Extending the Reach of Quasi-Operational Harmful Algal Bloom Forecasts to Estuarine Shellfish Harvesting in Coastal California

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Thank you, Woody and Jay!
What is the Harmful Algal Bloom (HAB) Problem in California?

Domoic acid (produced by *Pseudo-nitzschia*) is the leading HAB issue on the U.S. West Coast.

Unprecedented West Coast HAB of 2015

- closed Dungeness Crab fishery for entire season (~$60M in losses)
- contributed to an Unusual Mortality Event of sensitive and protected species

Kudela et al. 2008
C-HARM hosted by CeNCOOS for routine demonstration – Transitioning to operational support at NOAA Coast Watch

http://www.cencoos.org/data/models/habs

SCCOOS-NCCOS-West Coast CoastWatch Collaboration to create C-HARM Bulletin on CeNCOOS & SCCOOS data portals

Stakeholder engagement is done via web surveys and continual outreach to super end-users
What does the domoic acid problem mean for shellfish consumption?

- CA Department of Public Health monitors for DA if the diatom is present at high abundance in the water
- Recreational harvests regulated via fixed quarantine periods

Shellfish Monitoring Sites: 2015

- All samples tested for PSP
- DA analyses based on-phyto observation, environmental cues
- # sites doubled for DA
- DA samples 2-3X normal

California Commercial Shellfish Growing Areas

- Humboldt Bay: 4164 Acres
- Tomales Bay: 230 Acres
- Morro Bay: 269 Acres
- Santa Barbara Channel: 240 Acres
- Agua Hedionda Lagoon: 5 Acres

*Map: CDPH*
HAB Hotspots Align with Shellfish Growing

**City of Humboldt**
- Humboldt Bay: 4164 Acres, 4 Companies

**San Francisco Bay Area**
- Tomales Bay: 230 Acres, 7 Companies

**Santa Barbara Channel**
- Santa Barbara Channel: 240 Acres, 1 Company
- Agua Hedionda Lagoon: 5 Acres, 1 Company

**Central California**
- Monterey & SLO: 269 Acres, 2 Companies

[Map: CDPH]
What does C-HARM tell us about shellfish toxicity?

- Crab toxicity generally tracks nearshore model.
- Shellfish toxicity is often decoupled from model.

Crab/Shellfish DA (ppm)

Monterey
Santa Barbara
Humboldt Coast

Model Probability (pDA>500 ng/L)

Red=Crab, Yellow=Mussel

Crab Data from: http://www.cdph.ca.gov/healthinfo/pages/fdbdomoicacidinfo.aspx
What does C-HARM tell us about crab (benthic) toxicity?

Mean Particulate Domoic Acid Risk April-July 2017

Mean Cellular Domoic Acid Risk Sep-Oct 2017

Nov 2017 – Jan 2018: delays in North Coast Dungeness Crab due to high DA levels and poor meat quality

Rock Crab closure north of Sonoma County, ended spring 2018

Spiny lobster closure at SB Channel Islands Oct 2017-Jan 2018
**Humboldt Coast** is a DA Hot Spot – but shellfish rarely break the regulatory DA threshold in Humboldt Bay

### Trinidad Head – Opportunistic Sampling

**Particulate Domoic Acid**  
**Winter-Spring 2015**

**April** – all stations out to 30km experienced a sudden increase in pDA  
**May** – pDA concentrations fell but were still high for most stations

Broke the DA record at 100,000 ng/L
**Hypothesis**: Is there a hydrological barrier preventing DA-laden particles from entering shellfish beds in Northern Humboldt Bay?

