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

NASA Applied Sciences Program
Award 80NSSC17K0049
Thank you, Woody and Jay!

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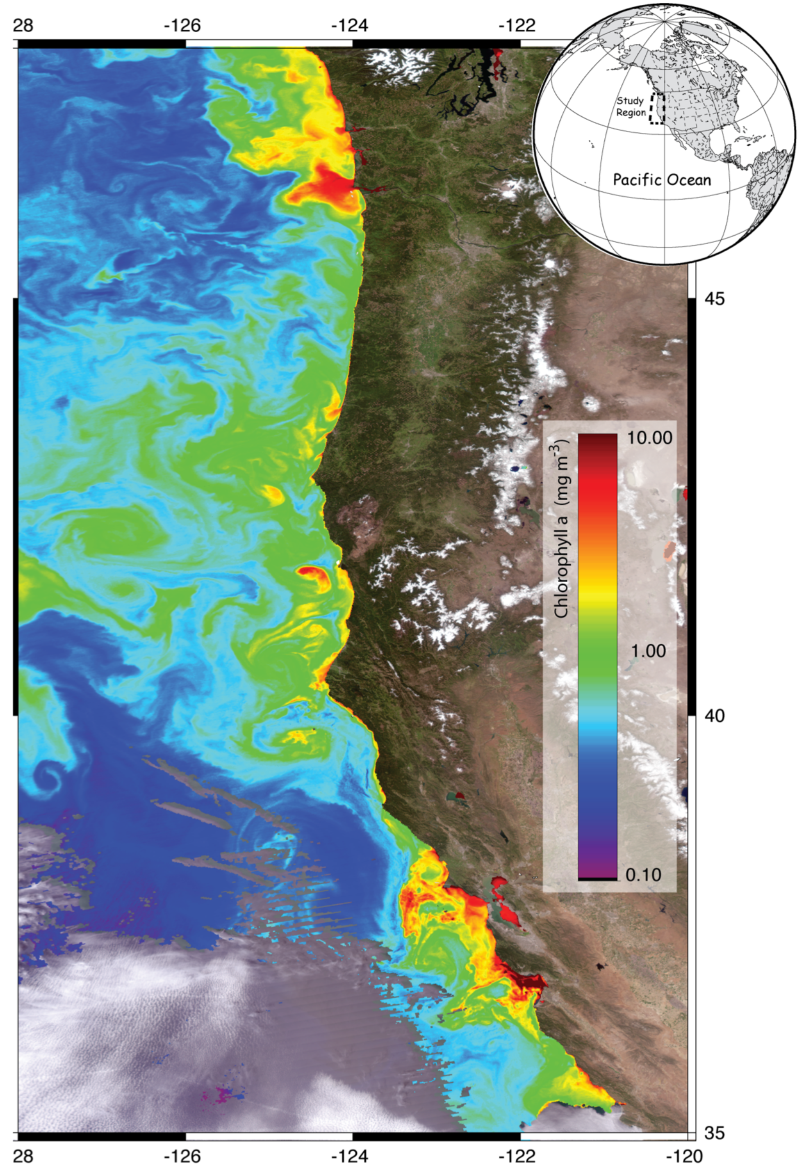
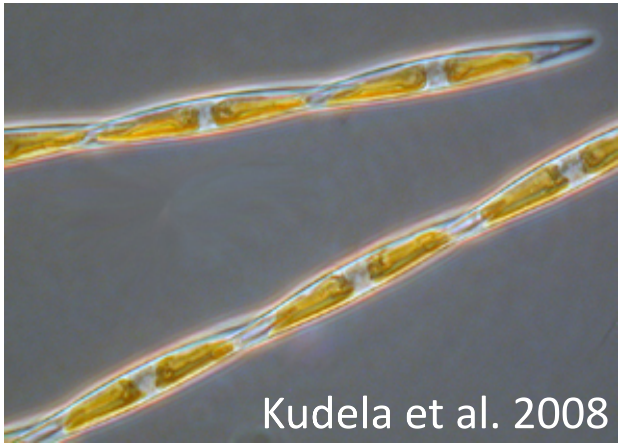


What is the Harmful Algal Bloom (HAB) Problem in California?



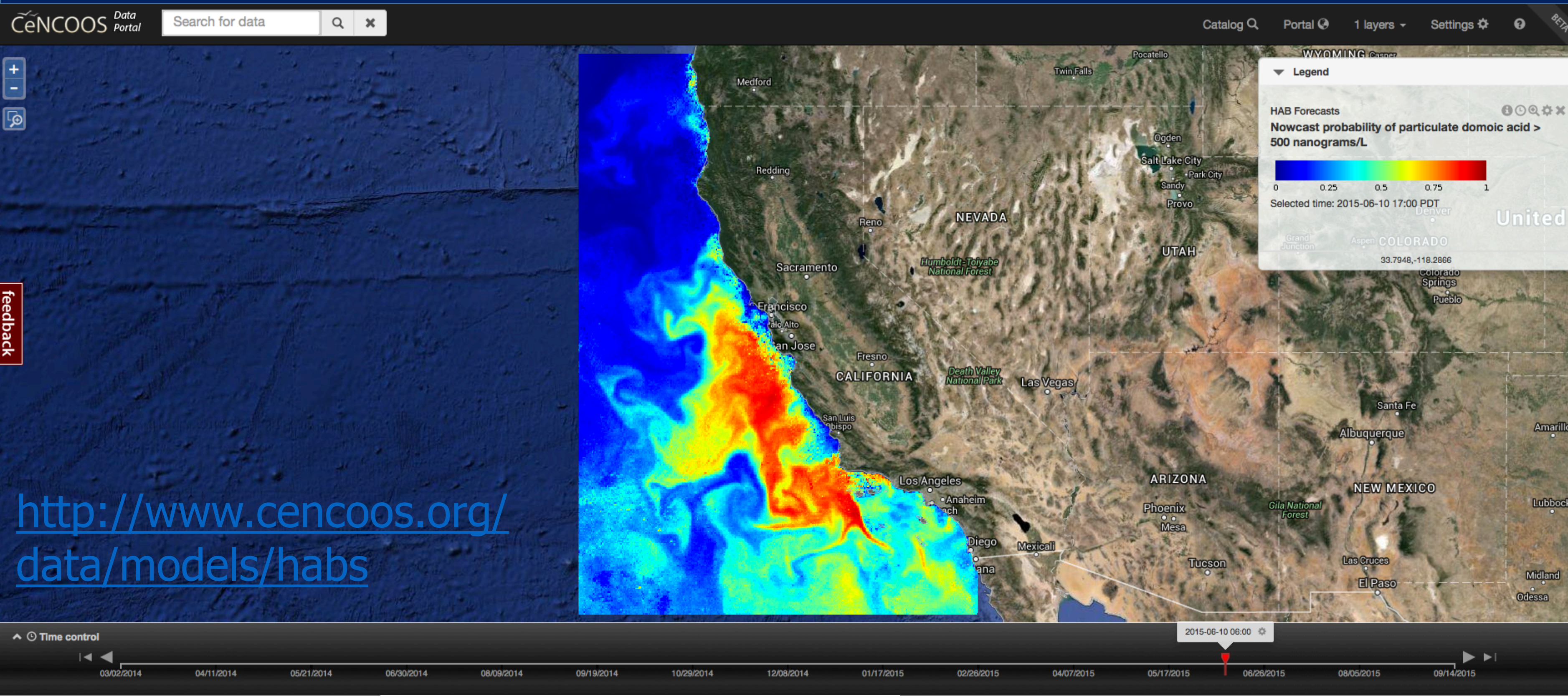
Kudela et al. 2008

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

Unprecedented West Coast HAB of 2015

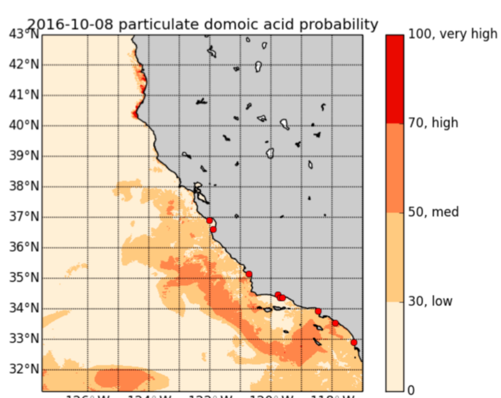
- closed Dungeness Crab fishery for entire season (~$60M in losses)
- contributed to an Unusual Mortality Event of sensitive and protected species

