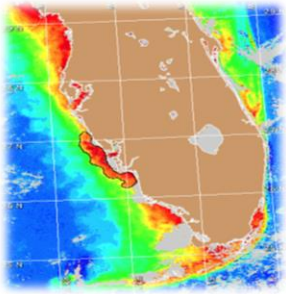
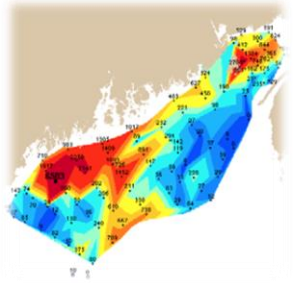
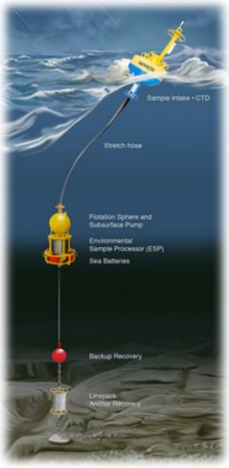
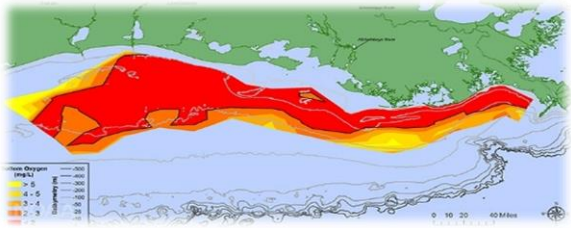
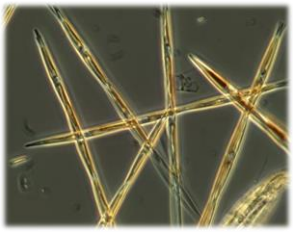
External Peer Review: NCCOS Harmful Algal Blooms and Hypoxia Portfolio

Silver Spring, Maryland

26-28 February 2018

Briefing Book and Meeting Materials

Steven Thur, Ph.D.

Director, National Centers for Coastal Ocean Science

National Ocean Service, NOAA

https://coastalscience.noaa.gov/

NCCOS HAB and Hypoxia Portfolio Review

DAY 1 (Monday, 26 February 2018)

0830 – 0845: Introductions and opening remarks [also introduce Russell] – Steven Thur, NCCOS

0845 -- 0900: Welcome from the NOS Assistant Administrator – Russell Callender, NOS

0900 – 0930: NCCOS mission, strategic direction, and charge to reviewers – Steven Thur, NCCOS

0930 – 0945: Review requirements for research and development in NOAA – Jawed Hameedi, NCCOS

0945 – 1000: Question / Answer session

1000 -- 1015: BREAK

1015 – 1030: Competitive Research Program Overview, collaboration with intramural research – Alan Lewitus

1030 – 1045: ECOHAB – program profile, achievements and future direction – Quay Dortch, NCCOS

1045 – 1100: PCMHAB – program profile, achievements and future direction – Quay Dortch, NCCOS

1100 – 1115: MERHAB – program profile, achievements and future direction – Marc Suddleson, NCCOS

1115 – 1130: Event Response – actions, achievements, and future direction – Marc Suddleson, NCCOS

1130 – 1145: Question / Answer session

1145 – 1230: LUNCH BREAK

1230 – 1240: Introduction to NCCOS Hypoxia Research – Alan Lewitus, NCCOS

1240 – 1310: Hypoxia modeling, nutrient reduction targets, and stakeholder engagement (northern Gulf of Mexico) – Nancy Rabalais, LSU and Alan Lewitus, NCCOS (presenter)

1310 – 1340: Hypoxia modeling, relationship with nutrient loading, water quality targets, and transition planning (Chesapeake Bay, Lake Erie, Gulf of Mexico) – Don Scavia, U Michigan

1340 – 1410: Hypoxia modeling, inter-annual variability, water quality improvements (Narragansett Bay) -- Candace Oviatt, U Rhode Island (remote)

1410 -- 1440: Hypoxia impacts on living resources and coastal economies – Kevin Craig, F/SEFSC

1440 – 1450: Runoff Risk Advisory Forecast (NOAA video)

1450 – 1520: Question / Answer session

1520 – ADJOURN

1520– 1620: Executive Session [Review Panel only]

1800 – Dinner with Panel

DAY 2 (Tuesday, 27 February 2018)

0830 – 0845: NCCOS sub-priority on HAB and hypoxia, and Implementation Plan – Sherri Fields, NCCOS
0845 – 0915: HAB Modeling and Forecasting Branch profile, achievements and future direction – Wayne Litaker, NCCOS
0915 – 0945: HAB Monitoring and Reference Branch overview – John Ramsdell, NCCOS
0945 – 1000: Question / Answer session
1000 – 1015: BREAK

1015-1055: Satellite imagery-derived HAB forecasting, transition to operational forecasts, outreach and communication [include HAB bulletins] – Rick Stumpf, NCCOS
1055 – 1125: HAB modeling in the Gulf of Maine, toxin detection and estimation of toxicity, and use of ESP data in producing operational forecasts – Dennis McGillicuddy, WHOI
1125 – 1155: Flow Cytobot imaging and modeling of HABs in the Gulf of Mexico -- Lisa Campbell, TAMU
1155 – 1210: Question / Answer Session
1210 – 1300: LUNCH BREAK

1300 – 1320: Phytoplankton Monitoring Network – Steve Morton, NCCOS
1320 – 1340: New HAB detection technologies and monitoring platforms – Greg Doucette, NCCOS
1340 – 1400: Analytical methods and reference materials – Maggie Broadwater, NCCOS
1400 – 1420: Monitoring and observations in Lake Erie – Tim Davis, BGSU
1420 – 1440: NOS-EPA Agreement on HABs in freshwater lakes – Antonio Bravo, US
1440 – 1500: Question / Answer session
1500 – 1530: BREAK

1530 – 1545: HAB bulletins and emerging marine toxins (Pacific Northwest) – Jerry Borchert, Washington DOH (Marc Suddleson presenting)
1545 – 1600: Building Capacity – Tribal laboratory networks and response capabilities – Chris Whitehead, Sitka Tribes of Alaska
1600 – 1615: Building Capacity – international laboratories and NOS-IAEA Agreement – John Ramsdell, NCCOS
1615 – 1630: Question / Answer session

1630 -- ADJOURN
1630 – 1730: Executive Session (Review Panel only)

1800 – Dinner (on your own)

DAY 3 (Wednesday, 28 February 2018)

0830 – 1030: Review Panel deliberations and initial recommendations (Review Panel members only)
1030 – 1100: Review Panel oral presentations to NCCOS leadership -- individual review panel members
1100 – 1145: Presentation of summary of reviewers' comments to NCCOS leadership that may include salient points, recurring themes, or notable exceptions -- Chair, Review Panel
NOTE: Individual written reports from the Review Panel members will be due within 60 days of the review.
1145 – 1200: Thanks and final remarks – Steve Thur
1200 -- ADJOURN

Review Panel

Members of the Review Panel include technical experts in different fields, program directors, and users of information. We have tried to balance the composition of the Review Panel, considering affiliation (Federal and non-Federal), scientific expertise (analysis of satellite imagery, ecological modeling, algal toxin detection methods and monitoring, nutrient management and mitigation, etc.), and users of information (i.e., public health officials, coastal resource managers, etc.).

The panel consists of the following:

1. Stacey DeGrasse: Science Advisor, Seafood Safety, FDA (Panel Chair)
2. James Ammerman: Science Coordinator, Long Island Sound Study, SUNY-Stony Brook
3. Dan Ayres: Coastal Shellfish Manager, WA Department Fish & Wildlife
4. Sherry Larkin: Associate Dean of Research, University of Florida (IFAS)
5. Barbara Kirkpatrick: Executive Director, Gulf of Mexico Coastal Ocean Observing System
6. Heather Raymond: HAB Coordinator, OH Environmental Protection Agency
7. Brenda Rashleigh: Assistant Laboratory Director for Water, NHEERL, US EPA

Steering Committee

The following individuals are members of the Steering Committee for this review. As with the Review Panel, they represent a variety of areas of expertise and affiliations within NCCOS. The committee includes:

1. Jawed Hameedi
2. Caitlin Gould
3. Quay Dortch
4. Alan Lewitus
5. Marc Suddleson
6. John Ramsdell
7. Wayne Litaker

Purpose of the Review

NOAA requires external peer-reviews of its research and development programs on a periodic basis. Such reviews can play a key role in program planning, management and oversight by providing feedback on both program design and execution. NCCOS is further interested in evaluation of its information products and their delivery to users, and engagement with stakeholders.

Specifically, the review is intended to do the following:

1. Assess NCCOS' role as a federal entity to improve scientific understanding of HABs and hypoxia, resulting in:
    a) More robust and effective environmental modeling and forecasts leading to operational forecasting and delivering early warning information to decision makers;
    b) New environmental sensors, observation platforms, monitoring protocols, and validated detection methods;
    c) Effective methods of prevention, control, and mitigation that can minimize HABs and their impacts;
    d) Event response that leverages the capabilities of other federal reference laboratories, monitoring programs and user laboratories to meet the needs of diverse management communities.
2. Evaluate NCCOS' role in delivering practicable research products, data and information, and engaging stakeholders.
3. Appraise NCCOS management and procedures for funding pre-eminent research that is coordinated across intramural and extramural programs, producing actionable results that engages stakeholders, and transitioning its research and development (R&D) to widely utilized applications.
4. Offer observations and make recommendations to better position NCCOS for implementing its HAB and hypoxia portfolio.

Scope of the Review

The review will cover all aspects of HAB and hypoxia related research, assessment, monitoring, and other activities conducted by NCCOS, both in-house and through extramural support, over the past five years. In particular, the review will focus on knowledge enhancement, forecasting, sensor development and monitoring protocols, response actions, and alleviation of HAB and hypoxia in U.S. coastal waters, including the Great Lakes. It will also consider the underlying assumptions, statutes, and organizational drivers that led to the current HAB and hypoxia portfolio and identify any changes to better position NCCOS for the future.

Program Evaluation Criteria

Following enactment of the Government Performance and Results Act (GPRA) in 1993, the National Academies' Committee on Science, Engineering, and Public Policy produced a report on the unique purpose of federal research programs and inherent challenges in their evaluation. The committee concluded that federal research programs could be evaluated using three criteria: quality, relevance, and leadership, and noted that such evaluations should consider factors beyond peer review of research publications by scholars in the field (National Academy of Sciences, 2001).

In its 2008 Guide to the Program Assessment Rating Tool (PART) and citing the National Academies report, the US Office of Management and Budget (OMB) identified relevance, performance, and quality as criteria that can be used to assess the effectiveness of federal research and development (R&D) programs. This approach was further endorsed in a 2008 National Research Council (NRC) report, which stated that research program efficiency must be evaluated in the context of relevance, effectiveness, and quality.

NOAA, through an Administrative Order (NAO 216-115A, dated October 3, 2016, and its previous editions), has adopted Quality, Relevance and Performance as core evaluation criteria. The NAO also calls for a periodic evaluation of research, development and transition activities as well as outreach efforts and stakeholder engagement.

In general terms, these criteria may be described in the following terms:

- ***Quality***: Quality is a measure of soundness, accuracy, and reproducibility of a specific body of research, and is the most widely and traditionally used criterion that is evaluated by peer review committees. In general, it refers to the merits of R&D within the scientific community – research publications, awards, innovations, and patents – and implies adherence to values of objectivity, fairness, and accountability (NAS, 2017). It also requires evidence of established procedures for competitive, merit-based procedures for research funding, and assuring scientific integrity.
- ***Relevance***. In essence this criterion asks for "what would not have happened if NCCOS did not exist, and how much would society have missed?" Program personnel identify public benefits of the program, including added benefits beyond those of any similar effort that has been or is being funded by others. In this context, an "other" may be another program at the same or another agency, an interagency initiative or partnership, or a firm or other organization. R&D benefits include increasingly more skillful and reliable program output, technology, or methodology that satisfies legal mandates and user needs, expert counsel and technology transfer, and new options in the future.
- ***Performance***: Performance refers to an ability to manage in a manner that produces identifiable results, both effectively (achieving desired results) and efficiently (with maximum productivity and minimum wasted effort or money). This is judged by program management structure that produces the desired results, guidance or framework for tracking progress toward agency's strategic goals and objectives, flexibility to address events or changing priorities, interaction with stakeholders, and extramural collaboration.

Reviewers' Responsibility

NCCOS will present data and information relevant to its HAB and hypoxia portfolio during the course of the review, primarily as lecture presentations and in the briefing book. Each member of the Review Panel will use that information and any ensuing discussion to come up with independent observations, evaluation, and recommendations on different aspects of the portfolio (reviewers are encouraged to use the attached format). We have formulated the following questions to guide your review and to conform to the three core evaluation criteria:

Quality

1. How well are NCCOS scientists, both intramural and extramural, and program managers recognized as leaders in their scientific disciplines for the quality of their contributions (e.g., authors of peer-reviewed publications; congressional briefings; invited lectures; awards and recognition; and national and international leadership positions in the scientific community)?
2. How effective are NCCOS intramural and extramural studies in developing (a) new and validated analytical methods and technologies in wide use, and (b) advanced tools to understand and mitigate HAB and hypoxia events (e.g., forecast models, sensors, and prevention-control-mitigation (PCM) technologies?
3. How does NCCOS assure and does it have procedures for funding preeminent research and impactful science?

Relevance

1. How well has the portfolio supported noteworthy achievements in improving scientific understanding of causes of HAB that have led to improvements in HAB management and response?
2. How effective are the hypoxia modeling and related studies in informing Federal guidance on nutrient management strategies in upland states?
3. Is there evidence of the application of the NCCOS-produced scientific knowledge for improving preparedness and response to HAB and hypoxia events by local, state, tribal, and regional governments and for preventing or minimizing HAB and hypoxia occurrence?
4. How effective has NCCOS been in transitioning research to applications, i.e., operations, commercialization, and management use, and how such transitions may be improved.

Performance

1. How effective is the NCCOS HAB and hypoxia portfolio in meeting the requirements of HABHRCA (e.g., documenting improved scientific knowledge and communicating information on HAB and hypoxia impacts, delivering an assessment plan for the Great Lakes HAB and hypoxia, and promoting and coordinating a national research strategy on HAB and hypoxia).
2. How well does NCCOS execute its research and related studies in an efficient and effective manner given the resources?
3. How effectively does NCCOS utilize collaboration and partnerships to achieve desired outcomes, and how well are stakeholders engaged in transitioning research to applications?
4. How effective are NCCOS roles in leading workshops, symposia and training that result in outputs that drive management outcomes?

Given the scope of planned presentations as well as anticipated use of the panel's recommendations, the "Relevance" criterion is the most important one. Prior to the review, the reviewers may suggest additional criteria, and at the review, each reviewer will be free to ask additional questions as appropriate.

Anticipated Products

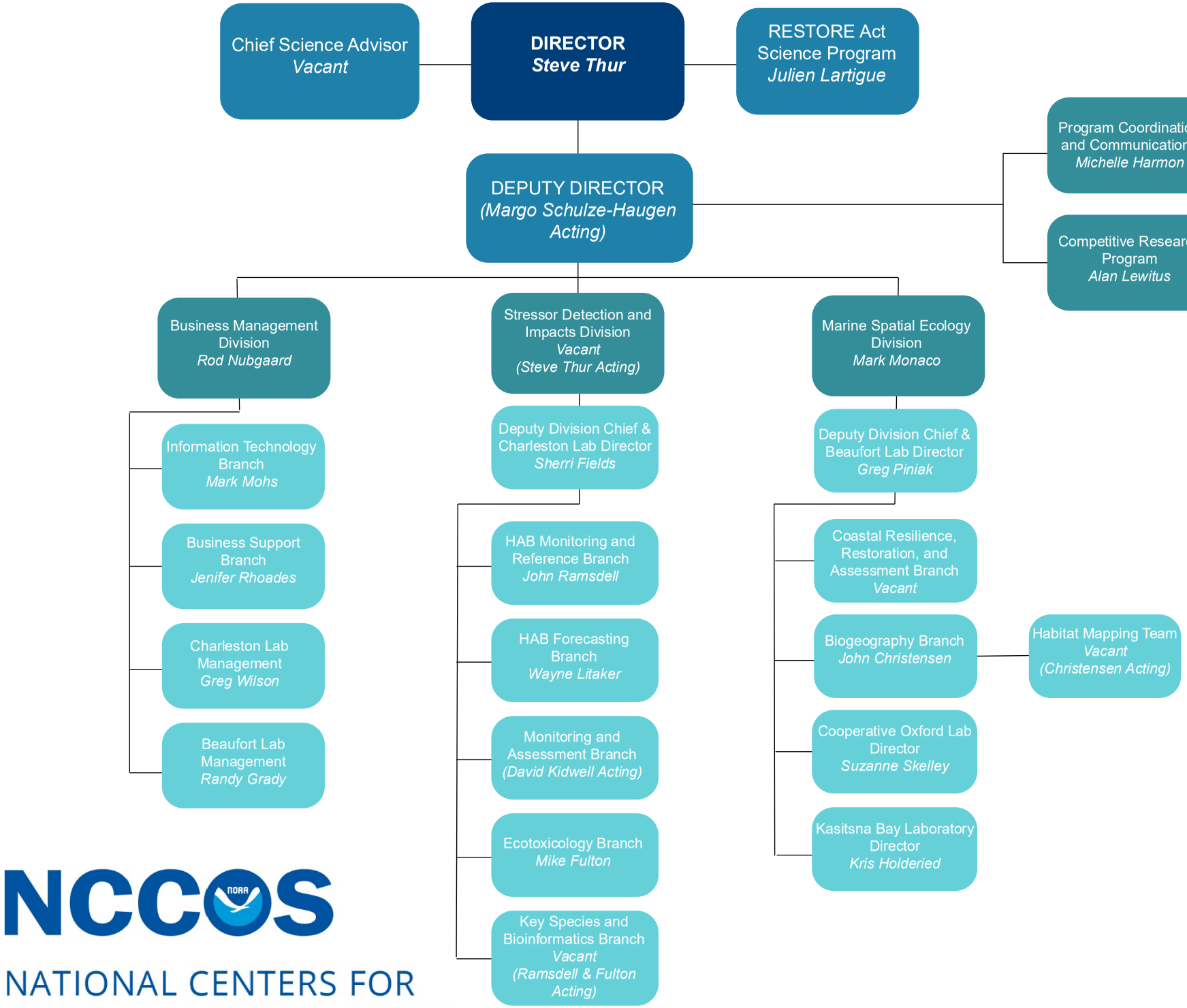
Each member of the review panel will use her / his scientific expertise and professional judgement to provide independent observations, evaluation, and recommendations on different aspects of the NCCOS HAB and hypoxia portfolio, including product value and utilization. Each member of the Review Panel will also prepare notes on his/her observations, comments and recommendations that, at a minimum, address the three core evaluation criteria: Quality, Relevance, and Performance. For convenience, a tabular format is provided for recording comments on different aspects of the review (attachment).

Panel members will present their preliminary finds to NCCOS and NOS leadership (Day 3 of the review). Individual written reports, following the attached format, will be due within 60 days after the review. ***No consensus report is required.*** The Review Panel chair may summarize findings from the review (e.g., salient points, recurring themes, or notable exceptions) in the Review Panel's presentation to NCCOS and NOS leadership (Day 3 of the review) and in a written report (due within 60 days after the review).

NOAA procedures allow for "evaluation ratings" with a bipolar construct for program components, e.g., Exceeds Highest Expectations, Exceeds Expectations, etc. However, we are not requiring the panel members to do that. Also, note that answering the question merely by "yes" or "no" will not be sufficient in conveying your observations, assessment and recommendations and should be avoided.

Review Report

Individual reviewer reports will be compiled in a document for use by NCCOS director and program managers. The document will be used for planning of future science and related activities and improving the performance of current and near-term projects. Individual review reports will not be made public, and will only be used by NCCOS as background for the final report. Internal distribution of the individual reports will be limited.



