <u>Validated</u> for California Current with a published case study
  - Strong correspondence to observed abundance data

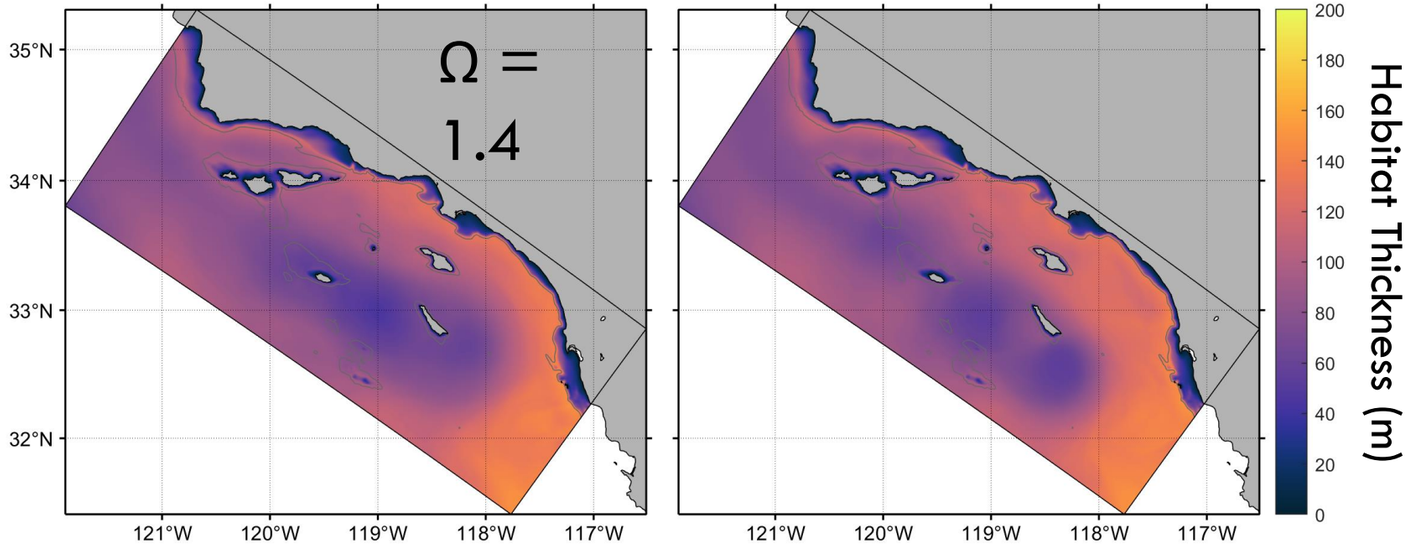


THRESHOLD APPLICATION IN MODEL-BASED ANTHROPOGENIC CHANGE ASSESSMENT

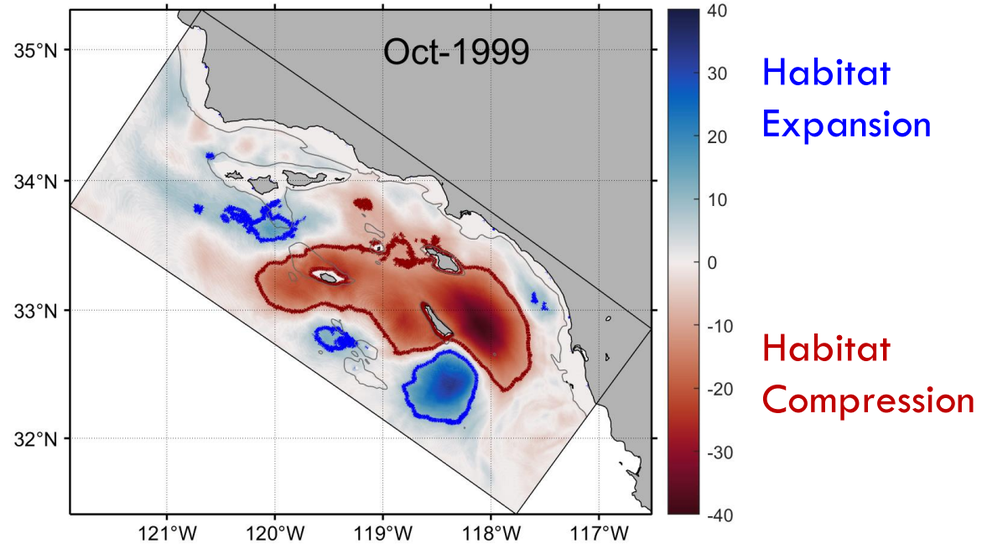


w/ land-based inputs

ocean only



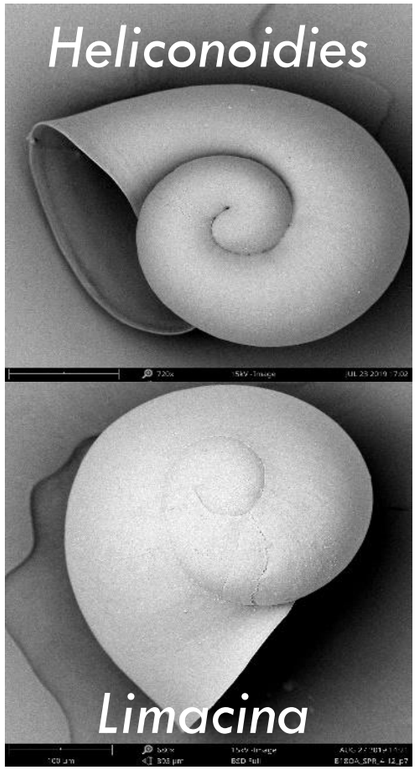
% Change in Habitat Thickness

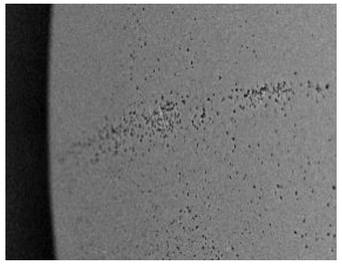


