

NCCOS Annual Science Review: Harmful Algal Blooms and Hypoxia Program

Silver Spring, Maryland 28 - 30 November, 2023

Review Website: NCCOS HABs and Hypoxia Program Review

NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

INTRODUCTIONS AND WELCOME!

Sean Corson, NCCOS Director





Agenda and Process for the Day

DAY 1 (Tuesday, 28 November 2023)

- 8:30 8:35 Introductions and Icebreaker Sean Corson, NCCOS Director
- 8:35 8:45 Setting agenda and process for the day Lonnie Gonsalves and Dave Kidwell
- 8:45 9:00 High level recap of introductory information and videos - Lonnie Gonsalves and Dave Kidwell
- 9:00 9:30 Graffiti board activity
- 9:30 9:45 BREAK
- 9:45 10:15 Overview of Feedback from 2018 HAB and Hypoxia Program Review - Dave Kidwell, CRP Director; John Ramsdell, HAB-M&R Branch Chief
- 10:15 11:15 Causes and Impacts of HABs and Hypoxia Presentation - Maggie Broadwater, Program Manager, CRP
- 11:15 11:30 Panel reflection time
- 11:30 1:00 LUNCH

- 1:00 2:45 HAB Observing and Monitoring Presentation Greg Doucette, Research Oceanographer, HAB-M&R Branch; Marc Suddleson, Program Manager, CRP; Shelly Tomlinson, Oceanographer, HAB-F Branch
- 2:45 3:00 BREAK
- 3:00 4:45 HAB and Hypoxia Forecasts Presentation Alex Hounshell, Research Oceanographer, HAB-F Branch; David Scheurer, Oceanographer, CRP; Rick Stumpf, Oceanographer, HAB-F Branch; Quay Dortch, Senior HAB Scientist, CRP
- 4:45 5:00 Executive session Facilitated by Review Chair, Pat Brown
- 6:00 Dinner with panel at Mandalay in Silver Spring (930 Bonifant St, Silver Spring, MD 20910)





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HABs and Hypoxia by the Numbers

A Review

HABS AND HYPOXIA PROGRAM REVIEW | NOVEMBER 28th - 30th | SILVER SPRING, MD





Congressional Direction-*Federal Appropriations*

- Manage two separate lines of appropriations
 - Coastal Science, Assessment, Response and Restoration
 - "Base appropriation"
 - \$55M in FY23
 - Competitive Research
 - Managed by Competitive Research Program
 - \$22.5M in FY23





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Congressional Direction

- Direction via HABHRCA and frequently in annual appropriations
 - Accelerate deployment of effective methods of intervention and mitigation...
 - Understand causes and impacts...
 - Within CRP funding: "...not less than \$14M for HABs research.."



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HAB-F

• Helps stakeholders mitigate HAB impacts	HAB Forecast Branch	 Develops and delivers ecological forecasts Conducts applied research needed to inform ecological forecasts Advances satellite methods for detecting HABs Helps stakeholders mitigate HAB impacts
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COASTAL OCEAN SCIENCE

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HAB-M

HAB Monitoring & Reference Branch

- Produces reference methods, materials and • validation
- Designs, fabricates and calibrates toxin sensors •
- Advances HAB prevention and control • technologies
- Establishes and transitions regional user • laboratories
- Sustains citizen science for HAB monitoring and • underrepresented communities



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CRP

CRP HAB and Hypoxia Programs

- ECOHAB Ecology and Oceanography
- MERHAB Monitoring and Event Response
- PCMHAB Prevention, Control, and Mitigation
- SEAHAB Social and Economic Assessments (new)
- Event Response
- Coastal Hypoxia Research



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COASTAL OCEAN SCIENCE

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Strategic Approach

Observing

R&D

- Research and development of improved detection technologies and validation of data;
- Marine and freshwater satellite remote-sensing;
- PMN monitors marine and estuarine HAB species at over 250 coastal sites.

Operations

 NHABON Implementation Plan with IOOS

Forecasting

R&D

- Applied research needed to inform ecological forecasts;
- Advancing satellite methods for detecting HABs;
- Developing and delivering regional forecasts.

Operations

Plan in development with IOOS



PCM

R&D

- Control advances promising technologies for preventing, controlling, or mitigating HABs;
- HAB Event Response provides enhanced monitoring and response to events;
- Prevention through understanding the causes and impacts of HAB events.

HABs and Hypoxia By The Numbers





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Questions.....



Additional Logistics

- WIFI
 - Guest Username: HABProgramReview
 - Guest Password: HABPR1315
- Review Website
 - NCCOS HABs and Hypoxia Program Review
- Zero Waste Kit
 - Reduce and reuse!
 - Place items in sink at end of use and Shelby will wash and dry for next day

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Graffiti Board Activity

Peg Brady, Facilitator Shelby Butz, Review Coordinator





Graffiti Board Activity

- Break into groups of three
- Prompt: "What are you most looking forward to learning, sharing, digging into this week?"
 - Bonus points: Draw a review mascot.
- 10 minutes for writing ideas on sticky pad
- Select representative from each group for sharing

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15 min Break!

Return by 9:45 AM



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2018 HAB/Hypoxia Program Review: Recommendations and Actions

Dave Kidwell and John Ramsdell



Overview

- A compilation of reviewers' comments was submitted by the chair of the review panel on May 8, 2018.
- NCCOS consolidated into 20 recommendations for a coherent statement on the topic
- NCCOS staff provided a response narrative for 15 recommendations with action items.
- Five recommendations were deemed not appropriate for identifying an action item (i.e., progress was already being made on the subject of the recommendation).





HAB Recommendation: Revise or produce a different HARRNESS report

NCCOS Response: NCCOS recognizes that this is an important topic that should be discussed within the IWG-HABHRCA, as well as in consultation with the university community and other stakeholders.

Actions 2018-2023:

 HARRNESS 2020-2030 plan has been completed and building on major accomplishments from past efforts, provides a state of the science update since the previous decadal HARRNESS plan (2005-2015), identifies key information gaps, and presents forward-thinking solutions



HAB Recommendation: Reconsider "biological controls" as important HAB remediation tools, including efficacy of products currently available

NCCOS Response: Biological intervention is an approach to controlling HABs, with the others including chemical and physical intervention. The use of biological controls must be approached with great caution.

- Embraced chemical and biological control research as a potential control solution
- CRADA between NOS and AMURI for Nanobubble Ozone Technology, 2019
- Regional biocontrol project (DinoSHIELD) funding, 2020
- US HAB Control Technologies Incubator Funding, 2022
- Provisional Patent Awarded to CRADA, 2023



HAB Recommendation: Event Response Program needs to be funded at a much higher level

NCCOS Response: The ART continues to provide coordinated assistance to coastal managers during HABs and related health incidents. The current bills for reauthorizing HABHRCA (S 1057 and HR4417) include a section on providing responses to HAB and Hypoxia Events of Significance.

- NCCOS provides <u>integrated response capacity</u>; satellite monitoring, toxin analysis, and funding
- CRP Event Response Program increased to \$100K annually
- NCCOS led the IWG HABHRCA IWG to host a Federal HAB-Related Biospecimen Lab Inventory
- NOS initiated CRADAs for a network of user laboratories to conduct regional toxin monitoring

HAB Recommendation: ©NCCOS COASTAL CENTERS The Phytoplankton Monitoring Network (PMN) should be more strategic in program expansion

NCCOS Response: The PMN has improved its strategic recruitment of volunteer groups in high-priority HAB impacted regions of the country.

- NCCOS funded five year program to develop an aquaculture PMN Empower shellfish farmers with advance warning of HABs, mitigate the threat of HABs, and minimizing economic losses to the aquaculture shellfish industry, 2021
- NCCOS funded a two year program to increase STEM diversity in Latino communities 2021
- NCCOS collaborated with EPA Managing Harmful Algal Blooms in Tribal Waters Webinar Series, 2021
- NCCOS receives diversity and inclusion grants for PMN to include lower income urban and rural communities, 2022,2023
- NCCOS funded work to promote Inclusion of Sensory Impaired Individuals in NOAA Citizen Science 2023



HAB Recommendation:

NCCOS should focus on developing observational and monitoring technologies that are easily transferable to, and affordable by, non-federal entities.

NCCOS Response: Developing better monitoring and observing capabilities and technologies is a very high priority for NCCOS. The Environmental Sample Processor (ESP) has been an NCCOS focus for autonomous toxin sensor development during the past five-years. This has been a joint effort with the intramural and extramural programs and many other partners.

- Initiation of partnership with MBio Diagnostics (now LightDeck) to evaluate planar waveguide technologies, 2018
- Initiation of partnership with MBARI for toxin detection capability to ESP downsized to "tackle box", 2018
- NCCOS Funding for "Right Sizing HAB Sensors" 2020 to adapt ESP core processor to SPR, 2020
- NCCOS releases R2A Video on "Toxicity of Lake Erie Algal Bloom in Near Real-Time", 2020
- ECOHAB AND MERHAB funding to LightDeck, 2020



HAB Recommendation: Conduct studies that improve socioeconomic understanding of impacts from HABs

NCCOS Response: NCCOS agrees that there is a need for better estimates to compare the costs and benefits of various mitigation strategies following HAB [or hypoxia] events.

- Funded two economic impact projects following large and prolonged FL red tide event
- Funded and collaborated to hold a HAB economic impact workshop
- Collaborated in development of <u>"Hitting Us Where it Hurts"</u> story map
- Initiated the Social, Cultural, and Economic Assessment of HABs funding program



Hypoxia Recommendation: NCCOS should focus on developing observational and monitoring technologies that are easily transferable to, and affordable by, non-federal entities.

NCCOS Response: NCCOS will continue to engage with the HTF on monitoring and other Federal and State efforts, and improve coordination with internal and external monitoring programs.

- Continued to support ship-based annual monitoring cruise
- Provided oversight and technical support for a suite of autonomous vehicle development projects
- Collaborated with OMAO's uncrewed systems program to test applicability of surface vehicles.



General Recommendation: Engage and collaborate with other agencies to avoid duplication and define respective roles and responsibilities more clearly.

NCCOS Response: NCCOS agrees...

- Increased staff support and coordination through the IWG-HABHRCA
- Established a MOU in FY19 with the U.S. Centers for Disease Control and Prevention
- Collaborated with USACE, EPA, USGS, and NASA to develop CYAN
- Actively coordinates funding and projects with USACE, particularly for HAB control



External Factors Influencing Action Status

Over the intervening time, our actions have necessitated adaptation

- Congressional direction Feedback from briefings and appropriations language
 - e.g., focus on socioeconomic impacts
- Evolving stakeholder needs
 - Maturing technologies, emerging species, and climate
- Regulatory landscape
 - NEPA has limited our ability to significantly advance biological controls
- HAB events



Open Discussion

External Peer Review: Harmful Algal Blooms and Hypoxia Portfolio February 26-28, 2018

NCCOS Response to Review Panel Recommendations October 30, 2018

Link to all recommendations/actions: https://docs.google.com/spreadsheets/d/1Q1XH0P9iR2M6qip2Uy8 hJ07AfCWbIAGYqpp22N2Z3es/edit?usp=sharing



HABs & Hypoxia Understanding Causes & Impacts to Advance Solutions

Maggie Broadwater, PhD NCCOS Competitive Research Program













R2A: It's about the partnerships

MAKING INTENTIONAL CONNECTIONS AMONG PARTNERS, PURPOSE, ACTIVITY, AND APPROACH



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Science transition approach



Example - NCCOS Research Provides Scientific Foundation for U.S. Supreme Court Ruling (NCCOS News)

Science transition to application







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California

A holistic approach to HABs & OAH informs management



NCCOS R2A timeline: Causes & impacts of HAB/H events in California

Pre-2019

- → SDI/HABMR Projects: Marine mammal impacts from recurrent DA events & UMEs with TMMC & NOAA OPR
- → MERHAB 2005: <u>RAPDAlert: Pseudo-nitzschia & domoic acid</u> (USC) with SCCWRP
- → ECOHAB 2011: Comparison of Upwelling and Coastal Land Use Patterns on the Development of HAB Hotspots (UCSC) with SCCWRP
- → News: 2015 West Coast HAB Event Response "the Blob"
- → MERHAB 2015: Monitoring Multiple HAB Toxins at the Land-Sea Interface (SCCWRP)
- → OA 2015: Modeling OAH to Support Ecosystem Prediction and Environmental Management in the CCS (UCLA) with SCCWRP
- → CHRP 2018: Biological Vulnerability to Hypoxia in the CCS (UW) with SCCWRP & OPC
- → CHRP 2018: Causes and Consequences of Hypoxic Events in Low-Inflow Estuaries (UCSD)
- → MERHAB 2019: Emerging Algal Toxins in the California Current System (UCSC) with SCCWRP



- → Multistressor research to improve predictions
- → Model validation increasing focus on prevention where appropriate
- → Continued engagement with SCCWRP, OPC & partners

R2A: Causes & impacts of CA <i>Pseudo-nitzschia</i> blooms & DA events		
WHY? - DESIRED PRODUCT/SERVICE Quantitative understanding of the oceanographic, cellular, and anthropogenic factors that regulate CA <i>Pn</i> blooms and DA events	WHO? - TARGET USER GROUP WQ & natural resource managers: SCCWRP, OPC, WCOA, CA Water Boards, POTWs — R2A - Early warning, mitigation, informing prevention strategies	
 WHAT? HOW? - CURRENT STATE OF PRODUCT/SERVICE → Predict: ROMS-BEC-Pn model for S-CCS → Understanding offshore vs coastal drivers → management interventions → Localized effects vs. global climate drivers → DA biosynthesis - Predicting toxicity → DA thresholds for impacts to marine mammals → Related products: C-HARM; California HABMAP; California IFCB network, Dashboard & HABDAC; California HAB Bulletin 	WHO? - NCCOS ORGANIZATION UNITS & KEY PARTNERS CRP & SDI/HABMR — UCSD/Scripps, UCSC, UCLA, USC, MBARI, SCCOOS, CenCOOS — R2A: SCCWRP [OPC, WCOA]	
\rightarrow Early warning, mitigation, prevention		
Outputs/Outcomes: Model application to water resource management



- → ROMS-BEC-Pn: Multistressor understanding of *Pn* bloom dynamics (offshore vs coastal drivers) leading to <u>appropriate</u> management interventions
- → Regulatory agency acceptance OPC & State/Regional Water Boards
- → January 2024: Model review by independent panel
- → Prevention strategies future evaluation using WCOA HAB & OAH report card system

SCCWRP FACT SHEET

Coastal Water Research

Partner

R2A

Southern California

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rogram

Modeling as a tool to support coastal water-quality decisions

A primer on how computer modeling is used to understand the effects of discharging nutrients to Southern California's ocean

When coastal communities face water-quality problems, they often struggle to understand the extent of the problem across space and time. Environmental monitoring programs can provide some insights, but only for a limited number of sites at discrete time points.

