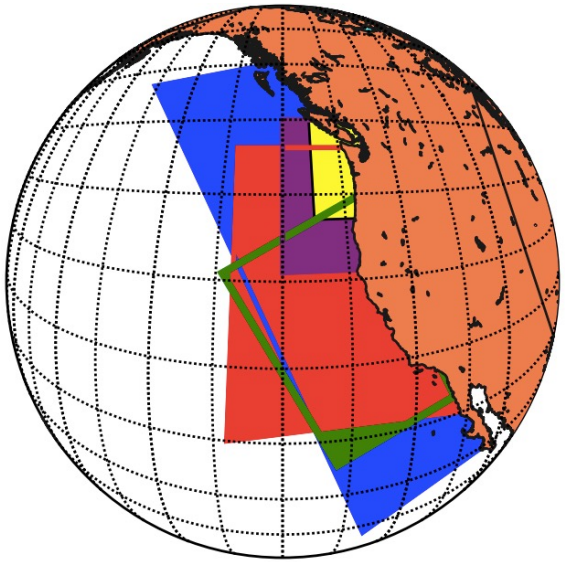
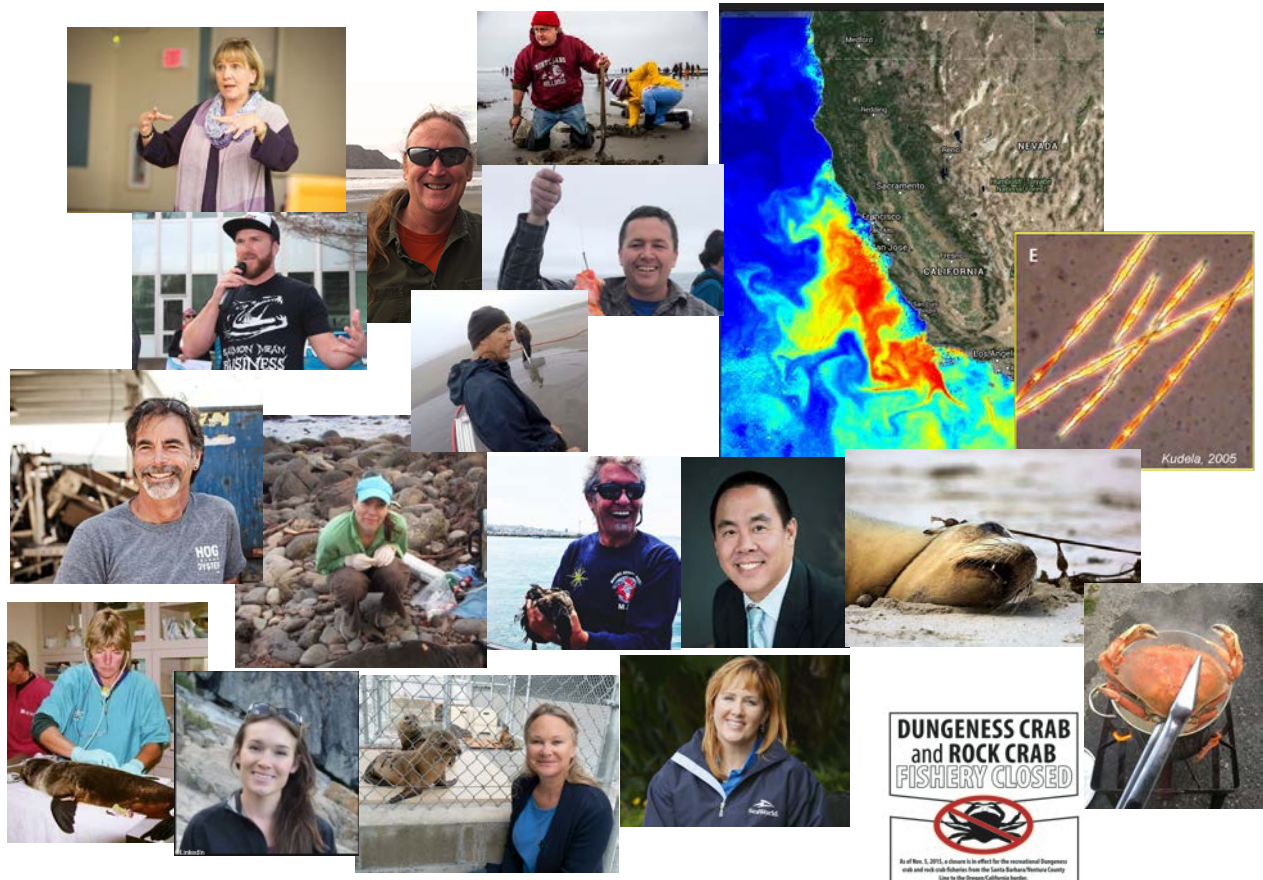
Can/Do user requirements shape HAB prediction tools in the coastal zone?

Clarissa Anderson, *Southern California Coastal Ocean Observing System (SIO/SCCOOS)*





IOOS Coastal Ocean Modeling Testbed (COMT): evaluate impact on regional models - UCSC, CA, OSU, LiveOcean (UW)