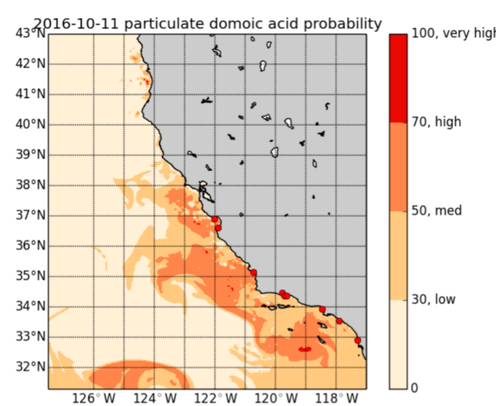
C-HARM hosted by CeNCOOS for routine demonstration – Transitioning to operational support at NOAA Coast Watch



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

CROSSING THE "VALLEY OF DEATH" to ARL9

REMOTE SENSING OCEAN COLOR* & SST *VIIRS

Transition Development
CeNCOOS to NCCOS
Final Implementation
NOAA CoastWatch

DINEOF

RECONSTRUCTED OCEAN COLOR & SST

Transition Development
CeNCOOS to NCCOS
Final Implementation
NOAA CoastWatch

HYDRODYNAMIC MODEL FIELDS

Transition Development
RSS ROMS
Final Implementation
WCOFS at CSDL

Proposal to IOOS OTT

DINEOF (FORECAST)

***IN SITU* OBSERVATIONAL DATA**

Transition Development
CeNCOOS
Final Implementation
SCCOOS & CeNCOOS

REGIONAL OPERATIONAL FORECAST PRODUCTS
Transition Development
NOAA NCCOS
Final Implementation
NESDIS/NOAA CoastWatch

BIOLOGICAL MODEL FIELDS

Transition Development
CeNCOOS*
Final Implementation
NOAA CoastWatch

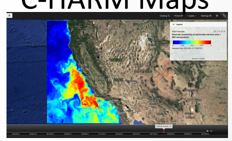
*S4 HPC @ Univ of WI

CROWDSOURCED DATA

Transition Development
CeNCOOS
Final Implementation
SCCOOS & Marine Mammal Health Map

INTEGRATED FORECAST & ANALYSIS TOOL

C-HARM Maps

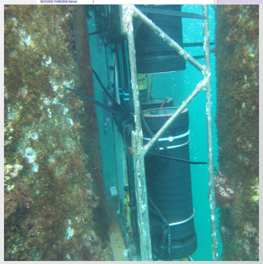


California HAB Bulletin

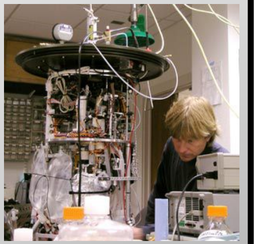
HABMAP
OBIS
SCCOOS & CeNCOOS

Near real-time Marine Mammal Stranding Data

Imagine Flow Cytobot
Catalina Sea Ranch
SF and Monterey Bays



Scripps Plankton Camera, Jules Jaffe



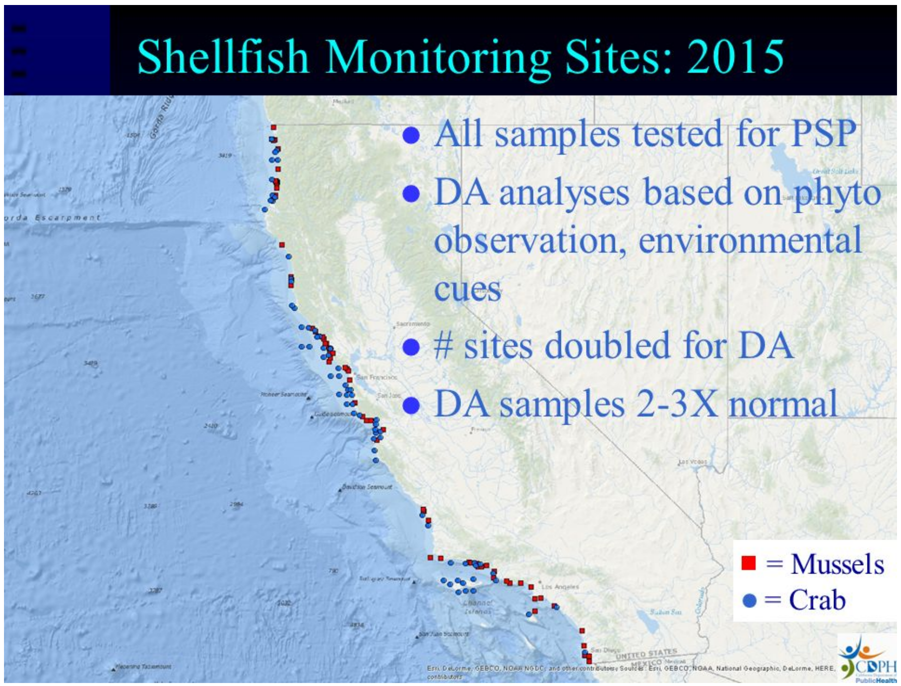
Environmental Sampling Processor (ESP) - Monterey

NCCOS = National Centers for Coastal Ocean Science
CSDL = Coast Survey Development Lab
RSS = Remote Sensing Solutions, Inc.
WCOFS = West Coast Ocean Forecast System

"Operational" Centers
NOAA Coast Watch, West Coast Node
SCCOOS = Southern California Coastal Ocean Observing System
CeNCOOS = Central and Northern California Ocean Observing System