Moreover, as communities identify possible solutions over time to solve water-quality problems, they need assurances they'll get tangible environmental benefits - before investing millions or even billions of dollars in a particular solution. Monitoring programs can quantify the success of these solutions once implemented, but do not provide insights about the likelihood of success for solutions that have yet to be implemented.

Modeling helps communities make informed choices

For decades, managers have relied on computer modeling to generate a more comprehensive picture of coastal ecosystem health and to evaluate if proposed interventions to protect water quality will be effective. Through modeling, stakeholders can:

- · Weigh the benefits vs. costs of different possible interventions
- · Consider the risk of taking no action vs. taking action that turns out to be wrong or inadequate
- · Use a common set of facts and data to reach consensus on the best course of action

Examples: Modeling informing decisions

Managers routinely use proven computer models as a basis for taking action:

» During hurricanes, weather forecasting models help public officials determine when and where to issue evacuation orders to move millions out of harm's way.

» When a body of water needs to go on a "pollution diet," water-quality models help predict how much pollution levels need to be reduced to restore healthy conditions for plant and animal communities.

» Policymakers rely on global climate models to understand how Earth's climate will change in the future and how reducing carbon emissions could slow these changes.



Human activities on land can adversely affect the health of aquatic resources, including Southern California's coastal ocean, above. Coastal communities rely on computer modeling to better understand these problems and evaluate if proposed interventions will be effective

Should a model's predictions be trusted?

"All models are wrong; some are useful." -British statistician George Box

All models generate predictions with some degree of error, which can lead to questions about how much their predictions can be trusted. The key to developing confidence in a model's predictions is to scrutinize how a model is performing - a critical step known as quantifying modeling uncertainty. When managers understand modeling uncertainty, they have context for deciding how much confidence to place in what the model is predicting.

Uncertainty is not unique to modeling

All types of scientific measurements have uncertainty. Field and satellite measurements - often held up as the gold standard for assessing coastal water quality - have uncertainty too. The main difference is scientists have an easier time quantifying uncertainty in monitoring data than in models.

How modeling uncertainty is quantified Scientists commonly quantify modeling uncertainty in multiple ways,

including:

- · Comparing the model's predictions to field data; any difference represents the model "uncertainty," which is a combination of error in the model's predictions and error in field measurements
- · Conducting a sensitivity analysis, where the data that are fed into the model are intentionally tweaked to determine how vulnerable the model's outputs are to various modeling assumptions
- Running a model comparison analysis, where the model is compared. to other models that predict similar variables to identify differences in their predictions

The more ways that modeling uncertainty gets quantified, the more confidence that managers can have in the model's predictions - and thus the more likely managers are to make informed decisions based on modeling insights.

Case study: Modeling the effects of nutrient discharges on Southern California coastal waters

BEC

nutrients to fuel growth of algal blo

sume oxys

their death, are decomposed by bacteria that

en and lower pl

Southern California communities face a conundrum

Increased greenhouse gas emissions are warming Earth and causing ocean pH and oxygen levels to fall along the West Coast, leading to widespread problems for marine life. Although greenhouse gas emissions are viewed as the primary driver of these changes, scientists are studying the extent to which nutrients discharged from heavily populated Southern California coastal communities could be exacerbating these problems. Computer models are foundational to these investigations; the outcomes could have significant cost implications for communities.



Modeling is used to simulate multiple aspects of coastal ocean health, including changes in a property of seawater chemistry known as aragonite saturation state, above, at two different depths over time

How the coastal water-quality model works

Southern California's coastal water-quality model is made up of two component models collectively known as ROMS-BEC - that work in tandem to predict the influence that local nutrient discharges are having on coastal ocean health.

Southern California's ROMS-BEC coastal water-guality model



ocean water circulates - a key predictor of how nutrient discharges disperse in coastal waters

» Assessing influence of local human discharges

Scientists are using the model to predict how coastal ocean health is affected by local nutrient discharges, then repeating the modeling simulation - except this time, reducing local nutrient discharges. The difference between the two simulations represents how much nutrient discharges have the potential to alter coastal ocean pH and oxygen levels.

» Evaluating effectiveness of possible interventions

Just as scientists are working to model what is happening now, models also have the potential to help understand the effectiveness of possible future nutrient management decisions. Scientists are using ROMS-BEC to simulate the combined effects of these potential management scenarios and projected future local and regional changes to ocean pH and oxygen levels driven by climate change.

A publication of the Southern California Coastal Water Research Project (SCCWRP)

Key management questions

As scientific understanding of the effects of coastal nutrient discharges improves. Southern California will be faced with tough questions about whether to act - and the costs of action vs. inaction:

» Will investing in reducing nutrient discharges make a measurable difference for coastal ocean health?

» How could nutrient reductions result in measurable changes in coastal water quality?

» Are there nutrient management alternatives - such as offshore kelp farming - that could measurably improve coastal water quality?

Building management confidence in modeling

To build confidence in the ROMS-BEC model's predictive abilities, scientists are quantifying uncertainty in multiple ways, including:

algal blooms, pH and oxygen levels in coastal waters to more than 20 years of corresponding field monitoring data (see "More reading" links below), focusing on areas where nutrient reductions have already occurred to

» Partnering with stakeholders to invite outside experts to independently review the ROMS-BEC modeling work and evaluate modeling uncertainty

These and other model validation activities are ongoing.

More reading

Findings of ROMS-BEC water quality application

Findings of model skill assessment





March 2023

» Comparing hindcast modeling of assess model performance

California case study overview

	Quality		Performance		Relevance
→	Scientists recognized as national and international leaders	→	Addressing HABHRCA & Action strategy recommendations	→	Research products directly inform improvements to HAB/H
→	New and validated technologies	→	SDI/HABMR project participation		management & response
	(models, LRAUV/ESP, Wirewalkers)		(Doucette & Mikulski) - Sensors	→	CA is leading holistic, multistresso
\rightarrow	30 peer-reviewed publications to	→	CRP PMs actively participate in		research applications (HABs &
	date (2 ECOHAB projects) - more in		project meetings, external		OAH)
	progress		communications	\rightarrow	Predicting toxicity to inform
\rightarrow	Multiple funding sources including	→	Project team/partners active in US		strategies for early warning &
	CHRP & National Competitive HAB		NHC, NHABON, GOOS, GlobalHAB,		mitigation, preparedness &
	program funding (ECOHAB,		IOC & UN Decade initiatives		response
	MERHAB, PCMHAB) - Competitive	→	SCCWRP - direct link to users and	\rightarrow	Source attribution to inform
	merit review by expert panel,		active participation in R2A		strategies for prevention via
	relevance, scientific/technical merit	→	NCCOS leadership: 2020 OA/HAB		nutrient management
	(70%)		workshop, 2021 NMS Climate	→	Multiple products targeted to

Change Science Priorities Workshop

→ Leveraging OPC, SG, NIEHS, NASA & other funding streams

- → Multiple products targeted to specific end users
- → Focus on interpretation of results (R2A)



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Florida

Recurrent *Karenia brevis* blooms & hypoxia on the West Florida Shelf - Improving management efficacy





Florida Fish and Wildlife Conservation Commission

FWC Fish and Wildlife Research Institute

NCCOS R2A timeline: Causes & impacts of Florida K. brevis blooms

Pre-2019

→

- 1997 ECOHAB Florida (FWRI) & 1998 Eco-Sim-WFS (USF) →
- 2006 ECOHAB: Karenia Nutrient Dynamics in the Eastern Gulf of Mexico (FWRI & Mote) \rightarrow
- 2017 PCMHAB: Alternative Method for NSP Monitoring and Management (FWRI) →
- 2017 ECOHAB: Mechanism Based Intervention for Brevetoxin Induced Oxidative Stress (FIU & Mote) \rightarrow
- 2018 News: NCCOS, Partners Respond to Prolonged Florida Red Tide **→**



- Prevention, mitigation, control applications \rightarrow
- Discerning the roles of HABs, warming and extreme weather events in hypoxia events on the oligotrophic WFS (CHRP) \rightarrow

Life and Death of Karenia brevis Blooms in the Eastern Gulf of Mexico					
WHY? - DESIRED PRODUCT/SERVICE	WHO? - TARGET USER GROUP				
Improve FL red tide management efficacy	Florida coastal communities Coastal resource managers Industry: aquaculture/shellfish/tourism — R2A - Management, mitigating impacts, communication				
WHAT? HOW? - CURRENT STATE OF PRODUCT/SERVICE	WHO? - NCCOS ORGANIZATION UNITS & KEY PARTNERS				
 Field/Lab Studies & Modeling to inform: → Longer-term prediction → Mitigation of economic impacts → Effect of physical factors/nutrients/extreme events on <i>Kb</i> bloom variability → Bloom dispersal/termination → Management & mitigation of impacts 	CRP & SDI/HABF — Mote Marine Lab, UMCES, NYU, USF, Bigelow Laboratory, UF — FL FWRI GCOOS & SECOORA SFWMD Ocean Era (Offshore Aquaculture Demo Project)				

Outputs/Outcomes: Research informing state, local stakeholders & public interest

- → Assessing the role of climate factors in driving Kb bloom occurrence & severity
- → What is the role of climate in regulating bloom severity, duration and the occurrence of unusual summer blooms?
 - FWRI HAB historical database
 - *Kb* bloom severity index
- → ROMS-RCA-MIXO modeling of *Kb* blooms
- → Piney Point event support
- → Hurricane Ian & 2022-2023 FL red tide
- → Public attention Spring Break & 2022-2023 FL red tide
- → Media communications
- → Ocean Era offshore aquaculture siting



Representation of Florida FWRI HAB historical database 1954-2021 (Heil, ECOHAB Annual Report 2023)



Google Analytics - Red tide short-term tracking and forecast products during 30 days of 2023 Spring Break season (Heil, ECOHAB Annual Report 2023)

R2A Partners: FL Red Tide Task Force, FWRI & Mote Marine Laboratory

- → FL RTTF Long term focal area (Dec 2021):
 - strategic research into the biology and ecology of HAB species
 - detection, tracking, modeling, and prediction of blooms
 - fate of algal toxins
 - impacts of blooms on valued facets of society
 - prevention, control and mitigation of blooms



Florida Harmful Algal Bloom Task Force Consensus Document #2:

Progress and Recommendations Regarding Red Tide (*Karenia brevis*) Blooms



DECEMBER 2021 MyFWC.com/HABTaskFo Resource Guide for Public Health Response to Harmful Algal Blooms in Florida, Version 2.0 g. MEGHAN ABBOTT, JAN H. LANDSBERG, ANDREW R. REICH, ELKE UBSN AND MONCASAMIT EDITORS



In progress:

South Florida Interim Integrated Assessment

Report to Congress (HABHRCA 2017)

Florida case study overview

Quality		Performance		Relevance
 → Scientists recognized as national and international leaders → New and validated technologies (models, HABScope) → 32 peer-reviewed publications to date (2019 ECOHAB) → Multiple funding sources including CHRP & National Competitive HAB program funding (ECOHAB, MERHAB, PCMHAB) - Competitive merit review by expert panel, relevance, scientific/technical merit (70%) → Leveraging FL Red Tide Mitigation & Technology Development Initiative, NSE EL COMPS & other funding 	$\begin{array}{c} \rightarrow \\ \rightarrow \\ \rightarrow \\ \rightarrow \\ \rightarrow \\ \rightarrow \\ \rightarrow \end{array}$	Addressing HABHRCA & Action strategy recommendations State agency stakeholders (FWRI) participating on project team SDI (HABF) collaboration CRP PMs actively participate in project meetings, external communications NCCOS CRP & Project team participation in Florida Red Tide Task Force Direct collaboration with FWRI, FL RTTF, other Mote Red Tide initiatives	→ →	Responsive to FL Red Tide Task Force Recommendations Application of ECOHAB project knowledge for preparedness and response to HABH events following Piney Point disaster and Hurricane lan ECOHAB knowledge contributions to South FL Interim Integrated Assessment Report to Congress (HABHRCA)