<u>Note--</u> it is a longer road to develop biologically relevant water quality criteria

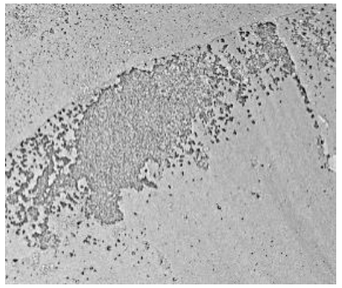
CONSENSUS ON INDICATOR ORGANISMS AND METRICS HAVE SPURRED INVESTMENTS IN COUPLED CHEMICAL BIOLOGICAL MONITORING, LINKING REGIONAL PROGRAMS TO WEST COASTWIDE OBSERVATIONS

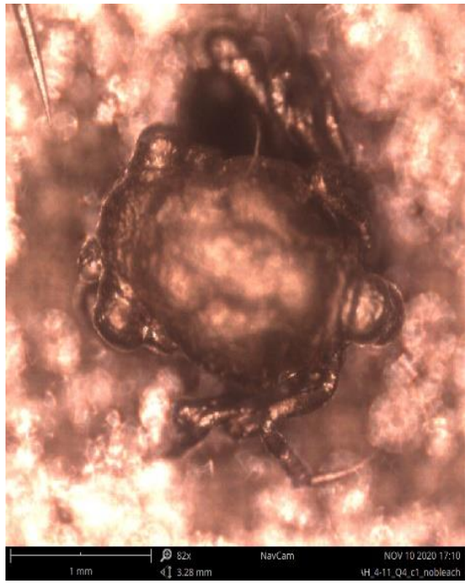
How do observed species distributions match model predictions based on temperature, dissolved oxygen and pH/carbonate saturation state?