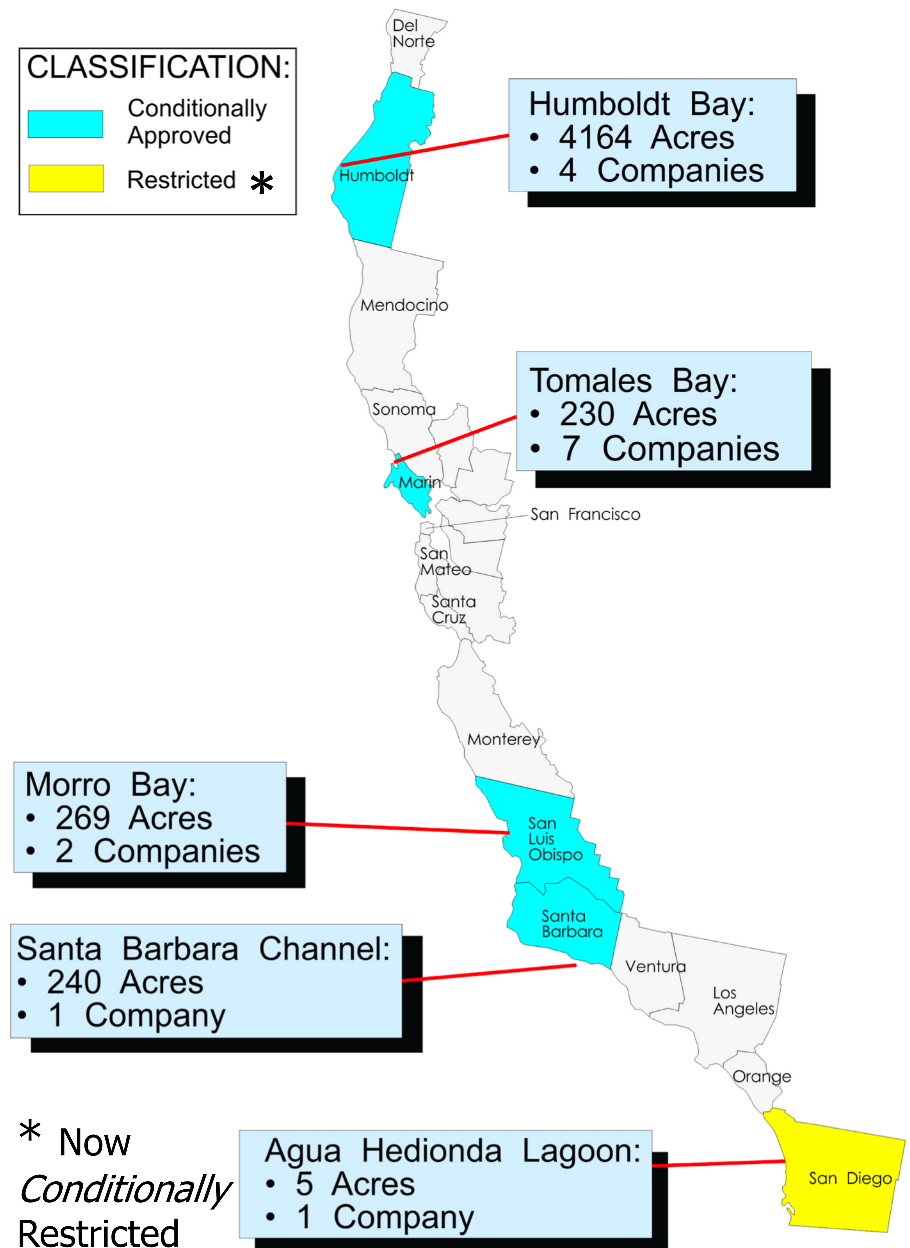
CeNCOOS

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

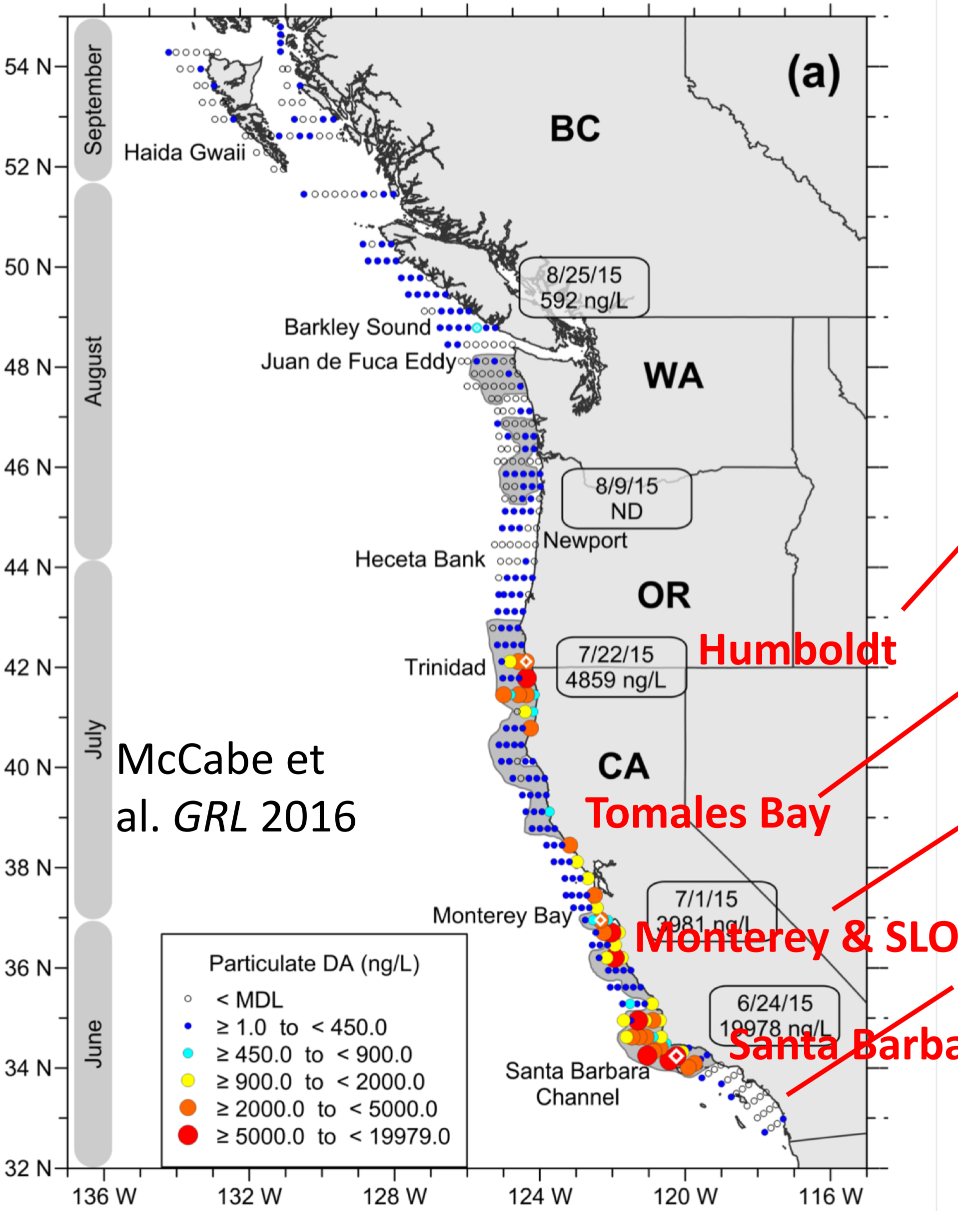
California Commercial Shellfish Growing Areas