REGIONAL INFORMATION COORDINATION ENTITY
CERTIFIED
INTEGRATED OCEAN OBSERVING SYSTEM
est. 2015

IOOS
Integrated Ocean Observing System

Observations

Data Management

Forecasts/Modeling

User Products

Outreach and Education

Leverage and Link

SOUTHERN CALIFORNIA COASTAL OCEAN OBSERVING SYSTEM

CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

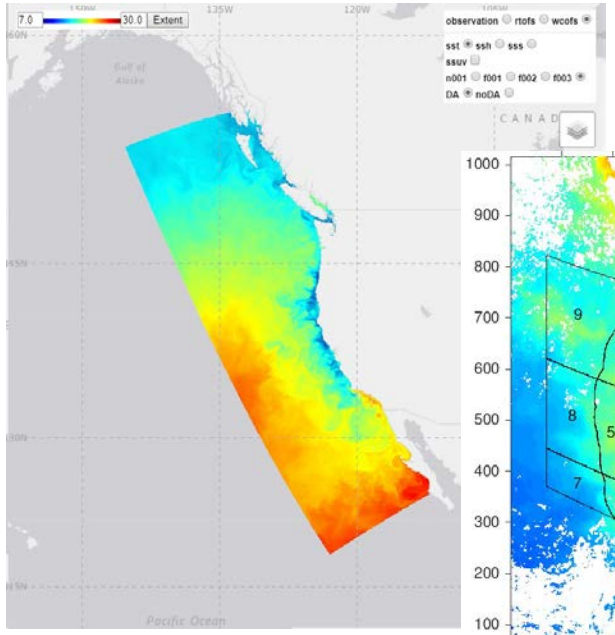
NANOOS

CONSISTENT NATIONAL CAPABILITY

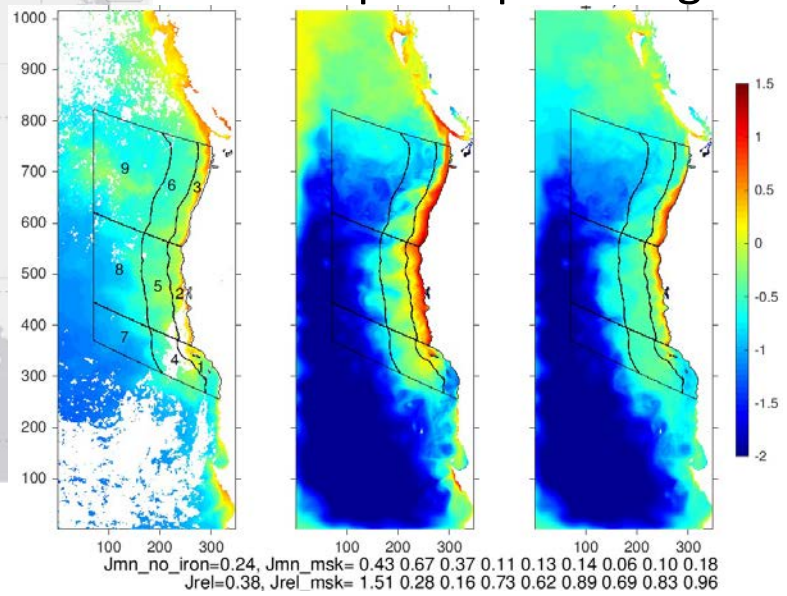
DIVERSE LOCAL STAKEHOLDERS

IOOS Coastal Ocean Modeling Testbed Program

West Coast Coastal Ocean Modeling (WC-COMT) Testbed Project to Evaluate WCOFS



$\log_{10}$(Chlorophyll (mg/m^3))
2013 April-Sept Average



Developing a BGC model for WCOFS

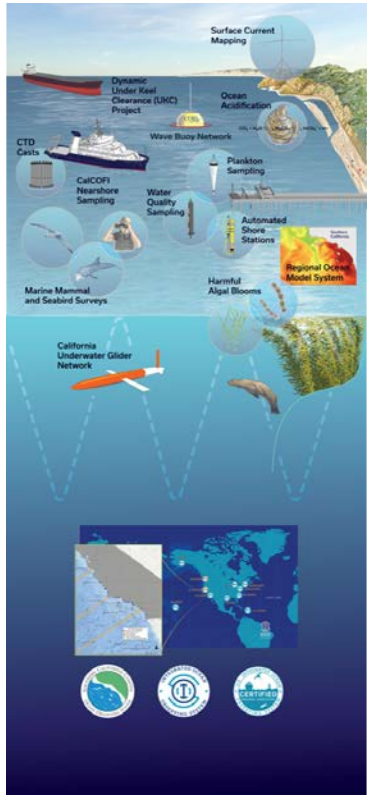
4D-Var ***Data assimilative, biogeochemical*** model
(UCSC model: Edwards/Mattern/Moore/Fiechter)

Lead PI: Christopher Edwards, UCSC
Transition PI: Clarissa Anderson, SCCOOS

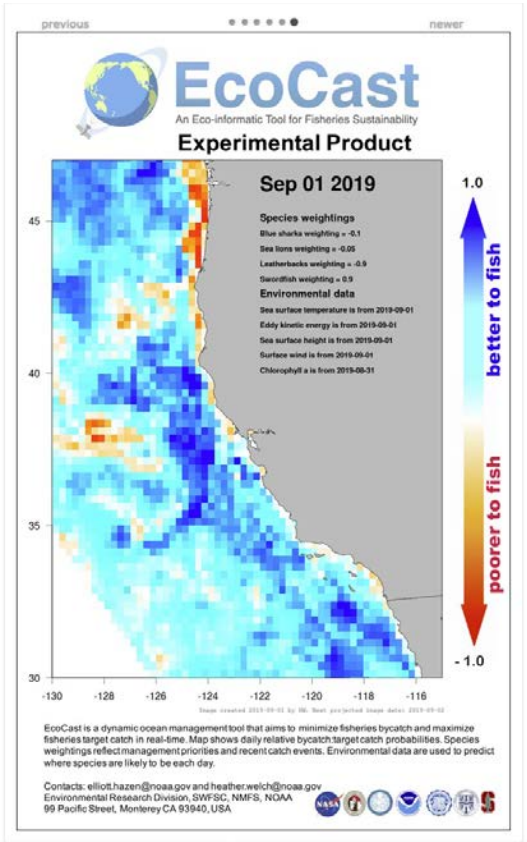
1) To advance coastal ocean modeling, analysis, and prediction through enhancements to the WCOFS model
   - Evaluation
   - Data Assimilation
   - Biogeochemical Model development – NEMURO (with OAH subsystem)

2) To transition established products relevant to NOAA Ecological Forecasting Roadmap to using WCOFS output
   - **HAB prediction**
   - **Dynamic Habitat modeling**
   - **Ocean Acidification and Hypoxia**

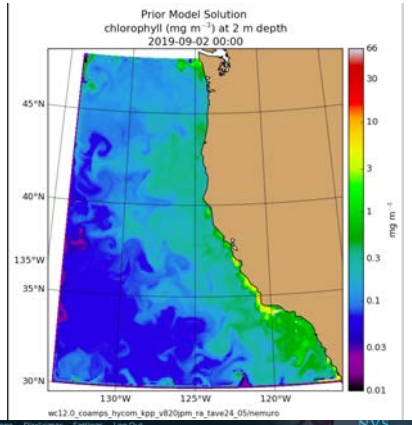
Observational Impacts in Data Assimilation

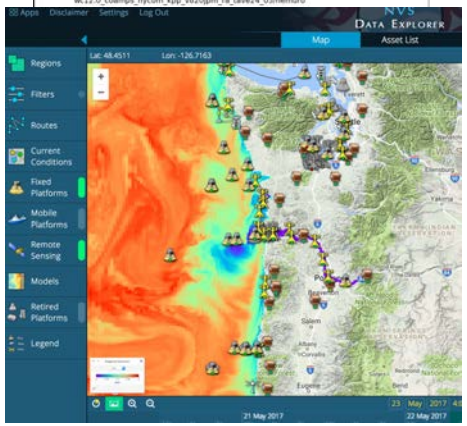


Fisheries Habitat

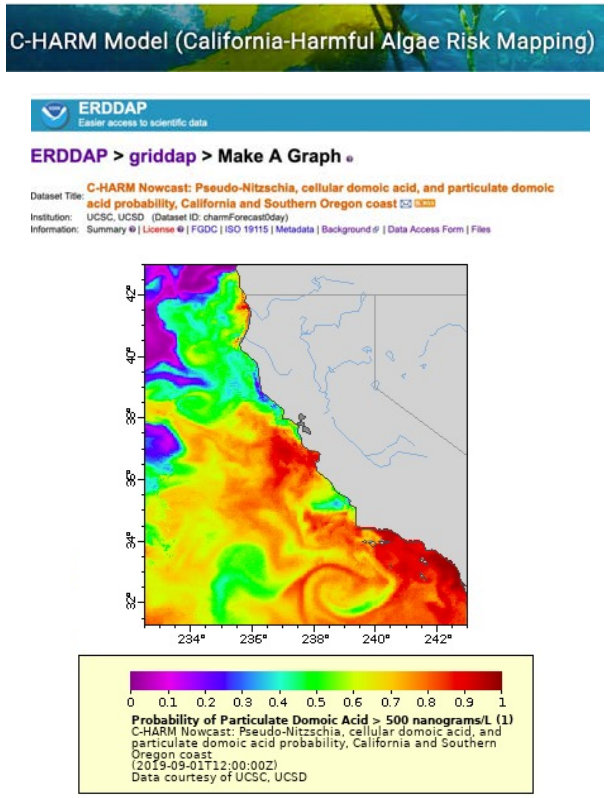


Ocean Acidification & Hypoxia





Harmful Algal Blooms



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CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

NANOOS

WC-COMT Stakeholder Workshop – Priority Themes

Broad participation of end-users and technical practitioners from the entire West Coast

+++ **38 Participants** +++ Across Five Major End-User Sectors

Physics
(Report: Andrew DeVogelaere)

- Characterizing the physical environment for optimal placement of physical structures at sea
- Modeling of currents + winds to optimize commercial ship traffic speed + fuel consumption
- Plume models around ports to inform ballast water zones
- Trajectory Models for….