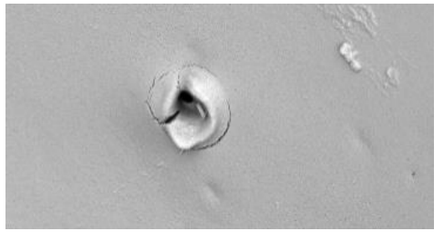
Intensity and % Cover of Dissolution



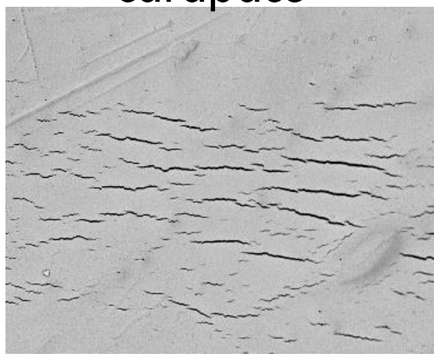


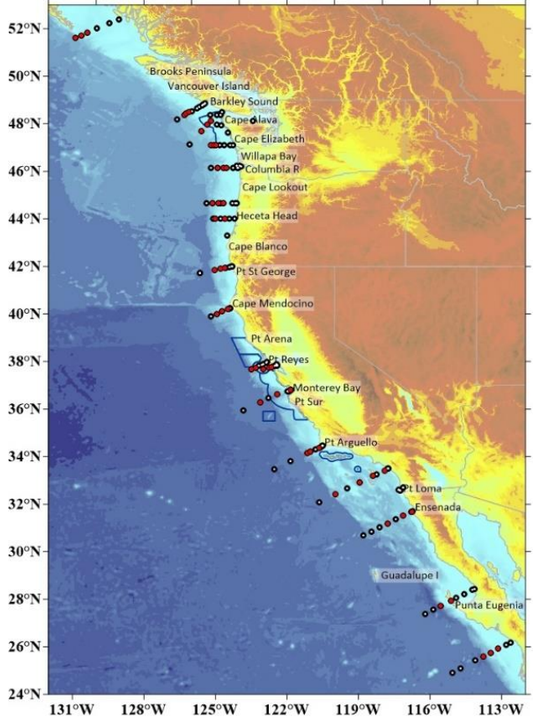
Crab Larvae

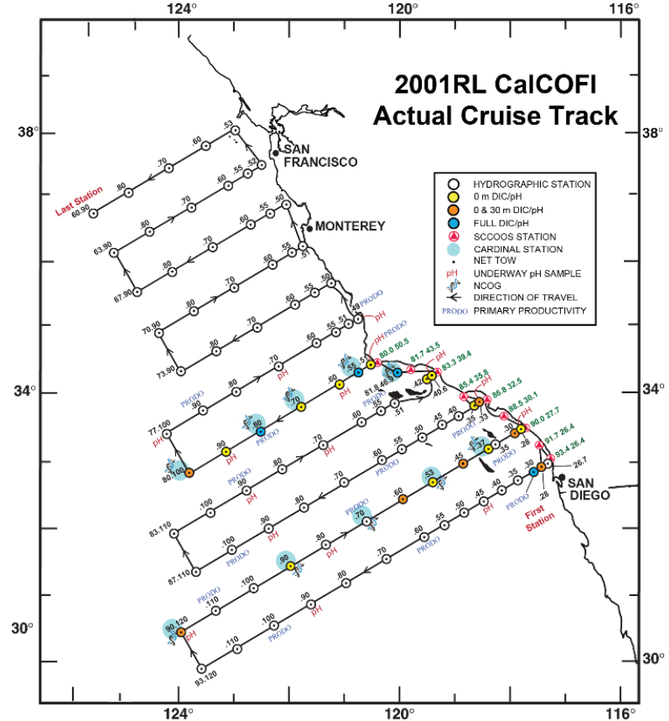
Dissolution of mechanoreceptors



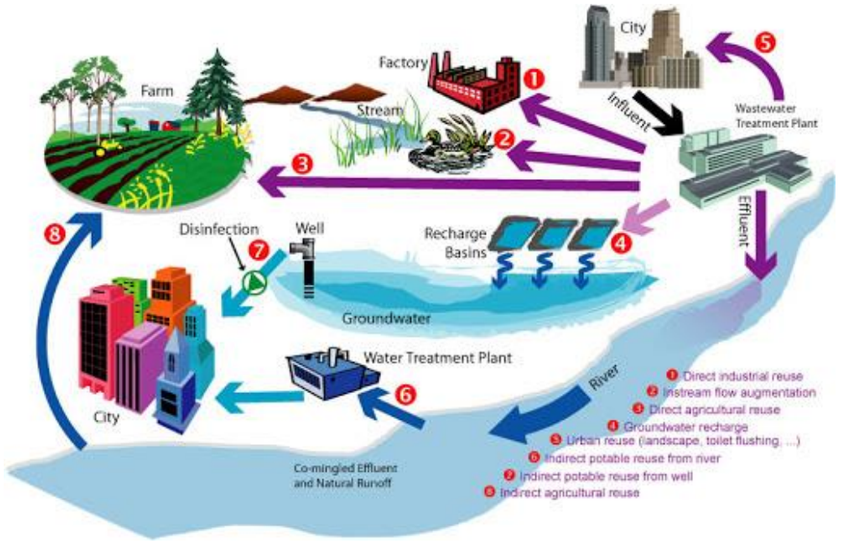