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Alaska

Shifting focus - HAB impacts to subsistence food safety & security



NCCOS R2A timeline: Causes & impacts of HABs in Alaska

Pre-2019

- → HAB Forecasting efforts in Kasitsna Bay & Kodiak with APIA & Knik Tribe
- → <u>Phytoplankton Monitoring Network</u> (PMN) partnerships
- → NCCOS support for <u>SEATOR shellfish program</u>
- → ECOHAB 2017: Understanding wintertime shellfish toxicity in the Gulf of Alaska (Eckert, UAF)
- → A00S 2017: <u>Alaska HAB Network</u>
- → News: 2018 HAB Event Response (SE Alaska Pseudo-nitzschia blooms)



News: HAB Event response

Future

- → Continued NCCOS support for HAB impacts to subsistence food safety/security. Meeting community needs (toxin detection)
- → Continued engagement with State, Tribal & community partners
- → Risk maps? Forecasting? Predicting impacts

R2A: Causes & impa	R2A: Causes & impacts of HABs in Alaska					
WHY? - DESIRED PRODUCT/SERVICE	WHO? - TARGET USER GROUP					
Understand/predict risks to the environment & human health <u>related to subsistence</u> food safety and security	Alaska coastal communities Subsistence resource users Marine mammal resource managers — R2A - Food safety & security, resource management					
WHAT? HOW? - CURRENT STATE OF PRODUCT/SERVICE	WHO? - NCCOS ORGANIZATION UNITS & KEY PARTNERS					
 → Map HAB cell densities & measure toxins → Define trophic transfer pathways → Document impacts to marine mammals, fish and seabirds → Develop models to predict toxins under different bloom scenarios and future events → Local/regional toxin testing support → Support subsistence use decisions in Alaska communities 	CRP, SDI (HABMR & HABF), and MSE — NOAA/NWFSC & AFSC, WHOI, USGS, USFWS, UAF, AOOS/AHAB, FL/FWRI — R2A: NSHC, SEATOR, ACSPI, NSB, KANA, ANTHC, UAF AK SG, Marine Mammal Commission, Eskimo Walrus Commission					

Outputs/Outcomes: It's about subsistence



Quilted art, Native Village of Savoonga Community Center

- → Subsistence: nutrition, culture, economy
- → HAB patterns are changing in Alaska & Arctic waters
- → HAB toxins are present and may affect subsistence food safety & security
- → T/LEK is not sufficient the only safe seafoods are tested seafoods
- → When, where, and in which foods are HAB toxins present?
- → Regional monitoring & toxin testing capacity can reduce human health impacts
- → Accurate and appropriate risk communication Relationships are important!

R2A Partners: UAF/Sea Grant & Norton Sound Health Corporation

- → UAF Sea Grant and NSHC OEH conduct regular water sampling near Nome (training by NCCOS/HABMR)
- → NSHC OEH analyzes water samples with microscopy for presence/absence of HAB target species
- TBD: Regional toxin testing laboratory \rightarrow
- → Goal: Protect human health by providing tools to make informed decisions when harvesting subsistence foods
- → 2022-2023 HAB Risk Communications: Alexandrium blooms in the Bering Strait region (WHOI, ECOHAB partners)
- → Strait Science Seminar Series UAF NW Campus & AK SG -Communication to stakeholders

Harmful Algal Bloom Toxins



farmful algal blooms (HABs) occur when tiny alg grow out of control and can produce Paralytic Shellfis oxins that can effect people, marine mammals abirds, etc. Saxitoxin is one of these toxins that ; isoning (PSP), HABs and PSP are not nd climate change is contri portant to understand how toxins occur in HABs to try to prevent dangerous health effects from occ

How do toxins get into seafood during a Harmful Algal Bloom?



Certain species of algae can produce naturally occurring toxins know noic acid and saxitoxin





Filter feeders like mussels.

Walruses, whales, seals, and crabs that eat animals/shellfish contaminated with these toxins can potentially also contain the toxins, especially in the c and the guts/butter of the crab.



consuming seafood contaminated with biotoxins. Paralytic Shellfish Poisoning (PSP) can occur when people eat clams crabs, and other seafood contaminated with high levels of

Symptoms of PSP include diarrhea, vomiting or nausea tingling or numbness of the tongue and lips; throat irritation or difficulty breathing. If you feel sick or have any of these symptoms after eating shellfish or 'crab butter' immediately call the Nurse Call Line at (907) 443-6411 or 844-586-8773.

Alaska case study overview

	Quality		Performance		Relevance
→	Scientists recognized as national and international leaders	→	Addressing HABHRCA & Action strategy recommendations	→	Imperative to understand HAB risks to subsistence use in Alaska
→	9 peer-reviewed publications to date	\rightarrow	SDI (HABF & HABMR) participation	→	Subsistence use differs by region
	(2020 ECOHAB) - more in progress		(Kibler, Leighfield, Morton, Fuquay)	\rightarrow	Future implications with climate
→	Multiple funding sources including	→	CRP PMs actively participate in		change
	National Competitive HAB program funding (ECOHAB & MERHAB) -		project meetings, external communications	→	Preparedness & response - preventing impacts to human health
	Competitive merit review by expert	\rightarrow	Strait Science Seminars	\rightarrow	Establishing relationships for
	panel, relevance, scientific/technical merit (70%)	→	NCCOS HABF leadership: 2023 Alaska HAB Workshop		accurate & appropriate risk communications
\rightarrow	Leveraging NPRB, BIA, EPA, NIEHS,	\rightarrow	Summer 2022-2023 HAB Risk		
	NSF OPP and NOAA ARP funding		Communications		
		→	AHAB - Project team/partners		
			active on AHAB SSC		
		\rightarrow	PIs active in US NHC, PICES, ICES,		
			IOC & UN Decade initiatives		

Acknowledgements:









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NORTON SOUND HEALTH CORPORATION



Questions



Panel Reflection Time

11:15 - 11:30 PM



LUNCH!

11:30 - 1:00 PM





HAB Observing & Monitoring: Addressing region-specific stakeholder needs

Greg Doucette – SDI; HAB Monitoring & Reference Branch Marc Suddleson – Competitive Research Program Shelly Tomlinson – SDI; HAB Forecasting Branch

> NCCOS HABs & Hypoxia Program Review November 28-30, 2023



HAB Observing & Monitoring:

Addressing region-specific stakeholder needs

'TAKE-HOME MESSAGE'

"NCCOS aims to provide sustained, stakeholder-driven observations and accessibility of actionable, region-specific data products/services essential for managing and mitigating HAB impacts."



National HAB Observing Network (NHABON): a framework & implementation plan for HAB observing & monitoring

NHABON Vision:

A sustained, national network for regional HAB observing

NHABON Mission:

Delivers sustained HAB observations for: detection, early warning, and forecasting; managing/reducing socioeconomic & environmental impacts

NCCOS & IOOS Lead NOAA's Implementation of NHABON

NHABON Pilot Projects run through all 11 IOOS RAs (3 years; \$9.5M)



National Centers for Coastal Ocean Science and U.S. Integrated Ocean Observing System National Oceanic and Atmospheric Administration December 18, 2020

Implementation Strategy for a National Harmful Algal Bloom Observing Network (NHABON)

ANUARY 2021



National HAB Observing Network (NHABON): a template for <u>regional</u> HAB observing & monitoring

Relies on <u>transition</u> of HAB observing & monitoring data into products & services designed & delivered to address stakeholder needs – <u>coupled with</u> <u>feedback for continuous improvement</u>



As NHABON Community of Practice Steering Committee members, we facilitate continuous engagement with diverse stakeholder groups via topical webinars and create opportunities for feedback via town halls at national meetings.

HAB Observing & Monitoring: Topics to be Addressed



HAB Sensors & Uncrewed Observing Systems

Sensors for HAB toxin & species detection and their uncrewed deployment platforms are designed to address regionally specific <u>and</u> changing user needs across marine and freshwater systems



Towable Pontoon Barge (solar) (IFCB + 2G ESP co-deployed)



2G ESP – Lab-in-a-Can (fixed position)



LRAUV/3G ESP: map-track-analyze (mobile asset)



USV/3G ESP & IFCB (Microscope-in-a-Can) (extended offshore duration (solar); shallow draft)



HAB Sensors & Uncrewed Observing Systems



2G ESP - shallow & deep moorings

HAB Sensors & Uncrewed Observing Systems

Transitioning HAB Sensors – sensors & deployment platforms can be at different Readiness Levels (RLs), including those NCCOS has helped commercialize





HAB Sensors & Uncrewed Observing Systems

HAB Sensor R&D: guided by close interactions and deep listening with a broad spectrum of partners, stakeholders, and end-users of these tools &



All HAB toxin data from a 2G or 3G ESP deployed in US coastal waters or Great Lakes relies on NCCOS-designed toxin sensors & support from NCCOS competitive awards

HAB Sensors & Uncrewed Observing Systems

<u>Service Delivery</u> – <u>Stationary HAB Sentinels</u>: Early warning and dissemination of actionable NRT HAB toxin data to managers as decision support tool (*RL 8*)

PNW: ESP Toxin Data on NANOOS Real-Time HABs Website and PNW HAB Bulletin

<complex-block>

WLE: ESP Toxin Data on GLERL HABs/ Hypoxia Website and GLOS HABs EWS



Engagement with stakeholders in PNW and WLE happened 'early & often'; feedback continues to harmonize product development & service delivery with their needs

HAB Sensors & Uncrewed Observing Systems

Synergistic Technologies: Co-deployment of complementary IFCB & ESP assets for early warning, assessing bloom toxicity, and event response (*RL* 7/8)



Towable Barge (solar) (IFCB & 2G spESP co-deployed; profiling CTD)

- addresses needs of aquaculture sector, targeted monitoring programs, event response
- ESP toxin analysis triggered by IFCB HAB detection

spp. ID

- data disseminated in NRT via HABON-NE and HABhub (in progress)
- enables efficient redistribution of sensors according to service delivery requirements

HAB Sensors & Uncrewed Observing Systems

<u>Mobility Matters!</u>: LRAUV/3G ESP addresses stakeholder need for easily deployed mobile asset for HAB mapping, tracking, and toxicity/biomass assessment (*RL* 7/8)



Multi-vehicle LRAUV/3G ESP deployments for adaptive, coordinated HAB monitoring

- 24x7 offshore ops; deploy from small boat
- cost-effective alternative to ship sampling
- wide coverage w/ high spatial/temporal res.
- complements satellite & aircraft RS
- delivers NRT reporting of in-situ HAB data
- signed transition plan in place via ORTA; ultimately integrate LRAUV w/ NOAA UxS fleet



HAB Sensors & Uncrewed Observing Systems

HAB Sensors: 'TOP LINE MESSAGE'

Decisions on management actions to mitigate HAB impacts require <u>sustained</u>, timely, actionable observing data to assess <u>regional</u> risks associated with toxicity and biomass

'RECOMMENDATION'

<u>NCCOS support for HAB sensor development</u> is key to enabling the stakeholder-driven, adaptive R&D required to maintain high quality performance and long-term relevance

'THE PATH FORWARD'

<u>Enhance dialog with regional stakeholders</u> to ensure HAB sensor R&D and capabilities remain relevant by identifying new gaps and harmonizing technologies with applications



Satellite-based Harmful Algal Bloom Monitoring





Cyanobacteria Assessment Network (CyAN) Multi-agency project EPA, NOAA, USGS, NASA

GOAL: Support the environmental management and public use of U.S. lakes by detecting and quantifying algal blooms and related water quality indicators using satellite data records.

Approach

Remote Sensing

Uniform and systematic approach for identifying cyanobacteria blooms. Strategy for evaluation and refinement of algorithms across platforms.

Information Distribution

Leveraged EPA regions to bring the technology, training and tools to EPA, states and tribal partners. Provide notifications and decision support

Economics

Behavioral responses and economic value of the early warning system.

Environment

Identify landscape linkages causes of chlorophyll a and cyanobacteria.

Health

Exposure and human health effects in drinking and recreational waters.









Real-time delivery of tools and products



https://www.epa.gov/water-research/cyanobacteriaassessment-network-mobile-application-cyan-app

CyAN App

- easily share data and information with large numbers of people
- focus on individual lakes, current conditions and historic
- compare lakes of interest





- Contiguous US (CONUS) tiles available for US and Alaska
- MERIS (2002-2012)
- OLCI (2016-)
- Full resolution (300 m)
- Provided tools for working with imagery and training through EPA regions



https://oceandata.sci.gsfc.nasa.gov/api/cyan_file_search/



Aaron Borisenko, State of Oregon Department of Environmental Quality: "... using CyAN app as an early warning system."

Bart Johnsen-Harris, Environment America:

"...CyAN has proved to be a uniquely helpful tool."

Angela Shambaugh, Vermont Department of Environmental Conservation: "... visualize that patchiness and provides additional context..."