NCCOS

NATIONAL CENTERS FOR
COASTAL OCEAN SCIENCE

Updated February 7, 2018

NOAA HABHRCA (HAB and Hypoxia) Expenditures (in Millions) FY 2010 – FY 2018									
	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018 Pres Bud+
PPA: Coastal Science Assessment, Response, and Restoration									
Intramural Research and Assessment Activities*	4.60	5.00	4.40	3.40	4.00	4.04	3.92	3.35	3.35
Operational HAB Forecasting	0.57	0.57	0.40	0.30	0.40	0.40	0.40	0.40	0.40
NCCOS intramural total	**5.17**	**5.57**	**4.80**	**3.70**	**4.40**	**4.44**	**4.32**	**3.75**	**3.75**
PPA: Competitive Research									
Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)	4.60	3.90	1.90	1.50	2.20	2.90	1.06	2.27	0.00
Monitoring and Event Response for Harmful Algal Blooms (MERHAB)	0.60	1.40	0.80	0.98	1.30	1.30	0.93	1.37	0.00
Prevention, Control and Mitigation of Harmful Algal Blooms (PCM HAB)	1.00	1.00	1.20	0.55	0.90	0.68	1.21	0.97	0.00
Event Response	0.02	0.06	0.02	0.04	0.03	0.03	0.02	0.03	0.00
Gulf of Mexico Ecosystems & Hypoxia Assessment (NGOMEX)	2.40	2.20	1.40	1.20	0.60	0.12	0.95	0.81	0.00
Coastal Hypoxia Research Program (CHRP)	1.30	1.00	0.57	0.70	0.70	0.00	0.91	0.44	0.00
Infrastructure (support for the HAB National Office)	0.05	0.20	0.17	0.19	0.25	0.22	0.21	0.23	0.00
NCCOS extramural total	**9.97**	**9.76**	**6.06**	**5.16**	**5.98**	**5.25**	**5.29**	**6.12**	**0.00**
COASTAL SCIENCE & ASSESSMENT + COMPETITIVE RESEARCH (NCCOS) TOTAL	**15.14**	**15.33**	**10.86**	**8.86**	**10.38**	**9.69**	**9.61**	**9.87**	**3.75**
Other NOAA (external to Coastal Science & Assessment Sub-program)									
Other intramural**	3.70	1.60	0.70	1.40	3.60	1.59	1.45	1.76	1.76
Ship Costs (Office of Marine and Aviation Operations – OMAO)	1.30	1.60	0.50	0.57	0.40	0.10	0.02	0.00	0.00
Sea Grant (competitive)** $						1.08	1.78	1.81	0.00
IOOS (competitive)**						2.30	1.73	0.57	1.28
OTHER NOAA TOTAL	5.00	3.20	1.20	1.97	4.00	**5.07**	**4.97**	**4.13**	**3.04**
NOAA Intramural Total						**6.13**	**5.79**	**5.51**	**5.51**
NOAA Competitive Total						**8.63**	**8.79**	**8.49**	**1.28**
NOAA TOTAL	**20.14**	**18.53**	**12.06**	**10.83**	**14.38**	**14.76**	**14.58**	**14.00**	**6.79**
+ Based on FY18 Pres Bud which zeros SG and NCCOS Competitive. All else is assumed level.									
* Includes FTE labor and discretionary funds supporting HABHRCA. Does not include facilities (e.g. rent, utilities, safety etc.). $0.33M was excuted as Cooperative Institue Awards									
** Prior years reported 'other NOAA', as a single number that included intramural and competitive research funded outside the two NCCOS PPAs. In FY15 we broke out the intramural vs competitive funds in the 'other NOAA' category to increase transparency.									
$ Sea Grant requires matching funds from its programs. The matching funds are not included in this table.									
Updated November 2017 (RK)									

Harmful Algal Bloom and Hypoxia Research and Control Act

https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/habhrca/

By the 1990s, researchers identified serious and large-scale water-quality problems in United States waters, including HABs and hypoxia, most prominently in the northern Gulf of Mexico, Lake Erie, Chesapeake Bay, and Long Island Sound. These problems prompted Congress to pass HABHRCA in 1998. Recognizing the ongoing nature of HABs and hypoxia, and how they continue to affect the entire U.S., Congress has reauthorized HABHRCA twice, mostly recently in 2014 (HABHRCA 2014, P.L. 113-124).

The legislation requires the creation of an Interagency Working Group on HABHRCA (IWG-HABHRCA). This body is tasked with coordinating and convening Federal agencies and their stakeholders to discuss HAB and hypoxia events in the United States, and to develop action plans and assessments of these situations. NOAA co-chairs the IWG-HABHRCA with EPA. Other member agencies include:

- FDA
- USDA NIFA, NRCS
- CDC
- USACE
- NASA
- NPS
- USGS
- BOEM
- Navy
- NIEHS
- NSF
- State
- US FWS

The 2014 HABHRCA reauthorization is unique for several reasons. It calls for Federal agencies to consult with stakeholders when developing action strategies, in order to develop recommendations that directly address needs and concerns related to mitigating and preventing HABs and hypoxia. It expands the focus of HABHRCA to include a specific emphasis on HABs and hypoxia in the Great Lakes and in fresh waters around the country, and recognizes the need for further coordinated action across the Federal sector to address these issues. Additionally, the legislation calls for Federal agencies to provide integrated assessments identifying the causes, consequences, and approaches to reducing HABs and hypoxia nationally, with particular emphasis on the Great Lakes. It calls for operational forecasting, observations, and modeling tools required to support forecasting, all of which are of particular relevance for the region.

Programs

HABHRCA 1998 and 2004 authorized funding for intramural research and for competitive research programs on HABs and hypoxia:

- Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)
- Monitoring and Event Response for Harmful Algal Blooms (MERHAB)

- Prevention, Control, and Mitigation of Harmful Algal Blooms (PCMHAB)
- Gulf of Mexico Ecosystems & Hypoxia Assessment (NGOMEX)
- Coastal Hypoxia Research (CHRP)

Reports

Each authorization of HABHRCA has required the IWG-HABHRCA to produce a number of reports. These are listed below by the amendment that required them, and, if completed, are linked:

HABHRCA 2014 – Required

- HAB and Hypoxia Comprehensive Research Plan and Action Strategy
- Report on Implementation of the HAB and Hypoxia Action Strategy
- Great Lakes Hypoxia and HAB Integrated Assessment (Incorporated into the Research Plan and Action Strategy)
- Great Lakes HAB and Hypoxia Plan
- Progress Report on Northern Gulf of Mexico Hypoxia
    - Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2015 Report to Congress

HABHRCA 2004 – Submitted to Congress

- National Assessment of Efforts to Predict and Respond to Harmful Algal Blooms in U.S. Waters, 2007
- Scientific Assessment of Marine Harmful Algal Blooms, 2008
- Scientific Assessment of Freshwater Harmful Algal Blooms, 2008 Based on Proceedings of the Interagency, International Symposium on Cyanobacterial Harmful Algal Blooms (ISOC-HAB): State of the Science and Research Needs, also available as Cyanobacteria Harmful Algal Blooms: State of the Science and Research Needs
- Harmful Algal Bloom Management and Response: Assessment and Plan, 2008 Based on Research, Development, Demonstration, and Technology Transfer National Workshop Report: A Plan for Reducing HABs and HAB Impacts
- Scientific Assessment of Hypoxia in US Coastal Waters, 2010

HABHRCA 1998 – Submitted to Congress

- National Assessment of Harmful Algal Blooms in U.S. Waters, 2000
- An Integrated Assessment of Hypoxia in the Northern Gulf of Mexico, 2000
- Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico, 2001
- An Assessment of Coastal Hypoxia and Eutrophication in U.S. Waters, 2003

NOAA Research to Transition and Readiness Levels

Readiness Levels (RLs): A systematic project metric/measurement system that supports assessments of the maturity of R&D projects from research to operation, application, commercial product or service, or other use and allows the consistent comparison of maturity between different types of R&D projects. (Note: NOAA RL's are similar to Technology Readiness Levels developed by NASA (Mankins, 1995) and embody the same concept for quantifying the maturity of research). A project achieves a readiness level once it has accomplished all elements described within a readiness level. A program may include projects at different RLs depending on the goals of each project. Inventions may be generated at any RL. The nine readiness levels are as follows:

a. RL 1: Basic research, experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. Basic research can be oriented or directed towards some broad fields of general interest, with the explicit goal of a range of future applications (OECD, 2015).
b. RL 2: Applied research, original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. Applied research is undertaken either to determine possible uses for the findings of basic research, or to determine new methods or ways of achieving specific and predetermined objectives (OECD, 2015).
c. RL 3: Proof-of-concept for system, process, product, service, or tool; this can be considered an early phase of experimental development; feasibility studies may be included.
d. RL 4: Successful evaluation of system, subsystem, process, product, service, or tool in a laboratory or other experimental environment; this can be considered an intermediate phase of development.
e. RL 5: Successful evaluation of system, subsystem process, product, service, or tool in relevant environment through testing and prototyping; this can be considered the final stage of development before demonstration begins.
f. RL 6: Demonstration of a prototype system, subsystem, process, product, service, or tool in relevant or test environment (potential demonstrated).
g. RL 7: Prototype system, process, product, service or tool demonstrated in an operational or other relevant environment (functionality demonstrated in near-real world environment; subsystem components fully integrated into system).
h. RL 8: Finalized system, process, product, service or tool tested, and shown to operate or function as expected within user's environment; user training and documentation completed; operator or user approval given.
i. RL 9: System, process, product, service, or tool deployed and used routinely. At this time, projects are considered to be a collective set of activities necessary to transfer R&D output to a capability ready for an operation, application, commercial product, or service, or other use.

Transitions encompass the transfer of an R&D output to a capability ready for an operation, application, commercial product or service, or other use. Transitions may require **transition plans:** A document that represents an agreement between clearly identified researchers and potential recipients, organizations, or other users of the product resulting from the transition of an R&D output. Transition Plans are essential for describing and facilitating the transition of R&D to potential end use, and represent an agreement between researchers, operators and/or users that describes a feasible transition pathway and potential Concept of Operations (CONOPS).

To meet mission needs, NOAA will optimize the timely and efficient use of R&D, including but not limited to that conducted by and funded by NOAA. To fulfill this goal, NOAA shall maintain:

a. A mission-oriented enterprise capable of quickly identifying and applying demonstrated R&D outputs to provide new and improved products, services, or more efficient operations while continuing to maintain reliable, cost-effective services for users;
b. An R&D enterprise that routinely provides proven R&D outputs to serve NOAA's mission while adapting its portfolio to address new research frontiers; and,
c. Project management, planning, and oversight processes that include routine identification of new opportunities/needs for research, development of Transition Plans, status reporting, and test and evaluation procedures.

Transition Plans should be developed as early as possible to reflect the relationship between R&D and NOAA's mission and the commitment by the entities involved to the potential transition of R&D. Transition Plans are recommended for projects that seek to progress beyond RL 4. The determination of whether a transition project shall have a written transition plan is at the discretion of the AA(s), or their designees, from the affected LO(s). In making this determination, factors that may be considered include but are not limited to the following:

a. The risks associated with, and the sensitivity of, the transition;
b. The organizations involved in the transition, and their history of implementing transition activities together;
c. The duration of the transition activities;
d. The cost of transition activities;
e. Potential societal impact; and
f. The complexity of the transition, including whether the project is novel or a routine update to existing operations or applications.

Transition Plans shall incorporate the following:

a. A description of the activities necessary to transfer an R&D output;
b. Clearly defined goals for the new/revised product or service, milestones, schedule, and transition success/acceptance criteria;
c. To the best estimate, the amount and source of funds needed to cover the costs associated with the transition, as well as the cost of future operations as necessary, including relevant requirements for equipment, upgrades, staff training, and maintenance of redundant application capabilities during the transition period;
d. A clear designation of potential researcher(s), operational entity(ies) and/or end user(s), and a description of when they will engage and as often as necessary to ensure all parties are fully invested in the R&D transition process;
e. A mechanism for providing clear communication among all participants concerning the transition, including routine engagement of the management chain in the affected LO(s) and partner organizations; and
f. A mechanism for updating the plan as necessary to reflect changes in the plan warranted by results of the transition process or unforeseen events (e.g., updated budgets).

From: http://www.corporateservices.noaa.gov/ames/administrative_orders/chapter_216/216-105B.html

HAB Forecast Branch Overview

The Stressors Detection and Impacts (SDI) Division's Harmful Algal Bloom (HAB) Forecasting Branch focuses on collaboratively producing accurate and timely HABs forecasts. The branch's goal is to develop capabilities to identify, track, and forecast HABs, and to provide that information in a readily understandable form so managers can implement early action to more cost-effectively and efficiently mitigate the impacts/effects of HABs (e.g., changes in water treatment protocols, targeted closures of certain fisheries or shellfish harvests, etc.). Inherent in this effort is attempts to provide timely information on when a bloom will start, how large will it be in biomass and geographic coverage, the potential risk, at what point will it be toxic enough to need mitigation, and when might that intensity abate.

Each forecast effort incorporates the following key components:

- Stakeholder engagement and participation in observations is a critical component of the process in order for NOAA to develop and maintain products that address users needs,
- Scientific engagement with the community involved with the research on the blooms of concern, 3) Maintenance and growth of observations networks, including ever improving satellite surveillance, and utilization and improvement of robust computing platforms,
- Cross-NOAA coordination and engagement with regional decision makers and partners (IOOS, Regional Associations [RAs], non-governmental organizations [NGOs] and academic institutions) who drive product development and implementation, and
- Continued laboratory and field research essential to providing the information improving the forecast products to meet user requirements with the latest scientific advances.

The forecast research to operations work done by the branch proceeds through a defined path of readiness levels (RL). The RLs are defined separately in this briefing book.

Forecasts currently under development by the HAB Forecast Branch.

1. Gulf of Maine (GOM) HAB Forecast (RL7)

GOM is a continental shelf sea that supports productive shellfisheries frequently impacted by bloom of the microalga *Alexandrium catenella*, which produces potent neurotoxins, known as saxitoxins. Over a decade ago, user groups in New England approached Woods Hole Oceanographic Institution and NOAA about developing methods to predict and track these blooms that they agreed to undertake. Because toxic *A. catenella* blooms are only occasionally observable from satellite, the forecasting approach taken was to develop a combined biological and hydrodynamic model for predicting *A. catenella* blooms in the Gulf of Maine. Most of the developmental work was by NOAA-funded partners at Woods Hole Oceanographic Institution and North Carolina State University.

NOAA has recently advanced the forecast by identifying specific hydrodynamic and biological criteria used to evaluate a coupled physical-biological model, and assessed the skill of the GOM *A. catenella* model for evaluation as an operational product. The predictive model currently involves a cyst cruise in the fall to estimate residual cysts concentrations, which initiates the biological component of the model. The hydro-dynamic component of the model has been incorporated into the ROMS Trunk code and has the potential to be used in other areas, such as Puget Sound, Washington, and along the coast of Alaska,

to support improved ESP support of shellfish toxicity forecasts. In the near future, the improved biological model will also transfer to CO-OPS when completed for inclusion in a subsequent ROMS update.

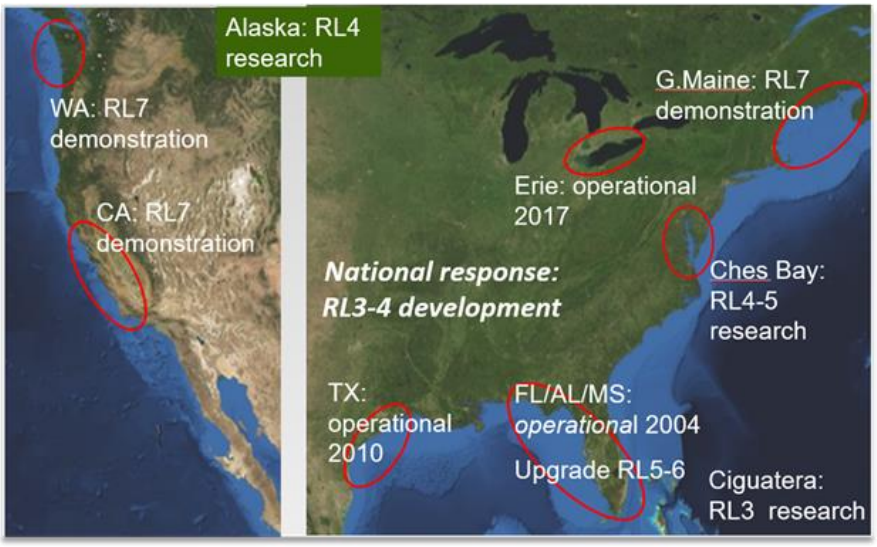


Figure 1. Overview of regional HAB forecast projects and their associated readiness levels. Not shown is the CyAN project, which encompasses the entire continental United States.

Users of the model output include the states of ME, NH, MA; MA Regional Water Authority; commercial shellfish aquaculture and harvesters. Key partners include Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) and the National Weather Service (NWS), which provides critical field measurements. The forecast is being run by NCCOS. A major user group meeting was held at the end of January to solicit input regarding additional ways to improve delivery of the model results and any future needs that can be addressed through coordinated collaboration between stakeholder groups and NCCOS, NERACOOS, and the NWS.

2. Lake Erie Forecast (RL9 Operational)

Lake Erie has been plagued by a steady increase of HABs over the past decade. To address this persistent issue, NCCOS developed a satellite based surveillance system for identifying and tracking the blooms. Weekly bulletins for HABs in Lake Erie were produced as an experimental product starting in 2009, and twice weekly starting in 2014. These forecasts include satellite imagery, models, and analysis with water sample data. NCCOS also produces a forecast of the bloom severity for the year, which is used by local partners to make management, business and recreational decision. In 2017, the Bulletin became an official NOAA product produced by the Center for Operational Oceanographic Products and Services (CO-OPS). The societal and economic benefits include increase drinking water safety, optimization of expenditures by wastewater treatment plants, improved sampling & management decisions, reduced risk of recreational poisoning, better utilization of Lake Erie's economic and recreational resources including improved ecosystem and fisheries management and improved public information/education. Further information is available here.

Identified user groups include states (OH, MI), wastewater treatment plants, Great Lakes Commission, and Lake Erie Collaborative Science and Monitoring Initiative. Partners include Ohio EPA, US EPA, GLERL, GLRI, CO-OPS and NESDIS. Senators Portman and Brown have shown direct interest in the work along with representative Kaptur, Joyce, and Latta.

3. HAB: Florida / Gulf of Mexico Enhancement ("every beach, every day") RL5-6

NCCOS initially began addressing the issue of *Karenia brevis* bloom detection when it developed a satellite-based regional forecast system in 1999. The bulletin production system that was developed by NCCOS became operational within CO-OPS in 2004. NCCOS continued bulletins for Texas until 2010, when that forecast was turned over to CO-OPS for operations. These forecasts have run continuously by CO-OPS since that time. As mentioned, this system does not have the resolution needed for distinguishing which beaches will be impacted on a daily basis. Given this limitation, various stakeholder groups approached NCCOS about developing more effective "every beach every day" respiratory warning system. To address the issues, the HAB forecast group collaborated with Mote Marine Laboratory and the Florida Department of Health to apply for and obtain a NASA funding ($1M) grant to develop a forecast system to predict respiratory exposure for individual beaches in Florida and Texas. The proposed system is designed as follows. Trained citizen scientists and professional life guards collect water samples from various beaches and take live videos of swimming *K. brevi*s cells using IPhone Touch enabled microscope (cost $450.00). The videos are uploaded to a GCCOS website via hotspot and *K. brevis* cell concentrations are estimated using a trained neural network program. Cell counts are combined with local high-resolution wind speed and direction for each beach obtained from the NWS and calculates risk based on wind speed and direction and the cell contractions. Results are currently posted to an experimental website. The system is fully functional except for final testing of the web site. Trained citizen scientists are currently collecting samples during the ongoing *K. brevis* bloom in Florida and trained volunteers are standing by in Texas.

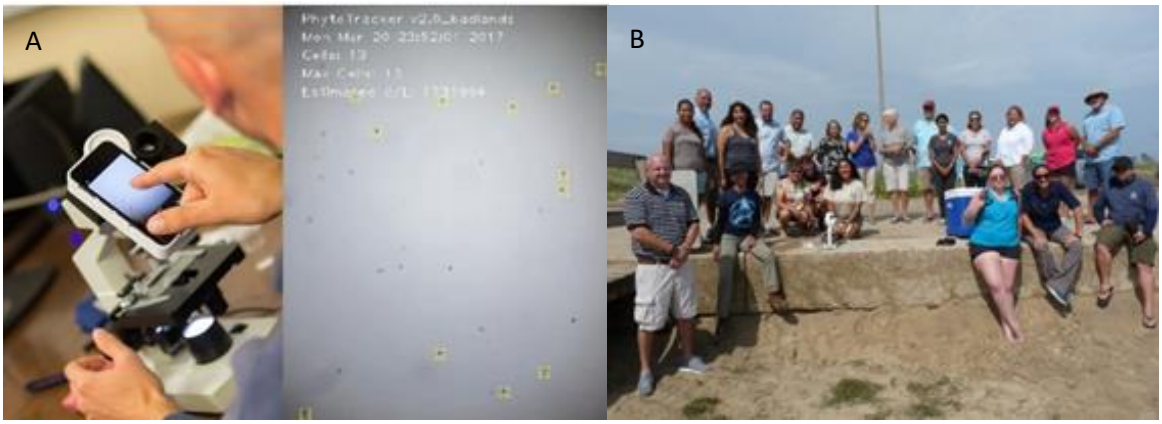


Fig. 2. (A) HabScope system and data analysis program working to count cells. (B) Group "Red Tide Rangers" trained in summer of 2017.

The primary user groups that have been involved in developing this project include local public health and environmental agencies in Florida and Texas as well as the beach business community. Active partners include GCOOS, Mote Marine Lab and its volunteer network, and the Sea Grant Extension agents (Red Tide Rangers, T).

4. Cyanobacteria Assessment Network (CyAN) Project (RL 7-8)

Cyanobacteria can proliferate to become HABs, and are a huge environmental problem across the United States. To address this issue, NOAA, EPA, NASA, and USGS are working together to develop the Cyanobacteria Assessment Network (CyAN), which uses historical and current satellite data to provide an early warning indicator system for HABs in U.S. freshwater and coastal systems. Since the project's

inception in October 2015, CyAN imagery has been used to detect algal blooms in OH, FL, CA, VT, NH, MA, CT, and RI, before traditional monitoring efforts alerted watershed managers. See this link for additional information.

The NCCOS HAB forecasting group is responsible for providing processed satellite imagery, optimizing the detection algorithms and working with the other agencies to ground truth the algorithms to ensure their accuracy. The group is also working actively to incorporate 300 m Ocean Land Color Imaging (OLCI) to improve resolution and assess its use for smaller lakes. The data being generated are already being extensively used by California, Florida, Ohio and Utah. CyAN gives states the ability to respond more quickly than if they were relying on public reports and monthly sampling. It also ensures that *in situ* bloom-response data are representative of recent bloom conditions, allowing them to better target field sampling and more efficiently use their limited resources to determine where posted warnings are needed. Further goals include developing an information dissemination system for expedient public health advisory postings and data synthesis to better understand connections between health, economic, and environmental conditions to cyanobacteria and phytoplankton blooms. The data are currently provided in a format that allows states to customize how the data are displayed. California has produced the most fully integrated CyAN visualization product to date. This product allows monitoring of all the medium and large lakes in California on a daily basis. The current wintertime scenes show relatively few blooms compared to late spring through early fall, when intense blooms develop in numerous lakes.

