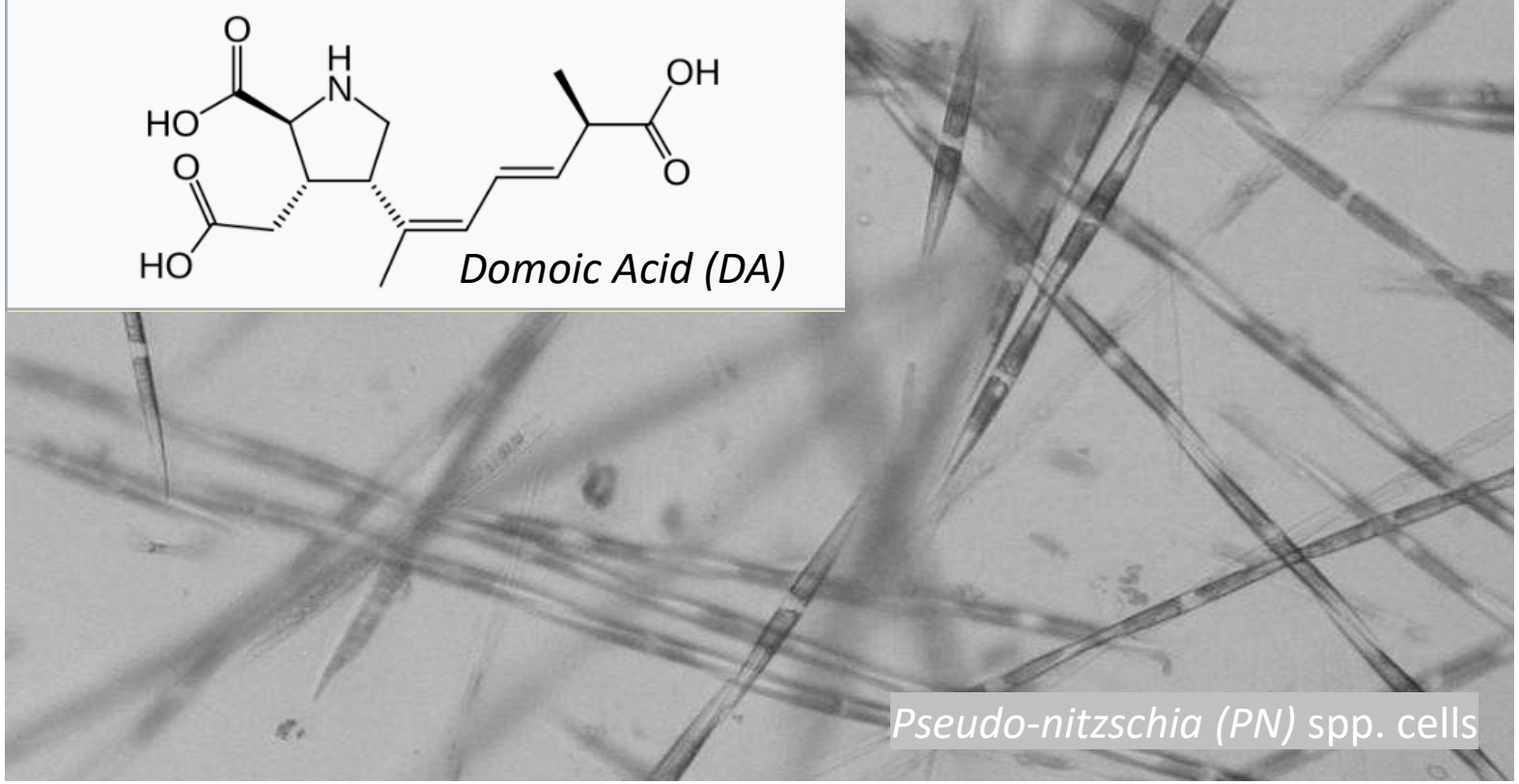
Environmental Drivers of Domoic Acid Producing Harmful Algal Blooms in the Bight