Lenard Long, Lake Cascade Citizen Scientist Monitoring Group:



American Possibilities: A White House Demo Day

"...enhance the community's ability to rapidly respond to and manage the growing threat posed by toxic algae...the CyAN app helps us do that....has been extremely useful...."

Benjamin Holcomb, Utah Department of Water Quality:

"... allows UDWQ to better target field sampling and more efficiently use our limited resources to protect public health..."



California Cyanobacteria and HAB Network Website



V


Chesapeake Bay – Aquaculture, Water Quality



M. polykrikoides

Pictures courtesy of Kim Reece (VIMS), Rusty McKay (MDE) and Jen Wolny (FDA)

Since Since State of the State of State

Sentinel 3 Relative Fluorescence algorithm (RBD) from EUMETSAT processed at NCCOS, 300 m every day



*Resulted in NCCOS HAB Event Response funds to support additional sampling

Stakeholder engagement in Northeast and Mid-Atlantic

 Joint NCCOS/SeaGrant workshop in Jan 2023 for Chesapeake Bay (Follow up to MD SeaGrant workshop in 2014)

Goal: Applying novel techniques to asses and forecast HABs in Chesapeake Bay to protect fisheries, aquaculture and human health

Outcomes:

- Two needs assessments and Final Report
- New Industry contacts and engagement (recreational fishing, aquaculture, state resource managers)
- Introduction of NCCOS Phytoplankton Monitoring Network (PMN) and subsequent training in Chesapeake Bay

 Additional engagement with Aquaculture Industry through: NOAA CoastWatch
 NMFS Office of Aquaculture
 SeaGrant Aquaculture Extension agents in the Northeast



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https://www.flseagrant.org/wpcontent/uploads/2023/05/CB_HABWorkshopReport_Final050423.pdf



<u>San Francisco</u> *Heterosigma akashiwo* bloom



A harmful algal bloom is spreading in San Francisco Bay

By Jessice Weifrom | Exeminer steff writer | Aug 15, 2022 Updeted Sep 13, 2022



Atypical *Heterosigma akashiwo* bloom in San Francisco Bay causes massive fish kills (rays, various fish, bass, sturgeon) in mid-August 2022, impacting 9 counties. Last bloom was more than 10 years ago.

NOAA processed several algorithms (chl *a*, high biomass fluorescence) to help delineate the bloom.

A National monitoring system would have provided improved guidance for sampling efforts and validation of bloom extent and movement

*Resulted in NCCOS HAB Event Response funds to support additional sampling

Relative chl *a* levels from Sentinel-3 satellite imagery

"Had we not had remote sensing imagery, we definitely would not have realized the bloom had expanded after our 8/17 sampling and probably would have missed a key moment in the blooms trajectory", Keith Bouma-Gregson, USGS California Water Science Center

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Prompted Rapid Development of CA Waterboard Fact Sheet

FAQ

Frequently Asked Questions about the San Francisco Bay Harmful Algal Bloom

First reported in late July, a specific kind of harmful algal bloom known as a red tide has spread throughout much of the Ean Francisco Bey, alarming onlookers who've seen the heavy tou'it has a lateraly taken on agustic life. While teams of scientists continue to investigate the cause, many are left to wonder about the ongoing impact. Here are answer to some of the most common questions we are getting.

Why is the water in San Francisco Bay reddish brown?

The San Francisco Bay is experiencing a type of <u>harmful size</u> (bloom (HAB) now as a red tide, no pecies associated with the biolom, *Hereney* and *Hereney*

Is this normal?

Red tides are known to occur off the coast of California, usually from early spring through late summer. They can be bioluminescent at night, often looking like glowing weves from the beach. They can last days to months and it is difficult to predict how long they will last due to sumplify, temperature, idial how, stretified water columns and nutrients. Red tides are often attributed to depletion of avygen in the water that marine life needs to survive. It is not as scommon for red tides to earth the starting removiment tils the none in the Ban Prancisco Bay.

Is it safe eat the shellfish or swim?

This type of red tide is not known to cause human illness, but we always encourage people and pets to avoid contact with any discolored water that may be caused by the red tide and to practice <u>healthy water habits</u>.

The San Francisco Bay Regional Witer Quality Control Board has worked with various agencies, including the City of Oakland, Alameda County, San Mateo County and East Bay Regional Park District to post caution <u>advisory</u> adjum near affective dwater (e.g., Lake Merritt, the Oakland Estuary, Coyote Point, and Crown Beach), so the public knows to avoid contrast with the discioned water caused by the red tide. We encourage other waterbased facilities that observe discioned water to post imimis rights to kee the public informed.

On May 1, the Department of Public Health (CDPH) issued a prohibition against harvesting for eating mussels along the entire California coast, including bays. The prohibition is still in place. For updates or questions regarding the prohibition, contact the CDPP mains biotoxin monitoring programmer resting(coah ca.gov).

Why are there so many dead fish?

We sing getting reports of find leaths arouss San Francico Bay that appear to be linked to the red bids, including sturgeon, striped bass, sharks, bar eray, smelt and anohovy. We are coordinating with the Office of Environmental Health Hazard Assessment (OEHHA), the California Department of Public Health (CDFH), and the California Department of Fina and Wildife (CDFW) to investigate the potential link between this bloom and fish dests. Algal bloom, such as this one, can create toxins that are detirentiat to fish and other animals, and as algal matter dies off using and after a bloom, the decomposition process uses up oxygen in the surrounding water that can clease organisms and fish to surfocate.

At Lake Merritt, which is connected to San Francisco Bay, reports suggest as many as 10,000 fish died in late August. On Aug. Sj. San Francisco Bay Regional Water Foord starf consulted a field investigation at Lake Merritt, where very low dissolved oxygen levels were measured in the water. Water samples were collected for isonflication of signit podes and toxins. Updates to this sampling event will be posted on the <u>MAR were map</u>.



ectember 2, 2022

Satellite Imagery of Harmful Algal Bloom (HAB) in San Francisco Bay and Estuary

Overview:

The San Francisco Bay and estuary is currently experiencing a <u>harmful altal bloom</u> (HAB), more specifically a red tide. The species associated with this bloom, <u>betweetaweetaweetawebwe</u>, is one of several marine species shat can cause water to appear a reddish-brown color. These red tides are harmful to marine animals, including fish. The Water Boards have received numerous reports of fish kills aross the star Francisco Bay that appear to be linked to the red tide. This red tide cause an allergic reaction or irritation of the eyes, skin, or respiratory system. We recommend people and pest to avoid contact with any discolored water that may be caused by the red tide and to practice <u>healthy water habts</u>.

The Freshwater and Estuarine HAB (FHAB) Program under the CA Water Boards has been collaborating with federal, state, and local apencies to respond to this extensive HAB, particularly to collarse recreational health posting tracking. Federal agencies are providing processed satellite imagery that shows this HAB event to support tracking of the bloom's programsion and density so that field investigations can be better directed.

Satellite imagery can help track HABs:

We use processed satellite imagery to track HABs with an indicator called chlorophyll-a. These algal blooms consist of algae and bacteria cells that contain photosynthetic pigments, one of which is chlorophyll-a. This pigment is detected by instruments on satellites and complex calculations translate what the instrument is detecting to estimate the amount of chlorophyll-a. Chlorophyll-a can also be measured on the ground by collecting water samoles for analysis.

Maps are used to display the satellite imagery. The figures below display snap shots in time on days in August when the satellite crossed overhead. The density of the indicator detected at the water surface is represented on a scale of cool to warm colors, the warmest colors represent the highest densities.

Satellite imagery summary from August 2022:

Daily snaphots of the satelline imagery are presented in Figure 1 showing the spatial development of the bloom across the bay. Estimated density of the chlorophyll indicator is displayed in the scale bar. Based on this data the bloom peaked from August 20-28 and appears to be dissipating. Experts have caudioned that if the conditions that promoted growth of the bloom do not decrease the bloom may rebound, the heat wave in early September may support bloom growth and decrease dissived oxygers in the water needed by fish.



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Observing and Monitoring: Data Integration

Top Line 1Coordination and integration of HAB data at regional and national levels
harmonizes accessibility and interoperability





Observing and Monitoring: Data Integration

Top Line 2

from NOAA and partners to meet regionally-specific stakeholder needs NOAA National NOAA NCCOS National Activities NCCOS Activities Obser Regional te sensina of Other Observing Regional Assoc 1 s distribution Observing Partner Regional Regional Entity Assoc 1 Partner In situ continuous ality samplers DATAFLOW water egional Regional Partne **DNR** quality mapping Parks Service Maryland DNR NOAA NHABON Partner UMCES Regional (100S & NCCOS) Partner Regional Partner NOAA NHABON Program Southern California Coastal Ocean Observing System (IOOS & NCCOS) Field collection of water SCCOOS is a Scier Support System quality samples Maryland DNR Collection of Regional National Parks Service Mand Coastal Bays samples of fish IOOS NOAA Partner Assoc. NCCOS animals and Clearance (UKC) Project macroalgae Observing Marvland DNR CTD Regional Plankton Observing Casts mplin Regional Assoc. 3 Regional ian.umces.edu Regional Partner Assoc 2 Partner Sampling Automate 1005 Shore Regional Assoc. Stations Partner Regional **Regional Ocean** Harmfu Partner Regional Model System Regional Algal Blooms Partner Partner Marine Mammal and Seabird Surveys

Flexibility to integrate sensor, satellite, toxicity, and ancillary data sourced

Regional Data Integration – WHOI HABHub

a web server supporting data integration, visualization and product sharing

Development Goals

- Best possible situational awareness automated data ingestion, standardized plots and products
- Serve diverse audiences

fishermen, aquaculturists, resource managers, scientists, K-12 educators, public

Open source design

accessible, changeable architecture allows transfer to other HAB observing networks.

Data attribution to facilitate reuse and sharing
 OProvide direct access to data sources (provenance)
 OLinked SOP documentation (IFCB, ESP, etc.)

NCCOS MERHAB NHABON Northeast 2019-2023



WHOI HABHub data prototype data layers include toxin monitoring data, shellfish closures, and Imaging Flowcytobot sensor data.



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Regional Data Integration – WHOI HABHub

Challenges Overcome:

- How to show multiple species/toxins simultaneously?
- Consider different measurement sources (sensors, microscopes) and different partners (state, grower, academic, NOAA)
- Provide direct hooks to inspect primary sources of data, export of data and visualizations by end users
- Facilitate retrospective comparisons how are current conditions similar or different than the past?
- Institutional barriers to transferring data between partners (state, NOAA, other feds, etc).

NCCOS MERHAB NHABON Northeast 2019-2023





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SNCC Regional Data Integration – WHOI HABHub

Responding to Stakeholder Needs

Objective: Develop HABhub for broad adoption by management agencies and other stakeholders.

- Annual meetings with Gulf of Maine Stakeholders and NOAA
- Meeting annually since 2002
 - (states, growers, academics, & NCCOS)
- Exchange updates and get stakeholder feedback
- HABhub Features Guides, Tutorials
- NERACOOS RA Director (co-PI) exploring transition of WHOI data management capacity to NERACOOS to support an operational HAB observing network
- NCCOS Li & Stumpf (co-PIs) working to visualize forecast products in HABhub and display model and sensor outputs.
- WHOI Anderson & NCCOS Doucette (co-PIs) to add shellfish toxicity predictions from ESP data to HABhub





WOODS HOLE OCEANOGRAPHIC INST	ITUTION	ABOUT WHOLE WHOLE DIRECT
northeast harmful algal bloc	ABOUT HABS MONITORING	FORECASTING FOR EDUCATORS DATA ARCHIVE NEWS
Learn more about HAB	up features and canabilities	I
Leanninore about nAbi	iub reatures and capabilities	
Please browse the below blog posts to learn analysis.	more about latest updates to the HABhub, and how t	hese tools and features promote data access and
GHABhub	her have a factor of the second surpresenters	
	Annual Carlos and and an	
	and the statement of th	The first sector is a sector in the sector is a sector
Visit the HABhub Guide	Timeframe Selection	Create IFCB Data Graphs
March 0, 2022	March 7 3022	March 5, 2023





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Toward Data Infrastructure for NHABON

California HAB Data Assembly Center

- Responding to Stakeholder Needs ID in 2019 West Coast COMT workshop, via NCCOS project TAC, and NHABON Community of Practice.
- Leverage California IFCB investments to harness the power of networked imaging HAB sensors to meet regional stakeholder needs
- HABDAC is a centralized hub for IFCB HAB data, ancillary observations, and technologies for IFCB image classification\ annotation, and user support.
- Envision expansion a national scale to promote harmonized data feeds and generation of management-relevant products



NCCOS PCMHAB Harmful Algal Bloom Community Technology Accelerator 2020-2024





Toward Data Infrastructure for NHABON



Credit: PIs: Anderson Scripps/UCSD/SCCOOS; Bochenek, Axiom



MATLAB development environment \rightarrow Python operational environment



HAB Observing & Monitoring: Summary & Wrap-Up

'TAKE-HOME MESSAGE'

"NCCOS aims to provide sustained, stakeholder-driven observations and accessibility of actionable, region-specific data products/services essential for managing and mitigating HAB impacts."