This project has great potential to make a major management impact in all 50 states. The project has processed data for the entire United Sates for the past decade and is analyzing those data to determine which lakes have been getting worse and what portions of the larger lakes are most impacted. It will also allow analysis of seasonal patterns to determine when blooms are most problematic. These analyses will inform mitigation strategies. The CyAN system will also allow long-term evaluation of whether those mitigation measures have been effective.

5. HAB: California Harmful Algae Regional Model (C-HARM; RL 7)

The model approach for predicting the spatial distribution of HABs in the coastal region of the southern California Current System (CCS) employs a unique blend of numerical models, ecological forecast models of target phytoplankton species (the toxigenic diatom *Pseudo-nitzschia* and its neurotoxin, DA), and improved satellite ocean color imagery. NCCOS has been responsible for providing the improved satellite portion of the model.The initial validation studies of the system indicate the current system does a good job of predicting when and where blooms will occur and is being transitioned to operations within NOAA (CeNCOOS). The model allows for a more rapid response to the onset of a bloom, more effective monitoring, improved public health protecion and timely harvesting closures.

6. Pacific Northwest Early Warning HAB Forecast (RL 7)

Assisted by funding from the NCCOS external grant program, groups such as the Olympia Harmful Algal Bloom Program (ORHAB), Washington and Oregon state natural resources and public health agencies, the Northwest Sciences Fisheries Center (NWFSC) and tribal agencies were able to produce preliminary bulletin warning of *Pseudo-nitzchia* bloom events and evaluated domoic acid levels between 2009 and 2011. Through NCCOS user engagement, this stakeholder group in conjunction with support from the University of Washington Joint Institute for the Study of the Atmosphere and Ocean (UW JISAO) and the

Northwest Association of Networked Ocean Observing Systems (NANOOS), was able to restart the bulletin in 2017. The new system incorporated advances in satellite oceanography developed by NCCOS, more advanced oceanographic modeling, and the latest findings regarding the ecology and toxicity of *Pseudo-nitzchia*. The result of the collaboration was the production of an improved Pacific Northwest HAB Bulletin, which informs managers from Oregon and Washington on the distribution, trends and likelihood of toxicity. It also shows location, risk, and key (oceanographic) risk factors. The efforts of the combined stakeholders to pool resources allowed for more effective toxin monitoring, increased seafood safety and better utilization of valuable shellfish resources. The forecast also allows strategic adjustment of fisheries openings (clam, crab) to "beat" bloom sampling. The HAB Forecast Branch has provided guidance on designing the bulletin products, organizing data to create an effective product, and development of the transition plan.

7. Gulf of Alaska (RL 3)

Alaska is the only location in the US where people still die of paralytic shellfish poisoning (PSP). Despite this threat, little was known about which specie(s) were causing paralytic shellfish poisoning in Alaska or their ecology. The fact that shipping samples for analysis was often impractical led tribal groups in the Aleutian and Kodiak Islands, as well as the Homer region, to request assistance to determine better ways to assess PSP risk. The Ecological Forecast branch determined that this was an important problem and began investigating two different approaches. The first approach was to determine if an ecological based model could be used to predict periods of highest PSP risk. To acquire the information needed for this model we undertook molecular and ecological studies that identified the predominant toxic species present in Alaska (*A. catenella*), clarified the taxonomic confusion regarding names of major *Alexandrium* species and developed species-specific molecular assays that could be used to monitor *A. catenella* cell densities. This foundational work was followed by a five-year collaborative study between NCCOS, Alaska Ocean Observing System and the Kachemak Bay National Estuarine Research Reserve to study the relationship between environmental factors, *Alexandrium* cell densities and shellfish toxicity. Analysis of the data indicated that cell densities and toxicity are controlled primarily by water temperature. The results also showed that annual increases one degree over the mean annual temperature for the past three decades is a good predictor of increased PSP risk. A temperature based model of PSP risk is currently under development and being evaluated. Results were used in formulating a recent study published in PNAS by Gobler et al., modeling how climate change will likely affect HAB blooms in the Northern Atlantic and Pacific. The next step will be to incorporate hydrodynamic factors in addition to temperature related growth model. All shellfish toxicity measurements collected during the study are being provided to the Alaska Harmful Algal Bloom (AHAB) network so that ongoing risk factors can be evaluated. The AHAB network was created with support from the CSCOR external grant program and the EPA.

The second approach was to work toward developing a rapid detection kit that could be used to assay for saxitoxins in local communities. The work was undertaken at the request of the Aleutian Pribilof Islands Association (APIA) and funded by an award from the North Pacific Research Board ($110,000) titled "Implementation of Community Based PSP Testing for Subsistence and Recreational Shellfish Harvesting in Southwestern Alaska". This project was done in collaboration with Alaska Sea Grant, the Alaska Department of Environmental Conservation, and APIA. In addition to developing and testing a new detection technology, the study has provided APAI communities with ongoing STX monitoring results, shown that deploying oyster bags followed by rapid toxin analysis is one of the best ways to

monitor for increased PSP risk, and made possible a collaboration with USGS personnel regarding how to test for the presence of PSP in birds collected after unusual mortality events. The study is also examining how different shellfish processing techniques affect the risk of PSP poisoning.

7. Ciguatera in Gulf of Mexico and Caribbean (RL 3)

Concerns regarding ciguatera fish poisoning (CFP) led managers at the Gulf and Caribbean Fisheries Institute, the Jamaican Ministry of Health and Environmental management division of Trinidad and Tobago approached our branch with requests for a better way to assess CFP risk. In addition, a previous survey by NCCOS of 32 territories and countries in the Caribbean and Gulf of Mexico regions indicated numerous locations where CFP was of concern. Branch staff deemed this an important HAB issue and undertook two different approaches to address the issue. The first approach was to investigate the basic biology of the organisms to determine if an ecological based risk assessment model was possible, work that was supported by an award from the NCCOS Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) program.

When this work was initiated, virtually nothing was known about the taxonomy, ecology and physiology of the *Gambierdiscus* and *Fukyoa* species. Consequently, a series of ecological and laboratory studies were undertaken to identify the *Gambierdiscus* species and related species in the Caribbean and elsewhere; determine the physiological response of those species to temperature, salinity and light; determine the toxicity of individual species; develop improved sampling methodology for these benthic dinoflagellate species; examine the habitat requirement of each species; developed qPCR methods for unambiguously identifying species abundances and distribution; and develop models that predict how climate change over the next century will likely alter the distribution of ciguatera causing microalgae and predict the regions where CFP is most likely to occur (Kibler et al. 2015, 2017). The latter model does a good job of predicting broad patterns of CFP occurrence and will be vetted with user groups to determine if efforts to combine the results with habitat are warranted.

The other approach was to develop an improved method for measuring ciguatoxins in fish. To address this need, NCCOS staff collaborated with University of North Carolina at Wilmington, SeaTox Research Inc., the FDA, North Carolina State University, and Institut Louis Malardé in French Polynesia to develop a rapid screening method to measure ciguatoxin concentrations in fish. The only other rapid method commonly used to measure ciguatoxins employs a radioactively labeled component that limits its use to laboratories with the required radioactive licenses. In contrast, the new assay uses a fluorescent detection method, requires no special licenses, is more cost effective, and allows high sample throughput. As a result, the assay makes it easier to expand ciguatoxin testing of commercially harvested fish. The assay was published and is now commercially available. The method was also applied to assess whether or not invasive contain sufficient ciguatoxins to prevent commercial harvesting as a potential control mechanism.

8. Chesapeake Bay HAB forecast (RL 4-5)

NCCOS is partnering with researchers and managers in VA and MD to begin evaluating different approaches to distinguish these blooms and provide a reporting system that allows them to better direct limited sampling resources to blooms with the highest probability of being a bloom of concern. Initial work has shown that algorithms developed previously by the HAB forecast group may do a good job of identifying cyanobacterial blooms, but that most of the other blooms occur as mixed assemblages

that are difficult to distinguish. As resources allow we are conducting laboratory and field experiments to determine if there are any spectral differences that will distinguish certain non-cyanobacterial species, even in a mixed assemblage. The planned laboratory studies will also investigate how the physiological state of the different algal species may affect their spectra and whether this information may used profitably in better calibrating the satellite imagery.

The other approach that NCCOS will use is a habitat-based approach coupling satellite imagery with real-time ROMS temperature and salinity data for the Chesapeake Bay and known habitat criteria (temperature, salinity, time of year, historical location of occurrence, etc.). The satellite imagery will be used to identify the location of the bloom, and to identify the species present, to the extent possible

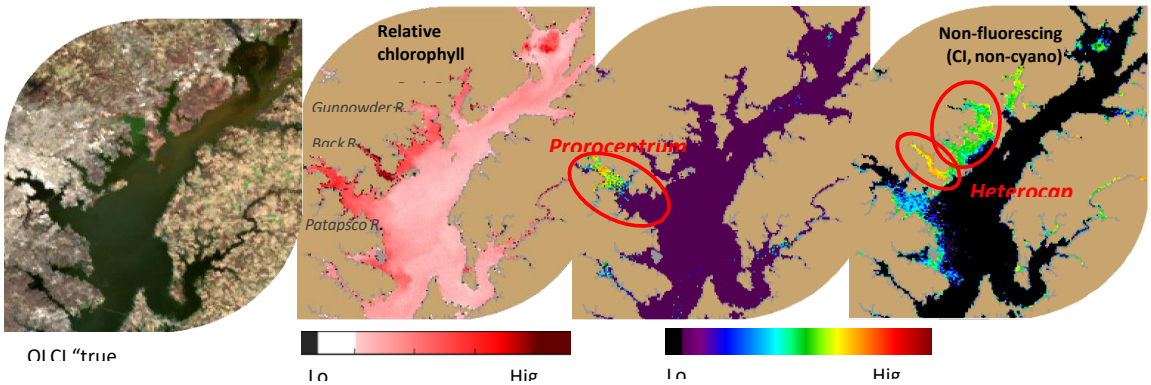


Fig. 3. Figure shows individual OLCI algorithms for HABs in the western tributaries of the Chesapeake Bay, on Dec 20, 2016. Blooms were identified by microscopic examination of samples from each region.

based on spectral characteristics and the prevailing characteristics. The model will be verified by comparing the predictions to the phytoplankton samples collected and identified by MD and VA. If successful, modeling efforts could allow for more effective utilization of sampling resources, and to inform management decisions such as nutrient runoff limits, location of aquaculture facilities, where to post warnings, and informing citizens of areas about favorable water conditions for recreation.

Other projects - Blooms in the Albemarle Sound region of North Carolina RL3

The Albemarle Sound region of NC has been experiencing significant cyanobaterial blooms over the past four years. A citizen-scientist group from, particularly near the town of Edenton, NC, approached NCCOS to determine if they could obtain assistance dealing with the problem. Given that NCCOS was already processing OLCI data for this region, branch members began providing images to local residents who found the images extremely useful in deciding on where to boat and fish. NCCOS staff also held town hall meeting to discuss the images and the local citizen scientist agreed to provide chlorophyll *a* samples to NCCOS that were useful for further evaluating satellite chlorophyll *a* algorithm for this region. In addition, NCCOS collaborated with North Carolina State University and the local citizen scientist network to test a new passive sampling device system to measuring algal toxins. NCCOS' next goal is to work with NC Sea Grant, the NC Water Resources Research Institute, local interest groups and either the Southeast Coastal Ocean Observing Regional Association (SECOORA) or Coastwatch to determine if they are willing to develop and maintain a website that is automatically updated with processed OLCI data as soon as it becomes available. That site would be available to anyone who wishes to check local conditions. This would allow coastal residents to better utilize existing resources.

HAB Monitoring and Reference Branch

Transitioning Toxin Detection Methods to User Laboratories

Primary Contact: tod.leighfield@noaa.gov

NCCOS-led efforts are leveraged through shared expertise and infrastructure with other federal partners (FDA, NIST, CDC, and others) to produce validated methods and materials that are available worldwide. Standardized methods, materials, and training are transferred to user laboratories to conduct their own toxin testing, to ensure accurate and reproducible measurements nationwide. Access to these tools increases the capacity for responding to harmful algal bloom (HABs) events to reduce the impact of algal toxins on local economies, and to help protect human and animal health.

Why We Care

HABs and the toxins they produce have become an increasingly global problem over the past several decades. The threat posed by algal toxins results in negative economic impacts (e.g., reduced aquaculture development, mass mortalities of farmed species, and loss of export income) and public health effects (e.g., contaminated fishery products and local avoidance of seafood by consumers). U.S. states, tribal nations, and developing countries face the challenges of detecting HAB toxins. They need reliable, easy-to-use, and cost-effective detection methods to monitor algal toxins in seafood. Providing transfer and technical support for the implementation of reliable technologies is necessary to address this critical need. Providing technologies falls within NOAA's mission to understand and predict changes in oceans and coasts, and to share this knowledge and information with others.

What We Are Doing

Since 1998, the United Nations' International Atomic Energy Agency (IAEA) has supported us to serve as technical experts worldwide. We transfer and implement the receptor binding assay (RBA) for detecting and measuring algal toxins through training courses, hosting fellowships, and serving as technical experts. In the US, we have worked with state, federal, and tribal groups to implement these methods in U.S. based laboratories, The RBA for paralytic shellfish poisoning toxins has completed rigorous, international interlaboratory validation trials, which has resulted in its acceptance as an official method by the Association of Official Analytical Chemists (AOAC) International and the Interstate Shellfish Sanitation Commission (ISSC).

Benefits of Our Work

Acceptance of this method by regulatory bodies (ISSC) has confirmed the suitability of the RBA for toxin determination to ensure the safety of shellfish products for human consumption in both export and domestic markets. Countries adopting this cost-effective and reliable technology will benefit through increased economic growth and public health protection.

Next Steps

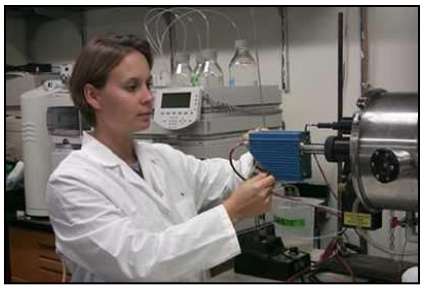
The IAEA and NOAA have a Practical Agreement to continue supporting the transfer of RBA technology to developing countries and provide technical guidance on implementing the assays, and participate in joint efforts to ensure the supply of essential reagents. Domestically we have collaborative research projects with tribal governments (Sitka Tribe of Alaska), state (California, Florida), and federal agencies (FDA, CDC), to further the application of the RBA in other sample types (geoduck clams, human fluids), which will provide safer resource utilization (harvests, export/import) and increase the ability of scientists to respond to future poisoning events.

HAB Monitoring and Reference Branch

National Analytical Response to Harmful Algal Blooms

Primary Contact: maggie.broadwater@noaa.gov

We provide coordinated assistance to coastal managers during HABs and related health incidents. We limit our assistance to small sample sets when states lack these capabilities to ensure accurate, science-based decision-making. NCCOS shares methods, materials, and training with other federal agencies without duplicating other agencies' priorities (e.g. seafood and drinking water testing, human poisoning). We accurately identify HABs and their associated toxins using a two-tiered analysis approach. High-throughput toxin class-specific assays (e.g. receptor, N2A cytotoxicity and ELISA) that rapidly determine toxin activity are followed by confirmation of specific toxin composition using liquid chromatography with tandem mass spectrometry. We then provide customers with formal written reports.



Why We Care

Determining HAB toxins in water, algae, and shellfish provides early warning of events so that coastal managers can make informed decisions regarding public safety. Detecting HAB species and toxins in the field provides data to support improved forecast resolution and document the impacts of HABs on coastal ecosystems. Because HAB toxins affect animal and human health, ecosystem and animal health assessments during hazard response efforts must evaluate HAB toxins as potential cofactors in damage assessments and stranding/mortality investigations. HAB toxin data are included in statistical analyses and models used to investigate impacts of hazards (e.g. oil spill). Without these data, investigators cannot determine whether observed effects are attributable to the hazard of interest.

What We Are Doing

We provide customers with timely and actionable information on HABs and associated toxins to support a risk communication framework, including evaluation of toxins in water, algae, shellfish, marine animal strandings, and health assessments to support:

- NOAA's Phytoplankton Monitoring Network;
- NOAA's Unusual Mortality Event (UME) investigations;
- New and ongoing hazard response efforts (e.g. Natural Resource Damage Assessments).

Benefits of Our Work

Prior to the establishment of NCCOS Analytical Response to HABs, data on the role of HAB toxins in marine animal mortality events were sparse and inconsistent. NCCOS scientists developed standardized procedures to extract toxins from water, algae and animal samples, and validated methods for toxin detection using biological assays and liquid chromatography with tandem mass spectrometry. Consistency of methods and quality assurance of resulting data is essential in hazard impact assessments where results must withstand scientific and legal scrutiny.

Next Steps

We are focusing on advancing analytical methods and reference materials in concert with other federal agencies participating the Interagency Working Group on HABHRCA to support the development of standardized methods and training for testing laboratories and validation of their use to ensure accurate and reproducible measurements of HAB toxins nationwide. We will continue leveraging existing analytical capabilities for event-driven consultation, and support confirmation of HABs and/or toxins during unusual events when states lack capabilities to ensure accurate, science-based decision making.

NOAA
NATIONAL OCEANIC &
ATMOSPHERIC ADMINISTRATION

Certified Reference Materials and HAB Toxins

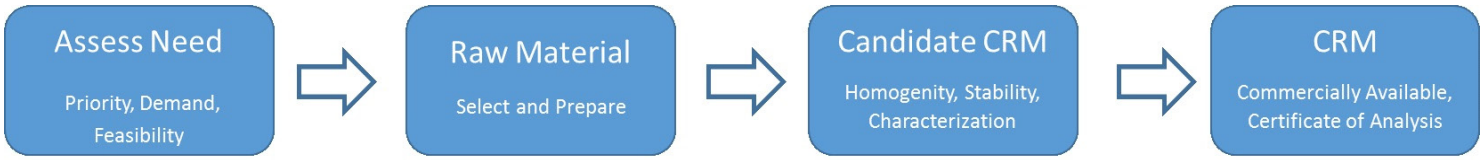
Harmful algal blooms affect a diverse number of states (left to right, top then bottom): KS, CA, WI, OH, OR, ID, UT, FL, WA, IL, ME, NY.

What are Harmful Algal Blooms?

Harmful algal blooms (HABs) result when naturally-occurring freshwater and marine microscopic algae and cyanobacteria in surface waters grow and accumulate to high levels. These organisms produce potent chemical toxins that contaminate air, water, and food; harm humans, domestic animals, and wildlife; degrade the value of marine and freshwater ecosystems; and impact the economic well-being of communities. HAB events are widespread, affecting all U.S. states and territories and are increasing in frequency and severity. Understanding why and when HABs occur, and what makes their effects worse, requires knowledge gained from a range of disciplines including biology, chemistry, environmental science, ecotoxicology, oceanography, meteorology, public health, and economics. A particularly important aspect of this work is the accurate measurement of HAB toxins. Those measurements, however, often are difficult to obtain due to lack of certified reference materials (CRMs) required to quantify the diverse array of toxins produced by HABs.

What are Certified Reference Materials (CRMs)?

CRMs are high-quality analytical standards that are used to ensure the accuracy of scientific measurements made throughout the world. CRMs for chemical analysis, including HAB toxins, are sold as solutions of pure chemicals for calibrating measurement devices and as chemicals in matrix materials for assuring performance in “real world” samples, such as measuring toxins in mussel tissue. Only accredited laboratories can produce CRMs, which come with a certificate that provides a guarantee of the material, its properties, safety information, and a description of its intended use.



The creation of a CRM is a lengthy process, with many technical hurdles that must be overcome before the standard makes it to market.

National Centers for Coastal Ocean Science
National Ocean Service
National Oceanic and Atmospheric Administration

For more information, contact: Michael.Jarvis@noaa.gov
http://coastalscience.noaa.gov
@NOAAcoastalsci

N O A A
NATIONAL OCEANIC &
ATMOSPHERIC ADMINISTRATION

Using CRMs to Communicate Risk

Why are CRMs for HAB toxins important?

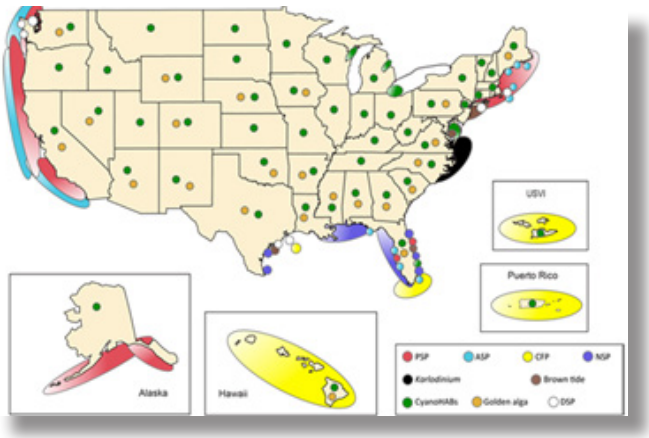
It is important to determine and communicate the risks and economic impacts of HABs as accurately, effectively, and quickly as possible to minimize harm to people, the environment, and communities. CRMs are critical tools used by nearly every branch of science to provide the fundamental understanding required to accomplish this goal. As a specific example, CRMs are needed to demonstrate when drinking water and seafood are safe or unsafe after suspected contamination by HAB toxins occurs. If the amount of a toxin in a drinkable water source is determined to be above a safe level, officials can instruct the public not to drink contaminated tap water. If the water supply used in farming shellfish is contaminated, state officials can restrict their harvest, and protect consumers by keeping contaminated seafood out of markets. However, because cutting off water supplies and creating concerns about seafood safety can have devastating effects on local economies, officials need reliable scientific measurements, which are best when linked to the use of a CRM. Unfortunately, laboratories lack CRMs for several classes of HAB toxins, restricting their ability to provide timely, cost-effective, and reliable monitoring.