Evidence from Modeling Studies



Martha Sutula, Ph.D.
SCCWRP Biogeochemistry Department Head

Commission Meeting
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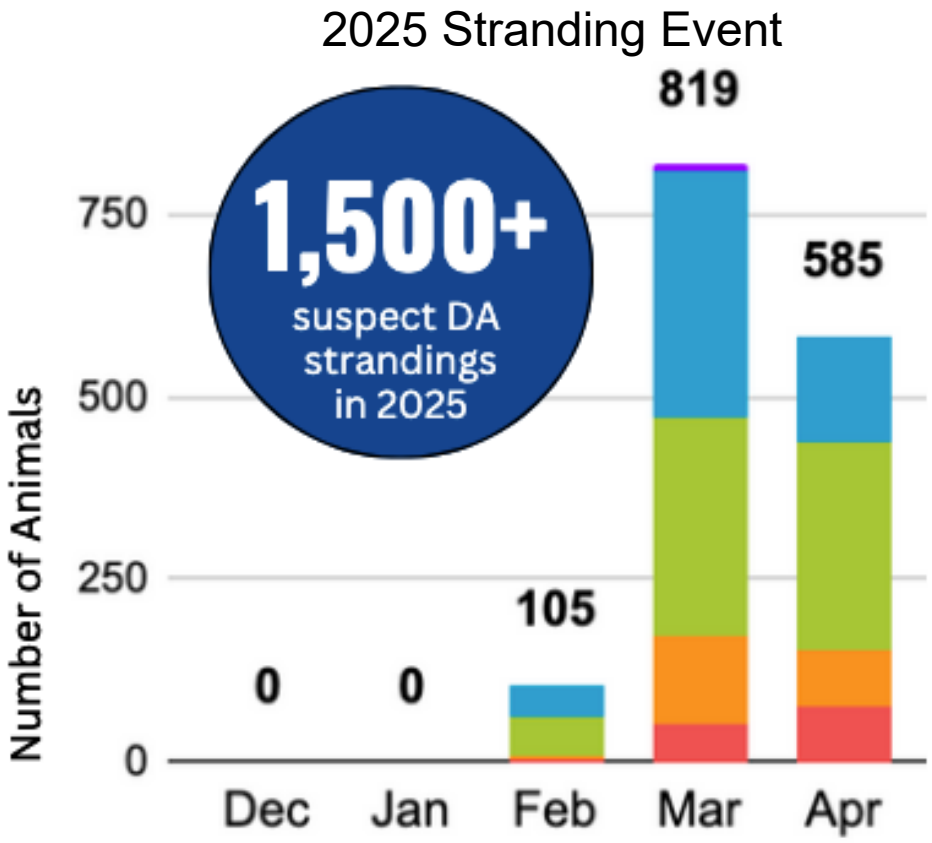
With contributions led by:

Fayçal Kessouri

Marco Sandoval-Belmar
Daniele Bianchi

Why We Care



Stranding counts collated by SCCOOS from CA stranding network

We Have Strong Observational Evidence that Domoic Acid Producing HABs Are Linked to Nutrients

Nutrients are important

In general, algal blooms need nutrients to grow

The higher the nutrient levels, the more algal biomass you grow

As biomass increases, window of opportunity for toxic HABs increase

.....but it's complicated

Multiple drivers, e.g.,

- Climate regime (El Ni*n*o versus La Ni*n*a)
- Warming and climate change
- Nutrient ratios (iron: nitrate, silicate: nitrate)

Combination of natural and human influences

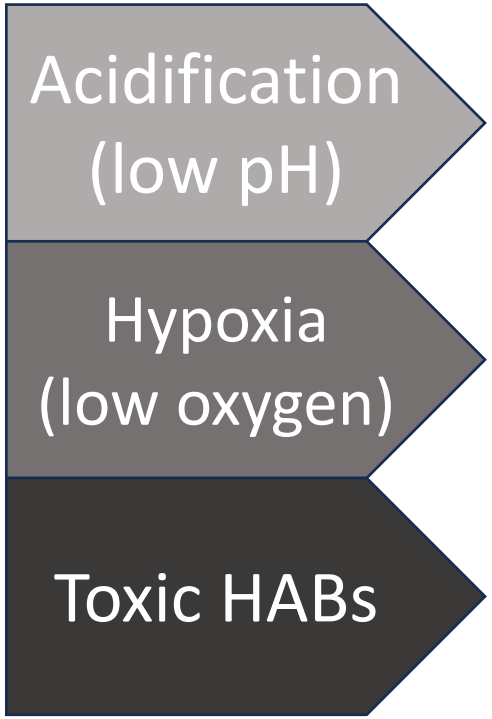
Interacting effects

Ucla

Sandoval-Belmar et al. *Harmful Algae* 2023 doi.org/10.1016/j.hal.2023.102435

Observations Have Limitations in Answering Management Questions

West Coast Expert Panel: Invest in an Ocean Numerical Model to Support California's Climate Change Response Strategy



Can we disentangle the factors driving these problems?