Fisheries Habitat
(Report: Isaac Kaplan)

- Dungeness crab – forecasting fisheries catch + recruitment
- Whale entanglement in crab pot gear
- Real-time or 1-3 day forecasts of squid
- Seasonal predictions of whiting (a la Malick, Hunsicker, Siedlecki)
- Ratios of expected catch:bycatch (a la EcoCast)

OA & Hypoxia
(Report: Tommy Moore)

- Thresholds + Indicators of chronic vs acute stress, habitat compression etc.
- Model reanalysis to evaluate vulnerable areas, long-term trends
- Real-time forecasts for event response
- Seasonal and annual forecasts to help policy makers
- Long-term climate scenario models

Harmful Algal Blooms
(Report: Clarissa Anderson)

1) Improved lead times for warnings (out to 2 weeks)
2) Tracking the precise interstate trajectories of *Pseudo-nitzschia* blooms and their impacts
3) Nearshore impacts of HABs on aquaculture and fisheries
4) Complexity in food web interactions and surface to benthic coupling
5) Predicting offshore bloom initiation relative to nearshore dynamics

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COMT Stakeholder Workshop: Summary Table for Program Managers

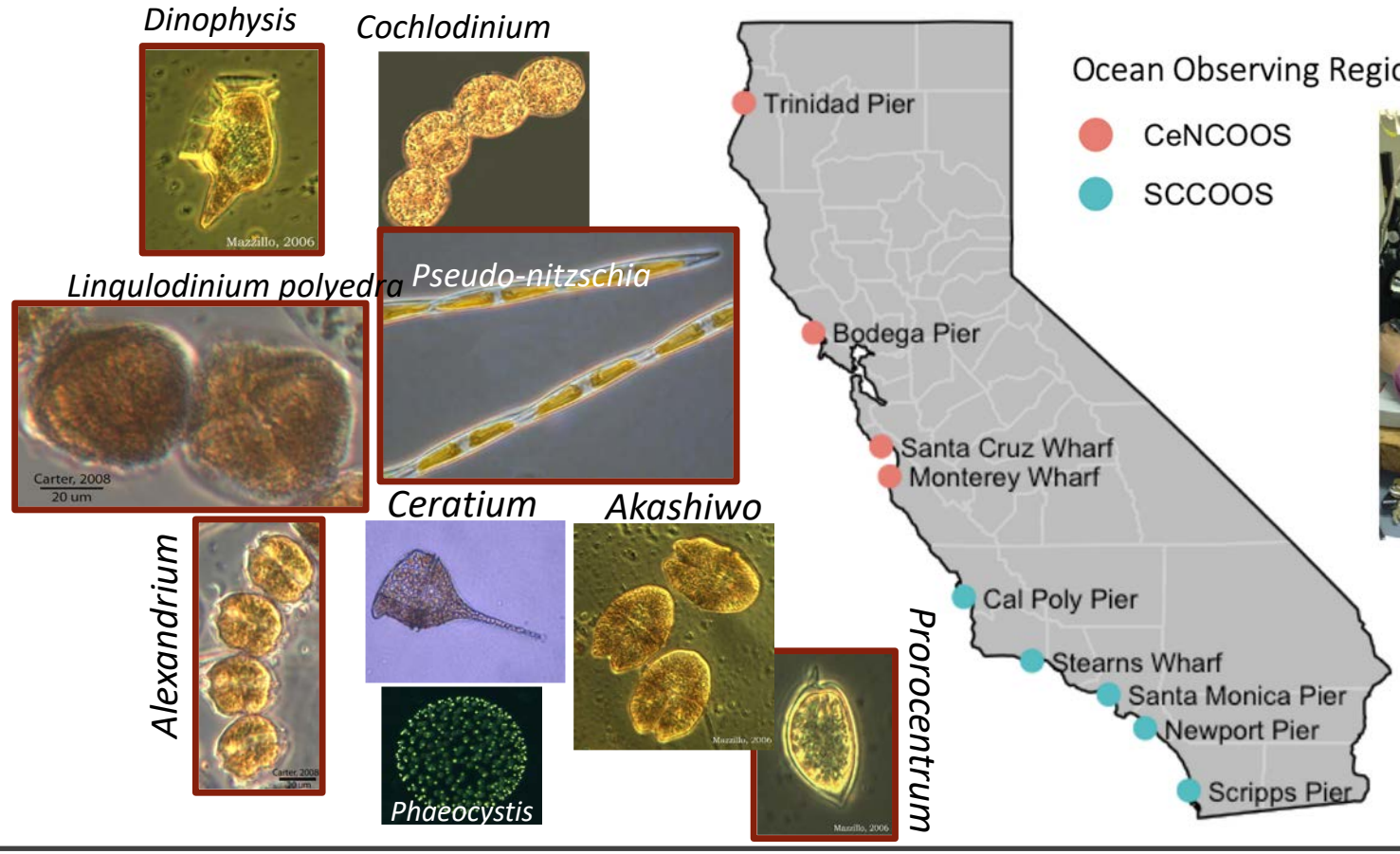
Compiled a table of prioritized user requirements & metrics across themes

1a. Improved lead times for HAB warnings

Weekly measurements:

- **HAB spp. (8-9 taxa)**
- Chl-a, Temp, Salinity, **Nutrients**
- **Domoic Acid + SPATT toxins**
- Weekly alerts to HABMAP listserv
- Monthly QC'd data now served via ERDDAP
- Synthesis with models: **CA HAB Bulletin**

- **10 academic institutions**



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HARMFUL ALGAL BLOOM MONITORING & ALERT PROGRAM

Grass-roots origin in 2008; now fully supported by SCCOOS + CeNCOOS

Limitations: Only provides a weekly snapshots of a highly dynamic system; $$$ prohibitive to do daily monitoring; toxins and nutrients not even close to real-time; users want forewarning!

California Harmful Algae Risk Mapping (C-HARM) System: CROSSING THE "VALLEY OF DEATH" to ARL9

R&D started w/ NASA Grad Fellowship in 2004 (Advisors: Dave Siegel & Mark Brzezinski), over a decade before 2015 Dungeness Crab crisis

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
UCLA/JPL 3-km ROMS
Final Implementation
WCOFS at CSDL

IOOS COMT

***IN SITU* OBSERVATIONAL DATA**

Transition Development
CeNCOOS
Final Implementation
SCCOOS & CeNCOOS

CROWDSOURCED DATA

Transition Development
CeNCOOS
Final Implementation
SCCOOS & Marine Mammal Health Map

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

DINEOF (FORECAST)

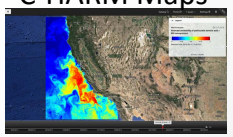
BIOLOGICAL MODEL FIELDS

Transition Development
CeNCOOS*
Final Implementation
NOAA CoastWatch

*S4 HPC @ Univ of WI

INTEGRATED FORECAST & ANALYSIS TOOL

C-HARM Maps



California HAB Bulletin

OBIS

HABMAP SCCOOS & CeNCOOS

Near real-time Marine Mammal Stranding Data

CA IFCB Network

Scripps Plankton Camera

Environmental Sampling Processor (ESP)