What is being done?

While there are a number of CRMs produced by the National Research Council Canada that meet certain needs for U.S. users, many of the other available standards (particularly those that are not CRMs) are of unknown or questionable quality, limiting the usefulness of the materials when highly accurate results are needed, e.g. setting regulatory drinking water limits to ensure public safety.

The major challenge is to identify the gaps where the national need for CRMs are paramount, but high-quality standards are not currently available. Representatives from eight Federal departments and agencies, are assessing the CRMs of greatest need to safeguard communities from emerging and re-emerging HAB problems in the U.S.

A variety of CRMs are produced by the National Research Council Canada.



Generalized view of U.S, with region-specific HAB impacts represented. Note: all U.S. states and territories are impacted by cyanobacterial HABs (green dots). Credit: WHOI

Goals

- Make specific recommendations for CRM acceptance,
- Increase public awareness about CRMs and analytical methods for HAB toxins,
- Foster strategic federal and private partnerships to accelerate CRM development, and
- Further coordinate Federal action and leverage resources for producing critical CRMs.

For more information, please contact:

Caitlin Gould - 240.533.0290 - Caitlin.Gould@noaa.gov

NCCOS supports the achievement of NOAA's coastal missions by providing cutting–edge research, scientific information, and tools that help balance ecological, social, and economic goals.

National Centers for Coastal Ocean Science
National Ocean Service
National Oceanic and Atmospheric Administration

For more information, contact: Michael.Jarvis@noaa.gov
http://coastalscience.noaa.gov
@NOAAcoastalsci

National Phytoplankton Monitoring Network

Primary Contact: steve.morton@noaa.gov

HABs impact the coastal economy an average of $82 million a year. Because every coastal state suffers HABs the problem is too much for any one agency. The National Phytoplankton Monitoring Network collects ecological data at low taxpayer expense at 250 sites in 22 states and territories. This is a true "citizen science" program that combines expertise from NOAA, state and federal agencies, and industry with the energy of volunteers from schools, universities and civic groups.

Why We Care

The National Phytoplankton Monitoring Network (PMN) is a community-based network of volunteers monitoring marine phytoplankton and HABs. PMN recognizes the interrelationships between humans and coastal ecosystems while providing volunteer citizen scientists with meaningful opportunities for hands-on science engagement. The PMN enhances the nation's ability to respond to and manage the growing threat posed by HABs by collecting important data for species composition and distribution in coastal waters and creating working relationships between volunteers and professional marine biotoxin researchers.

What We Are Doing

1. We train volunteer groups through workshops and on-line webinars on how to: collect samples, identify 26 species of phytoplankton using digital microscopy, and report their data using an online database.
2. After we supply the groups with plankton nets, thermometers, and salt refractometers, the groups start collecting and analyzing algae samples either weekly or biweekly.
3. Volunteers preserve their samples and send them to the NCCOS Marine Biotoxins Program for confirmation and potential toxin determination. This is of particular importance when volunteers come across a species they do not recognize.
4. PMN personnel notify state shellfish managers of blooms to serve as an early warning system of potential human health impacts.

Quality assurance and quality control of volunteer results is achieved using digital microscopy by members of the Marine Biotoxins Program. The NOAA Center for Coastal Monitoring and Assessment (CCMA) and NOAA Center for Operational Oceanographic Products and Services (CO-OPS) are notified about any blooms reported by volunteers. This assists the operation and validation of the HAB forecast.

Benefits of Our Work

Since 2001, PMN volunteers have discovered over 225 blooms throughout coastal United States, and have generated over 300,000 observations of environmental conditions. Volunteer data is directly incorporated into the state HAB monitoring plains of Texas, Mississippi, Alabama, Georgia, and South Carolina. HAB managers of other states are notified of potential blooms by PMN staff directly.

Next Steps

PMN will continue creating a sustainable monitoring program using new tools and user-friendly technologies developed under partnerships with smartphone app developers, NOAA's National Centers for Environmental Information web mapping experts and built relationships with Olympus, Gano Technologies and Sea-Gear.

HAB Monitoring and Reference Branch

Robotic, Underwater Sensor for Harmful Algal Bloom Toxins

Primary Contact: greg.doucette@noaa.gov

We developed the technology to provide resource managers and public-health officials with actionable, near-real time data on HAB toxicity, transmitted autonomously from remote, offshore locations. These robotic, underwater sensors provide timely and accurate measurements of HAB toxins associated with bloom events in marine and freshwater systems. Since bloom toxicity can change rapidly and significantly over time, managers and other stakeholders need this information to inform decisions aimed at mitigating adverse health effects on humans and wildlife, and reducing economic impacts on coastal communities.

Why We Care

Cyanobacteria events in the Great Lakes have resulted in "do not drink" advisories being issued by water treatment plants, as well as major social, human health, and economic losses. Providing timely and accurate toxicity measurements to resource managers and public health officials is essential for assessing whether a bloom will contaminate shellfish, threaten human and animal health or drinking water supplies, and impact local economies. These actionable, near-real time data are best provided by autonomous toxin sensors located in the water where and when a bloom event is developing. This information on bloom toxicity enhances the efficiency and effectiveness of monitoring programs and water treatment plants, as well as supporting development and improvement of NOAA's HAB forecasts.

What We Are Doing

We have partnered with the Monterey Bay Aquarium Research Inst., Woods Hole Oceanographic Inst., NMFS/NWFSC, and OAR/GLERL to develop and deploy autonomous, underwater sensors that detect HAB species and toxins, including domoic acid, paralytic shellfish toxins, and microcystins, on the commercial 2nd generation Environmental Sample Processor (2G-ESP) platform. The 2G-ESP enables sample acquisition, processing, and analysis, as well as near-real time data transmission from sub-surface locations off the US coasts and in the Great Lakes.

Benefits of our Work

This technology includes early warnings of increasing toxicity, allowing strategic shellfish harvesting closures/re-openings and application of water treatment protocols, minimizing the risk of human exposure; generation of data streams supporting development of HAB toxicity forecasts that augment NOAA's current biomass-based assessments; improved understanding of environmental drivers of bloom growth and toxicity to improve predictive forecast models/algorithms.

Next Steps

The 2G-ESP's HAB species and toxin detection capabilities are being transitioned onto the payload of an autonomous underwater vehicle (AUV). Deployment of the AUV-mounted 3rd generation ESP (3G-ESP) will provide an unprecedented ability to track HABs in both time and space. Concurrently, it will intelligently and adaptively measure changes in cell concentration and toxicity, along with other environmental factors (e.g., temperature, salinity, nutrients) that may influence bloom development and toxin production. The first end-to-end field trial of the 3G-ESP prototype demonstrating domoic acid detection was completed during 2016 in Monterey Bay, CA, and a similar test deployment for microcystin detection is planned for 2018 in Lake Erie.

Defining Domoic Acid Epileptic Disease

Primary Contact: john.ramsdell@noaa.gov

Domoic acid epileptic disease, a central nervous system disorder caused by the algal toxin domoic acid (DA), first showed up in humans in a 1987 shellfish poisoning in Quebec, Canada. The disease later appeared in California sea lions as a chronic epileptic syndrome following DA poisonings. The sea lion study provided insight into unusual behaviors, brain pathology, and epidemiology. Our experimental model defines the disease and its progressive steps from poisoning to an epileptic state.

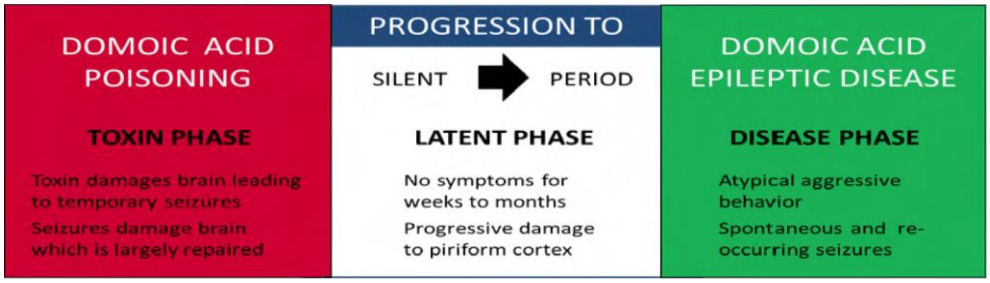
Why We Care

Long-term effects of poisoning by harmful algal bloom toxins concern us. Direct evidence showing epileptic disease develops months after DA poisoning was needed to understand the linkage between short-term DA poisoning and long-term epileptic disease.

We promptly developed a model to demonstrate that DA poisoning weeks to months later lead to epilepsy and aggressive behavior in laboratory rats. Armed with an experimental model, we were ready to investigate what triggers this disease, what is happening during the silent while the disease develops and what type of brain damage causes the epilepsy and aggressive behavior to promote effective treatment of sea lions and establish a basis to understand this disease in humans.

What We Did

We first developed a testable model of disease progression by inducing the disease state in rats, followed the animals' behavior carefully and mapped damage to their brain. We determined that nearly all of this damage is temporary and repaired over several weeks. However, some damage continues and becomes worse in the deep layers of the piriform cortex, a brain area where certain forms of human epilepsy originate.



Animals that showed aggression also had damage to the secondary olfactory cortex, a part of the brain important in social recognition by sense of smell. This additional damage can affect the ability of animals to recognize members of their social group and lead to the type of aggression typically seen in sea lions with DA disease.

Benefits of Our Work

A case definition for domoic acid epileptic disease founded on experimental and clinical findings classifies the first HAB toxin disease state established for animals and humans. Ramsdell and Gulland 2014 Domoic Acid Epileptic Disease. Marine Drugs 12:1185-2007. Supl.Materials

Next Steps

This experimental work has defined an option to treat aggressive animals with a short-acting drug to restore social recognition.

NCCOS Competitive Research Program

Program Overview:

The NCCOS Competitive Research Program (CRP) supports a suite of research programs that provide the critical information and predictive capabilities required to manage the nation's coastal resources in an ecosystem context. CRP identifies national and regional research priority issues on behalf of NCCOS and the National Ocean Service, and addresses these issues via a stressor-based or regional-ecosystem approach. The issues addressed typically require multi-disciplinary research teams and a significant long-term commitment of resources because of their complexity and the effort required to reach a new level of understanding sufficient to drive future coastal management decisions.

Research Strategy:

CRP research priorities are based on Congressional direction, administration priorities, NOAA mandates and strategic plans, and constituent needs. Research projects are selected through competitive, merit-based processes that identify the most qualified teams of scientists in the nation, drawing from academia; governmental agencies; and other research, management, and conservation organizations. Research often is coordinated and leveraged with offices within NOAA and other federal agencies. By strategically targeting research priorities and management, and synthesis of results, CRP produces outcomes that transition to application for improved decision-making on important coastal management issues. In many cases, these outcomes lead to predictive tools, which then serve as prototypes that transition to application within NOAA or to outside management entities.

Center of Excellence:

CRP, previously known as the "Coastal Ocean Program", and later the "Center for Sponsored Coastal Ocean Research", is well respected across NOAA as a center of excellence for planning, managing, and executing competitive research awards. Much of CRP's success is attributable to the comprehensive end-to-end, 3-phase model that the program employs to ensure the highest returns on investment of supported research programs and projects. It maintains its success in the following ways:

Research Prioritization: *To identify the most critical research needs for the CRP portfolio of national and regional based programs*. Efforts focus on leading workshops and conferences involving scientists and managers to develop scientific and stakeholder consensus on regional ecosystem management priorities. They also concentrate on prioritizing and developing new and existing research capabilities through engagement of partners to address identified regional research priorities that most effectively meet management needs.

Program Oversight: *To ensure the proper use of funds for achieving progress towards stated program and project objectives*. Efforts focus on developing program prospectuses, strategic plans, and competitive funding announcements aimed at meeting priority regional research and management needs. Furthermore, they focus on conducting peer review panels to ensure funding for the highest-quality and most cutting-edge scientific ideas with management applications. This also includes conducting project oversight, and providing guidance to develop necessary links with management agencies and other stakeholders throughout projects, ensuring scientific advancement towards management applications.

Synthesis and Transition to Application: *To ensure that research results and tools are used by stakeholders to achieve societal benefits*. Efforts focus on leading national and regional coordination, planning, and implementation efforts to ensure that research findings, publications, and tools are used to inform coastal ecosystem management and that they result in management outcomes. This also includes engaging potential users of research products and outcomes, to ensure the delivery and transition to management applications.

Research Focal Areas (Ecosystem Stressors Research):

CRP addresses the major stressors affecting the nation's coastal resources, including nutrient and other types of pollution, hypoxia, harmful algal blooms, climate change, invasive species, sea level rise, ocean acidification, and the combined effects of several stressors. Outcomes of this research follow two tracks to real-world application that improve coastal resource management: through the development of ready to use products, such as sensors, models, and other tools and information that can be used by coastal managers; and via CRP's Regional Ecosystem Research projects.

Research Focal Areas (Regional Ecosystem Research):

CRP Regional Ecosystem Research addresses priorities in a regional context for the major coastal ecosystems of concern to NOAA, including coastal estuaries, national marine sanctuaries, coral reefs, the coastal ocean, and Great Lakes. This type of research is multidisciplinary and considers the major components of the regional ecosystem, including human dimensions, with a focus on the identified threats to the health of the ecosystem and the information needed to manage them. Its products primarily target ecological forecasts. Forecasts can include long-term scenarios of alternative management options or short-term forecasts of ecosystem condition for more limited issues and immediate response. The long-term scenarios are important for a scientifically informed ecosystem approach to management. Short-term forecasts are particularly useful in mitigating the impacts of recurring threats such as harmful algal blooms. Forecasts are typically developed with the assistance of prior research and monitoring programs, including CRP's Ecosystem Stressors Research programs and other centers within NCCOS, as well as other non-NCCOS research programs. Similarly, transitioning ecological forecasts to application requires close coordination with those using or operating the forecasts in the future.

Competitive Research Program Outreach

HABs

U.S. National Office for HABs provides critical coordination and technical support capabilities that enhance the nation's ability to respond to and manage the growing threat posed by HABs. These include:

- Informational web pages
- Current events Facebook page
- Support for National HAB Committee
- Administration of CRP Event Response Program
- Support for national and international HAB meetings, including student/post-doc/manager travel administration
- Other tasks that change from year to year: workshops, report publication

Biannual HABs Symposium Sponsorship

- US HAB Symposium HAB meeting—every 2-3 years since 2000
    - Meeting support—funding and assistance with planning
    - Student/post-doc/manager travel support
    - Website (except 2017) through National Office
    - Participate in program steering committee

Biannual International HAB Meeting

- Student/post-doc travel support

Gordon Research Seminar on Mycotoxins and Phycotoxins—meeting for graduate students and experts in the field for two days before the Gordon Conference on Mycotoxins and Phycotoxins (every 2 years)

- Support for the seminar

Outreach to shellfish managers and industry

- All PCMHAB and MERHAB projects are required to have outreach plans; NCCOS performs separate outreach through ECOHAB and event response projects
- Participate in Interstate Shellfish Sanitation Conference
    - Serve as NOAA representatives or advisors on Laboratory and Biotoxins Committees
    - Chaired a sub-committee of the Laboratory Committee that developed ISSC Priorities to Improve Shellfish Monitoring for Harmful Algal Bloom Toxins
    - NOAA representative on Task Force I
- Enhanced interaction with shellfish growers and harvesters associations raising awareness about advances in HAB science, highlighted HAB monitoring and early warning projects, technologies and plans for forecasting capabilities that benefit shellfish growers:
    - Interstate (Virginia, North Carolina, Maryland, New Jersey, and Delaware) Shellfish Seminar, 2014
    - East Coast Shellfish Growers Association—multiple interactions, including organized a HAB session at Northeast Aquaculture Conference & Exposition, and spoke to industry and regulators at the Northeast Shellfish & Sanitation Association Annual Meeting in 2017.
    - Pacific Coast Shellfish Growers Association—multiple interactions, including organizing a special HAB session and panel for growers at 71st Annual Pacific Coast Shellfish Growers Association Meeting in 2017.

Training

- Many PCMHAB and MERHAB projects have training as an integral part
- MERHAB Training course on the identification of Harmful Algae in United States marine waters
    - Participant costs, primarily managers, funded by MERHAB 2016, 2017, 2018, maybe 2019
    - Intent is to transition it to being self-supporting
- Funded Alaska PSP Workshop 2013

International Participation

- IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB)
    - CSCOR/CPR serves as NOAA representative at biannual meetings.
    - Chaired NOAA 2013, 2015. Led effort to develop ciguatera strategy.

Hypoxia

U.S. National Office for Hypoxia provides critical coordination and technical support capabilities that enhance the nation's ability to respond to and manage the growing threat posed by hypoxia. Housed at the Northern Gulf Institute (NGI), the office is a nexus for coordination of a network of hypoxia researchers, managers, and stakeholders directed at improving communication and advancing hypoxia mitigation through four target areas.

- Technical assistance to support scientific and research efforts related to hypoxia forecasting, modeling, and assessments, social and economic impacts, and impacts on marine resources;
- Observations and monitoring in hypoxic regions of the Gulf of Mexico, in support of NOAA's mission and goals and associated with NOAA's commitments to the Hypoxia Task Force.
- Coordinating hypoxia-related efforts in the Gulf of Mexico. Primary focus is on workshops promoting research exchange between Gulf hypoxia researchers, managers, and stakeholders.
    - 2010: 1st Annual NOAA/NGI Hypoxia Research Coordination Workshop: *Workshop to Coordinate Gulf of Mexico Hypoxic Zone Research:* - outputs:
        - FY10 Hypoxia Impacts on Fisheries Report;
        - FY10 Hypoxic Zone Monitoring Coordination Plan and Report;
        - Gulf Hypoxia Communications Plan.
    - 2011: 2nd Annual NOAA/NGI Hypoxia Research Coordination Workshop: *Coordination of Monitoring and Modeling Efforts* - output:
        - FY11 Hypoxia Monitoring Matrix
    - 2012: 3rd Annual NOAA/NGI Hypoxia Research Coordination Workshop: Purpose was to provide the Gulf Hypoxia Task Force with state-of-knowledge and information gaps on biogeochemical processes and living resource impacts to inform the next science reassessment of the 2008 Gulf of Mexico Action Plan - outputs:
        - Synthesis Report on Gulf of Mexico Hypoxia Impacts on Living Resources, and
        - Synthesis Report on Gulf of Mexico Biogeochemical Processing
        - Actions 5 and 9 of "Hypoxia task Force Reassessment 2013: Assessing Progress Made Since 2008"
    - 2013: 4th Annual NOAA/NGI Hypoxia Research Coordination Workshop: *Forum for Gulf of Mexico Hypoxia Research Coordination and Advancement*, includes:
      - *Gulf Hypoxia Glider Application Meeting* – output:
        - Glider Implementation Plan for Hypoxia Monitoring in the Gulf of Mexico
      - *Gulf Hypoxia Modeling Technical Review Meeting* – output:

        - Modeling Approaches for Scenario Forecasts of Gulf of Mexico Hypoxia
    - 2014: 5th Annual NOAA/NGI Hypoxia Research Coordination Workshop: *Advancing Ecological Modeling for Diversions and Hypoxia in the Northern Gulf of Mexico* – outputs:
        - Management Needs White Paper
        - Ecological Modeling Matrix
        - Proceedings paper: Advancing ecosystem modeling of hypoxia and diversion effects on fisheries in the Northern Gulf of Mexico (Ashby et al. 2015)
    - 2016: 6th Annual NOAA/NGI Hypoxia Research Coordination Workshop: *Establishing a Cooperative Hypoxic Zone Monitoring Program* – outputs:
        - Proceedings paper: Building a Cooperative Monitoring Program for Gulf of Mexico Hypoxia and Interrelated Issues;
        - Formation of eight Monitoring Workgroups to develop Cooperative Monitoring Program: Fisheries; the states of Louisiana, Mississippi/Alabama, and Texas; Autonomous Vehicles; Hypoxia Task Force; Oil/Gas and Ocean Acidification; and Gulf Restoration.
    - 2018: 7th Annual NOAA/NGI Hypoxia Research Coordination Workshop: *Building the Cooperative Hypoxia Assessment and Monitoring Program (CHAMP)* – outputs (in progress):
        - A workshop report identifying current monitoring components and key actions for obtaining longer-term support and demonstrating importance of new monitoring components;
        - Updated monitoring matrix highlighting key components of the CHAMP program;
        - Outreach plan and a suite of outreach documents to promote the importance of the CHAMP program to various stakeholder groups.
    - 2018 – Fisheries Monitoring Workgroup Workshop scheduled for May 15-16, 2018.

Outreach to Gulf Hypoxia Task Force (HTF):

- CRP personnel represent NOAA on the HTF Coordinating Committee
- Based on modeling and monitoring results from CRP-supported research, staff provide presentations annually at HTF meetings on hypoxic zone conditions/dynamics in a given year and its controlling factors, the long-term trends and assessment of HTF progress toward the Coastal Goal to mitigate hypoxia, and modeling guidance on goal-setting including nutrient reduction targets.
- Since the HTF was first established, CRP personnel have contributed substantially to HTF Congressional (HABHRCA-mandated) reports, annual operating plans, annual progress reports, and action plans (2001, 2008).
- CRP personnel lead the development of annual NOAA press releases announcing the seasonal hypoxic zone forecast and observed size, which are picked up by a large number of media outlets, drawing public and stakeholder attention to the issue – e.g. 2017 Dead Zone forecast press release and measured size press release.