Dissolution of carapace





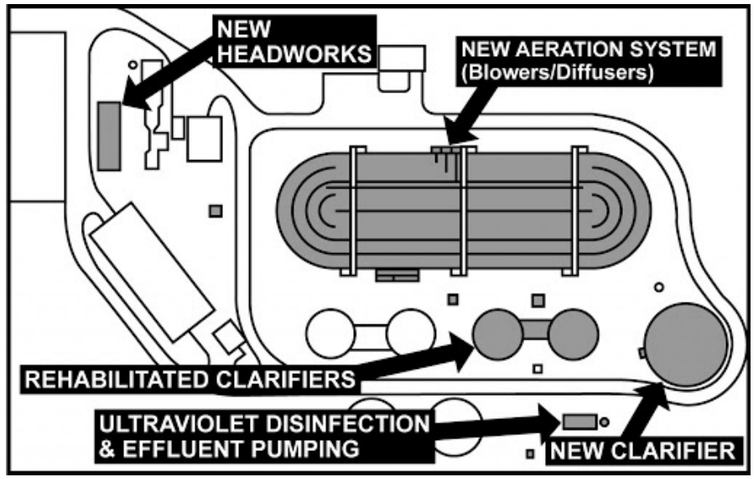


Wastewater and Stormwater Recycling and Recovery



Engineering Solutions

Wastewater Upgrades (Nutrient Management)



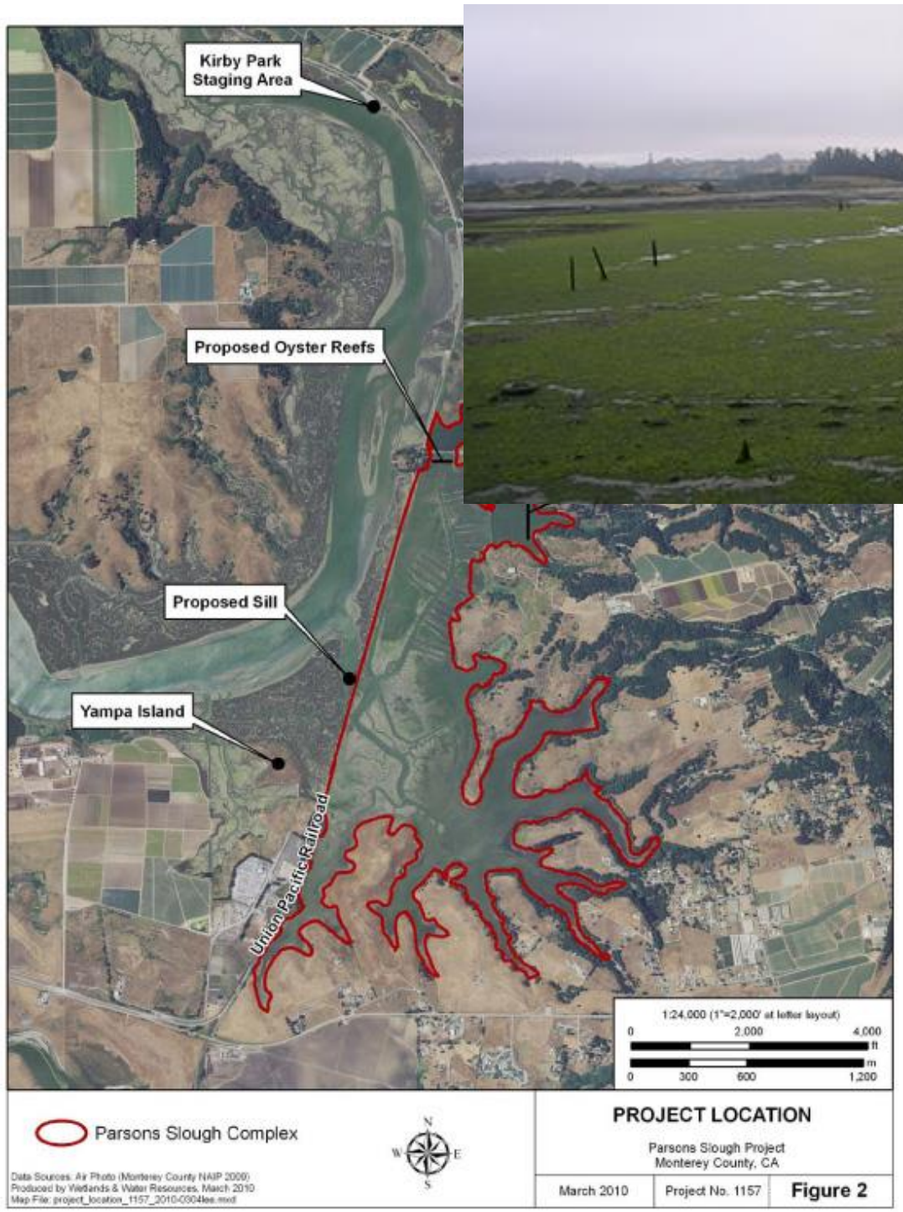
Ingredients to a Solution- #6: Innovative Options Beyond Nutrient Management Alone