HAB Observing & Monitoring: Summary & Wrap-Up

'RECOMMENDATIONS'

- NCCOS support for HAB sensor development is key to enabling the stakeholder-driven, adaptive R&D required to maintain high-quality performance and long-term relevance.
- NCCOS supports development of nationally relevant satellite products for algal bloom monitoring/ assessment, informed via close engagement with stakeholders on products and including integration of next generation, higher resolution satellite missions.
- NCCOS, IOOS, and RAs continue to assess piloted HAB data coordination/ integration systems (e.g. HABhub and HABDAC) to harmonize data accessibility/ interoperability and provide flexibility to ingest diverse HAB data to meet regional stakeholder needs.



HAB Observing & Monitoring: Sustained Service Delivery



<u>Continuous engagement with our</u> <u>regional stakeholders</u> is the foundation for enabling sustained delivery of services required to address their diverse and changing needs... NCCOS successfully transitions our world-class R&D to operations, applications, and commercial products

to meet our customers' needs!





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15 minute Break!

Return by 3:00PM



SCIENCE SERVING COASTAL COMMUNITIES



NCCOS HAB & Hypoxia Forecasts

Regional forecasts within a national framework

Session Co-Leads

Alex Hounshell, Ph.D. David Scheurer, Ph.D.



HAB Forecasting Branch



Competitive Research Program

Case Study Presenters

Richard Stumpf, Ph.D.



HAB Forecasting Branch

Quay Dortch, Ph.D.



Competitive Research Program

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- Multiple product lines & capabilities
- Sustained delivery based on HAB & stakeholder needs
- Co-development w/ stakeholders
- Responsive to emerging needs & bloom changes

Move from reactive to proactive management

Multiple Pathways for Development

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Forecast System	HAB/Hypoxia Stressor	Status	Research	Service Delivery
Gulf of Mexico	Karenia brevis	Deployed	Internal	Internal (NCCOS)
Lake Erie	<i>Microcystis</i> & Hypoxia	Deployed	Both	Internal (NCCOS)
Gulf of Maine	Alexandrium catenella	Deployed	External	Internal (NCCOS)
Pacific Northwest	Pseudo-nitzschia	Deployed	External	External (NANOOS)
California Coast	Pseudo-nitzschia	Deployed	External	External (SCCOOS)
Coastal Maine	Alexandrium catenella	Deployed	External	External (ME)
Lake Okeechobee	Microcystis	Development	Internal	External (USACE)
Chesapeake Bay	M. polykrikoides & A. monilatum	Development	Internal	Internal (NCCOS)
Gulf of Alaska	Alexandrium catenella	Research	Internal	Internal (NCCOS)
GoMex seasonal forecast & bloom movement	Karenia brevis	Demonstration	External	External (USF)

Since Studies Albert Constant Constant

- 1. Karenia brevis, Gulf of Mexico Forecast:
 - Internally developed & operated
- 2. Microcystis & Hypoxia, Lake Erie Forecast:
 - Cross-NOAA developed & transitioned to NCCOS for operations
- 3. Alexandrium catenella, Gulf of Maine Forecast:
 - Externally developed & transitioned to NCCOS for operations
- 4. Pseudo-nitzschia, Pacific Northwest Forecast:
 - Externally developed & operated



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Gulf of Mexico HAB Forecast

Presenter: Richard P. Stumpf, Ph.D. HAB Forecasting Branch, NCCOS

Forecast Lead: HAB Forecasting Branch, NCCOS

SCIENCE SERVING COASTAL COMMUNITIES

Since Since State of Coastal ocean science Addressing Public Health Risks

- Red tide (*Karenia brevis*) blooms nearly annually along the Florida Gulf Coast
- Negative impacts include:
 - Respiratory & eye irritation
 in humans
 - Neurotoxic Shellfish Poisoning (NSP)
- Blooms are patchy: impacts vary with time & location
- Advanced warning needed to limit health impacts of blooms



Current Status:

Products:

- Nowcasts, forecasts, & HAB monitoring provide info. on *K.* brevis location & impacts
- Developed for FL Gulf Coast; includes all FL & TX coastlines

Use:

- Early warning of negative impacts of *K. brevis* blooms at local to regional scales
- Beachgoers; County & State Managers; Public Health Officials; Community members

GoMex HAB Forecast

Key Partners:

- NOAA NCCOS HAB Forecasting; NOAA NWS; GCOOS; FWRI; Pinellas Co.; Sarasota Co.; SCCF; Mote Marine Laboratory
- Community scientists

- Internally developed & operated forecast w/ regional partners
- Next Gen. Forecast developed in response to stakeholder needs
- Additional updates prioritized to meet needs

GoMex HAB Forecast System - Florida

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	Product Use	Components/Partners	Targeted End-User
Respiratory Forecast	36 hr forecast of respiratory irritation at individual beaches along the FL Gulf Coast	 Cell counts from state, county, & community partners (GCOOS) NWS wind forecasts Respiratory reports from Mote, Pinellas Co. 	 Beachgoer Community members State & county public health officials State & county managers
<section-header></section-header>	10-day nowcast & forecast of the risk of <i>K.</i> <i>brevis</i> initiation or intensification along the SW FL Coast	 Cell counts from state, county, & community partners (GCOOS) Hydrodynamic model from academic partners (HYCOM) NWS wind forecasts 	 State & county public health officials State & county managers Academic, state, & local researchers
Satellite Nowcast	Nowcast of current bloom conditions along the FL Gulf Coast	 Cell counts from state, county, & community partners (GCOOS) Satellite imagery from Copernicus EUMETSAT, processed by NCCOS 	 Community members State & county public health officials State & county managers Academic, state, & local researchers

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Responding to Stakeholder Needs

- K. brevis blooms are patchy Better spatial & temporal resolution needed
- "Every beach, every day" Partnered w/ GCOOS to increase monitoring via HABScope

2021-Present

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Providing more support to managers - Early warning of blooms
 Legacy Forecast Next Gen. Forecast





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Benchmarks for success:

- Research: Use cell counts + wind dir./spd. to estimate respiratory irritation
- Demonstration: Use microscope counts & HABScope to produce forecasts every 3 hrs at specific beaches
- Operations: Transition to NCCOS & expand to GoMex wide 'every beach, every day'

Resources needed:

- NCCOS commitment to operational forecasts
- Transition plan & team from CO-OPs to NCCOS
- Multi-year demonstration & transition period
- Commitment from partners
 to maintain data collection
- IT infrastructure
- Long-term commitments for both research & operations

Multiple Methods of Service Delivery

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- Forecast Webpage General public; beachgoers; local residents; tourists
- NWS HAB Alerts via Social Media General public; TV & radio media; beachgoers; local residents
- Weekly Email Bulletin Long-term end-users; state & county managers; public health officials
- FWRI Red Tide Coordination meeting State managers & public health officials
- Inquiries/feedback to <u>hab@noaa.gov</u> General public; county managers; local residents; tourists
- Peer Reviewed Publications Academic, Federal, & State Scientists
- Outreach News & media articles

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- Engagement metrics:
 - >240,000 web page views
 - >7,000 email subscribers
 - >237,000 people reached via social media from Jun. 2022-2023
- FAMU survey to assess forecast use

"We find the HAB forecasts incredibly useful for communicating to our viewers... There is always strong demand for information regarding the potential effects of red tide..." -Jason Dunning (Meteorologist, WBBH-TV, Ft. Myers, FL)

Since Since Stational Centers FOR COASTAL OCEAN SCIEN MATINAL CENTERS FOR COASTAL OCEAN SCIEN

- Improving operational status (2023: >99.9% operational)
- Address stakeholder needs:
 - Improve forecast visualizations
 - Additional data to expand forecast locations
 - Invest in field data for model & forecast validation
- Investment in R&D is critical to maintain forecast relevance & quality



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Quality, Relevance, & Performance

	Quality	Relevance	Performance
Service Delivery	 Multiple, targeted delivery methods Updated delivery methods following changes in technology/best practices 	 Update to Next Gen. forecast following needs Multiple, targeted products Identify & address issues 	 >99.9% forecast delivery (2023) Methods in place to ensure successful forecast delivery
Research Transitions	 Extensive investment in research to incorporate new technology 	 Substantial updates following 'every beach, every day' Incorporated stakeholder feedback during development 	 Transition plan & team from CO-OPs to NCCOS Long-term investment in personnel & infrastructure

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Lake Erie HAB & Hypoxia Forecast

Presenter: Richard P. Stumpf, Ph.D. HAB Forecasting Branch, NCCOS

Forecast Lead: HAB Forecasting Branch, NCCOS & NOAA GLERL

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Multiple Environmental Stressors

HABs:

- Annual blooms of cyanobacteria in the Western Basin
- HAB toxins & scums pose risk to human health & drinking water
- Identify when & where impacts will occur



Hypoxia:

 Hypoxia ('dead-zone') impacts the Central Basin annually

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- Leads to fish kills, ecological community changes, & degraded drinking water
- Early warning of hypoxic events


				CCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE
Products:			<u>Use:</u>	
 HAB nowcasts, seasonal & short- term forecasts, & monitoring products Dissolved oxygen nowcasts, forecasts, & early warning 			 Proactive management of utilities Water treatment managers; County & State Managers; Public Health Officials; Fishers; Fisheries Managers 	
system	LE HAB 8	<u>S</u>	Hypoxia	
Key Partners:	Fore	90	cast	Current Status:
 NOAA NCCOS HAB Forecasting; NOAA NWS; NOAA GLERL; NOAA CO-OPs; GLOS; Heidelberg U. NCWQR; OH Sea Grant; Regional Water Treatment Plants 			 HABS: NCCOS developed w/ GLERL models & transitioned to NCCOS for operations Hypoxia: GLERL developed forecast & transitioning to NCCOS for operations 	

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W. Lake Erie HAB Forecast System

	Product Use	Components/Partners	Targeted End-User
<figure></figure>	Seasonal forecast of cyanobacteria bloom intensity - issued in late Jun.	 NWS OHRFC river forecasts NCWQR, Heidelberg U. nutrient loads Ensemble models from academic partners 	 Federal & state agencies Water treatment plant operators State & county managers Elected officials
<figure></figure>	Nowcast & 3-day forecast of bloom location & intensity in western Lake Erie	 Copernicus Sentinel-3 satellite imagery NOAA CO-OPs hydrodynamic model NOAA GLERL & NDBC field data NWS forecasts 	 Fishers, tourists, community members Federal & state agencies Water treatment plant operations Health depts.
Vertical Mixing Forecast	Nowcast & 3-day forecast of water column mixing & scum formation	 Copernicus Sentinel-3 satellite imagery NOAA CO-OPs hydrodynamic model NOAA NDBC wind NWS wind forecasts 	 Fishers, boat operators Water treatment plant operators State & county managers

Supporting Management Decisions

- Seasonal forecast water treatment operators, elected officials
- Nowcast/short-term forecast early warning for water intake impacts
- Models & forecasts help set nutrient reduction targets (US EPA, GLWQA Annex 4)
- Support annual OH EPA reporting for western, central, & eastern Lake Erie
- R&D supported by Great Lakes Restoration Initiative (EPA)



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- Engagement metrics:
 - >95,000 web page views
 - >8,000 email subscribers
 - 16 elected officials participated in Seasonal Forecast webinar

"The NOAA HAB forecast helps Monroe prepare for the HABs before they get close to our city water intakes. We use the forecasts to help water treatment plant operators.... Without the NOAA HAB forecast... we would not have any warning of HAB locations and the direction they are heading." -Chris Knight (City of Monroe, MI)

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Forecast date: 2023-09-21

Select different forecast year 2023 v Select different forecast date: 2023-09-21 v

Back to the main Lake Erie Hypoxia Forecast archive page



Email bulletin of potential hypoxic upwelling event





Experimental Lake Erie Hypoxia Forecast Update

Potential Central Lake Erie Upwelling Event September 22-25

Stakeholder Decision Making

- Provide 6-8 hypoxic event warnings annually to ~150 email subscribers
- Stakeholders: Water treatment operators; state & federal managers; fishers
- Focus groups to co-develop forecasts

Socio-economic Impact:

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- 18 public utilities affected
- 2 million people impacted
- ~\$2-10 million economic impact of a large event

"Since we've been getting those [hypoxia forecast] emails, we haven't been caught unaware...in the past the color change, the temperature drop is when we're finding out about it. At that point, it's already in the plant...The forecast changed that." -*Water Treatment Operator (2020 GLERL Focus Group)*

Transition from Research to Operations

- Multi-year transition from GLERL to NCCOS for operations
 - Experimental (GLERL): 2017-2021
 - Transition plan (GLERL/NCCOS): 2022
 - Demonstration (NCCOS): 2022-2023
 - Operational (NCCOS): Summer 2024 (est.)



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Since Since Stressor Forecast System



Hypoxia Forecast:



- Leverage existing capabilities:
 - Overlapping stakeholders
 - Efficiency gains using current forecasting platform
 - Utilize existing personnel expertise
- Challenges exist:
 - Additional personnel training & effort
 - Research to maintain relevance
 - Incorporate new capabilities, visualizations for existing system

Since Since

- R&D to maintain forecast relevance & accuracy:
 - Develop new models for seasonal forecast
 - Forecast water column concentrations
 - Include HAB toxin potential
 - Engage additional hypoxia stakeholder groups
- Investment in R&D is necessary to maintain relevance in a changing climate

Potential HAB Toxin Model



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Quality, Relevance, & Performance

	Quality	Relevance	Performance
Service Delivery	 Targeted delivery methods Leverage stakeholder groups for both forecasts 	 Increasing product use over time 'One-stop-shop' for multi-stressor forecasts 	 Daily web bulletins produced during bloom season Forecasts/models directly support management decisions
Research Transitions	 Collaborations with multiple NOAA offices Extensive research & validation 	 Forecast R&D aimed at increasing accuracy, relevance Incorporated stakeholder feedback during development 	 Transition plan & team from CO-OPs to NCCOS Long-term investment in personnel & infrastructure

Multiple Data & Model Providers



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Questions?