Summary 2012-2017
Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Program

History

- Established 1997, guided by *ECOHAB Report*[1]
- Authorized 1998-present by the Harmful Algal Bloom Hypoxia Research and Control Act
- Interagency from 1998 to present
- Regional rotation 2010 to 2015; otherwise, national competitions

ECOHAB Program Goals

1) Quantitative understanding of HABs and, where applicable, their toxins in relation to the surrounding environment with the intent of developing new information and tools, predictive models and forecasts, and prevention strategies to aid managers in coastal environments.
2) Understanding leading to models of trophic transfer of toxins, knowledge of biosynthesis and metabolism of toxins, and assessments of impacts of toxins on higher trophic levels.

Priority Objectives/Topics

1) Understanding the factors controlling HAB growth and toxicity by focusing on HAB genetics, physiology, and toxin production;
2) Understanding community ecology and ecosystem dynamics, including top-down and bottom-up control of HABs;
3) Delineating the biosynthetic pathways and metabolism of toxins;
4) Determining the trophic transfer of toxins within food webs and the impacts of toxins on individual organisms and food webs;
5) Determining the effects of environmental changes, such as eutrophication, ocean acidification and/or climate change, on HABs and their impacts.

Examples of ECOHAB Accomplishments (in collaboration with other extra- and intramural HAB programs in NOAA and other agencies)

HAB predictive models in various stages of development and transition:

- *Alexandrium* Gulf of Maine
- *Pseudo-nitzschia* California
- *Pseudo-nitzschia* Washington Coast
- *Alexandrium* Puget Sound
- *Karenia* Texas
- *Karenia* Florida
- *Procentrum* & *Karlodinium* Chesapeake Bay
- *Microcystis* toxins Lake Erie
- Ciguatera Greater Caribbean

[1] Anderson, D.M. 1995. ECOHAB, the Ecology and Oceanography of Harmful Algal Blooms. Woods Hole, MA: Woods Hole Oceanographic Institution. http://www.whoi.edu/fileserver.do?id=24158&pt=10&p=19132

Major Accomplishments

- Developed ecogenomics approach for assessing causes of HABs and applied to Long Island brown tide
- Developed shipboard screening dockside testing method for paralytic shellfish toxins in clams on Georges Bank—opened up lucrative fishery in federal waters; now being applied in other regions
- Responded to 2015 West Coast HAB-resulted in Congressional briefings and advice to state legislators and regulators to minimize impacts to fisheries
- Developed method of treating brevetoxicosis in endangered sea turtles
- Determined that nutrients driving *Karenia* blooms on West Florida shelf are not directly derived from land-based sources, but rather a variety of natural sources
- Developed transport models to track and predict *Karenia* blooms on West Florida shelf that proved instrumental in tracking and predicting movement of oil from Deep Water Horizon spill
- Coupled physical-biological models to predict *Pseudo-nitzschia* blooms on the Washington coast that are now being used to predict hypoxia and ocean acidification

ECOHAB Publications

2012-2017— 216 publications in a 5-year period, including 3 special issues of journals on regional ECOHAB projects.

Table 1. ECOHAB project list 2012-2017

Recipients	PIs	Other Investigators	R/T	Title	Total Funds
WHOI FDA NMFS	Anderson, D., Manning, J., Etheridge, S.	McGillicuddy, D., He, R., Keafer, B., Deeds, J., Manning, J., Etheridge, S, Bricelj, V., Couture, D., Hall, S., Cowie-Haskell, B., Hickey, J., Keafer, B., Martin, J., Pettigrew, N., Pilskaln, C., Thomas, A., Townsend, D., Turner, J., Wallace, D., Whittaker, D.	R	GOMTOX: Dynamics of *Alexandrium fundyense* distributions in the Gulf of Maine: An observational and modeling study of nearshore and offshore shellfish toxicity, vertical toxin flux, and bloom dynamics in a complex shelf sea	$8,989,201
FWRI	Heil, C.		R	*Karenia* nutrient dynamics in the Eastern Gulf of Mexico	$4,730,070
UW UCSC	Hickey, B., Kudela, R.	Lessard, E., MacCready, P., Banas, N., Foreman, M., Thomson, R., Masson, D.	R	PNWTOX--The Columbia River plume and the HABs in the Pacific Northwest: bioreactor, barrier or conduit?	$2,792,110
TAMU WHOI CCMA	Campbell, L., Olson, R., Stumpf, R.	Hetland, R., Sosik, H.	T	Mechanism of harmful algal bloom initiation in the western Gulf of Mexico	$978,703
NWFSC	Lefebvre, K.	Myers, M., Farin, F., Bammier, T., Beyer, R.	T	Effects of chronic HAB toxin exposure on gene expression in the vertebrate CNS	$349,434
Stony Brook	Dyhrman, S.	Gobler, C.	T	Linking biogeochemistry to Harmful Algal Bloom nutritional physiology with gene expression analyses: a case study with *Aureococcus anaphagefferens*	$488,414
WHOI	Anderson, D.	McGillicuddy, D., Pilskaln, C., Signell, R., Butman, B., Solow, A.	T	Deposition and resuspension of *Alexandrium fundyense* resting cysts in the Gulf of Maine; Phase II	$494,568
U ME	Karp-Boss, L.	Townsend, D.	T	Bloom dynamics of *Alexandrium*: the roles of resource competition and allelopathy	$593,101
UT	Erdner, D.		T	Causes and consequences of cell death in the toxic dinoflagellate *Alexandrium tamarense*	$373,627
NWFSC SFSU UME	Trainer, V., Cochlan, W., Wells, M.	Trick, C.. Miles, C., Rensel, J., Bright, K.	T	The ecophysiology and toxicity of *Heterosigma akashiwo* in Puget Sound: a living laboratory ecosystem approach	$815,303
NWFSC WHOI UW	Moore, S., Anderson, D., Slathe, E.		T	Modeling favorable habitat areas for *Alexandrium catenella* in Puget Sound and evaluating the effect of climate change	$1,005,911

Recipients	PIs	Other Investigators	R/T	Title	Total Funds
Stony Brook	Gobler, C.	Ammerman, J., O'Neill, C.		Establishing the sources of phosphorus promoting toxic cyanobacteria blooms in the US Great Lakes using gene expression assays	$460,516
FAU Mote FWRI	Milton, S., Walsh, C., Flewelling, L.	Bossart, G., Fauquier, D.	T	Brevetoxin metabolism and physiology - a freshwater model of morbidity in endangered sea turtles	$645,003
UCSC MLML MBARI UCLA USC SCCWRP CCEHBR	Kudela, R., Smith, G., Scholin, C., Chao, Y., Caron, D., Howard, M., Doucette, G.	Anderson, C., Jones, B., Sukhatme, G. ,Ryan, J., Birch, J., Rajan, K., Kerkering, H.	R	A regional comparison of upwelling and coastal land use patterns on the development of HAB Hotspots along the California coast	$4,076,929
FGCU WHOI UTMSI U VI USAL(DISL)	Parson, M., Anderson, D., Erdner, D., Kiene, R., Smith, T.	Richlen, M., Okolodkov, Y., Robertson, A.	R	CIGUAHAB: Ciguatera investigations in the Greater Caribbean Region: ecophysiology, population connectivity, forecasting, and toxigenesis	$4,015,370
CCFHR NCSU	Litaker, W., Shea, D.	Tester, P.	T	Species and Strain Differences in the Toxicity of Caribbean *Gambierdiscus* species: implications for ciguatera fish poisoning in the Caribbean	$255,458
U DE	Warner, M.	Coyne, K., Cohen, J., Miller, K.	T	Climate change impacts on the physiology and trophic dynamics of harmful algal species from Delaware's inland bays	$614,598
Stony Brook Columbia Cornell	Gobler, C., Dyhrman, S., Bunting-Howarth, K.		T	Resolving the effects of resource availability, predation and competition on brown tide dynamics using metatranscriptomics	$686,635
UNC U MD	Parrow, M., Place, A	Place, A.	T	Integrating cell and toxin cycles *of Karlodinium veneficum* with key environmental regulators: in situ studies of predictive determinants for bloom toxicity	$385,225
WHOI NCSU U ME	Anderson, D., He, R., Townsend, D.	McGillicuddy, D., Keafer, B., Deeds, J., Manning, J., Thomas, A., Turner, J, Stumpf, R., Martin, J.	T	Interannual variability of PSP toxicity in eastern Maine: testing the leaky gyre hypothesis and improving regional forecasts	$899,998

Recipients	PIs	Other Investigators	R/T	Title	Total Funds
U AK	Eckert, G.	Tobin, E., Whitehead, C., Sullivan, K.	T	Uncovering the mechanisms behind wintertime occurrences of paralytic shellfish toxicity in geoduck clam fisheries in Southeast Alaska	$247,054
VIMS	Reece, K.	Carnegie, R., Reay, W., Smith, J., Vogelbein, W., Small, H.	T	Toxicity and potential food-web impacts of *Alexandrium monilatum* and its toxins	$250,000
U MD	Li, M.	Glibert, P.	T	Development of a mechanistic ROMS-RCA-HAB model for predicting *Prorocentrum minimum* and *Karlodinium veneficum* blooms in Chesapeake Bay	$165,798
VIMS	Smith, J.	Campbell, L., Gobler, C., Trainer, V., Deeds, J.	T	Cross-regional comparison of *Dinophysis* bloom dynamics, drivers, and toxicity	$249,472
UCSC	Sison-Magnus, M.	Crews, P., Lee, J.	T	Investigating domoic acid biosynthesis and toxic bloom formation through *Pseudo-nitzschia* – marine bacteria interactions	$129,999
FGCU	Parson, M.	Robertson, A., Anderson, D., Richlen, M., Smith, T.	T	CIGUATOX: A study of *Gambierdiscus* "super bugs" and ciguatoxin fate in coral reef food webs	$249,916
OSU	Chaffin, J.	Verhame, E., Bratton, J., Davis, T., Auer, M., Xue, P., Bridgeman, T., Westrick, J.	T	Linking process models and field experiments to forecast algal bloom toxicity in Lake Erie	$248,413

ECOHAB: GOMTOX: Dynamics of *Alexandrium fundyense* Distributions in the Gulf of Maine: An Observational and Modeling Study

Program Manager: Quay Dortch

Project Period: 2006-2012 (no cost extension through 2014)

Project Funding: $8,989,201

Participants: The project was led by D. Anderson, Woods Hole Oceanographic Institution. Co-PIs: D. McGillicuddy and B. Keafer, Woods Hole Oceanographic Institution; R. He, North Carolina State University; V.M. Bricelj, Rutgers University; S. DeGrasse, J. Deeds, and S. Hall, U.S. FDA; B. Cowie-Haskell NOAA Marine Sanctuaries Division; J.P. Manning, NOAA NMFS; J. Martin, Canadian Department of Fisheries and Oceans; D. Townsend, N. Pettigrew, A. Thomas, University of Maine Orono; C. Pilskaln and J. Turner, University of Massachusetts Dartmouth. Associate investigators: D. Couture, Resource Access International, LLC; J.M. Hickey and D. Whittaker, Massachusetts Division of Marine Fisheries; and D.H. Wallace, North Atlantic Clam Association.

Summary: Extensive shellfish resources in the Gulf of Maine are frequently contaminated with toxins produced by the red tide dinoflagellate *Alexandrium fundyense*, leading to shellfish closures. To minimize economic disruption, this project developed models to predict toxic blooms and understand the transfer of toxins to shellfish in order to provide early warning. Protocols were developed for safe shellfish harvesting in areas too remote for routine monitoring.

Rationale: The objectives of this ECOHAB project were to establish a comprehensive regional-scale understanding of the factors influencing *A. fundyense* growth, the movement of cells and toxins around the Gulf and between the surface and the bottom, and their relationship to shellfish toxicity. By developing models to predict blooms and shellfish toxicity, both nearshore and offshore harvesting closures can be reduced, minimizing impacts to public health and coastal economies.

What was done: GOMTOX utilized a combination of large-scale oceanographic cruises, moored instruments and sediment traps, drifters, and satellite imagery to:

- Investigate *A. fundyense* bloom dynamics per environmental and oceanographic conditions;
- Determine the pathways by which toxins are transferred from *A. fundyense* to shellfish in nearshore and offshore Gulf of Maine and southern New England shelf waters;
- Assess interannual to interdecadal variability in *A. fundyense* cell and cyst abundance, PSP toxicity, and shellfish harvesting closures;
- Incorporate field observations results from this study, and those that preceded it, into a suite of numerical models for hind casting and forecasting applications; and
- Synthesize and disseminate the information and technology widely, emphasizing the need to transition scientific and management tools to the management community for operational use.

Benefits: The project produced a comprehensive understanding of the causes of *A. fundyense* blooms and the associated toxicity of nearshore and offshore shellfish across this highly complex region. Important hydrographic pathways and branch points have been identified, and key features and processes characterized. Conceptual models have been formulated to explain blooms and toxicity throughout the region, and sophisticated numerical models have been developed and tested that

simulate physical, chemical, and biological processes at a highly detailed level over the region. A major breakthrough was that the abundance of seed-like cysts, deposited on the ocean bottom by the fall of one year, along with ocean conditions the next spring, determines the severity of the outbreak during the next bloom season.

Since 2008, the model has been used to issue Gulf of Maine HAB seasonal outlooks. In addition, weekly forecasts of bloom intensity and location are provided to state shellfish managers. A PCMHAB project was funded to transfer of the model to the NOAA HAB Operational Forecasting System (HAB-OFS). At present, the model is being run as a pilot in NCCOS. Another pilot study for an onboard screening/dockside testing protocol was conducted as part of this project in order to facilitate safe harvesting of shellfish from federal waters on Georges Bank, where shellfish are sometimes contaminated with high levels of PSP toxins. Ultimately, this led to NOAA's National Marine Fisheries Service reopening a portion of federal waters closed to shellfish harvesting.

Metabolism and Physiology of Red Tide Toxins in Turtles

Program Manager: Quay Dortch
Project Period: 2011-2014 (no cost extension through 2016)
Project Funding: $563,615
Participants: S. Milton, Florida Atlantic University, Department of Biological Sciences. Project partners include L. Flewelling, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute; C. Walsh and D. Fauquier of Mote Marine Laboratory; and G. Bossart, Georgia Aquarium and Harbor Branch Oceanographic Institute.

Summary: Endangered sea turtles experience severe mortality during Florida red tides. This project used non-endangered freshwater turtles as a model animal to determine the effects of Florida red tide on endangered sea turtles. Researchers identified how red tide toxin gets into turtles, how long it stays, and the impacts on specific organs and the immune system, leading to new treatment methods for stranded turtles.

Rationale: *Karenia brevis*, the "Florida red tide" organism frequently blooms in some areas of the Gulf of Mexico and produces a suite of neurotoxins (called brevetoxins). The toxins cause human respiratory illness along beaches and accumulate in shellfish, which, when consumed by humans, cause Neurotoxic Shellfish Poisoning. Severe blooms result in mass mortality of fish and a number of protected and endangered species. Among the species impacted are threatened and endangered marine turtles. For example, in the severe Florida red tides of 2005 and 2006 at least 179 loggerhead sea turtles died, but other species may be impacted as well, including leatherback, green, hawksbill, and Kemp's Ridley sea turtles. Many turtles also strand on beaches and are taken to facilities for rehabilitation where some recover and are released back into the wild.

Understanding the risk of brevetoxin exposure to sea turtle health is critical as such impacts may affect sea turtle population survival. Even in mammals, toxin pharmacokinetics, residence time, and the pathogenesis of intoxication are unknown, as is the concentration that compromises organ and immune function; this is doubly true in sea turtles, where far less is known about basic physiological functions and where differences in metabolism and physiology may alter these parameters. Due to the nature of study on endangered sea turtles, however, these questions cannot be addressed directly, as they

require experimental investigation with controlled toxin doses. This makes it difficult to establish appropriate treatment methods, which can not be devised in advance.

What was done: In this study, the freshwater turtle *Trachemys scripta* and the diamondback terrapin *Malaclemys* were used as model organisms to characterize the effects of brevetoxins on turtle physiology and immunology. The results of these physiological studies led to development of effective treatment plans for rehabilitating turtles stranded with toxin poisoning (brevitoxicosis). Main objectives were as follows:

1. Determine the uptake, tissue distribution, and excretion of brevetoxin-3 (PbTx-3) in *T. scripta* and *M. terrapin* as model organisms for sea turtle physiology;
2. Determine the impact of brevetoxin on immune function in turtle;
3. Determine the mechanism of action of brevetoxin in neural tissue; and
4. Develop effective treatment plans for sea turtles exposed to brevetoxin, and share these with the veterinary and rehabilitation community.

Benefits: Developing a live animal model that can demonstrate how brevetoxins cause illness and death in freshwater turtles will provide a sound scientific basis for treatment of sea turtles at the numerous rescue facilities that rehabilitate sea turtles in the Gulf Coast state.The researchers found that much higher doses of oral and intra-trachael administered brevetoxin were required for turtles compared to mammals in order to see significant symptoms and address the objectives.

Summary 2012-2018
Monitoring and Event Response for Harmful Algal Blooms (MERHAB) Program

History

- Authorized 1998-present by the Harmful Algal Bloom Hypoxia Research and Control Act
- Initial NCCOS projects enhanced HAB monitoring in Chesapeake Bay (Maryland), St. John's River (Florida), and the Olympic Peninsula (Washington).
- NCCOS develops national MERHAB competitive program to tackle other impacted regions with first MERHAB federal funding opportunity (FFO) in FY2002.
- From 2010 to 2015, FFOs were part of regional rotation of HAB programs; otherwise, the awards given via national competitions.

MERHAB Program Goals

The principal objective of MERHAB is to build the capacities of local, state, and tribal governments, and the private sector, for less costly, and more precise and comprehensive monitoring of HAB cells and toxins, and for responding to HAB events. Improved monitoring and event response capability will be achieved through applications that meet management needs including:

1) Adopting faster, less expensive, and more reliable detection methods for HAB cells and toxins in routine monitoring programs;
2) Adopting instrumentation for low-cost, long-term observations of conditions that influence HAB dynamics;
3) Improving monitoring strategies and forecast models to enhance early warning capability, foster improved response to HAB events, and demonstrate operational capabilities;
4) Enhancing response capabilities to ensure trained and equipped personnel are able to mobilize quickly, conduct appropriate sampling and testing, and communicate effectively during HAB events.

Priority Objectives/Topics

1) Mitigate HAB impacts by incorporating research products into monitoring applications and encouraging their adoption into routine operation.
2) Support validation of HAB applications, comparison to existing technologies, and training needed to effectively utilize and support their adoption.
3) Demonstrate the value of using HAB technologies to increase utility of enhanced monitoring and regional observing system for HAB early warning and forecasting.

Examples of MERHAB Accomplishments (in collaboration with other extra- and intramural HAB programs in NOAA and other agencies)

Demonstrated enhanced HAB monitoring for early warning and supporting forecasts in various stages of transition and examples of successes:

- *Pseudo-nitzschia* and *Alexandrium* California (e.g. 1st IOOS Regional Association HAB monitoring, CalHABMAP)
- *Pseudo-nitzschia* and *Alexandrium* Oregon (e.g. MOCHA, HAB/climate link)
- *Pseudo-nitzschia* and *Alexandrium* Washington Coast (e.g Olympic Region HAB)

- *Karenia* Texas (e.g. resolving colored dissolved organic matter [CDOM] interference to enable satellite detection)
- *Karenia* Florida (e.g. Fish and Willdife Research Institute HAB monitoring)
- Cyanobacteria/toxins in Lower Great Lakes (e.g. 1st regional, multi-state cyanoHAB monitoring project)
- *Procentrum* & *Karlodinium* Chesapeake Bay (e.g. MD DNR Eyes on the Bay program and the Chesapeake Bay ROMS Community Model [ChesROMS])
- *Alexandrium* and *Pseudo-nitzschia* in Gulf of Maine (1st multi-environmental sample processor deployments).