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

SOUTHERN CALIFORNIA COASTAL OCEAN OBSERVING SYSTEM
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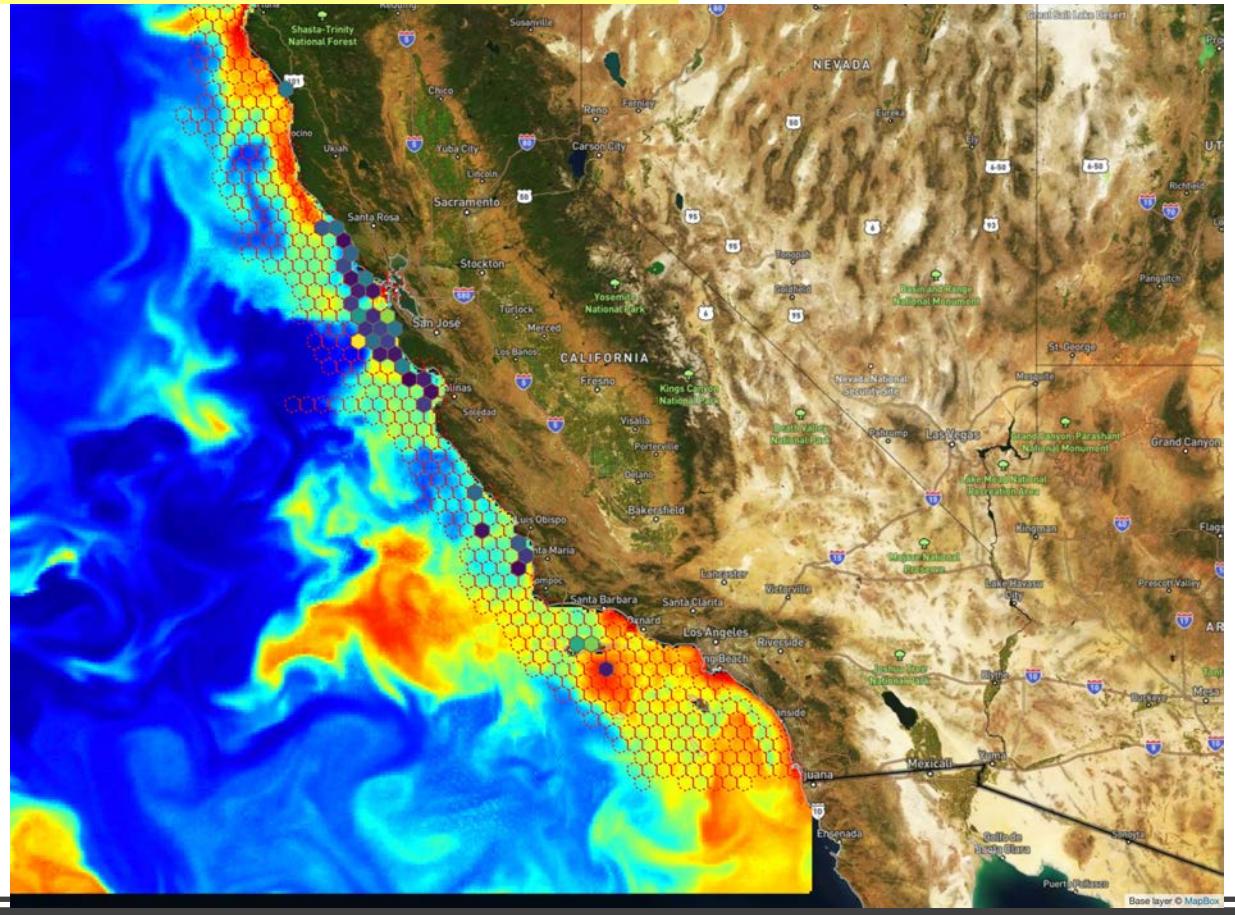
1b. Improving lead times for HAB warnings

SCCOOS
SOUTHERN CALIFORNIA
COASTAL OCEAN
OBSERVING SYSTEM

SIO/SCCOOS

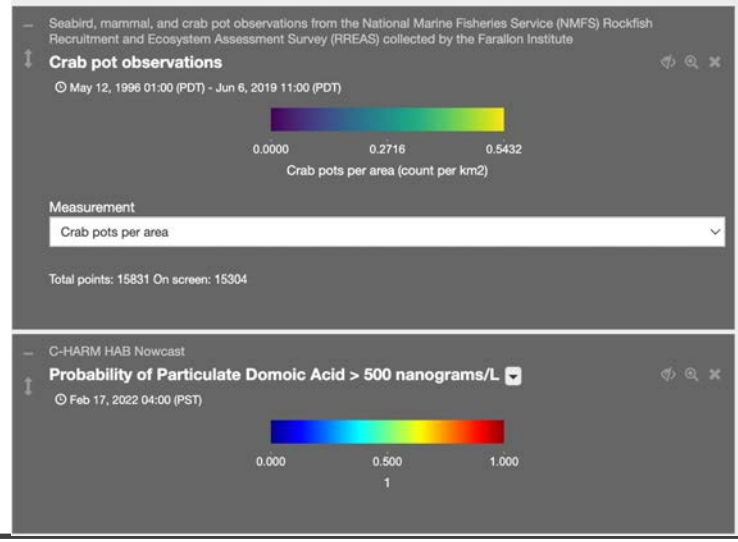
Dale
Robinson
NOAA



CalOOS Portal

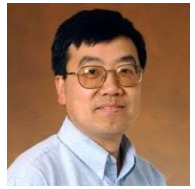
Particulate Domoic Acid
February 2022

Crab Pot Locations Overlayed



CeNCOOS
CENTRAL & NORTHERN
CALIFORNIA OCEAN
OBSERVING SYSTEM

Raphe Kudela
UCSC



Yi Chao -
Seatrec

California Harmful Algae Risk Mapping (C-HARM) System

Operational model at NOAA Coast Watch provides spatially explicit nowcasts and 1-3 day forecasts

NASA

<u>Limitations</u>: 3-km horizontal spatial resolution so does not capture nearshore variability; max accuracy 60-70% (missing BGC); only for PN/DA; no food web predictions

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Anderson et al., *Harmful Algae* (2009), *Geophysical Research Letters* (2011), *Harmful Algae* (2016)

2. Tracking Interstate Trajectories

SCCOOS
SOUTHERN CALIFORNIA
COASTAL OCEAN
OBSERVING SYSTEM

SIO/SCCOOS

Dale Robinson, NOAA

Remote Sensing-Ocean Color Imagery	Salinity	Temperature	Particulate Domoic Acid	Cellular Domoic Acid
MODIS Chl-*a*	WCOFS	WCOFS	C-HARM WCOFS	C-HARM WCOFS
MODIS $R_{rs}(555)$	3-km CA ROMS *"classic"*	3-km CA ROMS *"classic"*	C-HARM *Classic*	C-HARM *Classic*

CeNCOOS
CENTRAL & NORTHERN
CALIFORNIA OCEAN
OBSERVING SYSTEM

Raphe Kudela
UCSC

Chris Edwards
UCSC

Development of a West Coast C-HARM with WCOFS?

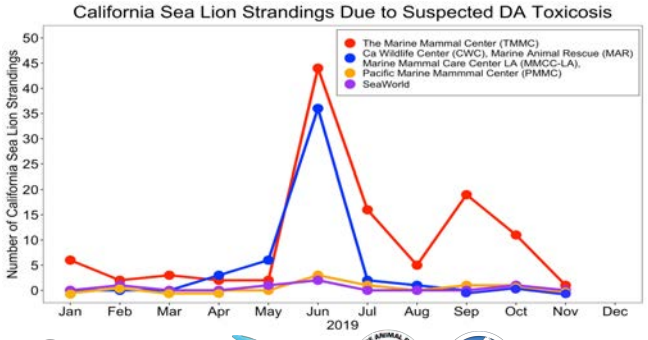
Comparing the UCLA ROMS Classic version of C-HARM with one that uses WCOFS inputs

***With WCOFS backbone, could be extended to entire West Coast + PNW HAB Bulletin*

Limitations: currently no parameterization of C-HARM for the PNW; computationally $$$ to run DINEOF for entire West Coast (plus larger temporal gaps)

3. Nearshore Impacts of HABs on aquaculture and fisheries

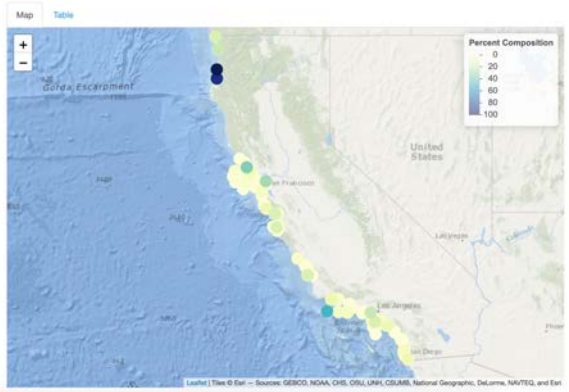
CA Marine Mammal Suspected DA Strandings