Map: CDPH

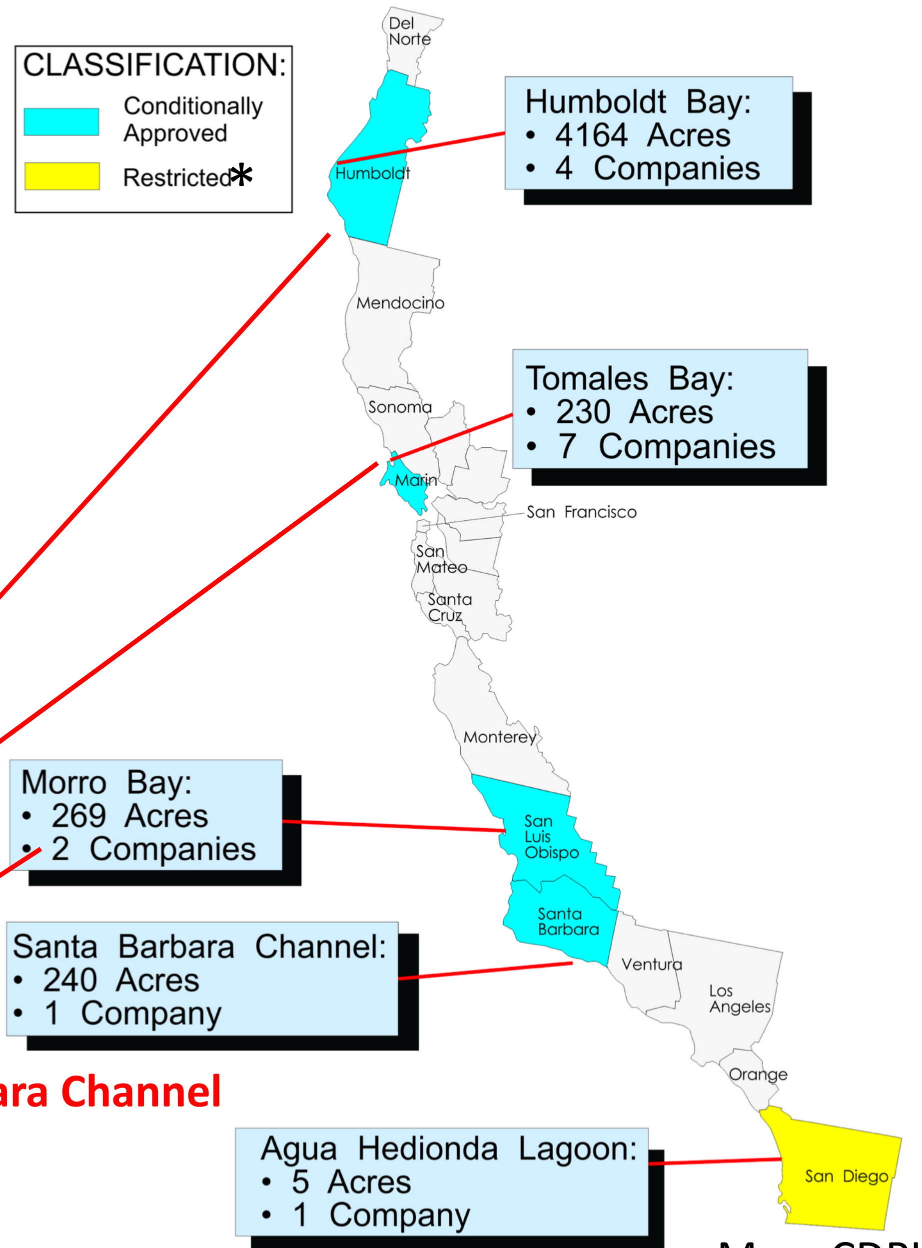
Project Augmentation: HABs and SHELLFISH

HAB Hotspots Align with Shellfish Growing



McCabe et al. *GRL* 2016

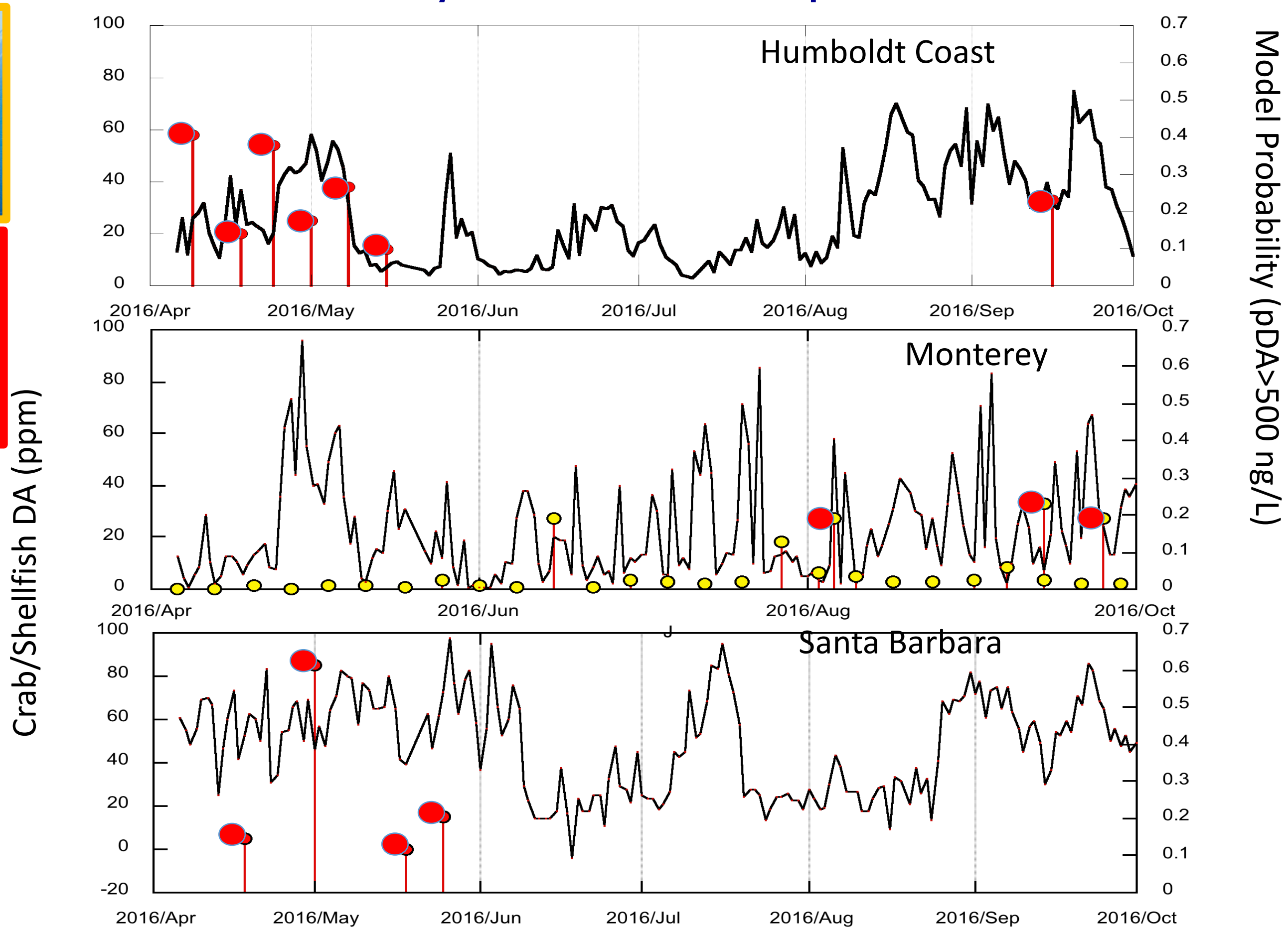
California Commercial Shellfish Growing Areas



Map: CDPH

What does C-HARM tell us about shellfish toxicity?