Expanded monitoring for emerging HAB species

- *Dinophysis*, *Azadinium* in Puget Sound
- *Cyanotoxins in estuaries* California

Enhanced national HAB infrastructure

- Sustainable, national HAB training program
- Cyantoxin rapid response lab at SUNY

MERHAB Publications

2012-2017— 153

Table 1. MERHAB project list 2012-2018

Recipients	PIs	Other Investigators	R/T	Title	Total Funds
USC, UCLA, UCSC, SCCWRP	Caron, D.	Jones, B., Sukhatme, G., Estrin, D., Miller, P., Weisberg, S.	R	RAPIDALERT: Rapid Analysis of Pseudo-nitzschia & Domoic Acid, Locating Events in near-Real Time	$2,480,192
OSU, UO, ODFW	Strutton, P.	Wood, M., Peterson, W., Hunter, M.	R	Integrated HAB monitoring and event response for coastal Oregon	$2,300,082
College of Charleston, SC DNR, UD	Greenfield, D.	Coyne, K.	T	Comparative analysis of quantitative detection methods for enumeration of HAB species: Applications for resource management	$672,681
WHOI, UMaine, MBARI	Anderson. D.	McGillicuddy, D., Keafer, B., Townsend, D., Scholin, C.A	R	GOM-ESP: Incorporation of Environmental Sample Processor technology into Gulf of Maine HAB monitoring and management	$5,307,591
Stonybrook, NCCOS, NYDEC	Gobler, C.	Morton, S., Chytalo, K.	T	Monitoring, forecasting, and enhanced response to PSP And DSP events in New York coastal waters	$523,136
UMaine	Connell, L.		T	HAB detection instrument validation and transition to State monitoring program	$574,028
Bigelow	Lomas, M.	Heil, C.	T	Training course on the identification of harmful algae in United Statesmarine waters	$330,819

NWFSC, NCCOS, Jamestown S'Kallum, WA Sea Grant	Trainer, V.	Doucette, G., Harrington, N., Twiner, M., King, T.	T	Clear and present danger: Monitoring and management of lipophilic shellfish toxins in Washington State	$700,525
SCCWRP, USC, UCSC, USGS	Howard, M.	Caron, D., Kudela, R., Loftin, K.	T	Improvement of monitoring tools and development of toxin strategy at the land-sea interface in Coastal California.	$842,125
UW JISAO, NWFSC, ODFW	McCabe R.	Hunter, M., Trainer., V.	T	An early warning system for *Pseudo-nitzschia* HAB's on Pacific Northwest outer-coast beaches	$1,297,336

MERHAB 2005 - RAPDALERT: Rapid Analysis of Pseudo-nitzschia and Domoic Acid, Locating Events in Near-Real Time

Program Manager: Marc Suddleson
Project Period: 2005 – 2010 (no cost extension through 2012)
Project Funding: $2,480,192
Participants: D.A. Caron, B.H. Jones, G.S. Sukhatme, University of Southern California; D. Estrin, University of California Los Angeles; P. Miller, University of California Santa Cruz; S. Weisberg, Southern California Coastal Water Research Project

Summary: This pilot project demonstrated the effectiveness of adding emerging technologies to HAB monitoring programs that focus on toxic blooms of *Pseudo-nitzschia*. Specifically, we improved the detection capabilities of an existing program by enhancing it with a network of *in situ* sensors, remote sensing, and species identification and algal neurotoxin (i.e., domoic acid) quantification methods.

Rationale: In the United States, domoic acid is recognized as a recurring human health issue for Dungeness crab, razor clams, and other shellfish along the U.S. West Coast. A 2016 bloom led to fisheries closures along the West Coast, resulting in millions of dollars in lost revenue. Domoic acid has resulted in poisonings of marine vertebrate populations, including sea lions, dolphins, and sea birds.

What was done: This project developed and implemented a fine-scale HAB sensing and sampling program in coastal waters of southern California (Southern California Bight) to study toxic blooms of microalgae, specifically the diatom *Pseudo-nitzschia*. The project piloted a HAB sampling program that incorporated innovative networking of *in situ* sensors. It advanced understanding of the relationship between *Pseudo-nitzschia* blooms and the coastal oceanography of this highly urbanized region, while piloting an intensive, highly autonomous HAB monitoring program for the southern California coast. Specific accomplishments included:

- Participants and NOAA CRP created the California Harmful Algal Bloom Monitoring and Alert Program (HABMAP)
- PIs incorporated data from existing small-scale sensor networks in King Harbor (Redondo Beach) and Marina Del Rey harbor into the RAPDALERT sensor network to aid in regional responses to potential HAB impacts like fish kills within the highly urbanized harbors of Santa Monica Bay. They collaborated with West Basin Municipal Water District to investigate the potential impact of HABs on seawater desalination operations anticipated within the Southern California region. They also conducted monitoring studies of pilot desalination operations with the Long Beach Water Department, providing HAB early warnings for the region. One component was the deployment of two, large monitoring buoys off the coasts of the cities of Redondo Beach and El Segundo, both within Santa Monica Bay. Data from the buoys was incorporated into the RAPDALERT network.
- PIs performed phytoplankton taxonomic analysis, chlorophyll concentration analyses, and phytoplankton toxin analyses (domoic acid, saxitoxins) in conjunction with partners, as part of the Marine Corps Base Camp Pendleton Nearshore Biological Baseline Assessment, improving overall monitoring coverage within the region. They also collaborated with bird and marine mammal regional rescue centers that deal with bird and mammal stranding and illness during outbreaks.
- RAPDALERT investigators initiated an informal regional working group in the greater Los Angeles region to formulate and test a Regional Oceanic Modeling System to predict HABs, providing biological data to enhance the model. Further, it provided the California Department of Health Services with *Pseudo-nitzschia* abundance information for use in monthly biotoxin publications.

Benefits: The project advanced the development of HAB monitoring, response, and forecasting capabilities in California being considered for NOAA operational support. It piloted pier-based HAB monitoring, which was expanded first to both California regional ocean observing associations, and then statewide via CalHABMAP. Further, it supported additional NOAA NCCOS Competitive and Internal investments. NOAA is moving the California forecasting and monitoring system into operations as part of a national HAB Operational Forecast System.

MERHAB 2016: An Early Warning System for Pseudo-nitzschia HABs on Pacific NW Outer-Coast Beaches

Program Manager: Marc Suddleson
Project Period: 2016 – 2021
Total Funding: $726,330 to date, approved total: $1,377,372
Participants: R. McCabe University of Washington; N. Banas, University of Washington; B. Hickey, University of Washington; M. Hunter, Oregon Dept. of Fish and Wildlife; R. Kudela, University of California Santa Cruz; P. MacCready, University of Washington, V. Trainer (NOAA NWFSC). Partners: Olympic Region Harmful Algal Bloom (ORHAB), Northwest Association of Networked Ocean Observing Systems (NANOOS), Makah Tribe, NOAA NCCOS, IOOS and NOAA Ecological Forecasting Initiative Steering Committee.

Summary: Using predictive models and toxin monitoring data, this project will pilot a monitoring and forecasting system initiating offshore HAB monitoring and utilizing existing HAB monitoring, ocean sensing, model output, and regional assets to generate and distribute forecasts to aid in managing HAB-impacted fisheries.

Rationale: Along the Washington coast, razor clams and Dungeness crabs are particularly likely to accumulate domoic acid. Nearly every year, HABs have some negative impacts on the economies of coastal communities in Washington and Oregon that are dependent on shellfish harvesting for subsistence and tourism revenues, which rely on the thousands of people who travel to the coast to sport harvest clams. Occasionally, as in 2015, a major HAB event forces closures of both razor clam and Dungeness crab seasons, leading to tens of millions of dollars in losses, and sustained regional hardship.

What was done: The project is developing a monitoring- and modeling-based forecast system for *Pseudo-nitzschia* and particulate domoic acid (DA) on beaches from Cape Flattery, Washington, to Heceta Head, Oregon. The project team is using particulate DA in water and razor clams from Washington and Oregon monitoring programs. The team will institute new, low-cost HAB monitoring for offshore HAB "hotspots" at the Juan de Fuca Eddy and Heceta Bank through partnerships with the Makah Tribe, Olympic Region Harmful Algal Bloom (ORHAB) program, and the NOAA Northwest Fisheries Science Center.

The project has also reinstated and improved the spring-to-autumn Pacific Northwest HAB Bulletin, last generated in 2011, to provide managers with summaries of when and where coastal blooms are likely to occur. The new Pacific Northwest HAB Bulletin will incorporate expert analysis and draw on the latest University of Washington LiveOcean forecast model hosted by the Northwest Association of Networked Ocean Observing Systems (NANOOS) and a variety of real-time observations. The project will improve the phytoplankton model embedded in LiveOcean to reduce false positives in forecasts of Pseudo-nitzschia and particulate domoic acid beach events. Finally, researchers will determine the optimal

means for incorporating LiveOcean transport forecasts and hindcasts into the bulletin to understand model skill and error in detail and develop a basis for semi-automation of the bulletin.

Benefits: This project will benefit coastal communities in the Pacific Northwest. Results will lead to improved fisheries regulations and support frequent management decisions to protect public health, seafood supply, and the ocean. Timely forecasts will help to make recreational harvests safer and worry free, and will minimize economic impacts by supporting targeted fishery closures. This project builds on more than a decade of NOAA- and partner-funded research, and will help demonstrate how to routinely generate HAB forecasts valued by the region. Improvements in predictive models and forecast dissemination will also help efforts to tackle other issues such as hypoxia and ocean acidification.

MERHAB 2015: Improving Tools for Monitoring Multiple HAB Toxins at the Land-Sea Interface in Coastal California

Program Manager: Marc Suddleson
Project Period: 2015 - 2019
Total Funding: $433,812 to date, approved total: $884,224
Participants: M. Howard (Southern California Coastal Water Research Project/ SCCWRP), R. Kudela (University of California Santa Cruz), D. Caron (University of Southern California), K. Loftin (U.S. Geological Survey). Partners: N. Chernoff (U.S. EPA), L. Busse (San Diego Regional Water Quality Control Board), S. Fluharty (Yurok Tribe), NOAA Tijuana River Estuary NERR, Newport Estuary Back Bay Science Center.

Summary: The impacts of cyanobacteria toxins are an emerging public health and environmental issue in brackish and marine ecosystems. We are studying the risks associated with the coastal cyanobacteria threat and developing monitoring protocols that will aid in better managing California ecosystems at the land-sea interface.

Rationale: HAB monitoring has generally been water body-dependent, focusing on marine or freshwater toxins, but not both. Cyanobacterial toxins previously were considered a public health issue only for freshwater, with concerns about impacts to drinking and recreational waters, and ecosystem impacts. However, a number of recent studies focused in California coastal waters have shown these toxins can have effects far downstream, creating cause for concern in brackish and marine habitats.

What was done: This project is assessing the extent and predominance of cyanobacteria and their toxins at the land-sea interface, and determining the influence of freshwater inflow and marine inputs on the algal community and toxins along the California coast. Field samples and lab cultures are being used to test and improve the passive toxin sampling device known as Solid Phase Toxin Tracking (SPATT). The team surveyed estuarine and coastal waters at sites from the Klamath estuary in Northern California, to the Tijuana River National Estuarine Research Reserve and several San Diego estuaries in Southern California. At more than 10 sampling locations, the team measured a suite of parameters (total toxin, dissolved toxin, dissolved nutrients, chlorophyll *a*, phytoplankton species/genera identification, temperature, pH, and alkalinity). They also deployed SPATT samplers at most locations.

The field studies will enable the team to recommend which toxins and toxigenic species should be targeting for routine monitoring. Best practice approaches for using SPATT to anticipate toxic events and expand temporal coverage of monitoring programs are also being developed for California monitoring agencies. Other stakeholders directly benefitting are regional ocean observing associations, the Yurok Tribe, the Southern California Coastal Water Research Project, San Diego Regional Water Quality Control Board, water quality managers, the U.S. Geological Survey, and the U.S. Environmental Protection Agency. USGS has also developed a new LC/MS/MS method for examining total and dissolved-phase cyanotoxins and marine algal toxins simultaneously in surface waters compatible with salinities from freshwater to at least 36 PPT.

Benefits: Expanding use of the proven HAB SPATT sampler and developing monitoring strategies will enhance existing HAB monitoring (e.g., California's HABMAP and Cyanobacteria HAB network) in these systems. It will add a HAB component to existing state water quality monitoring programs (e.g., surface water ambient monitoring program) by providing technology to identify algal toxins in areas previously not thought to be threatened. The project also will directly influence California's strategies to manage nutrients and develop water quality criteria for estuarine habitats.

Summary 2012-2017
Prevention, Control, and Mitigation of Harmful Algal Blooms (PCMHAB) Program

History

- Authorized 1998-present via the Harmful Algal Bloom Hypoxia Research and Control Act
- Established 2009, guided by *RDDTT Report*[1]
- Regional rotation, 2010 to 2015
- Focus on biotoxin detection methods, 2017

PCMHAB Program Goals

1) Foster the development, demonstration, and transition of existing and promising prevention, control, and mitigations technologies and strategies to end-users.
2) Assess the societal impacts of HAB events at local scales, and the costs and benefits of mitigation strategies.

Examples of PCMHAB Accomplishments (in collaboration with other extra- and intramural HAB programs in NOAA and other agencies)

- Transitioned Gulf of Maine HAB forecast from Woods Hole Oceanographic Institution/ North Carolina State University to NOAA, where it is being run as a pilot
- ISSC-approved brevetoxin ELISA method for limited use in hard clams, sunray venus clams, and oysters. Allows shellfish aquaculture to remain open during *Karenia* blooms
- Characterized a naturally-occurring algicide that is effective against some dinoflagellates, and which is in testing for its environmental effects prior to field tests.
- Expanded Imaging Flow Cytobot Network in Texas for early warning of *Karenia* and *Dinophysis* blooms. Working to improve image analysis and dashboard and to educate potential users.
- Determined clay flocculation is not effective against cyanobacterial blooms, but barley straw can be effective at small scales.
- Found most microcystin degradation in freshwaters occurs by previously unknown pathways.
- Developing and commercializing a quick test for *Karenia* cells using genetic markers. Same technology commercialized for verifying fish species, as GrouperChek.
- Applied a sociological-ecological framework orientation of HAB research and management to a small lake in the Chesapeake Bay watershed, to illuminate underlying drivers, factors that trigger particular responses or changes, and highlight challenges and opportunities for aligning human and ecosystem processes more effectively through directed interventions.
- Improved Environmental Sample Processor (ESP) functionality, which remotely measures HAB cells and toxins, by increasing robustness and increasing number of samples it can analyze, lowering power requirements. Streamlining manufacturing also decreased costs.

PCMHAB Project Statistics 2012-2017 - 12 projects totaling $7,862,831 in funding

PCMHAB Publications - 2012-2017— 48

[1] Dortch, Q., Anderson, D., Ayres, D., and Glibert, P., editors, 2008. Harmful Algal Bloom Research, Development, Demonstration and Technology Transfer: A National Workshop Report. Woods Hole Oceanographic Institute, Woods Hole, MA. http://www.whoi.edu/fileserver.do?id=43464&pt=10&p=19132

Table 1. PCMHAB project list 2012-2017

Recipient	PI	Other Investigators	Title	Funds
U DE	Coyne, K.	Warner, M.	Characterization of an algicidal agent produced by *Shewanella* sp. IRI-160 and its impact on dinoflagellate physiology and microbial community dynamics	$536,896
U Md	Place, A.	Bowers, H., Sellner, K., Paolisso, M., Michael, B., Wazniak, C.	Mitigating *Microcystis* in the Chesapeake (MMIC)	$870,445
WHOI	Anderson, D.	Ralston, D.	Suppression of *Alexandrium* blooms by resuspension and burial of resting cysts	$564,431
WHOI	McGillicuddy, D.	Anderson, D., He, R.	Implementation of an operational model for prediction of *Alexandrium fundyense* blooms in the Gulf of Maine	$1,798,413
U TN	Wilhelm, S.	Boyer, G.	Biological degradation of microcystins: a first step towards biofilters for high efficiency toxin removal	$703,779
McLane Lab, Inc	Engstrom, I.		ESP development: targeting cost reductions, robustness, and an improved user interface	$752,023
U DE	Coyne, K.	Warner, M., Cohen, J., Target, T.	The dinoflagellate-specific algicide IRI-160: Isolation, characterization and potential impacts on ecologically relevant metazoan species	$739,596
TAMU WHOI	Campbell, L. Sosik, H.		Expanding Harmful Algal Bloom mitigation in the Gulf of Mexico: operational support and training for the Imaging FlowCytobot Network	$838,380
USF	Paul, J.	Hubbard, K.	*Karenia* tricorder: introduction to coastal managers and technology upgrades	$759,068
USF	Weisberg, R.	Hu, C., Liu, Y., Zheng, L., Walsh, J., Hubbard, K.	Seasonal forecasting of *Karenia brevi*s blooms in the eastern Gulf of Mexico	$299,800
FWRI	Flewelling, L.		Integration of alternative methods of analysis into the neurotoxic shellfish poisoning monitoring and management framework	$285,269
Bigelow Lab	Archer, S.	McLeod, J.	Expanding the options for monitoring of DSP by promoting the ISSC approval of LC-MS/MS and two rapid screening approaches	$164,588

PMCHAB: Characterization of an Algicidal Agent Produced by the Bacterium *Shewanella*

Program Manager: Marc Suddleson
Project Period: 2010-2013 (no cost extension through 2014)
Funding: $536,896
Participants: K.J. Coyne and M. Warner, University of Delaware

Summary: A biological control agent isolated from a bacteria species that may provide a mechanism for halting the growth of certain types of toxic dinoflagellate harmful algal blooms. The activity of the algicidal agent and its impact on dinoflagellate physiology was characterized. The effect of the algicide on microbial community structure and function was evaluated to determine which natural bacteria work best.

Rationale: Biological control agents like viruses or bacteria may play a natural role in controlling HABs. Research is needed to find specific compounds from the microbial community that can be adapted to HAB control mechanisms without harming the environment. This work explores a promising control agent from the bacterium *Shewanella* sp. IRI-160.

What Was Done: The investigators characterized the algicidal agent IRI-160AA—produced by the marine bacterium *Shewanella* sp. IRI-160—and examined the effects of this compound on dinoflagellates and non-target species of plankton. The team characterized the mechanism of toxicity on several species of dinoflagellates, and used mixed cultures to study the broader effects of this agent on community composition and function. The investigators tested hypotheses regarding the effect of IRI-60AA on photosynthesis, cell cycle progression, and programmed cell death in target algal species.

Benefits: The results suggest that control of dinoflagellate blooms by *Shewanella* sp. IRI-160 may be a natural phenomenon. Application of the algicidal compound for control of dinoflagellate HABs will likely have the greatest impact in the early stages of a bloom, with minimal impact on the environment. More study is needed to confirm that the compound can be safely used in the environment as a means to control HABs. A follow-up PCMHAB project, "The dinoflagellate-specific algicide IRI-160: isolation, characterization, and potential impacts on ecologically relevant metazoan species", has been funded to take the next steps in developing a HAB control method.

PCMHAB: ESP development: targeting cost reductions, robustness, and an improved user interface

Program Manager: Marc Suddleson
Project Period: 2011-2015 (no cost extension through 2017)
Total Funding: $204,170
Participants: Engstrom, McLane Research Laboratories, Inc. Collaborators: C. Scholin, Monterey Bay Research Aquarium, D.M. Anderson, Woods Hole Oceanographic Institution, and C. Melancon, Spyglass Biosecurity. Transition Advisory Committee of resource managers, engineers, scientists, and other ESP users guided project outcomes.

Summary: The Environmental Sample Processor (ESP) is one of the first-available, in-water sensors to measure HABs, their toxins, and other parameters in near real-time and transmit data to shore. While it has been proven for multiple sensing applications and is recognized for its promise in advancing ocean observing and forecasting design, there were necessary improvements to encourage wider use.

Rationale: New, automated, in-water biological sensors nearing or just entering the market promise an unprecedented capability to deliver accurate, reliable, and cost effective early warnings and forecasts of HABs. Public-private partnerships continue to be critical to speeding sensors into widespread use by operational ocean observing and forecasting systems. NOAA recognizes that ESPs meet mission critical needs for operational HAB forecasting and observing systems currently in development. NOAA has invested in refining ESP deployment strategies, designing optimal ESP networks, and expanding the number of assays designed for ESP platforms for detecting target algae, toxins, pathogens, and other marine biota.

This private sector partnership project enabled NOAA and regional partners to re-engineer the ESP design in order to benefit from its full potential. It also demonstrated a viable pathway to expanding adoption of other marine sensors soon to be commercially available.

What was done: The ESP hardware and software were modified to make units more affordable, robust, reliable, and applicable to users in government agencies, the shellfish and aquaculture industries, and university labs. Specific accomplishments include:

- Increased sampling capacity by 45% by developing a "short puck" where sample collection, probe reactions, and detection occur.
- Engineering changes to increase robustness in response to tests in the lab and in the field with users.
- Retrofitted some existing ESPs with improvements, which have been included in all future units.
- Improved manufacturing process to make it more efficient.

Benefits: This project has made the ESP more robust for easier deployment, for longer periods, and in more environments. It reduced the cost of manufacturing, which will make it more widely available. This project also demonstrated a pathway for using PCMHAB to expand the adoption of other commercially available marine biological sensors. ESPs have been deployed in the following locations with funding from multiple programs in NOAA, including ECOHAB, MERHAB, IOOS Office of Technology Transfer (IOOS OTT), and Sea Grant:

- Gulf of Maine—includes the Bay of Fundy
- Salt Pond, MA
- Puget Sound
- Juan de Fuca Eddy
- Central and Southern California
- Lake Erie

Finally, it demonstrates a successful private-public partnership. PCMHAB funding provided seed money and motivation, McLane provided considerable in-kind resources, and investigators at many institutions collaborated in guiding and testing improvements to the ESP.

Summary 2012-2017
Event Response Program

History

- Established 2003; Authorized via the Harmful Algal Bloom Hypoxia Research and Control Act

Event Response Program Goals

Provide access to the best technology and expertise available, provide supplemental financial support for investigating a unique event, and ensure proper scientific documentation to add to the HAB knowledge base.

Priority Objectives/Topics

1) Appearance of species, toxicity, or harmful impacts that are unusual or unique for a particular U.S. coastal region, and that pose threats to public health and/or economically vital resources, or which may lead to new discoveries in HAB science.
2) Sudden or unexplained mortalities of seabirds, fish, or marine mammals for which a HAB linkage is suspected but which requires confirmation through additional sampling or observations.
3) HAB events with major management or resource impacts for which additional data – such as the size or extent of the outbreak, causative species, hydrographic characteristics of the associated water mass – will be of use in subsequent management decisions.