- natural variability
- climate change
- local human nutrient inputs?

Can we quantify how much these problems will change based on management actions?

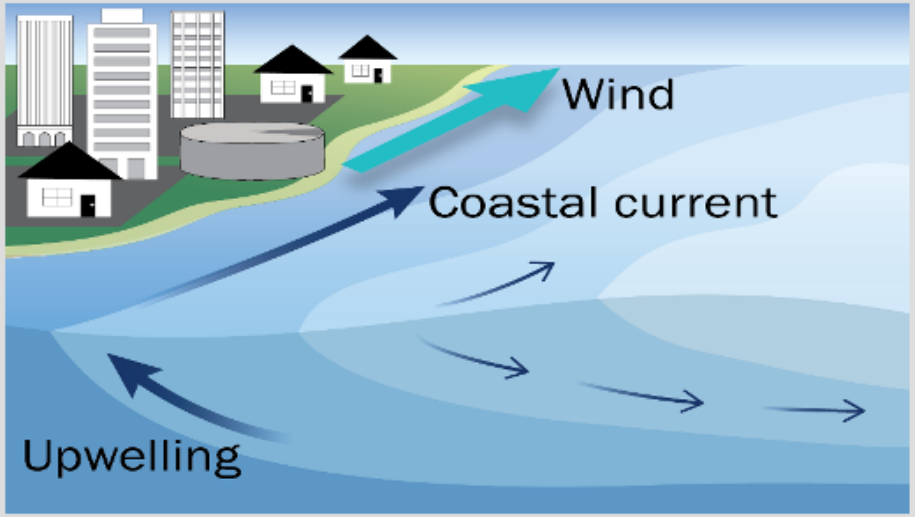
What will the future look like under climate change?

We Developed A Numerical Model Capable of Answering OAH-Related Questions

ROMS

Regional Ocean Modeling System

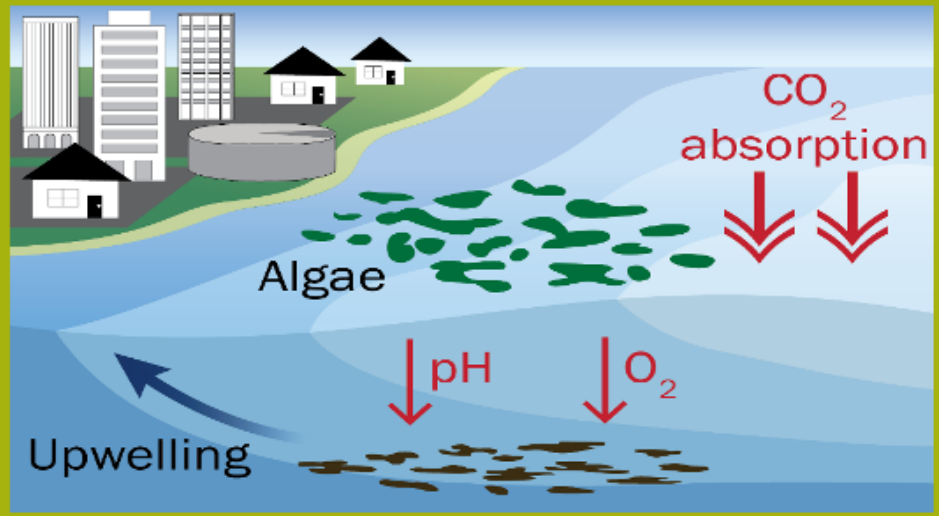
A physical circulation model that predicts how ocean water circulates



BEC

Biogeochemical Elemental Cycling Model

Predicts how human & ocean nutrient fuel plankton blooms that consume oxygen and lower pH