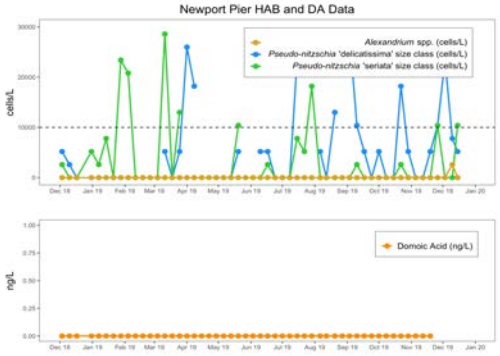
The Marine Mammal Center · PACIFIC MARINE MAMMAL CENTER · SEA LION HOSPITAL OPEN DAILY · SeaWorld · CALIFORNIA WILDLIFE CENTER

California Department of Public Health (CDPH)

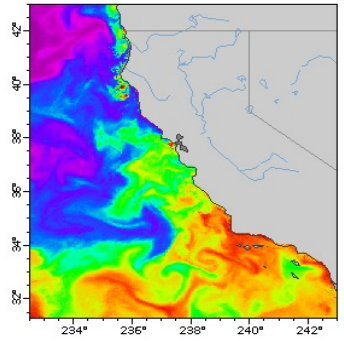
California Department of PublicHealth



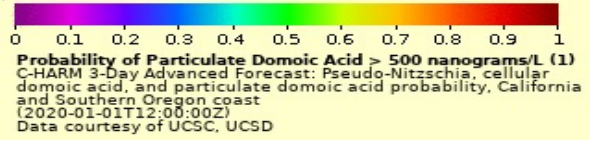
HABMAP weekly sampling at 9 piers for HAB species & DA



CA Harmful Algae Risk Mapping (C-HARM) System



Probability of
particulate domoic acid Jan 1 -31, 2020



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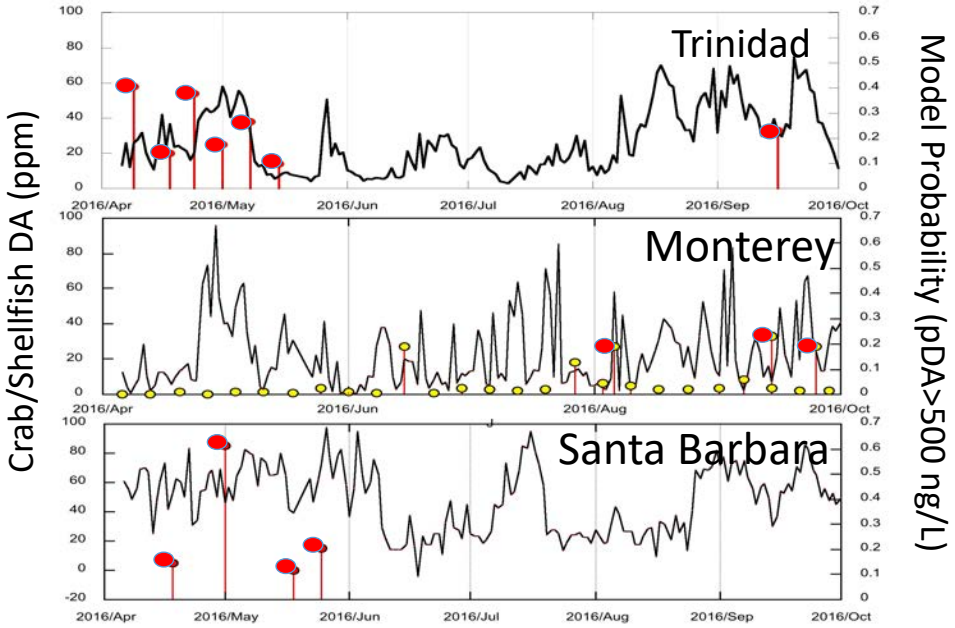
California Harmful Algal Bloom Bulletin

Provides context on regional variability as a measure of uncertainty in relation to food web impacts

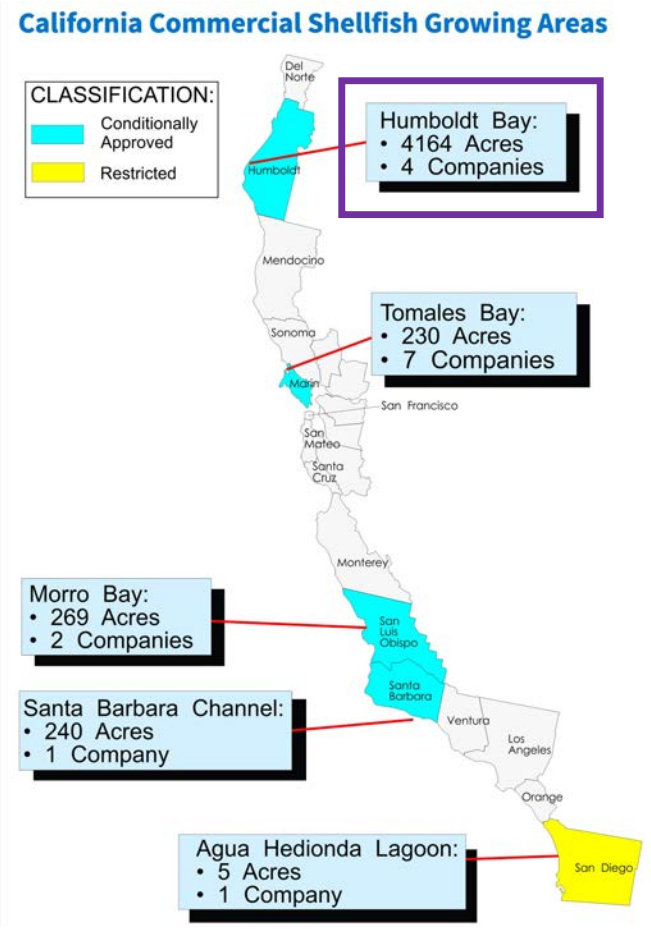
Limitations: retrospective synthesis with 1-2 month delay (due to toxin, Public Health, and marine mammal data acquisition); only covers two major toxigenic taxa

3. Nearshore Impacts of HABs on aquaculture and fisheries

Red=Crab, Yellow=Mussel



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



Many thanks to NASA Applied Sciences Program for Stakeholder Engagement Augmentation Funding

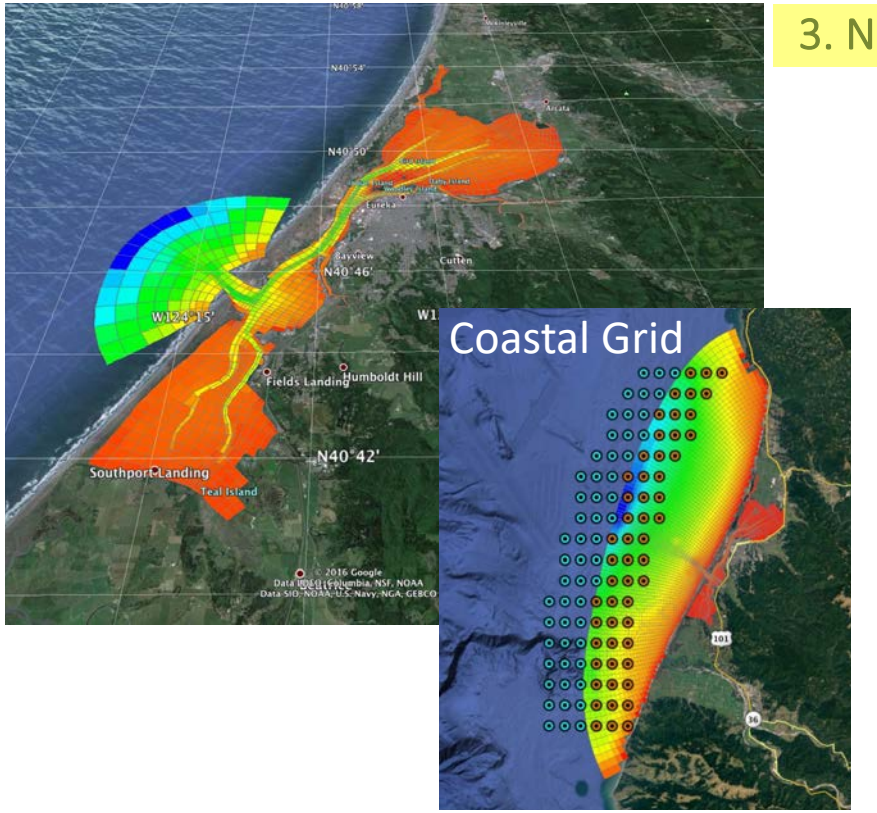
C-HARM not good at predicting estuarine toxicity