Examples of Event Response Accomplishments (projects may have more than one accomplishment)

- Mapped bloom extent, severity, and toxicity & environmental conditions, address causes: 10 events
- Assisted states and other management entities with immediate assistance with toxin monitoring: 8 events
- Assessed impact of blooms on higher trophic levels: 6 events
- ID organism: 3 events
- Develop/improve method of detection: 3 events
- Hold outreach event/develop outreach materials: 3 events
- Determined cause of mortality/stranding events: 2 events
- Training Workshop: 1 event
- Apply control method: 1 event

Event Response Project Statistics 2012-2017:

- # Projects - 23
- # Projects/year - 3.8
- Total funding 2012-2017: $170,743
- Average funding/project: $7,424
- Maximum funding/project: $22,000
- Minimum funding/project: $238 (bloom ended)
- # Publications - 24 (not primary purpose of program)

Table 1: List of Event Response Projects 2012-2017

Date	Recipients	Event	Funds	Title	Activities	Partners	Informational Web Sites
Apr. 2012	NYSDEC - Bureau of Marine Resources	PSP Long Island	$2,839	PSP Test Kits to Support Monitoring during lapse in state funding	Provide 100 Jellett PSP test kits. During budget standoff, state public health managers lacked funds for test kits to conduct monitoring.		
Jun. 2012	Aleutian Pribilof Islands Ass	PSP - Alaska	$1,250	Testing and Monitoring of PSP	Shipping from remote areaas and analysis costs from PSP-toxins in shellfish samples by AK DEC during a 1 year gap in EPA funding	AK DEC	
Jun. 2012	NOAA NWFSC	DSP - Puget Sound	$9,718	DSP Emergency Response Puget Sound 2012	Analyze DSP-toxins in shellfish and seawater particulate samples for State of Washington regulatory decisions during first-ever *Dinophysis* bloom.	WA DOH, Jamestown S'Klallam Tribe, FDA	
Aug. 2012	WHOI	ASP Gulf of Maine	$13,415	Maine ASP Event 2012	Conduct a rapid-response field survey of nearshore and coastal waters to complement ME DMR sampling of inshore waters of eastern ME. Identify and enumerate *Pseudo-ntizschia* species and toxicity, measure environmental conditions	ME DMR	https://coastalscience.noaa.gov/news/habs/nccos-assists-response-to-toxic-pseudo-nitzschia-bloom-in-gulf-of-maine/ https://coastalscience.noaa.gov/news/habs/noaa-supported-researcher-informs-gulf-of-maine-fishermen-of-harmful-algae-threat/
Sept. 2012	Stony Brook University	Brown Tide in Indian River Lagoon, FL 2012	$8,840	Understanding the outbreak of a novel brown tide bloom in the Mosquito and Indian River Lagoons, FL, USA	Identify the bloom-causing organism and develop a fluorescent probe for quickly and specifically enumerating it, assess the temporal and spatial scale of the bloom and environmental conditions that may foster bloom, determine the effects of the bloom on filter feeding bivalves (hard clams)	St. John's River Water Management District	https://coastalscience.noaa.gov/news/habs/first-florida-brown-tide-algal-bloom-in-indian-river-and-mosquito-lagoons-confirmed/ https://coastalscience.noaa.gov/news/habs/harmful-algae-from-brown-tides-in-texas-now-appearing-in-florida-waters/

Date	Recipients	Event	Funds	Title	Activities	Partners	Informational Web Sites
Oct. 2012	FWC	Red tide on FL west coast	$9,000	HAB Event Response in SW Florida	Follow *Karenia brevis* bloom on 2 4-day cruises following drifters; conducting nutrient bioassays, validating satellite data and physical models of bloom movement		
Mar. 2013	Mote Marine Laboratory	Manatee deaths during *Karenia* blom	$5,016	Health Impacts from Red Tide Toxin Exposure in Manatees	Investigate health impactst of natural brevetoxin exposure in wild Florida manatees during their rescue and rehabilitation at Lowry Park Zoo	Lowry Park Zoo	https://coastalscience.noaa.gov/news/habs/funds-aiding-therapeutic-improvements-for-manatees-afflicted-by-red-tide/
Aug. 2013	Stony Brook University	Brown Tide in Indian River Lagoon, FL 2013	$5,995	2013 Response to Brown Tide in Florida's Indian River and Mosquito Lagoons	Map bloom distribution, assess bloom effect on zooplankton grazing, assess role of nutrients in promoting blooms, help organize and speak in a public forum put on by the Marine Discovery Center in New Smyrna Beach, FL.	South Florida Water District, Marine Discovery Center, New Smyrna Beach, FL	https://coastalscience.noaa.gov/news/habs/nccos-responds-to-harmful-algal-bloom-event-threatening-important-florida-lagoon/
Aug. 2013	PA DEP	Cyano-HABs in Lake Erie near park with frequent recreatio nal use	$3,556	Monitoring cyanoHAB toxicity in Presque Isle State Park on Lake Erie	Purchase micorcystin test kits. Develop a response plan and outreach materials.		https://coastalscience.noaa.gov/news/habs/nccos-aids-pennsylvania-response-to-first-cyanohab-in-presque-isle-bay-lake-erie/ https://coastalscience.noaa.gov/news/habs/nccos-continues-to-help-pennsylvania-respond-to-lake-erie-harmful-algal-bloom/
Nov. 2013	NOAA NWFSC	Alaska PSP work-shop	$3,592	AHAB (Alaska Harmful Algal Bloom Partnership) Emergency Response to Alaska Illness due to PSP outbreaks 2013	Hold training workshop to help Sitka Tribe (and other tribes) of Alaska to establish a HAB monitoring program, building upon lessons learned from the Alaska Harmful Algal Bloom monitoring (AHAB) partnership.	NOAA CCEHBR, UAF Juneau, SE AK Regional Divers Ass	https://coastalscience.noaa.gov/news/helping-alaska-tribe-launch-a-harmful-algal-bloom-monitoring-program/

Date	Recipients	Event	Funds	Title	Activities	Partners	Informational Web Sites
Jul. 2014	USF	Red tide (*Karenia brevis* bloom) on FL west coast	$9,616	Deployment of gliders to map a large-scale *Karenia brevis* bloom in the Northeast Gulf of Mexico	Support deployment of a USF glider to compliment FWRI field sampling programs and nearshore glider deployments by MML. Data from gliders will provide information for models to predict transport and severity of *Karenia brevis* bloom.	Mote Marine Laboratory, FWRI	https://coastalscience.noaa.gov/news/habs/gliders-map-large-red-tide-bloom-gulf-mexico-rapid-response/ https://coastalscience.noaa.gov/news/habs/glider-begins-second-deployment-monitor-threatening-florida-red-tide/
Aug. 2014	NOAA GLERL	Cyano-toxins in Toledo water supply	$6,030	Elucidating the cyanotoxins present in the western basin of Lake Erie during the 2014 Toledo drinking water crisis	Analyzed plankton samples at drinking water intake for microcystin, anatoxin, cylindrospermopsin, and BMAA to insure accuracy of microcystin tests kits & to determine if other toxins, which are more toxic to humans, were present.	SUNY-ESF,UTN, BGSU, JMU	https://coastalscience.noaa.gov/news/habs/noaa-hab-event-response-delivers-timely-trusted-cyanobacteria-toxin-data-ohio-epa/
Oct. 2014	Mote Marine Laboratory	Red tide FL west coast	$4,894	Brevetoxin Exposure in Nesting Loggerhead Sea Turtles from Western Florida	Analyze brevetoxins unhatched eggs and dead-in-nest hatchling livers from females with known toxin expoxure in order to determine impact on reproductive success.		
Jun 2015	NY DEC	Mass mortality terrapins during *Alex-andrium* bloom	$3,750	Investigating the role of paralytic shellfish poisoning (PSP) toxins in a regional mortality event of diamondback terrapins (*Malaclemys terrapin*)	Measure PSP-toxins in tissues taken from dead terrapins from Peconic estuary on Long Island to determine if toxins from *Alexandrium* bloom were possible cause of death.	Bigelow Laboratory, Cornell University, Stony Brook Univeristy	https://coastalscience.noaa.gov/news/habs/investigating-diamondback-terrapin-die-offs-new-york/

Date	Recipients	Event	Funds	Title	Activities	Partners	Informational Web Sites
Jun 2015	NOAA NWFSC	*Pseudo-nitzschia* bloom & toxicity in fish & shellfish & animal mort-alities	$9,294*	Emergency response to the widespread US west coast 2015 domoic acid outbreak	Purchase domoic acid test kits for use by state, tribes, and ORHAB. Pay for ship time for sampling toxic *Pseudo-nitzschia* coming out of the Juan de Fuca eddy.	NANOOS, UW,WA DOH, WA DFW, Quileute, Quinault, Makah tribes, ORHAB, Olympic Coast NMSy	http://www.noaanews.noaa.gov/stories2015/072315-noaa-awards-88000-in-grant-funding-to-respond-to-west-coast-harmful-algal-bloom-outbreak.html http://coastalscience.noaa.gov/news/habs/west-coast-harmful-algal-bloom-draws-attention-congress/
Aug 2015	ODU	*Alex-andrium moni-latum* bloom, Chesa-peake Bay	$238	Impacts of an *Alexandrium monilatum* bloom in the lower Chesapeake Bay estuary	Bloom tracking by sampling water quality from small boats and docks. Measure algal biomass, nutrient concentrations, primary productivity. Conduct nutrient uptake, grazing rate, bioassay toxicity (multiple species) experiments. Isolate cultures & develop detection method.	VIMS, VA DOH, VA DEQ, Hampton Roads Sanitation District, Chesapeake Bay Foundation, Elizabeth River Project	http://www.noaanews.noaa.gov/stories2015/072315-noaa-awards-88000-in-grant-funding-to-respond-to-west-coast-harmful-algal-bloom-outbreak.html http://coastalscience.noaa.gov/news/habs/west-coast-harmful-algal-bloom-draws-attention-congress/
Apr. 2016	FAU	Brown tide in Indian River, FL	$7,096	Ecological and optical characterization of the 2016 *Aureoumbra* brown tide in the Indian River Lagoon	Characterize in situ and remote sensing optical proxies for *Aureoumbra,* measure phytoplankton species and key environmental parameters in order to develop methods for rapid assessment of extent of bloom and a better understanding of the causes.	SJRWMD	https://coastalscience.noaa.gov/news/habs/nccos-supports-enhanced-monitoring-brown-tide-floridas-indian-river-lagoon/

Date	Recipients	Event	Funds	Title	Activities	Partners	Informational Web Sites
Jul. 2016	Martin County	Cyano-HAB spread from Lake Okee-chobee to St. Lucie estuary	$9,273	Martin County HAB Event Response Request	Collect samples on 3 dates at locations not sampled by state. Send to SUNY Syracuse cyanotoxin lab foranalysis.	SUNY Syracuse	https://coastalscience.noaa.gov/news/habs/nccos-provides-support-floridas-martin-county-assessing-blue-green-algal-toxin-threat/
Aug. 2016	VIMS	*Cochlo-dinium* & *Alexan-drium moni-latum* blooms, Chesa-peake Bay	$8,200	Defining Effective Grow-out Strategies to Minimize Oyster Aquaculture Mortality During Late Summer Harmful Algal Blooms in the York River, Virginia Region	Deploy seed oysters at sub-tidal and intertidal sites during HAB event. Determine oyster mortality, HAB cell counts, water quality, oyster health, and oyster toxin content. Provide information to oyster growers at workshop funded by another program.	Chessie Seafood and Aquafarms, Hayes, VA	https://coastalscience.noaa.gov/news/scientists-assess-impacts-bioluminescent-algae-chesapeake-bay-fisheries/
Oct. 2016	WHOI & Bigelow Lab	*Pseudo-nitzschia bloom* in Gulf of Maine	$22,000	Maine ASP Event 2016	Map spatial extent, species composition, & toxicity of *Pseudo-nitzschia and environmental conditions during* bloom in Gulf of Maine	FWRI, ME DMR	https://coastalscience.noaa.gov/news/nccos-helps-new-england-respond-unprecedented-harmful-algal-bloom/
Feb. 2017	TAMU-CC	Micro-cystin causing bird & other wildlife mortality	$5,000	Toxic *Microcystis* blooms in freshwater ponds used by migratory birds, Padre Island National Seashore, Texas	Treat pond with hydrogen peroxide to oxidize the cells and toxin.	Padre Island National Seashore	https://coastalscience.noaa.gov/news/nccos-funding-hab-event-response-project-reduce-migratory-duck-mortality-padre-island-tx/

Date	Recipients	Event	Funds	Title	Activities	Partners	Informational Web Sites
May 2017	SCCWRP, USC, SCOOS, UCSC	*Pseudo-nitzschia* bloom & mortality of birds & marine mammals in S CA	$14,250	Spring 2017 Domoic Acid Event Response in Southern California	Determine acute impacts of DA to marine bird. Evaluate long-term impacts through analysis of domoic acid in sediment samples and in benthic organisms. Expand water sampling to include offshore subsurface regions.	Santa Barbara Channel Keeper	https://coastalscience.noaa.gov/news/nccos-responds-southern-california-harmful-algal-bloom-event/
Oct 2017	BGSU, U Toledo, SUNY-ESF, OH EPA, Defiance College	Unusual cyanobacteria bloom in Maumee River	$7,880	Elucidating the cyanotoxins and potentially toxic cyanobacteria present during the 2017 Maumee River bloom	Samples already collected along the entire Maumee River in Ohio . Determine microcystins and other cyanobacteria toxins, potential producers of multiple toxin via multiplex qPCR, genetic connectivity of microcystin producers from River to Lake		https://coastalscience.noaa.gov/news/nccos-helps-ohio-respond-unusual-harmful-algal-bloom/

**Reflects only Event Response contribution to a total amount of $88,000 that supported response efforts.*

Summary 2012-2017
Northern Gulf of Mexico Ecosystems and Hypoxia Assessment Program (NGOMEX)

History

- Established 2000; Authorized by the Harmful Algal Bloom Hypoxia Research and Control Act
- Guided by the Mississippi River/Gulf of Mexico Hypoxia Task Force 2008 Action Plan and 2013 Scientific Reassessment, plus annual scientific/stakeholder workshops
- Competitive peer-reviewed competitions held in 2009, 2015, and 2016
- Recent focus on glider application to hypoxia monitoring in 2015, and hypoxia ecosystem impacts in 2016

NGOMEX Program Goals

1) Develop a fundamental understanding of the northern Gulf of Mexico ecosystem with a focus on the causes/effects of the hypoxic zone and the prediction of its future extent and impacts; and
2) Identify and fill critical research gaps used in the interagency adaptive management program that connects monitoring, data analysis, and model predictions with management actions to restore and protect the Louisiana continental shelf ecosystem.

Priority Objectives

1) Characterize the magnitude and extent of the hypoxic zone;
2) Develop quantitative models to predict the extent of the hypoxic zone given varying levels of nutrient inputs, physical forcing, and other factors that control hypoxia; and
3) Develop quantitative models to determine the impacts of the hypoxic zone on ecologically and economically important living resources.

Examples of NGOMEX Accomplishments (in collaboration with other extra- and intramural hypoxia programs in NOAA and other agencies)

- Provided the scientific foundation for setting goals and measuring progress as the basis for guiding the multibillion-dollar state and federal nutrient management programs upstream, that are relevant for over 40% of the nation with countless secondary benefits including drinking water safety, fishing industry, and tourism.
- Provided the science, primarily in the form of forecast models, to guide the interagency (5 federal, 1 tribal, and 12 state agencies) Hypoxia Task Force (HTF) in setting and revising watershed nutrient reduction targets to meet the HTF coastal goal as originally established in 2001, and revised in 2008 and 2015.
- Developed and maintained the long-term measurements of the hypoxic zone in the Northern Gulf of Mexico for over 30 years, the key metric of HTF progress toward the coastal goal, and which is reported every year in a NOAA press release to inform stakeholders of progress.
- Revealed the contribution of phosphorus, in addition to nitrogen, to hypoxia, leading to the inclusion of phosphorus in the 2008 HTF action plan.
- Developed biogeochemical models that now allow the HTF to consider creative and novel management strategies and will allow for resource and economic impacts due to the hypoxic zone to be quantified and balanced against restoration costs.

- For the first time, provided the HTF, managers, and stakeholders with compelling scientific evidence that Gulf hypoxia has widespread sublethal impacts on important fish species, affecting reproduction and growth rates, as well as economic impacts on the shrimp fishery.

NGOMEX Publications

2012-2017 - 124

Table 1. NGOMEX project list 2012-2018

Recipients	PIs	Other Investigators	Objective	Title	Total Funds
LUMCON; LSU; U Mich; UMass/Dartmouth	Rabalais, N.	Turner, E., Justic, D., Scavia, D., Roberts, B., Sinclair, G., Chen, C., Fry, B., Li, C.	Causes + Monitoring	Integrated ecosystem modeling of the causes of hypoxia	$3,767,594
TAMU; Dalhousie; LUMCON; VIMS; CCU	DiMarco, S.	Hetland, R., Forrest, D., Harris, C., Bianchi, T., Fennel, K., Dagg, M., Chapman, P., Guinasso, N., Morse, J., Quigg, A., Walker, N., Xu, K., Howard, M.	Causes	Mechanisms controlling hypoxia: integrated causal modeling	$3,548,134
UMCES; LSU; NOAA/GLERL; Oregon St	Roman, M.	Pierson, J., Brandt, S., Cowan, J., Mason, D., Stow, C., Sable, S., Adamack, A., Sutter, F.	Impacts	Effects and impacts of hypoxia on production potential of ecologically and commercially important living resources in the Northern Gulf of Mexico	$1,464,820
NOAA/NMFS; Duke	Craig, K.	Bennear, L., Nance, J., Smith, M.	Impacts	Effects of hypoxia on harvest dynamics and economics of the shrimp fishery in the Northwestern Gulf of Mexico	$366,631
UT/Austin; FSU; LSU; Rutgers; TAMU; NOAA/NMFS	Thomas, P.	Rose, K., Justic, D., Grothues, T., Montagna, P., Craig, K.	Impacts	Modeling reproductive and population impacts of hypoxia in the Northern Gulf of Mexico	$2,048,181
TAMU	DiMarco, S.	Howard, M.	Monitoring	Glider application to Gulf of Mexico Hypoxic Zone monitoring: pilot study and transition to operations	$249,233

George Mason; Oregon St; Ecopath Intern Initiative; NOAA/NMFS	De Mutsert, K.	Brandt, S., Buszowski, J., Campbell, M., Laurent, A., Lewis, K., Steenbeek, J.	Impacts	User-driven tools to predict and assess effects of reduced nutrients and hypoxia on living resources in the Gulf of Mexico	$960,427
UMCES/Horn Point; LSU; Auburn; NOAA/NMFS; The Water Inst of the Gulf	Rose, K.	Craig, K., Huang, H., Justic, D., Meselhe, E., Tian, H., Xue, Z.	Impacts	Using linked models to predict the impacts of hypoxia on Gulf Coast fisheries under scenarios of watershed and river management	$1,257,560
NCSU; NOAA/NMFS	Obenour, D.	Craig, K.	Impacts	Synthesis and integrated modeling of long-term data sets to support fisheries and hypoxia management in the Northern Gulf of Mexico	$715,843

Integrated Ecosystem Modeling of the Causes of Hypoxia and Mechanisms Controlling Hypoxia on the Louisiana Shelf: Integrated Causal Modeling

Program Manager: David Scheurer
Project Period: 2009-2014 (Funded) with 2-yr no-cost extensions
Project Funding: $7.5M (with shiptime)
Participants: Project 1 – S. DiMarco, T. Bianchi, P. Chapman, N. Guinasso, Jr., R. Hetland, J. Morse, M. Howard (all TAMU), A. Quigg (TAMUG), C. Harris and D. Forrest (VIMS), M. Dagg (LUMCON), K. Xu (CCU), K. Fennel (Dalhousie University)

Project 2 – N. Rabalais, B. Roberts, G. Sinclair (LUMCON); E. Turner, D. Justic, B. Fry (LSU); D. Scavia (UM)

Summary: Complementary projects were funded as part of the FY09 NGOMEX FFO competition, which focused on supporting multi-year, interdisciplinary research projects to inform management of the northern Gulf of Mexico ecosystem in the region affected by Mississippi/Atchafalaya River inputs. They had a specific focus on understanding the causes and effects of the hypoxic zone over the Louisiana-Texas-Mississippi continental shelf and the prediction of hypoxia's future extent and impacts. The goal was to develop a predictive capability for this ecosystem within the adaptive management framework of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force's (HTF) Gulf Hypoxia Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin (2008 Gulf Hypoxia Action Plan).

Rationale: The 2008 Gulf Hypoxia Action Plan restates the coastal goal of reducing the 5-year running average size of the Gulf hypoxic zone to less than 5,000 km2, and recommends a dual nutrient strategy targeting reductions of 45% in both riverine total nitrogen and phosphorus flux. Validation of these estimates and evaluation of the effectiveness of management actions critically depend on the accuracy of models that assess and forecast the quantitative association between hypoxic zone properties and the biological, chemical, and physical processes that regulate hypoxia development, magnitude, and extent.

What was done: The projects provide the foundational investigations necessary for the HTF to understanding the key processes controlling hypoxia, monitoring progress toward achieving management goals, and providing robust and well-vetted tools for the nutrient reduction targets necessary to achieve those goals. The teams have two focal areas of study: monitoring and process studies, and modeling studies.

Benefits: The projects resulted in many improvements to our understanding of hypoxia formation and dynamics, our ability to model and predict hypoxia, the continuation of key monitoring studies to document the size of the dead zone, and the transition to application/operations of several major products from these studies. Key results are listed below:

- Developed and maintained the long-term measurement of the hypoxic zone in the Northern Gulf of Mexico for over 30 years that is the key metric of HTF progress toward the coastal goal, and is reported every year in a NOAA press release to inform stakeholders of progress.
- Developed biogeochemical models that now allow the HTF to consider creative and novel management strategies and will allow for resource and economic impacts due to the hypoxic zone to be quantified and balanced against restoration costs. Revealed the contribution of

phosphorus to hypoxia, in addition to nitrogen, leading to the inclusion of phosphorus in the 2008 HTF Action Plan.