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

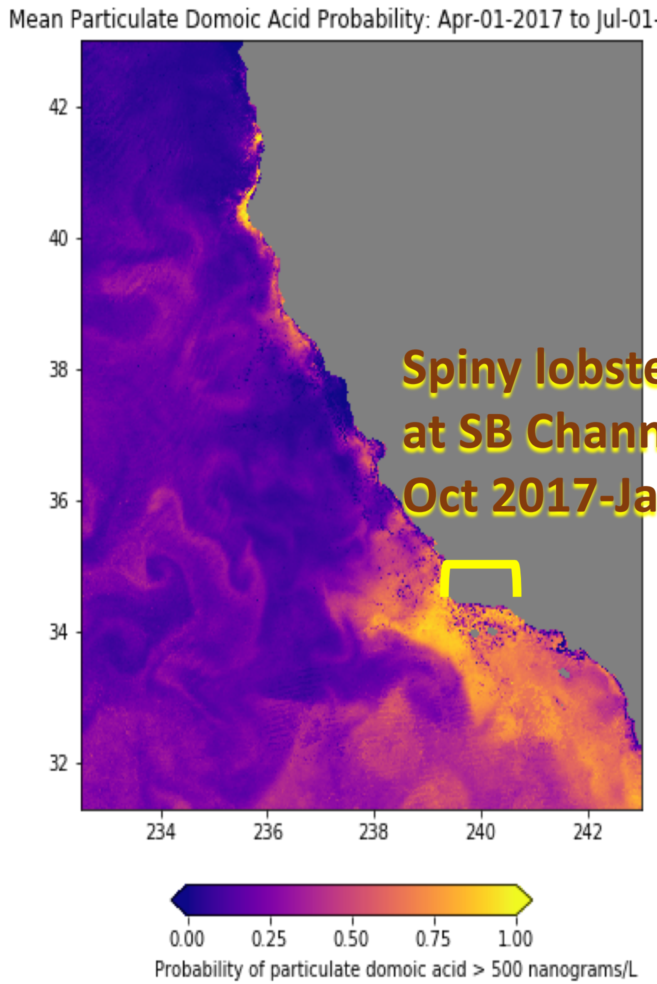


Red=Crab, Yellow=Mussel

Crab Data from: http://www.cdph.ca.gov/healthinfo/pages/fdbdomoicacidinfo.aspx

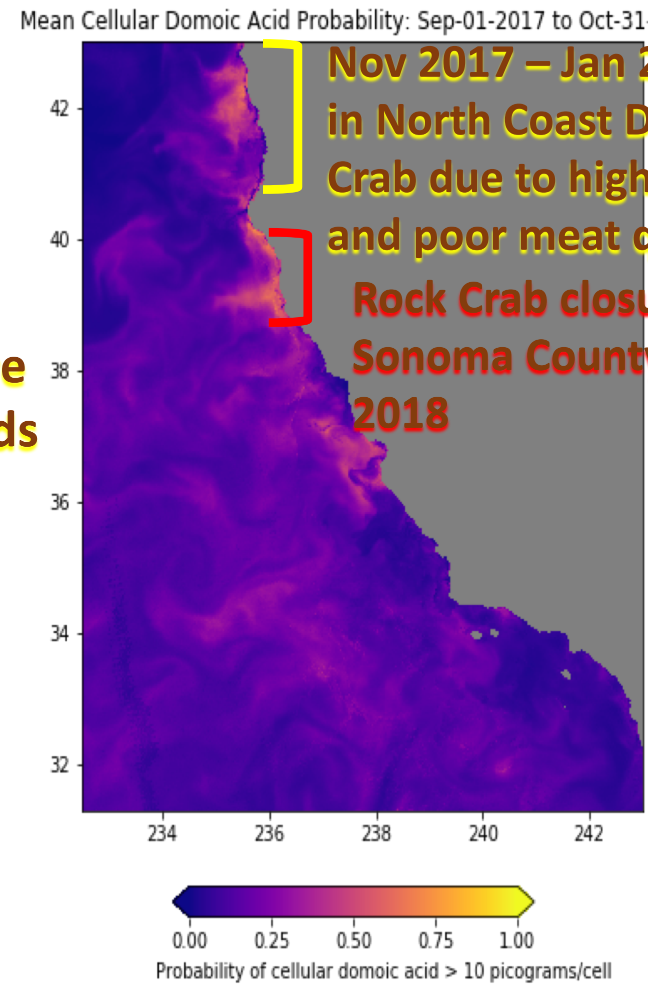
What does C-HARM tell us about crab (benthic) toxicity?

Mean Particulate Domoic Acid Risk April-July 2017



Spiny lobster closure at SB Channel Islands Oct 2017-Jan 2018

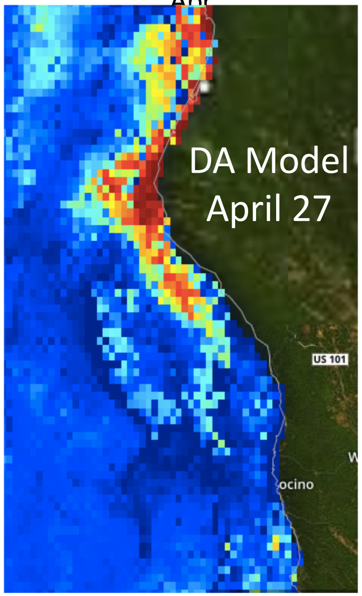
Mean Cellular Domoic Acid Risk Sep-Oct 2017

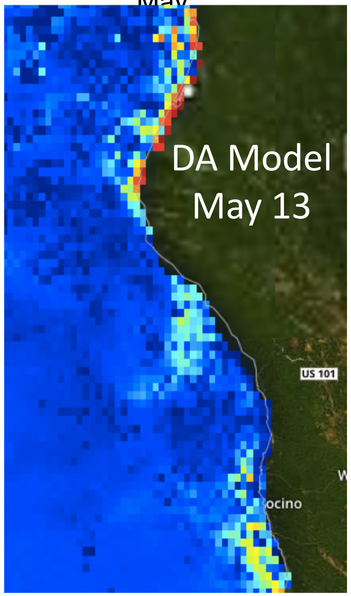


Nov 2017 – Jan 2018: delays in North Coast Dungeness Crab due to high DA levels and poor meat quality

Rock Crab closure north of Sonoma County, ended spring 2018

Humboldt Coast is a DA Hot Spot – but shellfish <u>rarely</u> break the regulatory DA threshold in *Humboldt Bay*





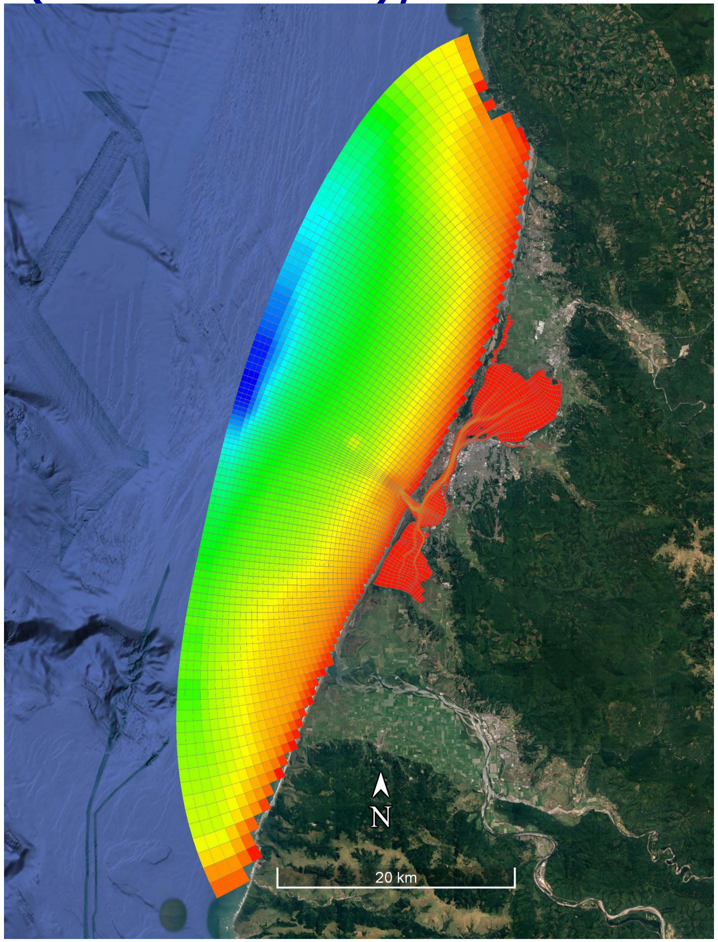
April – all stations out to 30km experienced a sudden increase in pDA

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?