10+ Years, 6 Research Institutions, > 30 scientists

UCLA · SCCWRP Established 1969 · PMEL · Southern California Coastal Ocean Observing System · Princeton University · University of California Santa Cruz

Predictions of HABs are Fundamentally Different than Biogeochemistry Alone

- **Biogeochemical models predict the transformations of carbon, oxygen and nutrients**
  - The fundamentals of this have been well established for a couple of decades

- **To predict DA from *Pseudo-nitzschia* (PN) spp., a diatom, need to know controls on:**
  - Diatom production vs other phytoplankton taxa
  - PN blooms vis-à-vis other diatoms species
  - Amount of DA production in PN cells

We now have "first generation" tools that could be used, but refinements are needed

A Key Concept Underlying Modeling Approaches to Toxic HABs is "Risk" or Window of Opportunity

Analogy: Smoking (i.e., your doctor advises you to quit or reduce, to minimize chance of illness or death).

- It DOES NOT mean that if you take action, your risk is zero!
- It also does not mean that if you smoke or overeat, that illness is imminent

Investigating DA Drivers Using Two Complementary Modeling Approaches

1. **Use ROMS-BEC to investigate controls on diatom production and risk of DA HABs**
   - *Pseudo-nitzschia spp.* is a diatom; diatoms dominate Bight algal biomass (Chl-a); DA risk increases with increased chl-a
   - Applied a chl-a threshold, derived from observations, to ROMs-BEC output to estimate where risk of detecting DA > 50%
   - Quantified natural versus anthropogenic effects on DA risk

2. **Developed a submodel of DA production, coupled to ROMS-BEC (a.k.a. ROMS-BEC-DA)**
   - Apply and assessed model skill to predict DA in the Bight
   - Apply to investigate risk of DA HABs from land-based nutrients

Sandoval-Belmar et al. 2023

We Applied Those Approaches to Investigate Drivers of DA HABs, Focused on Three Questions

1. **What is the natural susceptibility to DA HABs in the Bight?**

2. **How are anthropogenic nutrients modifying risk of DA HABs**?
   - Magnitude, extent, duration
   - Interannual variability
   - Relative importance of human nutrient pathways

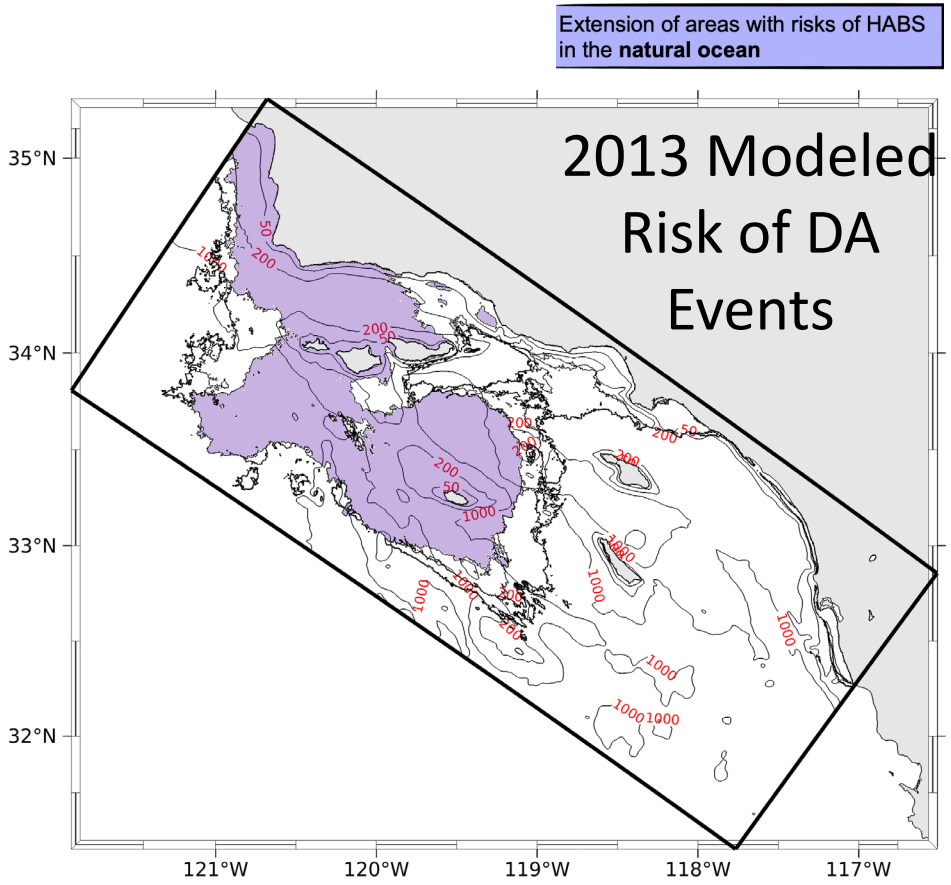
3. **What do we know about other factors controlling DA risk?**