Gulf of Maine Alexandrium catenella Predictive Models

Presenter: Quay Dortch, Ph.D. CSS Senior HAB Scientist, NCCOS Former NCCOS ECOHAB Program Coordinator & PCMHAB Program Manager

Forecast Lead: HAB Forecasting Branch, NCCOS

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- Potentially fatal poisoning syndrome from contaminated shellfish
- Caused by recurrent population blooms of *Alexandrium catenella*
- Significant economic losses result from shellfish harvesting closures



Source: WHOI / J. Kleindinst

Current Status:

Products:

- Nowcasts & forecasts provide information on the location, movement & growth of blooms
- Dashboard provides an integrated analysis of bloom potential

Use:

 Provide context for shellfish bed closures & testing frequency decisions made by state shellfish managers along the NE coast (ME, MA, NH)

GoME HAB Forecast

Key Partners:

- NOAA NCCOS HAB Forecasting; NE River Forecast Center; OMAO; WHOI; NERACOOS
- ME Dept of Marine Resources; MA Division of Marine Fisheries; NH Dept of Envir. Services
- Externally developed/tested w/ NCCOS support & transferred internally to NCCOS for sustained operations
- Working to expand coverage & address other HAB species

Gulf of Maine – HAB Forecast System

Product Use

Seasonal Forecast



Seasonal forecast of **bloom severity** from annual cyst survey (Released early May)

- <u>Components</u>
- Based on the number of *Alexandrium* cysts found in the sediment and model predictions

Application

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> Better planning for resourcing/staffing needs of State shellfish managers

Nowcast/Forecast



Nowcast & 3-day forecast for Gulf of Maine *Alexandrium* concentrations (Weekly: May-Jul)

- Wind, solar radiation, tidal constituents, heat fluxes, river discharge, SST, nutrient fields, population model for *Alexandrium*
- Advance warning to aid in shellfish testing frequency & location decisions

Dashboard



Alexandrium bloom potential dashboard synthesis product (Weekly: May-Jul)

- Integration of wind, ESP data, observed shellfish toxicity & modeled cell concentration
- Robust & integrated information on expected impacts of identified blooms

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NCCOS HAB-F Developed

NCCOS CRP Funded

Since Since

Progress

- Model platform testing/validation led to increased accuracy
- Added new model processes, capability to model blooms nearshore, & new bloom potential dashboard
- Dedicated & sustained funding to facilitate transfer

Challenges

- Based on different model platform than NOAA
- Large system w/ localized impacts - need for enhanced monitoring & targeted forecasts
- Loss of operational partner & need to develop research infrastructure at NCCOS
- Transition plan needed for full operational status

Funding: NCCOS Competitive Research Funding: 1997-2018 NCCOS Internal HAB Forecasting Support: 2016-Current



Method of Service Delivery

Annual GOM HAB Science Symposiums:

- Started out as MTAGs (circa 2002)
- Now key annual stakeholder event
- Critical forum for information exchange

Meeting Outcomes:

- Accelerated adoption of forecast products
- Identifying research priorities
- Optimized placement of monitoring assets
- Utility & accuracy of forecast products
- Refinement of new forecast products
- Model coordination for other regions



Source: Anderson laboratory, WHOI (red dots, manager proposed locations of ESPs in 2003)

Responding to Stakeholder Needs

- Development of bloom potential synthesis product
- Expansion of forecasts to include near-shore areas around Mass. bay & along coast
- Research to address emerging threat of Amnesic shellfish poisoning (ASP)



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Emerging Stakeholder Needs

- Expansion to other stakeholder communities
- Predictions of closure probability
- Site-specific information for near-shore shellfish production & harvesting
- Ecosystem changes impacting HABs



Source: Maine Aquaculture Roadmap 2022-2032

Quality, Performance, & Relevance

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	Quality	Relevance	Performance
Service Delivery	 Forecasts provide accurate & timely information to GOM stakeholders during bloom season Annual stakeholder workshops 	 Used to help manage high value economic shellfisheries Decisions have broad implications to affected communities 	 Extensive collaboration w/ partners to assess product use & value Published assessments of economic value
Research Transitions	 Substantial investments in R&D over multiple funding cycles NCCOS facilitated transition from R2A 	 Stakeholder feedback incorporated during development 	 Transition plan in development to move into full operations Working to address additional stakeholder needs

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ME Department of Marine Resources



MA Division of Marine Fisheries



NH Dept of Environmental Services



Woods Hole Oceanographic Institute



North East River Forecast Center



Office of Marine and Aviation Operations



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Pacific Northwest HAB Bulletin

Presenter: Quay Dortch, Ph.D.

CSS Senior HAB Scientist, NCCOS Former NCCOS ECOHAB Program Coordinator & PCMHAB Program Manager

Forecast Lead: Ryan McCabe, Ph.D. Research Physical Scientist, PMEL

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Since Since

- Annual blooms of *Pseudo*nitzschia (PN) produce neurotoxin
- Amnesic shellfish poisoning (ASP) caused by eating the toxic shellfish
- Shellfish managers monitor toxins & close fisheries resulting in economic losses



Current Status:

Products:

- Integrated monitoring & forecasting provides critical info. to PNW shellfisheries managers
- Understand onset, duration, & magnitude of toxin outbreaks

Use:

- Information on bloom location, movement, & toxicity
- WA Depts. of Health & Fish and Wildlife; OR Depts. of Agriculture Fish and Wildlife; Coastal Treaty Tribes

PNW HAB Bulletin

Key Partners:

- NOAA PMEL; NCCOS CRP; NOAA NWFSC; NANOOS; JISAO; OR Dept. of Fish & Wildlife; ORHAB; Makah Tribe; Quinault Indian Nation; WA Dept. of Fish & Wildlife; WA Dept. of Health
- Externally developed & operational product, w/ support from NCCOS
- Produced several times a year during the PN season by PMEL & hosted by NANOOS

Pacific Northwest - HAB Bulletin



Forecast summary based on monitoring & particle transport model

HAB risk based on PN & toxin monitoring

Pacific Ocean Indices



Research has shown that toxic HAB events off WA and OR tend to occur during or following periods of El Niño and/or positive phases of the PDO, when ocean temperatures are relatively warn Cumulative Wind

Stress

Month

Model

series salinity with

particles

released near

Fuca eddy and

Heceta Bank

the Juan de

predicted sea

North-south Wind Stress

Southward wind stress drives coastal unwelling that can lead to plankton blooms. Northward wind stress tends to pash any existing offshore plankton and toxins towards beaches. In addition, summer fall toxic blooms often occur in years with a moderate cummulative anwelling index (i.e. during years with fluctuating winds) rather than in years with sustained upwelling or downwelling winds

Columbia River Discharge



The Columbia River plume can help transport HABs and

and tracked three days into toxins from the south, northward alone the WA coast. the future. Red However, the plame can also serve as a protective barrier dots indicate by preventing offshore toxins from reaching beaches particle end Marine Weather Forecast

Fair weather can support plankton blooms whereas storms can concentrate any plankton and toxins on beaches.

Ocean Surface Currents Satellite Chlorophyll-8 Summary - Coastal winds have continued to MODIS Agus 01-Oct-2022 Millines Totals 25hr mean: Prom 91-Det-2022 23-0 te 63-Det-2022 23-60 DB

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-124 .105 Longitude [*WE Clouds often obstruct satellite views Primary currents flow north and south in but the extent of phytoplankton winter and summer, respectively, except within -10 km of shore, where fluctua-

Moores can at times be seen from space. Blooms do not necessarily tions follow changes in wind direction. reflect the mesonce of texting

-122

LiveOcean Forecast Mode



fluctuate over the past two weeks, and ocean currents still appear relatively weak. Recent satellite images show a narrow band of elevated chierophyli-a close to shore all along the coast. Parado-extrachia (PN) concentrations at WA teaches have recently waved. Large morpholog cells continue to dominate the PN community. Highest recent abandances in WA were at Long Beach (35,000 cell/L) on 22-Sen. In OR. Janue-siz PN cells have maintained high abundances >250,000 cells/L at northern beaches, with highest nhaes (965,000 cells L) at Garibaldi on 26-Sep Recent seawater particulate domoic acid (pIDA) concentrations were low (33 ng L) at southern WA eaches on 22-Sep. Samples from northern OR. braches on 26-Sep also contained low pDA (21-61 ng UA A sample from Garibaldi, however, had appionally high pDA (3637 ng/L) on that same date. Seawater samples collected from central and outhern OR beaches the week prior had pDA concentrations approaching 200 ng/L. Samples collected offshore of Newport and Garibaldi. OR from 23-26 Sen. found large JW abandant from 5-15 nm offichate. On average, rator claim DA concentrations in WA had not appreciably changed over the 11 days between recent sample collections. As of 25-Sep, Copalis, Mocrocks, and Quinault area beaches had values as high as 18-23 ppm. Twin Harbers and Long Beach had razor clam DA values in the 6-8 ppm range. Razor clam samples from OR heaches were all >20 ppm on 30-Sep, with highest values (93 ppm) at Newport.

Farecast - The current La Niña conditions are expected to continue through the winter months. The most recent PDO value is strongly negative. Northward winds are expected through Wednesday but a stable ridge of high pressure will give rise to generally upwelling-favorable conditions later this

week. The longer-term forecast suggests that such conditions should be maintained at least through the weekend. Given the recent elevated large PN cell abundances, pDA, and claim DA observation risk is clearly high in OR. Risk at southern WA. beaches is at least moderate. Any significant northward wind event, such as these through Wednesday, could pash texins in OR northward to outhern WA beaches. The PN community could also resurge, as has occurred twice already. We recommend scrutinizing additional beach cell and pDA observations and monitoring any wind shifts prior to and during the pending harvests in WA.



Since Since State of the State



Responding to Stakeholder Needs

- 1st Generation Bulletin produced from 2008-2011
- 2nd Generation Bulletin initiated in 2017
 - NCCOS regional project to develop an early warning system
- Continuation of the bulletin, upgrades, & pathway toward sustained funding
- Leverage State monitoring efforts & offshore monitoring

1st Generation Bulletin

- Coverage: WA
- No larger-scale ocean indices
- Physical circulation model w/ rudimentary particle tracking
- Sporadic offshore sampling

2nd Generation Bulletin

- Coverage: WA & OR
- El Niño & Pacific Decadal Oscillation risk factors added
- Live Ocean forecasting model w/ particle tracking
- Dedicated offshore sampling



Since Moving from Research to Operations

Progress

- Bulletin transferred from UW to NANOOS w/ lead forecaster at PMEL
- Funding diversified from research to operations through NANOOS
- Draft transition plan developed in 2019

<u>Challenges</u>

- Limited "base funding"
- Sustained service delivery provided through multiple diverse funding sources
- Vulnerable to changes in partner priorities or funding (e.g., Gap from 2011-2017)

Recent Funding: U.S. IOOS via National HAB Observing Network (NHABON); NOAA Pacific Marine Environmental Laboratory (PMEL); *NCCOS Monitoring and Event Response for HAB (MERHAB) program*; Olympic Region HAB (ORHAB) partnership

NCCOS Support for External Forecast

- Enable research based development early research
 needed to establish HAB monitoring & forecast development
- Sustained funding enable bulletin to progress to deployment & gain stakeholder support
- Funded regional, interdisciplinary projects ensure best management-relevant science is conducted & transitioned
- Support multi-disciplinary teams Co-PIs included state & tribal partners and engagement in regional stakeholder meetings (i.e., ORHAB)
- Provide a national framework NCCOS program managers provide integration between funding programs, regional entities, national initiatives (NHABON) & Congress

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Quality, Performance, & Relevance

	Quality	Relevance	Performance
Service Delivery	 Bulletin provides accurate & timely info. to PNW stakeholders Product integrates data from Federal, State, Academic & Tribal sources 	 Used to manage high value economic & subsistence shellfisheries Congressional interest in product & long-term sustainability 	 Extensive collaboration w/ partners to assess product use Documented instances of management utilization
Research Transitions	 Substantial investments in R&D over multiple funding cycles NCCOS facilitated transition from R2A 	 Stakeholder feedback incorporated during development Broad user base of bulletin & components 	 Formal transition plan in final development Sustained delivery achieved through multiple funding sources

NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE **HAB Bulletin Relies on Partnerships**



OR Dept of Fish and Wildlife



Cooperative Inst for Climate Ocean & Ecosystem Studies



WA Dept of Health



WA Dept of Fish and Wildlife











Hoh Indian Tribe

NOAR



Univ of Washington



Joint Inst for the Study of the Atmosphere and Ocean







Agriculture

ileute

Quileute Tribe



Univ of CA Santa Cruz



Strathclyde

Pacific Marine Environmental

Laboratory





Northwest **Fisheries** Science Center





NCCOS Supported HAB & Hypoxia Forecasting





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NCCOS NATIONAL CENT National HAB Forecast Framework