Seagrass and Kelp

"Living" Solutions That Enhance Coastal Resiliency

Kelp Culture and Kelp/Oyster Co-Culture

Ingredients to a Solution- #6: Innovative Options Beyond Nutrient Management Alone



INCENTIVIZE WATERSHED AND ESTUARINE RESTORATION, BECAUSE FACTORS OTHER THAN NUTRIENTS (E.G. HYDROMODIFICATION, WARMING) CAN CAUSE EUTROPHICATION!

Addressing human impacts on Coastal Ecosystems

Shared Challenges

- Multiple stressors: hypoxia and low DO, sea level rise, and ocean acidification, food web shifts, increasing toxicity, etc.
- Tremendous variability in pollution inputs, circulation, climate, biological communities
- Limited knowledge about biological impacts (where and when do you see the impacts?)
- Urgency to act quickly (short response time)
- Scarcity of support for combined monitoring and modeling to inform management actions
- Multiple jurisdictions (federal agencies, states, counties and/or municipalities)
- Lack of buy-in to shared vision and way forward

Ingredients to a Solution

Southern California Case study

#1 Willing partners to invest in solutions

#2 Sustained investment in coastal numerical models

#3 Investments to identify solutions worth chasing

#4 Model uncertainties are constrained

- regulated community engagement
- sustained investment in coastal monitoring and research

#5 Scientific evidence for thresholds of algal biomass, pH and DO impact marine biological resources

#6 Flexibility on what a solution could look like

Questions? Thank You!

marthas@sccwrp.org

Breakout Discussions

Today's Breakout Sessions

The breakouts specifically are intended to:

- **Get people excited**

- Continue regional discussions like the Marine Water Quality Implementation Strategy and the Nutrient Forum **where technical uncertainties were identified**.

- Be **a teaser to jump-start conversations** for the workshops this fall where we'll spend a more time on each technical uncertainty.

The specific goals of each breakout today vary in **detail and depth** depending on the existing consensus and parallel efforts.

Breakouts

Dissolved oxygen impacts on the biological integrity of key habitats and species *(week of 9/26)*

Martha Sutula, *Southern California Coastal Water Research Project*

Change in interannual variability of rivers and ocean impact *(week of 10/17)*

Tarang Khangaonkar, *Salish Sea Modeling Center, University of Washington*

Parker MacCready, *LiveOcean, University of Washington*

Phytoplankton and primary production *(week of 10/24)*

Julia Bos, *Phytoplankton and Primary Production Vital Sign Co-lead*

Sediment exchange *(week of 11/14)*

Improve watershed modeling to evaluate source reduction strategies to adaptively manage strategies *(week of 12/12)*

Bob McKane, *Environmental Protection Agency*

Wrap up

- We'll share the presentation materials, recording, and a synthesis of the discussion
- Subscribe for updates at http://eepurl.com/h5nxsr
- Share any people, programs, or studies we should connect with
- Continue the discussion
  - Email Stefano Mazzilli (mazzilli@uw.edu) and Marielle Larson (marlars@uw.edu) to connect directly
  - Join the workshops this fall to dig in further

Fall Workshops

Dissolved oxygen impacts on the biological integrity of key habitats and species *(week of 9/26)*

Change in interannual variability of rivers and ocean impact *(week of 10/17)*

Phytoplankton and primary production *(week of 10/24)*

Sediment exchange *(week of 11/14)*

Improve watershed modeling to evaluate source reduction strategies to adaptively manage strategies *(week of 12/12)*