Q1: Natural Oceanic Conditions have a Finite Risk of DA HABs

Preliminary findings

Kessouri et al. in review

- **Upwelling and eddies are dominant natural processes**
  - Controls vertical flux of DIN to the photic zone
- **Locus of natural risk offshore around the Channel Islands and Santa Barbara Channel**
- **Strong interannual variability in that risk**
  - Controlled by climate cycles, with the strongest risk during La Nina



Q2: Model Predicts Land-Based Nutrients Are Increasing DA Risk By a Non-Trivial Amount

Preliminary findings, *Kessouri et al. in review*

2013: 60 % Increase in Spatial DA Risk from Land-Based Sources Nutrients

- **Increase in the severity and spatial extent of risk**
- **Increase the duration of the DA event season**
  - Doubled the length of the DA HAB season in 2013, a median productivity year
- **Human nutrients inputs are modulating interannual variability in DA risk**
  - During high DA risk years, anthropogenic <u>enhances</u> natural oceanic sources
  - During low DA risk years, anthropogenic sources <u>dominate</u>

By Year	Spatial Coverage (km^2)		
	CTRL	ANTH	Increment
2013	16,707	26,741	10,034
2014	0	103	103
2015	186	611	424
2016	1,606	2,831	1,224
2017	3,715	5,807	2,092

Q3. Model Predicts Human Nutrients Increase Cellular DA Production By Increasing Silica Limitation

- **Natural oceanic state is nitrogen-limited**
- **Model predicts that anthropogenic inputs release that nitrogen limitation**
  - Increasing silica limitation, which know from lab studies and field data causes an increase in cellular DA production
- **ROMS-BEC-DA predicts anthropogenic nutrients increase DA production by non-trivial amount**
  - ~25% increase in DA concentrations averaged over 10 years
  - But this answer is dependent on resolution

Model parameterized from experimental data

DA → growth rate, diatom biomass, and nutrient limitation term:

- Nitrogen limitation → no DA
- Silica limitation → DA

Should We Trust These Model Predictions of DA Risk?

- **Preliminary assessment of model skill tells us we are making great progress**
  - Both modeling approaches show skill at capturing interannual variability and main spatial patterns of DA Bight wide
  - But there is poorly documented or inconsistent skill at subregional level, so enhancements are needed

- **Can trust the statement of "non-trivial" effects of human nutrients on DA HABs**
  - But be circumspect about the published numeric estimates

- **Tools could be used now, but with caveats**

Investments to Refine Models and Increase Confidence

- **Toolkit and model refinements**
  - Experiments to expand understanding of interactions among drivers
  - What happens to the DA: fate, transport, and bioaccumulation
  - Refine subregional chl-a thresholds

- **Validation and uncertainty quantification**
  - Can we predict actual “events”?
  - How well can we capture subregional occurrence?

- **To do this, we will need improved observational data**
  - Improve representation of riverine inputs
  - Inshore and offshore
  - PN speciation and DA measurements in both water column and biota

Future Vision, with Substantial Investments in Monitoring, Experiments and Modeling

- **Use numerical models, with uncertainty quantification methods, to predict the effect of management actions under consideration on DA HABs**

- **Better link DA events to probability of marine mammal strandings and shellfish bed closures**
  - Scenarios
  - Early warning: Nowcast and seasonal forecasts

- **Predict how climate change will impact magnitude, severity, and duration of DA events**

Questions?

Martha Sutula Marthas@sccwrp.org
Faycalk@sccwrp.org
Jayme Smith jaymes@sccwrp.org
Southern California Coastal Water Research Project

Marco Sandoval-Belmar

University of California Los Angeles