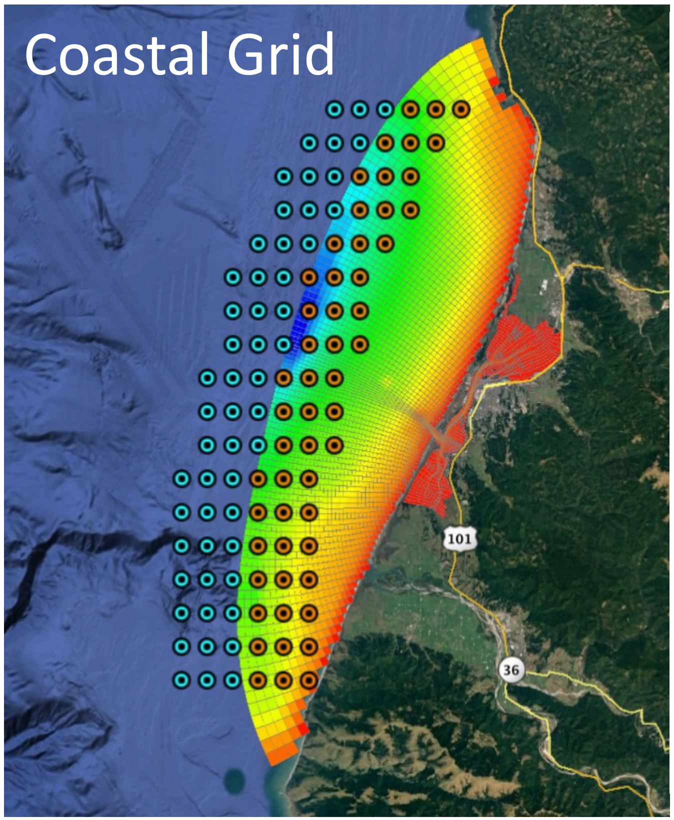
Approach: Conduct dye- and drifter-release experiments using a circulation model of Humboldt Bay and adjacent open coast (~shelf area); *collect coincident toxin/shellfish samples in the Bay*

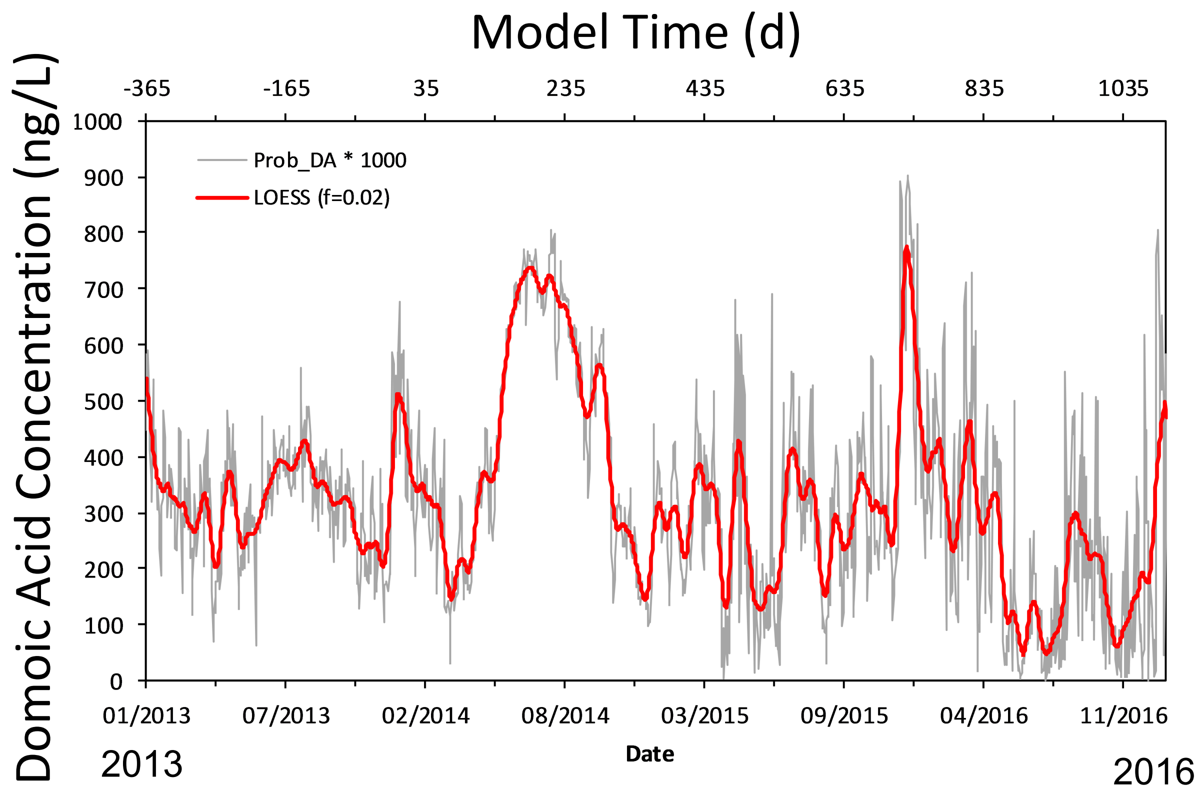


Humboldt Bay Circulation Model

- 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

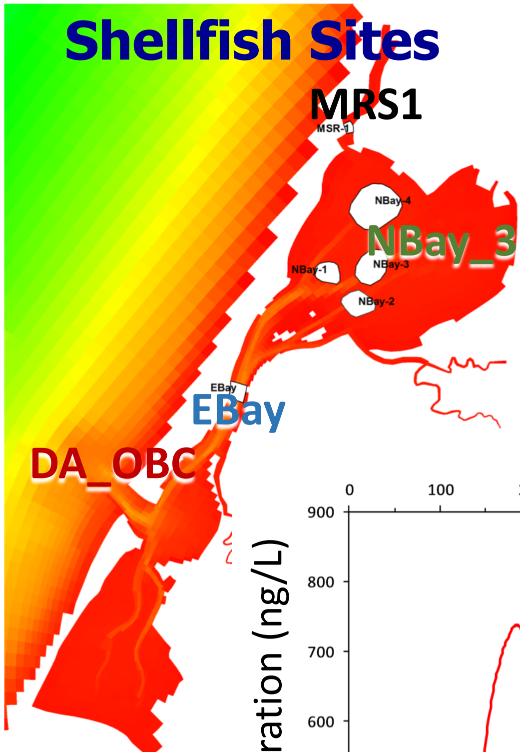
STEP 1: Extract time series of C-HARM toxin probabilities for the coastal grid just outside Humboldt Bay