- Systems are developed regionally but within a national framework
 - Forecast systems contain multiple capabilities: to meet different stakeholder needs
 - Co-development w/ stakeholders: via workshops, direct feedback, & as CO-PIs on research & transition grants
 - Extensive partnerships: including w/ IOOS RAs, State & County government agencies, Tribal communities, NOAA line offices
 - Transition plans guide R2A decisions: identify partners, dedicated resources, & guidelines for operations





Challenges & Opportunities

Challenges:

- Building a HAB operational forecast framework
- Balance research & operations
- Create buy-in for transition
 plans across organizations
- Extensive dependencies for monitoring & modeling
- Long timelines needed for research, development, & transition

Opportunities:

- Framework for operational, ecological forecasting
- Cross-leverage systems
- Technology advancements lead to higher resolution, more accurate products
- Incorporating multiple metrics of HABs - i.e., toxicity, severity, biomass
- Benefit from operational observational & modeling systems
Multiple Pathways for Development

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Forecast System	HAB/Hypoxia Stressor	Status	Research	Service Delivery
Gulf of Mexico	Karenia brevis	Deployed	Internal	Internal (NCCOS)
Lake Erie	<i>Microcystis</i> & Hypoxia	Deployed	Both	Internal (NCCOS)
Gulf of Maine	Alexandrium catenella	Deployed	External	Internal (NCCOS)
Pacific Northwest	Pseudo-nitzschia	Deployed	External	External (NANOOS)
California Coast	Pseudo-nitzschia	Deployed	External	External (SCCOOS)
Coastal Maine	Alexandrium catenella	Deployed	External	External (ME)
Lake Okeechobee	Microcystis	Development	Internal	External (USACE)
Chesapeake Bay	M. polykrikoides & A. monilatum	Development	Internal	Internal (NCCOS)
Gulf of Alaska	Alexandrium catenella	Research	Internal	Internal (NCCOS)
GoMex seasonal forecast & bloom movement	Karenia brevis	Demonstration	External	External (USF)



Questions?



NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

Executive Session

Review Panel only

Dinner at Mandalay following 6:00PM (930 Bonifant St, Silver Spring, MD 20910)





NCCOS Annual Science Review: Harmful Algal Blooms and Hypoxia Program

Silver Spring, Maryland 28 - 30 November, 2023

Review Website: NCCOS HABs and Hypoxia Program Review

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WELCOME BACK AND RECAP

Lonnie Gonsalves Peg Brady



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Toxin Detection "Eliminate HAB poisonings"

2023 NCCOS HAB & Hypoxia Review





Toxin Detection Approaches



Dillon et al. Sensors (2021), 21(7):2499





Rapid and accurate identification and quantification of HAB toxins is a direct measure of risk for the reduction of HAB poisonings



NCCOS has many touch points throughout service delivery & research transitions

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NCCOS empowers coastal managers and communities with validated and approved tools to inform decisions and issue consumer warnings about HAB toxins.

- **What:** Co-developing toxin detection tools through strong relationships to respond to various user needs.
- **How:** 1. Training stakeholders to implement standardized HAB toxin detection capabilities

2. Advancing regional HAB toxin detection solutions with a national perspective (standardized >> approved methods)



Tool development is an adaptive process





Service Delivery & Research Transitions

NCCOS is improving toxin detection by shepherding the development, acceptance, and implementation of new and/or improved technologies







Implementation and Expansion of User Laboratories Case Study: *Alaska Tribal Laboratories*

Sustained, Reliable Mission Activity with an Institutional Commitment to Deliver Products





Target end products and geographic application

Eliminate HAB Protect Human poisonings Health

- Alaska communities fill the knowledge gap
- Saxitoxin receptor binding assay

NCCOS units and partners involved

NCCOS	Alaska	NCCOS
Charleston	Natives	CRP

• Sitka Tribe of Alaska Environmental Research Lab

Alutiiq Pride Research Institute

Target uses and user groups

Recreational harvesters

Subsistence harvesters

 Tribal consortia: Southeast Alaska Tribal Ocean Research, Chugach Regional Resources Commission

Current state of product and next steps

receptor-based

antibody-based

- Operational use of approved saxitoxin RBA
- Capacity developing for emerging toxins
- Resource for other tribes outside the region



R2O: Alaska Tribal Laboratories

ISSUE: Communities need toxin detection tools to make informed decisions and issue warnings to consumers about HAB toxins in the absence of a systematic recreational/subsistence monitoring program.

- Alaska Dept Environmental Conservation monitors extensively for saxitoxins, but only in commercial harvests.
- Poisonings require improved knowledge of toxin presence.



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2015 - Alaskan communities create community of practice to monitor HABs through phytoplankton monitoring











2017-present - NCCOS Charleston provides training, guidance, and support to bring saxitoxin testing to support community harvests in a newly formed laboratory (Sitka Tribe of Alaska Environmental Research Lab 'STAERL')

Saxitoxin monitoring is currently providing harvest data, with no documented illness from any community harvest sites

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2024-2026 - NCCOS Charleston, Sitka Tribe's lab & Washington Department of Health to close the data gap needed for full FDA acceptance of saxitoxin RBA with validation of clams & oyster matrices (PCMHAB)





Harley et al (2020) Toxins





Domoic acid & diarrhetic shellfish toxin (DST) producing algae identified through community monitoring, increasing concerns about the harvest risks

\$ Image: Solution of the second structure2020-present - NCCOS Charleston and Sitka Tribe's lab develop toxin testing
capacity for domoic acid & DSTs using MERHAB funding







Lessons Learned

Developing community testing approach on a wider scale has region specific challenges and requires different interaction/timescales in order for the partner to take the lead.

Continued NCCOS involvement over a timeline longer than a grant cycle is key to building capacity.

Not all tools end up in the targeted audience (e.g. FDA methods at State regulatory agencies).

Additional investment and time may be needed to enhance impact to NCCOS products.

"when the tide goes out the table is set"

> B.C. folklore society Brian Robertson



Overview

QUALITY	RELEVANCE	PERFORMANCE
 Validation and implementation of toxin detection tools continues to advance for matrices and methods relevant to community needs. 	 Impact of toxin detection tools without precedence. Co-developed products enhance results 	 Solutions to control food safety by applying effective technologies Investment and evaluation of current and future needs continues

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Developing a Point-of-Need Toxin Detection Platform Case Study: LightDeck® Technology

R₂C







Target end products and geographic application

Point of Need Nationwide

- Rapid testing for shellfish or water
- Different products for freshwater & marine

NCCOS units and partners involved

NCCOS CRP & Private Charleston Academic Company

- LightDeck (mBio)
- Limnotech
- The Ohio State Univ Stone Lab
- Washington Dept Health

Target uses and user groups

Resource Managers Commercial & Recreational

- Canandaigua Lake Watershed Assn
- State Univ NY- ESF

Current state of product and next steps

Biological (antibody-based) Accuracy & reliability testing

- Validation efforts underway for ISSC
- Revision of extraction procedures



R2C: LightDeck Technology

ISSUE: Need for accessible and accurate toxin testing to support rapid decision making to protect public health from toxins







R2C: LightDeck Technology

- WHAT IS IT?
 - Antibody-based toxin detection and quantification
 - Rapid, portable, planar waveguide technology platform
 - Uses inexpensive, disposable test cartridges

• RELEVANCE:

- Cost/time improvements, multi-toxin tests, field testing
- Better testing access >> reduced risk





R2C: LightDeck Technology

LightDeck Example 1: Rapid, portable, multiplexed detection of HAB toxins in the Great Lakes

- Media: freshwater
- Toxins: MC, CYN, ATX, STX
- Targeted application: water monitoring

LightDeck Example 2: Multiplexed detection of HAB toxins in shellfish

- Media: shellfish
- Toxins: DA, PST, (DST)
- Targeted application: food safety / regulatory









 S 2019 - MERHAB "Portable Toxin Detection Technology to Support Great Lakes Decision Support Tools" Validate and deploy MC/CYN field testing

\$ 2020 - <u>PCMHAB</u> "Rapid, portable, multiplexed detection of harmful algal toxins in the Great Lakes" Develop and validate additional toxin assays for platform



2020 - <u>PCMHAB</u> "Validation of a triplex test for saxitoxin, domoic acid, and okadaic acid measured in shellfish tissue from New England and the Pacific Northwest" Obtain regulatory "Approval for Limited Use" of technology through validation





2020 - <u>Citizen Science Field Testing</u> w/ NCCOS Phytoplankton Monitoring Network

2020 - Virtual Training Workshop

2022 - Validation: Comparison of LightDeck & ELISA using environmental samples w/ NCCOS Charleston

Demonstration in an operational environment: SUNY-ESF (partner) working with Canandaigua Lake Watershed Association (end user)



Lessons Learned

Successes

- NCCOS co-developing product with industry, facilitating transition
- Value of partnering early with end users: adaptive development
- Trainings future end users to use new technology/product

Challenges

- Validation and demonstration with natural water samples

 detection limits
- Cell lysis
 - portable lysis system (USACE)
 - freeze-thaw cycles (cannot be done in field)
- Different toxins require different extraction procedures
- Ephemeral nature of commercial companies



Overview

QUALITY	RELEVANCE	PERFORMANCE
 Validating reliability and accuracy of method with rigorous, iterative testing. Product development is concurrent with the transition through the service delivery process. 	 Meets need for more efficient testing at the point-of-need. Incorporating target users and relevant field sites/samples into technology development and demonstration. 	 Incorporation of target users throughout R2X (e.g., researchers, citizen scientists). Direct communication between the commercial developer and target users.

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R₂A

Use of R&D Output as a System, Process, Product or Tool





Target end products and geographic application

Eliminate HAB Poisonings Nationwide

• Analytical detection of Diarrhetic Shellfish Toxins (DSTs) to ensure safe harvests

NCCOS units and partners involved

NCCOS CRP &State/FedInt'l Gov.CharlestonAgenciesAgencies

- FDA CFSAN & FDA Office Regulatory Sci
- Washington State Dept Health
- Bigelow Lab for Ocean Sci
- Netherlands Institute for Food Safety

Target uses and user groups

Resource Managers Commercial & Recreational

- Washington State Dept Health
- Maine Dept Marine Resources
- event response

Current state of product and next steps

Liquid Chromatography-Mass Spectrometry

- Technology widely applied in Washington
- Ongoing method improvement needed to address regional differences in toxin profiles

NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

R2A: LC-MS for Diarrhetic Shellfish Toxins (DST)

ISSUE: Validated and approved methods needed for emerging toxin groups that pose a risk to health and commerce

• DST-producing HABs likely expanding in intensity and geography

• Lipophilic toxins responsible for DSP emerges as U.S. issue (2008-11)

• Emerging knowledge of analytical detection provides opportunity to bring best in class detection to regulators



NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

R2A: LC-MS for Diarrhetic Shellfish Toxins (DST)

• WHAT IS IT?

- Liquid Chromatography-Mass Spectrometry
- highly technical, specific equipment
- chemical detection to elucidate & quantitate chemical structures
- unambiguous ID of known chemical structures




alkaline v. acidic solvents, calibration matrix issues identified and resolved







2015 - Washington Dept Health implements EU Harmonized method, because 2017 National Shellfish Sanitation Program method challenging to implement

approved method does not represent regional needs (species, technology)

• more than 500 samples in excess of regulatory limit with some harvest areas closed for weeks and others for months to years.





2023 - PCMHAB / Developing harmonized approaches to quantify and monitor DSP toxins in shellfish tissue

Expand to include blue mussels (gold standard)





regional differences in *Dinophysis* toxin composition, Ayache et al 2023



Lessons Learned

• Technical challenges associated with inaugural launch of a U.S. regulatory method based on chemical detection of HAB toxins.

• High cost of implementing advanced technologies may limit adoption. However, alternative DST methods (bioassays) are also challenging.

• "Final" products often revert back to research & development upon further understanding of the environment.

• The R2A process has yielded advanced knowledge of the previously unknown impact of DSTs across the U.S., resulting in methods applied in regulatory settings.



Overview

QUALITY	RELEVANCE	PERFORMANCE
• DST testing by LC-MS is the first regulatory method in the U.S. to apply analytical techniques	 DST testing by State shellfish authorities using LC-MS has resulted in actionable information (harvest closures) 	 Adapted to changing knowledge (new toxins), but required additional investment Researchers have direct participation in regulatory adoption

SCIENCE SERVING COASTAL COMMUNITIES

QUALITY	RELEVANCE	PERFORMANCE
Toxin detection products are recognized as reliable and accurate through their validation, acceptance, and use	Internal and external investments deliver HAB toxin detection products that can eliminate poisonings	NCCOS has developed tools to achieve desired results and adapt to changing priorities

Though continuous improvement of our scientific products, NCCOS serves at a unique crossroads with the ability to advance the development of toxin detection tools to meet the needs of HAB communities with both resources and expertise.

Toxin detection science supports our understanding and measurement of HAB toxins with the goal to ultimately eliminate HAB poisonings.

SCIENCE SERVING COASTAL COMMUNITIE

15 minute Break!