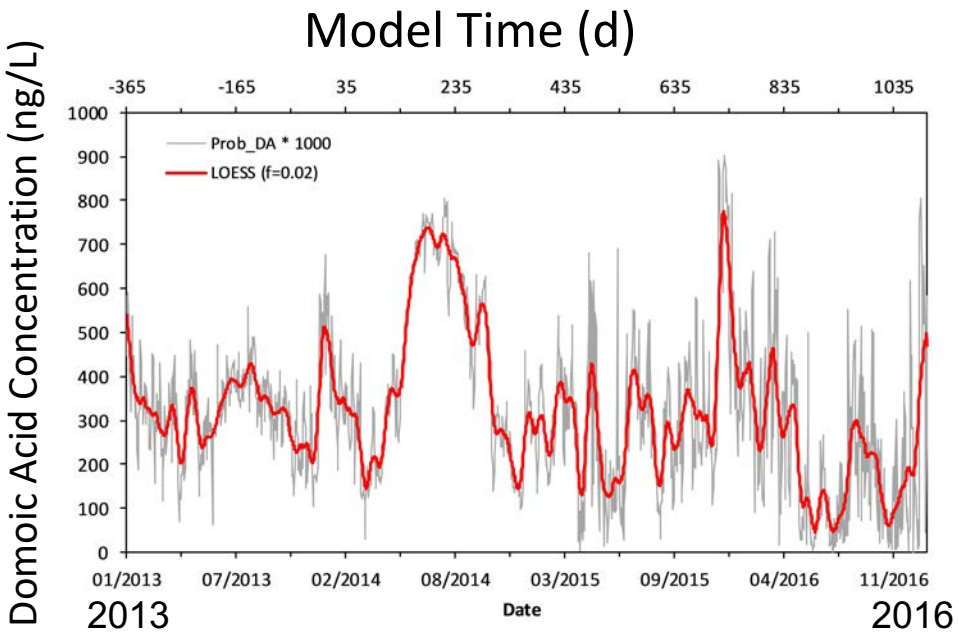
Stakeholders need estuary and bay-level accuracy

- Crab toxicity generally tracks nearshore C-HARM model; shellfish toxicity often decoupled from C-HARM
- Humboldt Coast became a new hot spot for DA during the 2015-2016 heat wave

Anderson et al., *Harmful Algae* (2009), *GRL* (2011), *Harmful Algae* (2016)

3. Nearshore Impacts of HABS on aquaculture and fisheries





Humboldt Bay Circulation Model to examine coast-to-estuary connectivity

- 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

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

Very High-Resolution Estuarine (Physical) Models

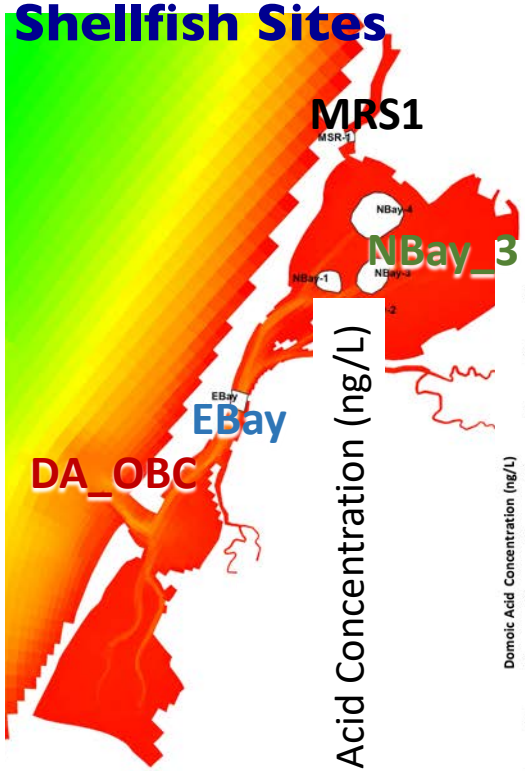
Humboldt Bay is home to major oyster growing facilities

Goal: use an ocean model like C-HARM to assess likelihood of toxic HABs in estuaries due to coastal exchange

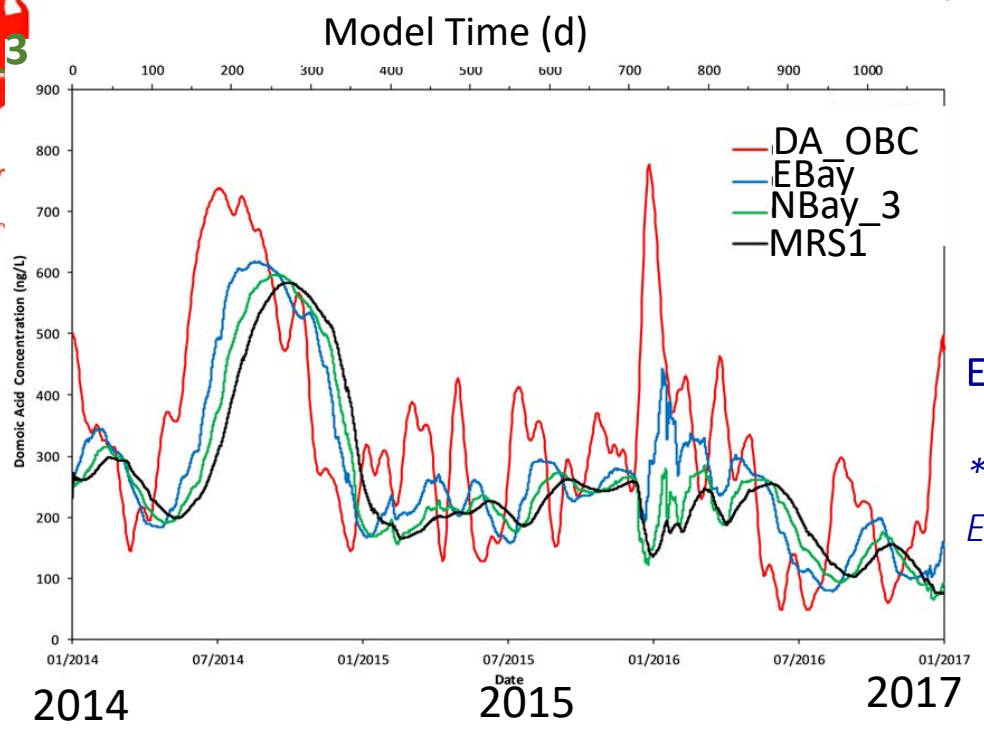
---

Limitation: passive tracer experiment only

Tracer Experiment Results



2014-2016 simulation of DA transport



Example of DA (dye) results

**Lagrangian Particle Tracking Expmts show same result*

➢ **Remaining Mystery**

Why do commercial shellfish beds rarely get closed in HB? Res time? Depuration rates?