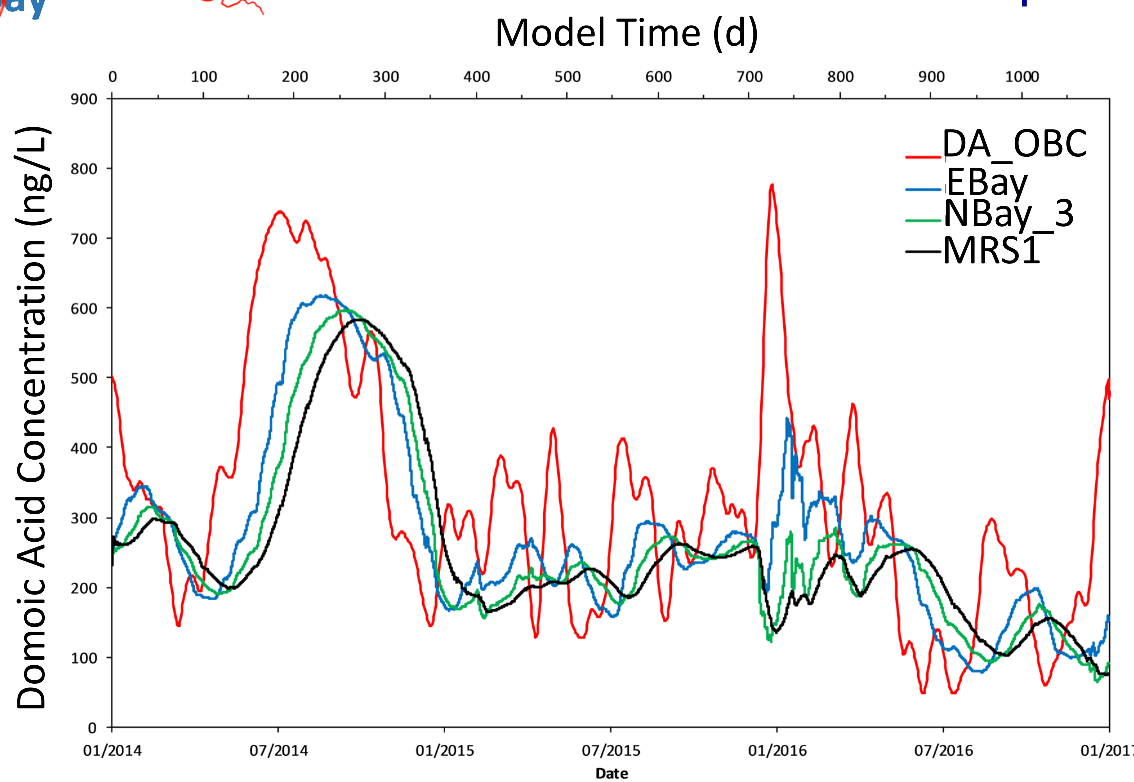
STEP 2: Convert C-HARM probability to DA concentration as a *conservative* dye tracer (DA_conc (ng/L) = Prob_DA * 1000)

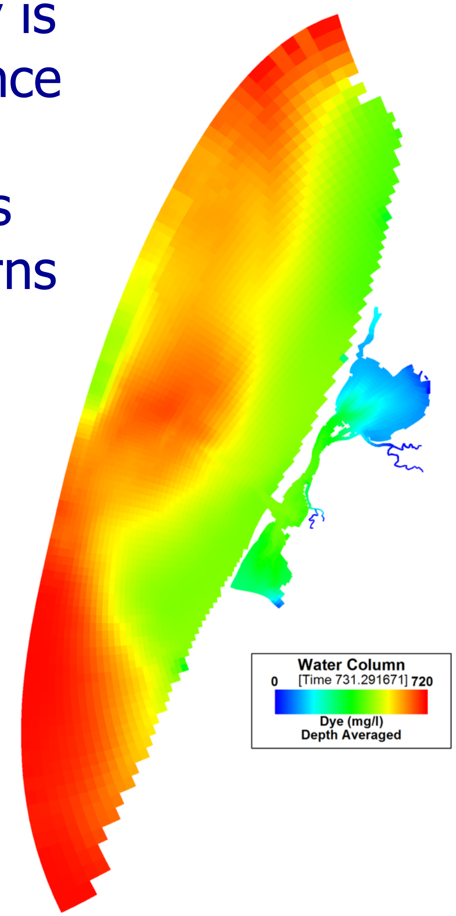
STEP 3: 2014-2016 simulation for DA concentration



DA (dye) results demonstrate

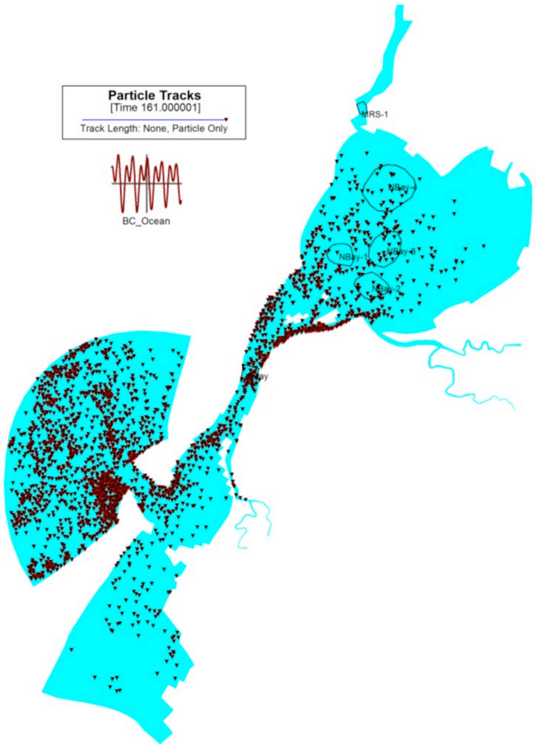
- Temporal lag of DA (dye) in Bay is function of distance from entrance
- DA (dye) dilution appears to be influenced by freshwater inflows and nearshore circulation patterns





