Wiring The Ocean to Understand Harmful Algal Blooms

Raphael Kudela
University of California Santa Cruz
What Pieces of the Puzzle Are Available?

US IOOS: Biology Task Team Identified Essential Biological Variables

GOOS: Biology & Ecosystems Task Team is Identifying Essential Ocean Variables

GEOHAB/GlobalHAB: Has identified a need for standardized data & time-series

GEO BON & MBON: Identified Essential Biodiversity Variables
2011-2016: USGS Deployment of SPATT

FRESH

OCEAN

SALTY, Long-Residence End-Member
San Francisco Bay

Focusing on SF Bay, we know that several algal toxins are nearly ubiquitous in the Bay.

The Bay seems to act as a mixing bowl for both freshwater and marine toxins...
Those toxins accumulate in the food web

Domoic Acid
(100% of mussels contaminated)

Microcystins
(82% of mussels contaminated)

Paralytic Shellfish Toxins
(25% of mussels contaminated)

Okadaic Acid, DTX-1, DTX-2
(100% of mussels contaminated)
Next-Generation Sensors

S2 Image from 17 September 2015

385 m

90 m
Wiring the Land-Sea Interface

San Lorenzo River, September 2015

Chlorophyll > 600 µg/L

218 ppb PSTs
146 ppb Nodularin
<table>
<thead>
<tr>
<th>#</th>
<th>Affected Birds</th>
<th>Location, Year</th>
<th>HAB Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>2250</td>
<td>Black Ducks, other waterfowl</td>
<td>New Hampshire, 1972</td>
<td><em>Gonyaulax tamarensis</em></td>
</tr>
<tr>
<td>140</td>
<td>Brown Pelicans, Brandt's Cormorants</td>
<td>Santa Cruz, CA, 1991</td>
<td><em>Pseudonitzschia australis</em></td>
</tr>
<tr>
<td>150</td>
<td>Brown Pelicans</td>
<td>Baja California, 1996</td>
<td><em>Pseudonitzschia spp.</em></td>
</tr>
<tr>
<td>550</td>
<td>Northern Fulmars, Common Murres, large grebes</td>
<td>Monterey Bay, CA, 2007</td>
<td><em>Akashiwo sanguinea</em></td>
</tr>
<tr>
<td>8000</td>
<td>Scoters, other divers</td>
<td>Washington State, 2009</td>
<td><em>Akashiwo sanguinea</em></td>
</tr>
</tbody>
</table>

September 2016
Landsat-8 Operational Land Imager (30m Resolution, 16 Day Repeat)

15 September 2016

Floating Algae Index (High Biomass Indicator)
Bridget Seegers was at the University of Southern California. Currently at NASA Goddard Space Flight Center Ocean Ecology Lab through GESTAR/Universities Space Research Association

Seegers et al. (2015)
HAB Toxin Detection on the 2nd Generation Environmental Sample Processor

toxin assays deployed for:
- domoic acid
- PSTs
- microcystins

‘pucks’ hold filter media for sample collection & analysis

membrane-based arrays used to conduct toxin cELISA; control & orientation features (green boxes) meter camera

assay time ~1 hour

calibration curve provides quantitative estimate of toxin concentration

Credit: G. Doucette
2013 – Species Matter!

Yellow: DA (ng/L)
Red Bars: P. multiseries
Blue Bars: P. australis

2015 – Species Still Matter!
“Ecosystem Moorings” or persistently dwelling autonomous vehicles would improve HAB detection from ~20% to 70% for California

Frolov et al., Harmful Algae, 2013
Interactive CeNCOOS Data Portal
C-HARM Nowcasts and 3-day Forecasts
http://www.cencoos.org/data/models/habs/

Probability Maps

Risk Maps
**C-HARM ESTIMATES AT CRUISE STATIONS**

Likelihood of elevated DA Levels

71% Accuracy, 20% False Positives

- **Trinidad**: DA slightly underestimated
- **SF Bay**: DA predicted to be further offshore than observed
- **South MB**: hotter, same as observed
- **Pt Conception-SBC**: known hot spot
- **DA overestimated in the Bight**

*R/V Shimada* NMFS Cruise-of-Opportunity
No...but we’re headed in the right direction!
Wiring The Ocean

• The technology exists for sustained ocean observing of phytoplankton, HABs, and toxins

• No sensor is perfect—we need to combine traditional and “simple” technology with next-generation methods

• We are (slowly) moving towards supporting these efforts (transition from Research to Operations)

• We’ve come a long way!
Kudela Lab:
Kendra Hayashi
Anna McGaraghan
Misty Peacock
Cori Gibble
Regina Radan
Nilo Alvarado
Dana Shultz
... and many more

Collaborators SF Bay:
Jim Cloern, USGS
Dave Senn, SFEI
Martha Sutula, SCCWRP
Lisa Campbell, Texas A&M
... and their teams

Forecasting:
Clarissa Anderson
Rick Stumpf
Mati Kahru
Fred Bahr, Jen Patterson

PNW Collaborators:
Vera Trainer
Ryan McCabe
Barb Hickey
Neil Banas
Eric Bjorkstedt

EcOHAB/MerHAB:
James Birch
Holly Bowers
Dave Caron
Greg Doucette
Meredith Howard
Burt Jones
Keith Loftin
Drew Lucas
John Ryan
Chris Scholin
G. Jason Smith
Yi Chao

Others:
Melissa Miller, Rob Ketley
Brian Maurer & Roger Phillips
Keith Bouma-Gregson

Logos: NOAA, NSF, Sea Grant, SCCWRP, CeNCOOS, IOOS, SFEI, Ocean Protection Council, California Water Boards, USGS, NASA