**Approach**: Conduct dye- and drifter-release experiments using a circulation model of Humboldt Bay and adjacent open coast (shelf area); *collect coincident toxin/shellfish samples in the Bay*

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**Humboldt Bay Circulation Model**
- Simulates depth, velocity, salinity, temp
- Model is forced by
  - Tide + sub-tidal sea levels
  - Freshwater flow (14 bay/coast inflows)
  - Salinity and temp at boundaries
  - Wind and atmospheric data
- Simulation period: 2014 to 2016
- Initial conditions: 2013 spin-up simulation
- DA represented as conservative dye
  - Ocean boundary is assumed DA concentration (Step 2 below)
  - Tributary DA concentrations are zero
**METHODS & RESULTS: Dye-Release Expmt**

**STEP 1:** Extract time series of C-HARM toxin probabilities for the coastal grid just outside Humboldt Bay

**STEP 2:** Convert C-HARM probability to DA concentration as a conservative dye tracer (\( DA_{conc} \text{ (ng/L)} = \text{Prob}_{DA} \times 1000 \))
**METHODS & RESULTS: Dye-Release Expmt**

**STEP 3:** 2014-2016 simulation for DA concentration

**DA (dye) results demonstrate**
- Temporal lag of DA (dye) in Bay is function of distance from entrance
- DA (dye) dilution appears to be influenced by freshwater inflows and nearshore circulation patterns

**Example of DA (dye) results**
Step 4: Drifter Release ~10-day snapshots after initial release

METHODS & RESULTS: Lagrangian Drifter-Release Expmt

Drifter results demonstrate

- Similar to dye simulation, number of drifters in bay is a function of distance from entrance
- Drifters appear to be influenced by freshwater inflow and bay circulation patterns
STEP 5: Collect paired samples of total in-water domoic acid and shellfish toxicity at Coast Seafoods from 2016-present

- Bioaccumulation of DA in mussels is coincident with ephemeral spikes of DA in the water
- Values of total domoic acid in Humboldt Bay are often extremely high
- Shellfish DA levels are always well below the regulatory threshold
What did we learn from short-term study?

- Dye-release experiments reveal that shellfish beds in N. Humboldt Bay can *theoretically* be exposed to high dissolved DA originating on the shelf and particulate DA from the nearshore.

- Freshwater inflow, nearshore, and bay circulation patterns appear to influence DA concentrations from the shelf.

- Total DA & mussel DA levels *suggests possible recirculation of DA from sediments into water column of Humboldt Bay... high depuration rates and/or low residence time*
What did we learn from the 4-year project?

- Communicate early and often with partner agency/operational end-user
- Be prepared for leadership turnover at agency level
- Carefully document and annotate your model system
- Stay flexible - do not get wedded to one idea of a model’s “forever home”
- Continue R&D efforts - operational does not mean perfect
**Good-bye NASA, hello NOAA**

- Create an **empirical model that predicts higher-trophic level toxicity** from coastal C-HARM predictions of domoic acid
  *proposal to California Ocean Protection Council/Sea Grant*

- Create end-to-end models of HAB risk and bioaccumulation in the food web in an ESM framework
  *new funding from NOAA ECOHAB & former seed funding from the Packard Foundation:

  Huge thanks to Woody Turner for this opportunity!
**Approach:** Conduct drifter experiments using modified circulation model of Humboldt Bay with smaller ocean domain (focus on drifter particles entering bay)

**Humboldt Bay Modified Circulation Model (small ocean domain)**
- Simulates depth, velocity, salinity, temp
- Model is forced by
  - Tide + sub-tidal sea levels
  - Freshwater flow (11 bay inflows, no ocean inflow)
  - Salinity and temp at boundaries
  - Wind and atmospheric data
- Simulation period: June 2009 (30-days)
- Initial conditions: spin-up simulation
- Drifter release strategy
  - Released drifters in ocean domain only
  - Released 120 drifters every hour during flood tide for 30-days
  - Drifters are buoyant, lasted 30-days
  - Released 43,316 total drifters
California Harmful Algae Risk Mapping (C-HARM) System

quasi-operational nowcasts and forecast

*Pseudo-nitzschia* Nowcast

**Domoic Acid Nowcast**

Demonstration = CeNCOOS: Fred Bahr, Dale Robinson

Transition Partner/End-User= NOAA NCCOS: Yihzen Li, Rick Stumpf

“Operational” End-User = NOAA CoastWatch: Dale Robinson

Anderson et al., 2016 *Harmful Algae*