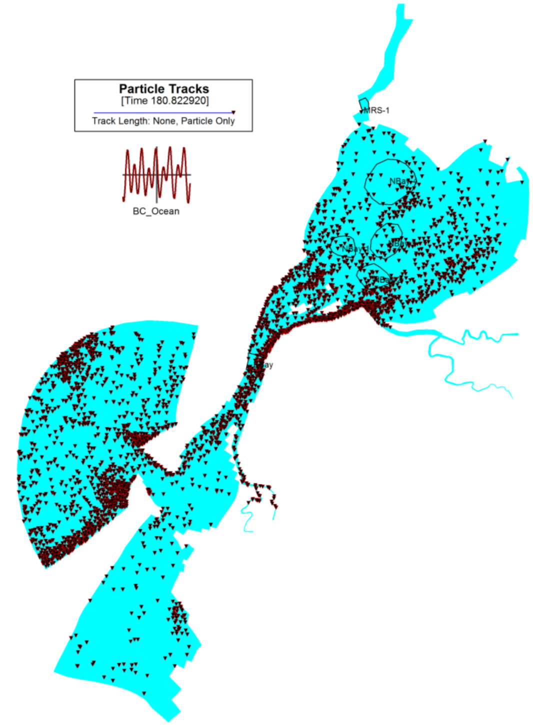
Example of DA (dye) results

Step 4: Drifter Release ~10-day snapshots after initial release



~10-days

~20-days

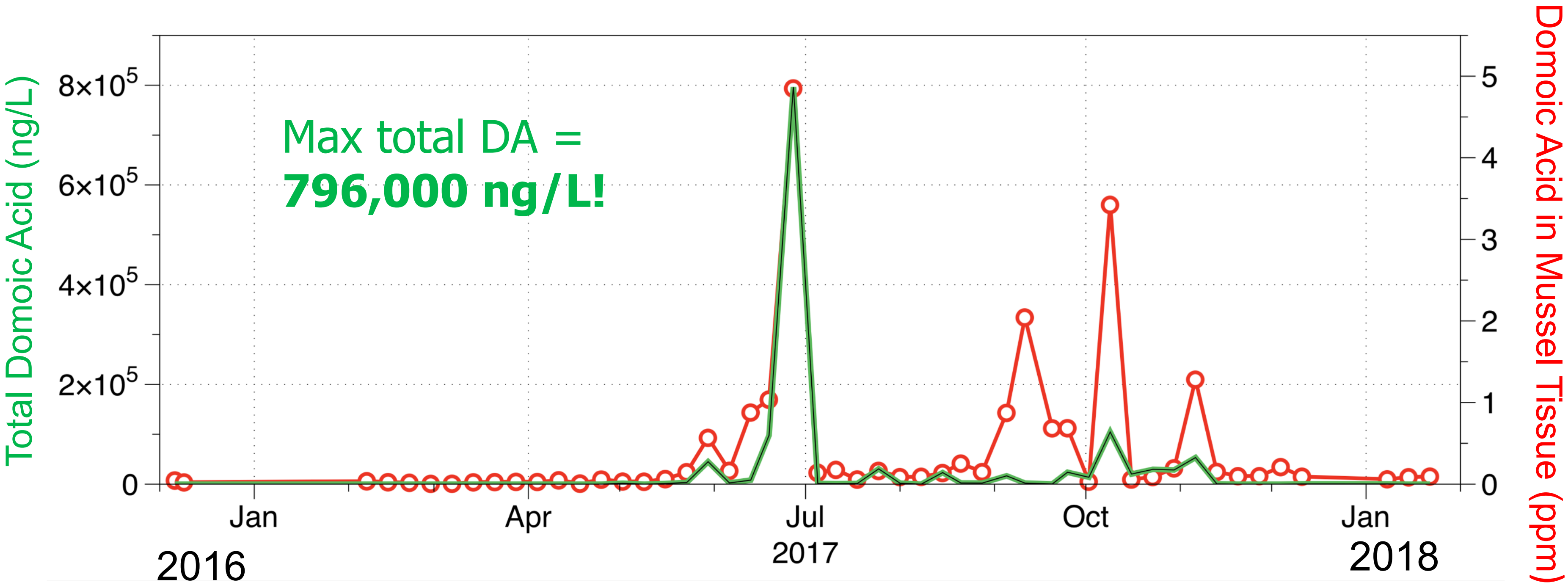


~30-days

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

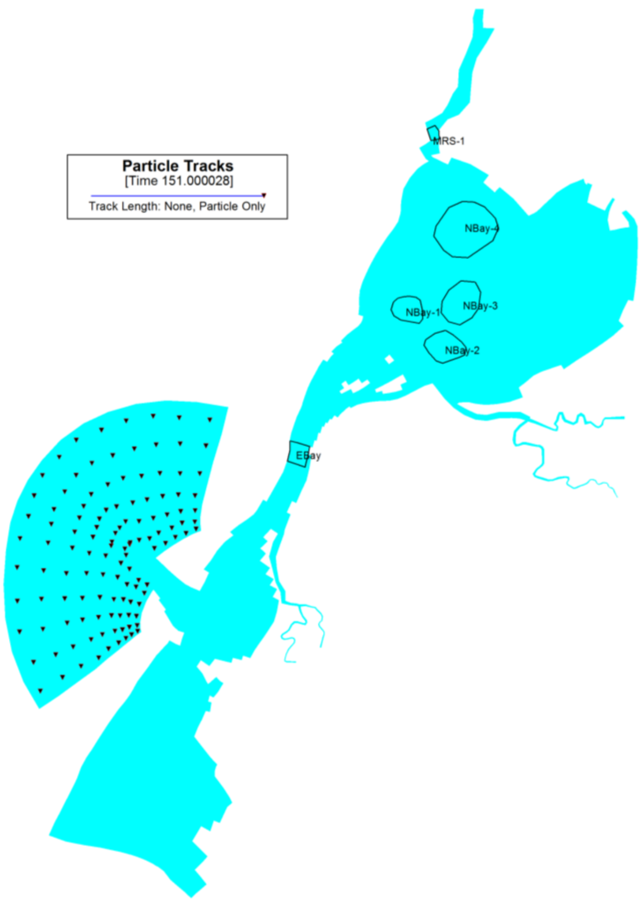
Good-bye NASA, hello NOAA

- 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)



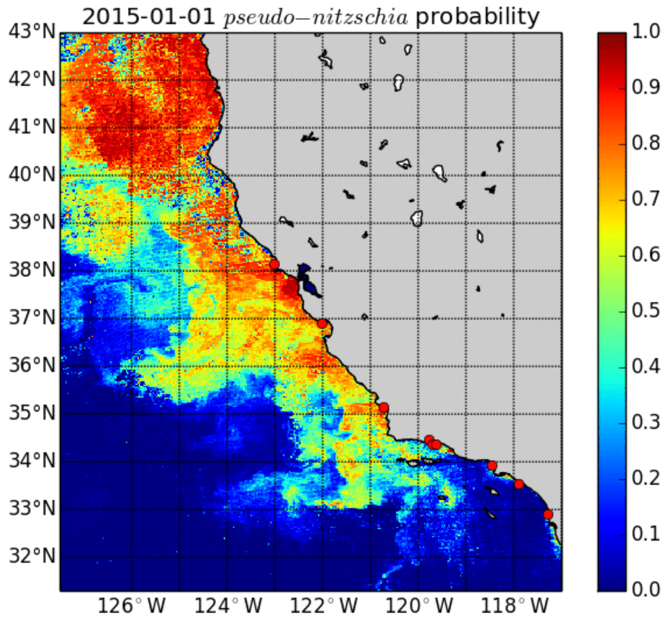
Humboldt Bay Modified Circulation Model (small ocean domain)

- 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

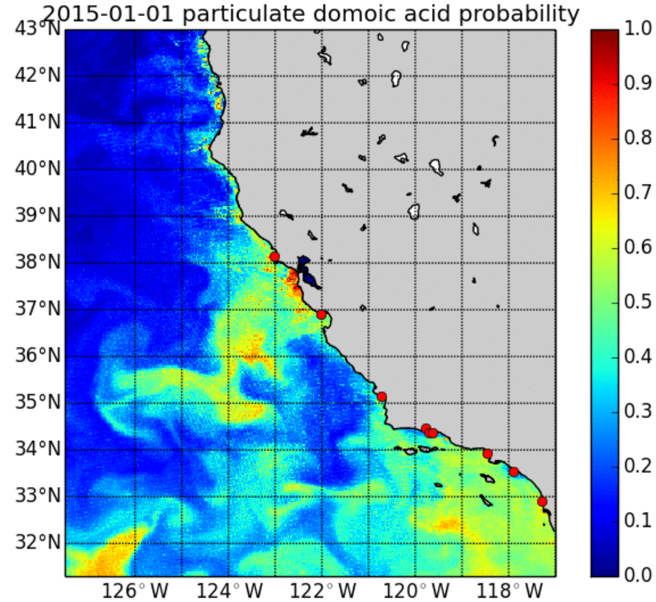
California Harmful Algae Risk Mapping (C-HARM) System

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*