Return by 10:30AM



SCIENCE SERVING COASTAL COMMUNITIES



HAB Control

Three Phases to Solutions & Adapting to Community Needs

Kaytee Pokrzywinski (HAB-F), Felix Martinez (CRP), & Peter Moeller (HAB-MR)



HAB Prevention, <u>Control</u>, & Mitigation

- Prevention
 - Reduce incidence and extent <u>before</u> initiation
- Control
 - Kill, destroy, or remove cells and/or toxins
 - Limit algal growth
 - Preemptively manage HABs
- Mitigation
 - Limit delay or inhibit undesirable impacts on ecosystems and communities





NCCOS Approach to HAB Control



- Case studies for in-water cell/toxin control strategies
 - DinoSHIELD
 - Clay Flocculation
 - Nanobubble Ozone Technology (NBOT)
- Adapting to emerging needs
 - US HAB Control Technologies Incubator
 - US HAB Control Technologies Clearinghouse



HAB Control Process





Collaborations & Partnerships



Industry & Non-profits, Academia, Resource Agencies & State/County Municipalities, Federal Agencies



Stakeholder Engagement Strategy



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DinoSHIELD Development, Testing, Validation

Project Lead: Dr. Kaytee Pokrzywinski (NCCOS)









Duration: 12+ years Funding: Primarily PCMHAB Partnership: IAA & CA Technology: Biological Target: Dinoflagellates Application: Marine (coastal)

What is **DinoSHIELD**?

A slow-release alginate hydrogel containing algicidal bacteria as 'mini *in situ* bioreactors'

Efficacy

- High specificity
- No effect on beneficial phytoplankton
- Fast response time (< 24hrs)

Safety

- Shewanella ubiquitous in DE & FL Gulf Coast
- Shewanella retained in DinoSHIELDs
- No effect on marine life

Application

- Easy to prepare and store
- Retreivable
- Non-toxic
- Biodegradable

Control







DinoSHIELD State of Science

- Scaling-up in FL (Winter 2024)
 - Deploy DinoSHIELDs during a red tide
 - 1 week exposure & 1 week posttreatment monitoring
 - Treat up to 1 acre (425x more volume that DE trial)
 - Confined using turbidity and bubble curtains
- Preparing for the field
 - Concentrate bacteria and/or raw algicide
 - Evaluate bacteria and matrix viability/stability
 - Re-evaluate deployment strategy
 - Working through site selection and local permitting



DinoSHIELD Stakeholder Engagement

- Developed regional technical bulletins
- Hosted workshop for DE Aquaculture
 Association
 - IRB approved pre/post-workshop surveys
- Planning to host FL workshop/survey series
 - Preparing animated videos
 - IRB approved pre/post-workshop surveys
- Also distribute via meetings, conferences and technical workshops
 - Annual TACs
 - US HAB, PICES, ICHA



DinoSHIELD: A Natural Approach to Control Red Tides

WHY DINOSHIELD?

Marine harmful algal blooms (HABs), sometimes referred to as red tides, are caused by microscopic algae that can produce toxins which are harmful to both humans and animals. Toxins produced by HABs can accumulate in shelffish tissue potentially leading to shelffish poisoning when consumed. The majority of available marine are the



WHAT IS DINOSHIELD?

DimoSHIELD is an emerging technology which aims to prevent and control HABs in marine waters, reducing the impact of HABs in ocoastal communities and economically important industries such as shellfisheries and tourism. DimoSHIELD technology relies on the slow release of an algicide naturally produced by a bacterium commonly found in coastal waters, including the Delaware Inland Bays. The bacteria are immobilized in a hydroged system that can release the algicide while relaring the bacteria oo that the adicide can be continuously delivered

HOW IS DINOSHIELD USED?

Following production of DinoSHIELD in the lab, the algicide-containing hydrogel beads are put into a mesh bag and suspended at various depths off of docks and other existing marine structures to ensure a consistent application rate across the target area. These mesh bags can be deployed for the prevention and control of marine HABs in ecosystems with chronic blooms. Following regulatory approxal. DinoSHIELD can be used by state managers, shellfish growers, and other end-users to safety manage HABs in their coastal walerbodies.

Oters

1305 East West Hwy, Rm 811 Silver Spring, Maryland 20910 240.533.0300 | coastalscience.noaa.go com/insacrastiduci | V Grease activity

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DinoSHIELD Stakeholder Engagement



"I was at the presentation last night on the DinoSHIELD technology under development... certain Shewanella species have been associated with potential for shellfish-borne illnesses... I'm sure this has already occurred to you, and probably the answer is as simple as your Shewanella being a different, non-pathogenic species..."

- Andrew Bell, DE Shellfish Standardization Officer

"Do you think you can get permits to deploy DinoShield in natural waters? Is it affordable? Might it work on Rust Tide? Do you want research partners? I think I can get grant funding and have investigators and industry partners lined up."

Bob Rheault, Executive Director, East Coast Shellfish Growers Association

"...thanks for setting up this presentation. I have great interest in this subject...."

- Mark Casey, President of Delaware Cultured Seafood (he sent us a ppt full of questions)













Clay Flocculation

Validation

<u>Project Lead</u>: Dr. Don Anderson (Woods Hole Oceanographic Institution)



Clay Flocculation Idea & Technology **Proof of** Transfer Concept NOAA **Research &** Demonstration **Development** & Validation



Duration: 5 year award Funding: PCMHAB* Partnership: CA Technology: Physicochemical Target: Dinoflagellates Application: Marine (coastal)



What Is Clay Flocculation?

- Through natural electrical charges clay binds to algal cells and causes them to sink to the bottom
- Clay compounds need to be evaluated in order to:
 - Confirm effectiveness/safety on US ecosystems
 - Obtain federal/state regulatory approvals



Clay dispersal and flocculation, leading to removal of HAB cells. Credit D. Anderson (WHOI) adapted from <u>Sengo et</u> al., 2005.

Clay Flocculation State of Science

• Status:

- Lab and mesocosms trials successful
- Original clay formulation removes cells but not extracellular toxin
- Next steps:
 - Large scale (1 acre) trials pending
 - Testing new clay formulations to enhance toxin removal (Mote/FL-RI funded)



Chinese vessels spraying clay. Credit D. Anderson, WHOI



Pilot study of clay dispersal conducted at the Sarasota Outboard Club canal, Sarasota, FL. Credit D. Anderson, WHOI



Clay Flocculation Stakeholder Engagement

• Socioeconomic value



- Cost-benefit analysis
- Discrete choice surveys
- Public perception
 - Journalism
 - Open educational public meetings



Experimental application of clay floc slurry during a small enclosure trial in Sarasota. Note the temporary coloration of the water at the time of application. Credit: Mote Marine Lab.





Development, Improvement, Validation

Project Lead: Dr. Peter Moeller (NCCOS)

CRADA <u>Other Key Collaborators</u>: (Academia) AMURI, CoC, USC; (Agencies) EPA, USACE, OHDEP, FLDEP; (Industry) Commercial Partners, CRADA Partners

NBOT CRADA & Recommondation Rependent Quality Testing





Develop for commercial use, ozone impregnated nano-bubble technology to address water safety & security issues including:

Algae mitigation/remediation.Toxin destruction and elimination.

The Lake Superior Research Institute's Great Waters Research Collaborative aims to provide unbiased and independent data to accelerate the development of technologies with potential to prevent the introduction and/or control the spread of non-indigenous organisms.

Great Waters

The overall conclusion from the biological effectiveness testing with NBOT-2.5HP is that the system is highly effective at controlling concentrations of algae, bacteria and motile zooplankton.

Determination of the chronic residual toxicity of NBOT 2.5-HP treated water to non-target organisms showed that in there was no statistically significant effects on any of the three organism types tested.



NanoBubbleOzoneTechnology





Duration: 7+ years Funding: CRADA & NCCOS Base Partnership: CRADA & LSRI Technology: Physicochemical Target: All HABs and Toxin Application: Marine and Freshwater



What Is NBOT?

Ozone Impregnated Nano-bubble Technology (NBOT) - Mitigating HABS, Toxins, Contaminants, Nutrients and Their Impacts : A Novel, Green Approach to Water Safety and Security



Technology Combines Four Unique Attributes 1.Scalable 2.Configurable 3.Self Contained/Controllable 4.No Legacy Residues

Complete Approach to Mitigation/Remediation

- **1.Destroys Microbes**
- 2.Destroys Toxins/Contaminants
- **3.Removes Nutrients**
- 4.Removes Heavy Metals And It's GREEN!

NBOT Research Focuses on the Entire Harmful Cycle at Multiple Points

🔵 Developed 🛛 📃

Under development

NBOT State of Science



Lake Newport: 1.5 Miles Long, 60-65 Acres

Responsible Mitigation/Control/Prevention *Main Requirements*

- 1. Treats HABS & Microbial Consortia (biology)
- 2. Treats Toxins and Contaminants (chemistry)
- 3. Reduces/Removes Nutrients and Metals
- 4. Maintains Environmental Stewardship



Data and results generated from Lake Newport NBOT treatment has led to ozone impregnated nano bubble technology being transitioned to and applied in waste-, drinking-, and industrial effluent water treatments.



NBOT Tech Transfer & Stakeholder Engagement

- Data and results generated by CRADA partnership is collated and interpreted for industrial partners to market/transition developed technology for commercial applications.
- All mesocosm or open water trials are coordinated with local communities prior to operation. Resulting journal articles, technical reports and videos are provided to industrial partners for dissemination to the public on demand.





Before and after Cape Coral NBOT mesocosm trial 2019



Case Studies Summary

- NCCOS HAB control strategies are targeted for
 - Specificity
 - Scalability
 - Environmental safety & sustainability
- Several products in various stages of development that may serve as **environmentally friendly means** to effectively control HABs
 - DinoSHIELD and Clay dinoflagellates
 - NBOT cyanobacteria
- Capitalize on various partnership strategies to advance control science & ensure products meet needs, budgets, and skill levels
 - CRADA Partner transfer & engagement
 - CA & IAA NCCOS transfer & engagement





Challenges to Control Science

- No one product will treat everything
- Require a basic understanding of target species and ecosystem
- Need to assess environmental and human health impacts
- Need seed funding for proof of concept studies
 - Feasibility
 - Effectiveness
 - Scalability

• Unique aspects that make transition challenging

- Community perception
- Regulatory requirements/approval processes (Federal)
- Permitting (State/local authorities) research & operational scales
- Commercialization (CRADA)






US HAB-Control Technologies Incubator and Clearinghouse New Ideas/Proof of Concept and Transition Project Lead: Dr. Allen Place (UMCES)

The state and the



US HAB-CTI & Clearinghouse

CA with UMCES & Mote Marine Lab (\$7.5M, 5+ yr)

Incubator (<u>\$5M</u>)

- Annual competition
 - Up to 1 yr
 - \$250K max/project
 - non-renewable awards
- Quick assessment of novel technologies for
 - Effectiveness
 - Scalability
 - Feasibility

Clearinghouse

- Permitting/Regulatory Requirements
 - Federal/state specific
- Resource list
 - Agency/private contacts
- Available technologies
 - By region, species, habitat, etc.



HAB Control Summary

Objective

- Develop nationally relevant products to address regional problems
- Flexibility to transfer strategies to other regions as problems emerge

ERDC

Sea Gřant

 Transition strategies for operational use

Key Partners

NCCOS Internal expertise (SDI, CRP)

VOODS HOLE

- Federal, state, and local agencies
- Academia
- Industry
- Private Sector

Syn

Key Users & Stakeholders

- Agencies (e.g. resource managers, drinking and wastewater operators)
- Industry (e.g. aquaculture, marina operators, industrial waste streams)
- Private (e.g. HOAs, NGOs with interest in improving surface water quality)

Synopsis & Next Steps

 Provide environmentally sustainable strategies for end users to safely incorporate into routine management practices



Takeaways

- Control is arguably the most challenging area in the HAB sciences
- Control science is often iterative working to improve on products or delivery vehicles
 - Reduce environmental impacts
 - Reduce cost
 - Improve effectiveness
- Adapt to community needs/filling in the gaps
 - Providing structure and direction
 - Driving control science (intramural & extramural)
 - Coupling government, academia and industry needs
 - Reduce duplication
 - Facilitate collaboration





LUNCH!

12:00 - 1:30PM



R2X Stakeholder Panelist Discussion

Closed Session



15 minute Break!

Return by 3:25PM





Public Communication and Societal Acceptance Stakeholder Discussion

Closed Session



Executive Session

Review Panel only

Panel Reception to follow at Silver Branch Brewing 5:30PM (8401 Colesville Rd #150, Silver Spring, MD 20910)





NCCOS Annual Science Review: Harmful Algal Blooms and Hypoxia Program

Silver Spring, Maryland 28 - 30 November, 2023

Review Website: NCCOS HABs and Hypoxia Program Review

WELCOME BACK!

Margo Schulze-Haugen, NCCOS Deputy Director



Reporting and Submission Overview

Pat Brown, Review Chair



Panel Discussion and Initial Recommendations

Pat Brown, Review Chair



Review Panel Presentation to NCCOS Leadership

Review Panel Members



Review Panel Summary to NCCOS Leadership

Review Panel Members



Thank You and Final Remarks

Sean Corson, NCCOS Director