C. Anderson, J. Anderson, R. Kudela, E. Bjorkstedt, B. Stacey, *in prep*

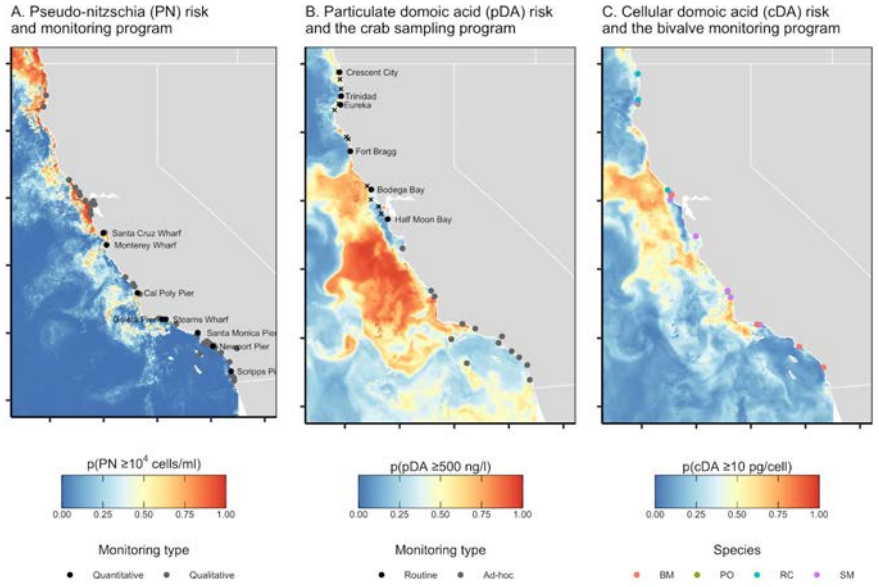
Very High-Resolution Estuarine (Physical) Models

Reveals that shellfish beds in N. Humboldt Bay can be theoretically exposed to high dissolved DA originating on the shelf and particulate DA from the nearshore

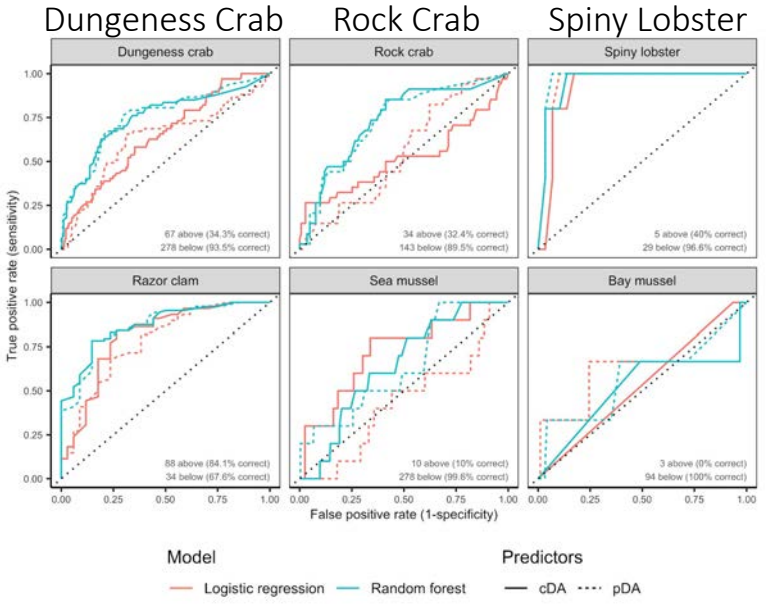
Limitations: lacks mechanistic or operational components; no biology

4. Food Web Interactions + Surface-to-Benthic Coupling

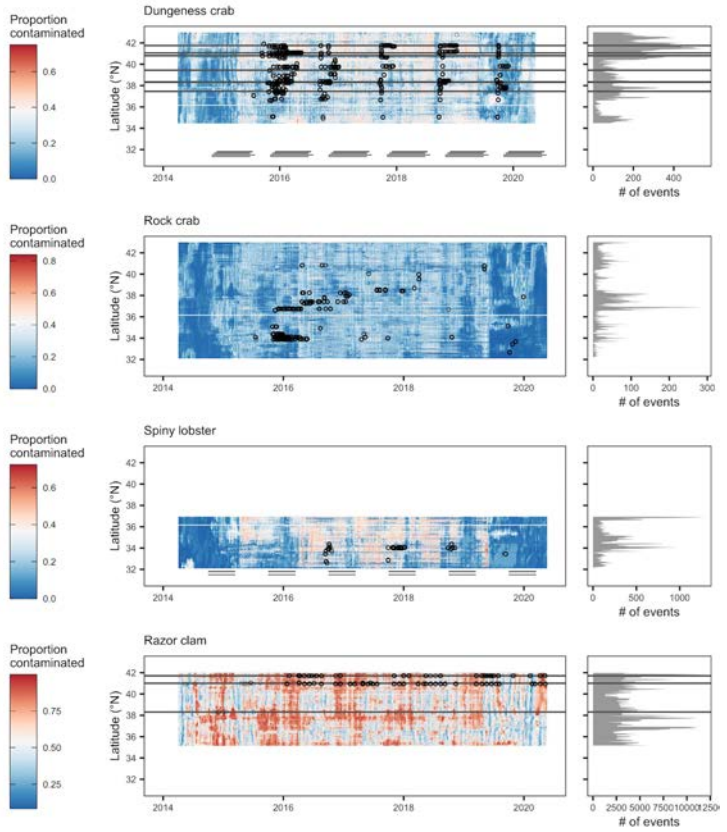
WATER COLUMN PREDICTIONS OF DOMOIC ACID FROM C-HARM



BENTHIC CRITTER DA ML Models



CONTAMINATION EVENTS w/in FISHING GROUNDS



C. Free, R. Kudela, E. Bjorkstedt, L. Bellquist, and C. Anderson, *in prep*

Predicting toxin contamination in harvested marine species to guide dynamic ocean management

Contamination in four wild capture species frequently exceeds management action thresholds

Stable Isotopes

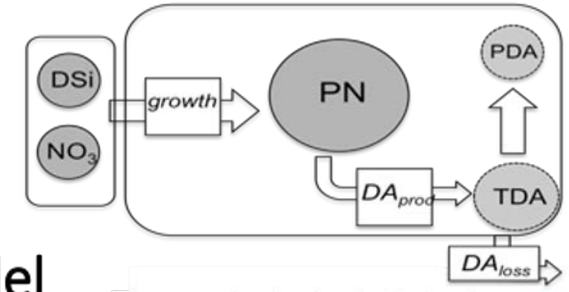
Contamination in four wild capture species frequently exceeds management action thresholds

4. Food Web Interactions + Surface-to-Benthic Coupling

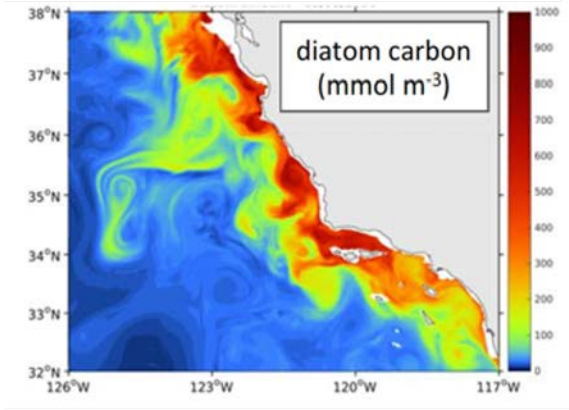
NOAA ECOHAB 2018

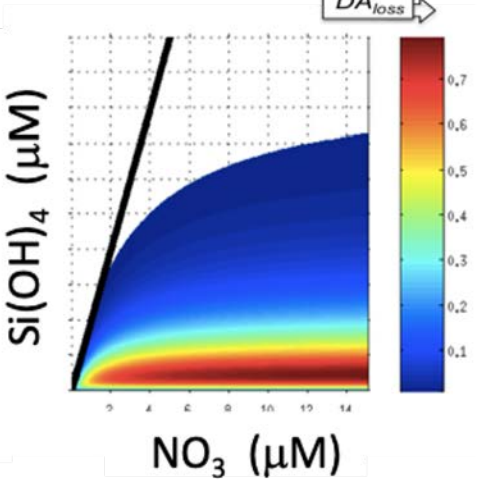
Daniele Bianchi, Jim McWilliams,
C. Anderson, Raphe Kudela, Martha Sutula
Faycal Kessouri

GOAL: Mechanistic modeling of DA production in a 3D coupled model



ROMS-BEC model





Leverages:

- **Packard Foundation & CA Sea Grant** investment in 0D DA model (Anderson, Edwards, Kudela)
- **NOAA & CA OPC investment** in ROMS-BEC and OAH modeling (McWilliams, Bianchi, Deutsch, Kessouri)

SCCWRP Established 1969 · Ucla · Scripps Institution of Oceanography, UC San Diego · Southern California Coastal Ocean Observing System

ECOHAB project establishes coupled modeling approach for toxin prediction

- ROMS-BEC is designed to allow study of HAB and OAH synergies

2. Predicting Offshore Bloom Initiation

NOAA ECOHAB 2019

Andy Allen, Brad Moore (Monica Thukral), Chris Scholin, John Ryan, Jim Birch, Greg Doucette, Clarissa Anderson, Drew Lucas

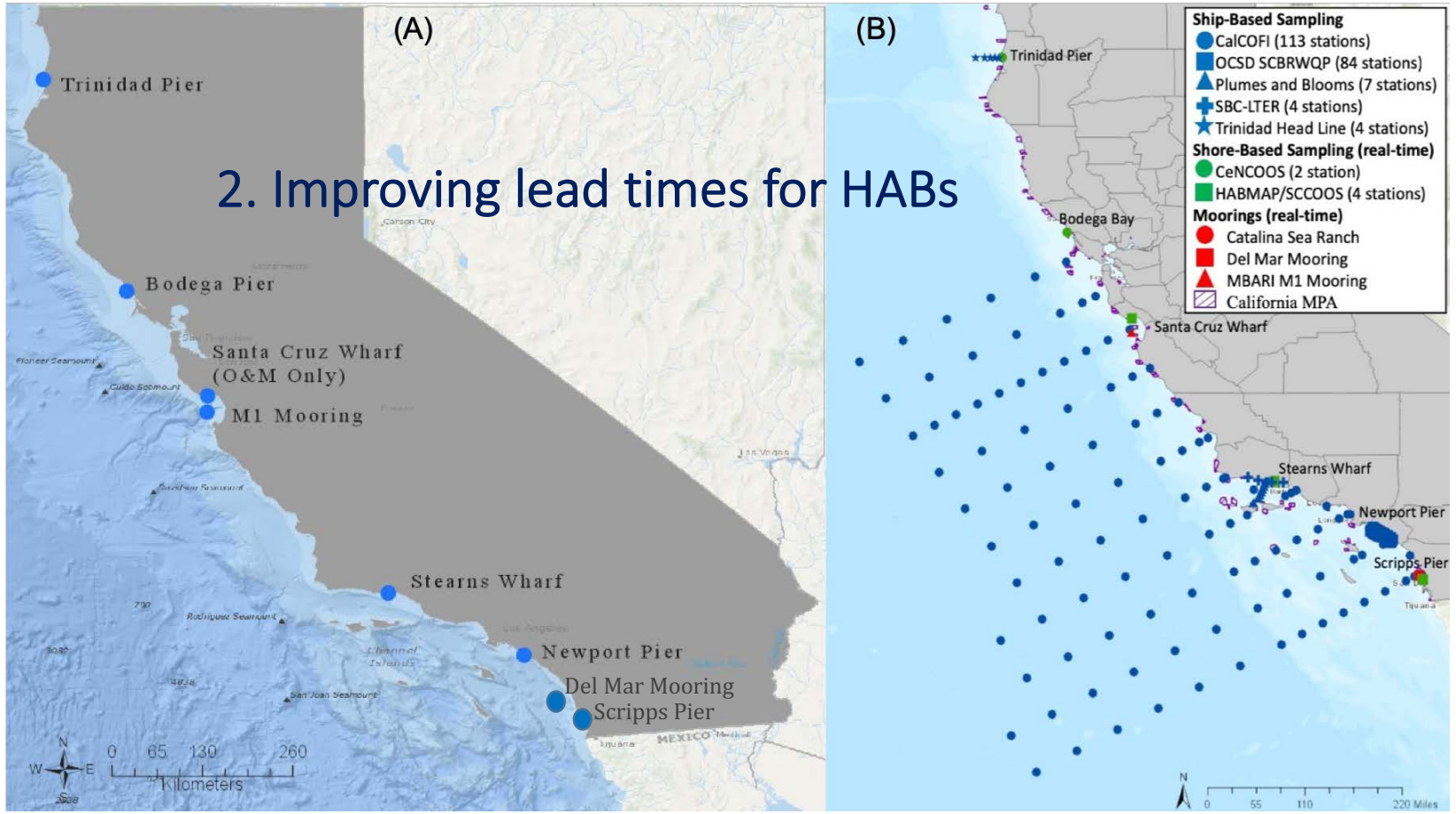
GOAL: Link genes to ecosystems to identify mechanistic drivers of variability in HAB toxicity in the California Current

IFCB deployed on CalCOFI cruises

Genetic basis of DA production discovered

- Offshore regulation of *dab* genes can be used to parameterize and validate ROMS-BEC

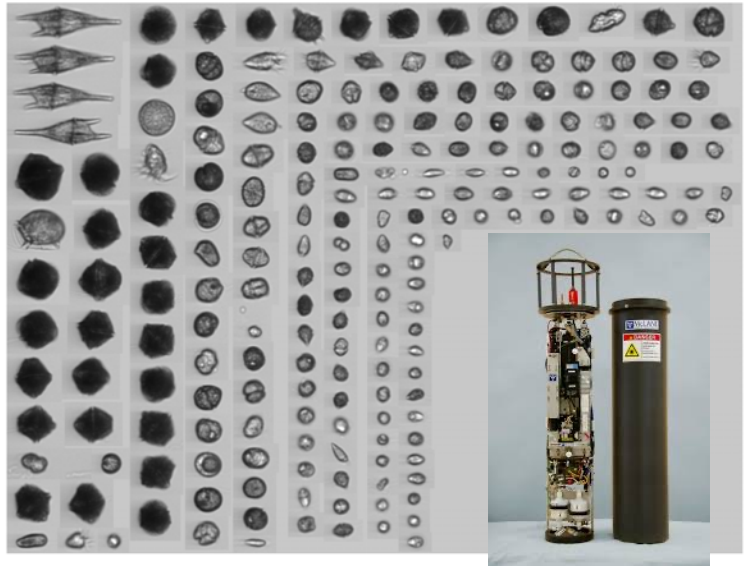
2. Improving lead times for HABs



Imaging Flow Cytobot (IFCB) Network

12 IFCBs Total: 6 piers + 3 moorings

- 6 new IFCBs via OPC + 1 OCSD
- 1 new IFCB via ECOHAB (PI Allen)
- 3 extant IFCBs (PI Kudela)



SOUTHERN CALIFORNIA COASTAL OCEAN OBSERVING SYSTEM

CENTRAL & NORTHERN CALIFORNIA OCEAN OBSERVING SYSTEM

California IFCB Network - CA Ocean Protection Council Prop 1 funding

- *Will provide high-frequency view of plankton dynamics along cross-shore gradients*
- *Many IFCBs will be collocated with pH and DO sensors – but we need more of that!*

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Stakeholder Recommendations

- WCOFS will be useful for a number of efforts but cannot replace the need for model hindcasts, seasonal to annual predictions, and long-term projections of ecosystem function.
- WCOFS will need to be coupled to a BGC model to provide the ecosystem benefits of extant models served by the IOOS West Coast RA Data Portals.
- Observations to support models are critical.
- Source attribution could be an important outcome of modeling efforts for tackling current challenges and charting future research.
- Economic valuation of data and model output will allow us to understand economic benefits of model predictions to stakeholders.

Thank you to the
Ocean Sciences Meeting 2020 & Session Organizers

SUMMARY – FUTURE RESEARCH

- Accurate nearshore forecasts remain elusive (aquaculture-scale)
  - Shellfish growers sample continually in collaboration with public health depts, which makes it hard to capture toxic events in models
  - Coupling offshore models to estuarine hydrological models should be stressed
  - Offshore initiation remains a focus for prediction

Thank you to the NOAA SAB for this opportunity

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OCEAN PROTECTION COUNCIL

Sea Grant
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Thank you to Senator McGuire
and the Committee for this opportunity

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