- Identified and quantified the role of nutrients in hypoxia formation
- Provided an ensemble forecast using four models that forecast the hypoxic zone size, and developed a transition plan for NOAA to perform the forecast as part of operational forecasting.
- Developed 3-D coupled hydrodynamic/biogeochemical models with the capacity to for real-time forecasts and ability to simulate hypoxia development over time and with high spatial resolution
- Provided the basis for the HTF's current action plan goals, and new information on how the timing and loads of nitrogen and phosphorus impact the zone size.

Summary 2012-2017
Coastal Hypoxia Research Program (CHRP)

History

- Established in 2005; Authorized by the Harmful Algal Bloom Hypoxia Research and Control Act
- Guided by the 2010 Congressional report, Scientific Assessment of Hypoxia in US Coastal Waters
- Competitive peer-reviewed competitions held in 2005, 2007, 2010, 2016, 2018
- Focuses on developing scenario forecast models to advance the understanding, prediction, and management of the causes, and ecological and socioeconomic impacts, of hypoxia nationally, with an emphasis on supporting the transition of mature models to management application.

CHRP Program Goals

Improve the capability of coastal managers to effectively prevent or reduce the ecological and socioeconomic impacts of hypoxia. Accomplished by:

1) Developing fundamental understandings of the causes and effects of hypoxia specific to a region.
2) Making available forecasting tools evaluating the effectiveness of alternative management strategies from an ecosystem level context.

Priority Objectives

1) Quantify in a holistic manner the effects of specific natural and anthropogenic factors on the spatial and temporal extent of hypoxia.
2) Quantify the ecological and socioeconomic impacts of hypoxia.
3) Develop predictive models to assess the parameters of hypoxia under a range of environmental scenarios and alternative management strategies.

Examples of CHRP Accomplishments (in collaboration with other extra- and intramural hypoxia programs at NOAA and other agencies)

- Lake Erie: Scenario forecast models informed regulators of phosphorus reduction targets needed for hypoxia mitigation, a key driver in setting new Great Lakes Water Quality Agreement (GLWQA) phosphorus loading targets. Model forecasts used by Lake Erie fisheries managers to guide fisheries policies in response to anticipated hypoxia impacts.
- Green Bay: Provided scenario forecast models to local agencies that demonstrated that a 50% reduction in nutrient runoff was needed to reverse low oxygen conditions in the bay. This finding led to revised nutrient loading targets for managers of Green Bay watersheds that fueled the implementation of nutrient-reducing best management practices and the development of a phosphorus-trading program to achieve economically amenable solutions for the region.
- Chesapeake Bay: Supported development of mechanistic models for the bay that allow for a dynamic assessment of annual changes in the magnitude, seasonality, duration, and distribution of hypoxia. This assessment provided the first evidence that management actions that reduced nutrient loading to the bay subsequently limited the duration of time that the bay is hypoxic.
- Narragansett Bay: Informed management of the progress of state-imposed nitrogen reduction regulations of sewage treatment facilities toward reducing hypoxia in the bay. Provided scenario forecast models to assess alternative nutrient reduction strategies, which have since successfully reversed the course of Narragansett Bay hypoxia onto a path of recovery.

Table 1. Hypoxia project list 2012-2018

Recipients	PIs	Other Investigators	Region	Title	Total Funds
CHRP Projects					
U Mich; Cornell; SERC; USGS	Scavia, D.	Helfand, G., Howarth, R., Alexander, R., Breitburg, D.	East Coast & Gulf of Mexico (outside "Dead Zone")	Watershed-estuary-species susceptibility to nutrient pollution	$2,556,843
UMCES/Horn Point; UMCES/CBL; Dalhousie; U Del	Kemp, M.	Li, M., North, E., Boynton, W., Secor, D., DiToro, D., Fennel, K.	Ches Bay	Modeling hypoxia and ecological responses to climate and nutrients	$1,857,466
URI; Brown; Narr Bay Est Prog; RIDEM; U Conn; VIMS	Codiga, D.	Kincaid, C., Nixon, S., Granger, S., Oviatt, C., Stoffel, H., Ullman, D., Kiernan, S., Deacutis, C., Prell, W., Vaudrey, J.	Narragansett Bay	Observations and modeling of Narragansett Bay hypoxia and its response to nutrient management	$766,004
SERC; U Del; LSU; NOAA/NMFS; MD DNR; EPA	Breitburg, D.	Batiuk, R., Culberson, C., Giordano, S., Michael, B., Naylor, M., Rose, K., Targett, T., Townsend, H.	Ches Bay	Shallow water hypoxia - tipping the balance for Individuals, populations and ecosystems	$790,325
U Wisc/Milw; U Wisc/GB; U Wisc/Mad; GB Metropol Sewerage Dist; Wisc DNR	Klump, V.	Baumgart, P., Bravo, H., Dolan, D., Fermanich, K., Kennedy, J., Lorenz, D., Richmond. N., Vimont, D., Waples, J.	Green Bay	Green Bay Hypoxia: biogeochemical dynamics, watershed inputs, and climate change	$551,609
VIMS; EPA/CBPO; USGS/CBPO; Penn St; ODU; Auburn	Friedrichs, M.	Hofmann, E., Linker, L., Najjar R., Shenk, G., Tian, H.	Ches Bay	Predicted Impacts of climate change on the success of alternative management actions in the Chesapeake Bay: using multiple community models in support of hypoxia management decision-making	$566,903

NOAA/GLERL; CILER/U Mich; City of Cleveland Div Water; Purdue; USGS	Stow, C. (GLERL) Rowe, M. (CILER)	Anderson, E., Beletsky, D., Burton, G., Collingsworth, P., Johengen, T. Joshi, S., Kraus, R., Mason, D., Moegling, S. Rowe, M., Ruberg, S., Zhang, H.	Lake Erie	Operational Lake Erie hypoxia forecasting for public water systems decision support (LEOFS-Hypoxia)	$743,281
Ocean Acidification Projects					
TAMU/CC; USF; UT/Austin; NOAA/NCEP	Montagna, P.	Byrne, R., Hu, X., Kim, H-C., Liu, Z., Wetz, M.	Texas Gulf Coast	The Hydrological Switch: a novel mechanism explains eutrophication and acidification of estuaries	$986,495
UCLA; UW; SCCWRP; NOAA/PMEL	McWilliams, J.	Alin, S., Ambrose, R., Bednarsek, N., Bianchi, D., Deutsch, C., Feely, R., Frenzel, H., Gold, M., McLaughlin, K., Sutula, M., Weisberg, S.	West Coast (CA to WA)	Integrated modeling of ocean acidification and hypoxia to support ecosystem prediction and environmental management in the California Current System	$617,719
UMCES/CBL; UMCES/Horn Point; U Del; Oregon St	Testa, J.	Cai, W-J., Cornwell, J., Kemp, M., Li, M., Waldbusser, G.	Ches Bay	Interactions between ocean acidification and eutrophication in estuaries: modeling opportunities and limitations for shellfish restoration	$937,102
ECOFORE Project					
U Mich; E2 Inc; Heidelberg College; LimnoTech; NOAA/GLERL; Ohio DNR; U Wisc/GB; Western Mich	Scavia, D.	Allan, J., Bartell, S., Beletsky, D., Brandt, S., Croley, T., DePinto, J., Dolan, D., He, C., Höök, T., Johengen, T., Knight, R., Ludsin, S., Mason, D.	Lake Erie	Forecasting the causes, consequences, and potential solutions for hypoxia in Lake Erie	$2,204,922

Observations and Modeling of Narragansett Bay Hypoxia and its Response to Nutrient Management

Program Manager: Alan Lewitus
Project Period: 2010-2015
Project Funding: $766,004
Participants: D. Codiga, C. Kincaid, S. Nixon, S. Granger, C. Oviatt, H. Stoffel, D. Ullman (all (University of Rhode Island); S. Kiernan (Rhode Island Department of Environmental Management); C. Deacutis (Narragansett Bay Estuary Program); W. Prell (Brown University); J. Vaudrey, J. Kremer (both University of Connecticut); M. Brush (Virginia Institute of Marine Science)

Summary: This project developed observational and modeling tools and analyses to help Narragansett Bay management agencies assess the response of bay hypoxia to nutrient management controls and to develop a better course of action for future management.

Rationale: Narragansett Bay (NB) is a mid-sized, temperate estuary subject to hypoxic events that persist from days to weeks several times every summer. In 2003, a hypoxic event occurred in NB's Greenwich Bay during a neap tide resulting in a large fish kill. This galvanized public opinion in support of taking action to improve NB water quality. In response, a state law passed in 2004 to impose nitrogen limits on the area's largest water treatment facilities (WTFs). The Rhode Island Department of Environmental Management (RI DEM) implemented nutrient load reductions through the permitting process to all WTFs discharging to NB, with a target of 50% reduction in overall summertime loads to NB relative to 1995-1996 levels. Costs of these WTF upgrades are in the hundreds of millions of dollars.

What was done: This project documented the effects of the transition to more efficient NB WTFs by assessing the extent to which NB hypoxia changes in response to nutrient reductions, characterizing the nature of the changes, and applying models to test their capability to predict these changes and use them in a forecasting/alternate management scenario analysis. Using a simplified ecosystem model linked to a 3-D hydrodynamic model, the project produced practical, science-based predictive modeling tools that simulate ecological responses and predict low oxygen events related to nitrogen inputs. It also included an integrated suite of observations with multiple modeling approaches. A network of RI DEM fixed-site stations that record time series of water properties (oxygen, salinity, temperature, chlorophyll fluorescence) were utilized. Complementary spatial conductivity-temperature-dissolved oxygen surveys, also used by RI DEM, characterized the geographic extent and spatial patterns of hypoxia and documented the prevalence of macroalgae. An updated nutrient budget was calculated.

This project team worked closely with resource management agencies to develop a set of models usable by anyone involved in NB nutrient management activities. Workshops held annually since 2006 – continued from an earlier CHRP project - allowed project researchers and the staff from local management and regulatory agencies to report on their recent activities and exchange information. A Management Advisory Group helped guide the research, ensure its applicability to management issues, and strengthen the interactions between researchers and management agency staff.

Benefits: The targeted 50% reduction in wastewater loading reached the final stages of completion in 2014. Load reductions were undertaken concurrent with a changing climate, presenting an ideal "natural experiment" for understanding estuarine responses to changing nutrient loads and warming temperatures, and for application of a novel, management-focused modeling approach to predict bay response and inform future nutrient loading targets. Models reproduced observed water quality and metabolic rates across the bay, and predicted strong responses to nutrient load reductions in summer

but not spring. The 50% load reduction resulted in a reduction in the duration and spatial extent of modeled hypoxia, but a 75% reduction was required to eliminate hypoxia from most of the bay. Effects of increased water temperatures on hypoxia due to climatic warming were small, given the dominance of inorganic nutrients compared to organic matter in the external loads. Both models were provided directly to managers for their use.

Ecological Forecasting: Hypoxia Assessment in Lake Erie
Forecasting the Causes, Consequences and Remedies for Hypoxia in Lake Erie

Program Manager: Elizabeth Turner
Project Period: 2006 – 2011, extended through 2013
Project Funding: $2,204,922
Participants: J.D. Allan, D. Beletsky, H. Han, T. Johengen, H. Zhang, M.A. Evans (University of Michigan); T. Höök (Purdue); S. Bartell (E2, Inc.); J. DePinto (LimnoTech, Inc.); D. Dolan (University of Wisconsin – Green Bay); C. He (Western Michigan University); R. Knight (Ohio DNR); P. Richards (Heidelberg University); S. Brandt (Oregon State University); S. Ludsin (Ohio State University); N. Bosch (Grace College); D. Mason, E. Rutherford, S. Ruberg, D. Schwab (NOAA)

Summary: This project aimed to better understand the conditions leading to and impacting hypoxia in Lake Erie, the controlling factors and dynamics of hypoxia, the impacts on fisheries, and direct development of nutrient reduction targets and strategies. The ultimate goal was to deliver that understanding to the principle management community through an integrated and inclusive approach.

Rationale: Lake Erie is the southernmost and shallowest of the Laurentian Great Lakes and is used extensively for drinking water, recreation, and by the fishing industry. Excessive phosphorus inputs in the mid-1900s may have contributed to the decline of important commercial fish species by the 1960s. Measures taken to reduce the phosphorus load enhanced oxygen levels, and, by the mid-1990s, several species began to recover. More recently, however, large-scale hypoxic events have returned conditions to levels comparable to those experienced in mid-1900s. Phosphorus target levels are also being reconsidered across states and between the US and Canadian governments. To improve water quality and fish production, we need a fuller understanding of the complex relationships leading to hypoxia before effective phosphorus target levels can be safely established.

What was done: This project used a multi-model approach to link nutrient loads, hypoxia, and ecological effects. Model outputs provided nutrient-load hindcasts (past) and forecasts (future), including statistical modeling approaches and a detailed hydrologic model (SWAT, the Soil and Water Assessment Tool) developed and tested extensively for Great Lakes tributaries. Different climate scenarios were tested for potential future impacts on the development and extent of hypoxia. Models predicted how fisheries' harvest rates would respond to hypoxia under different climate or management scenarios. The objectives were to develop forecasts in support of phosphorus control measures that could be used to guide plans for Lake Erie nutrient and fisheries management.

Benefits: The project achieved substantial scientific advancements (56 peer reviewed publications) and greatly increased the understanding of Lake Erie dynamics and ecosystem functioning. Moreover, it provided input to the International Joint Commission's Lake Erie Ecosystem Priority **report, including key evidence that reducing phosphorus loads is the single most important solution to Lake Erie**

hypoxia. In particular, the project found that total phosphorus increased, and specifically that dissolved reactive phosphorus had more than doubled due to changes in fertilizer use. Their results showed the International Joint Commission (IJC) that reducing the central basin hypoxic area to levels observed in the early 1990s (ca. 2,000 km2) required cutting total phosphorus loads by 46% (vs 2003-2011 average) or specifically reducing the contribution of dissolved reactive phosphorus loads by 78% (vs 2005-2011 average). The project also provided strategic input on how to achieve these nutrient targets, while taking into account changing weather patterns in the region that will cause increasing water running off the land in coming decades, exacerbating the issue.

The project identified not only the most important contributing watersheds (e.g., Detroit, Maumee, Sandusky), but also the regions within those tributary watersheds that release the most phosphorus. This knowledge should allow for more effective targeting of BMPs to high-load sub-watersheds. The SWAT model was used to simulate the influence of changing land management and crop insurance practices on nutrient loads. It suggested that landowner involvement was integral to reducing sediment and nutrient loads, and that linking crop insurance to conservation compliance could reduce nutrient loads.

Research Publications and Their Availability

NOAA scientists are encouraged and indeed expected to publish peer-reviewed journal articles, technical reports, and other peer-reviewed materials. The Department of Commerce Strategic Plan (2014-2018) included an agency performance measure on peer-reviewed publications: "Annual number of peer-reviewed publications related to environmental understanding and prediction". NOAA has nearly always exceeded the target number of peer-reviewed publications each year.

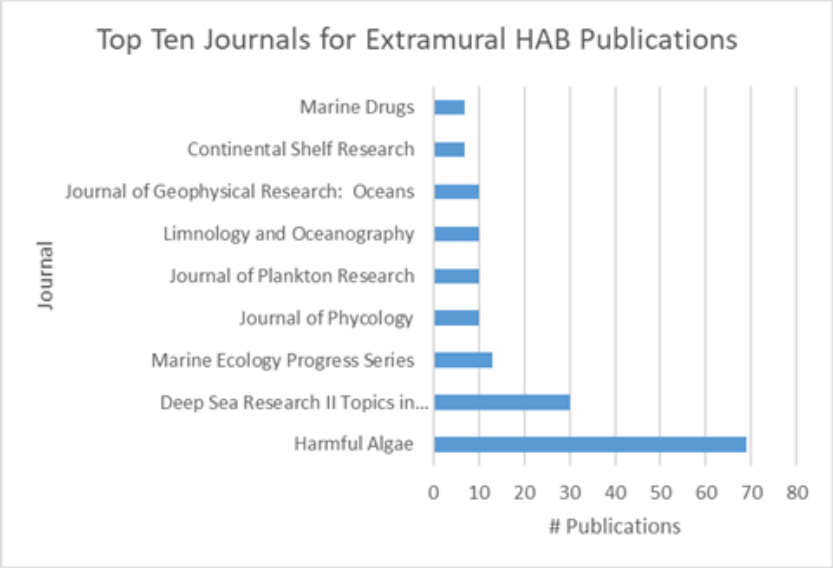
Different methods of tallying HAB and hypoxia publications have been used.

1) Web of Science records
2) Databases maintained by programs.

Both require investigators to both put grant numbers and NOAA NCCOS in the acknowledgements and, in the case of extramural programs, inform program managers about publications. This does not always happen, for a variety of reasons, so both counts are underestimates and differ from each other.

A recent query of the Web of Science records showed 1,657 NOAA publications over the past five years that dealt with harmful algal blooms, hypoxia, chlorophyll, eutrophication, toxins, and related topics. NCCOS accounted for 568 of those publications. This total includes both intramural and extramural research.

The Competitive Research Program keeps publication databases by program. The total number of publications from the HAB programs alone is 327. Of this number, 261 are in journals and 66 are other types of publications, such as book chapters and proceedings. The following graph demonstrates the top journals in which NCCOS extramural projects have published research.



NOAA has established, effective October 2015 and in response to a memorandum from the Office of Science and Technology Policy, a policy for increased public access to NOAA research publications. The policy applies to research publications as well as other scientific documents produced using NOAA funding and intended for public or limited external distribution. Products created through federal staff timer, contracts with third parties, and grants or other agreements are included. The NOAA Central Library manages the NOAA Institutional Repository, which collects, archives and makes available all digitized NOAA research publications. In addition, the repository includes documents in a NOAA series such as, but not limited to, NOAA professional papers, NOAA technical reports, and NOAA technical memoranda. The repository can be accessed at https://repository.library.noaa.gov/welcome.

Acronyms

CRP - NCCOS Competitive Research Program
ECOHAB - Ecology and Oceanography of HABs program
FFO - Federal Funding Opportunity
GLWQA - Great Lakes Water Quality Agreement
HABHRCA - Harmful Algal Bloom & Hypoxia Research and Control Act
HTF - Hypoxia Task Force
IJC - International Joint Commission
IOOS - Integrated Ocean Observing System
ISSC - Interstate Shellfish Sanitation Conference
IWG - Interagency Working Group
MERHAB - Monitoring and Event Response for Harmful Algal Blooms program
NCCOS - National Centers for Coastal Ocean Science
ORHAB - Olympic Region HAB partnership
PCMHAB - Prevention, Control, and Mitigation of HABs program
RA - Regional Association (relates to IOOS)

John Steven Ramsdell

Drew University	B.A., *magna cum laude*	05/1977	Zoology
University of California, San Francisco	Ph.D.	05/1982	Endocrinology
Harvard University	Fellow	05/1986	Toxicology

PERSONAL STATEMENT

Dr. Ramsdell serves as Chief of the Harmful Algal Bloom Monitoring and Reference Branch of the NOAA-NOS National Centers for Coastal Ocean Science. Trained as an endocrinologist at University of California, San Francisco and toxicologist at Harvard University, he joined the faculty at the Medical University of South Carolina conduct NIH sponsored research on growth regulatory control of pituitary tumors. He changed fields in 1992 to develop a Graduate Program on Marine Biomedical and Environmental Sciences at MUSC and NOAA's National Program on Marine Biotoxins and Harmful Algae. Dr. Ramsdell has served as major advisor and mentor for two College of Charleston master students, six MUSC Ph.D. students and four National Research Council Fellows. Research in his laboratory investigated the toxicology of algal toxins and their metabolites on marine animal populations. The research paradigm involves monitoring toxin exposure, characterizing toxin disposition and delineating the impact on disease states through combination of clinical/field observations and laboratory models.

PUBLICATIONS

One hundred thirteen Lead or Senior Author peer-reviewed research or review articles. Four representative publications follow:

Wang, Z, MH Broadwater and JS Ramsdell. 2015. Analysis of diarrhetic shellfish poisoning toxins and pectenotoxin-2 in the bottlenose dolphin (*Tursiops truncatus*) by liquid chromatography–tandem mass spectrometry. Journal of Chromatography A 1416, 22-30.

Leighfield, TA, N Muha, CO Miles and JS Ramsdell. 2014. Semisynthesis of radiolabeled amino acid and lipid brevetoxin metabolites and their blood elimination kinetics in C57BL/6 mice. Chemical Research in Toxicology 26: 868-877.

Ledreux, A and JS Ramsdell. 2013. Bioavailability and intravenous toxicokinetic parameters for Pacific ciguatoxin P-CTX-1 in rats. Toxicon 64, 81-86.

Tiedeken, JA, N Muha and JS Ramsdell. 2013. A cupric silver histochemical analysis of domoic acid damage to olfactory pathways following status epilepticus in a rat model for chronic recurrent spontaneous seizures and aggressive behavior. Toxicologic Pathology 41: 454-469.

ACADEMIC POSITIONS AND APPOINTMENTS

Harvard School of Public Health- Research Associate, 1986-1987.

Medical University of South Carolina- Assistant Professor of Anatomy and Cell Biology, 1987-1992, Associate Professor and Graduate Advisor of Marine Biomedical and Environmental Science 1992-1996, Adjunct Professor, 1996 -present.

College of Charleston-Adjunct Professor, Marine Biology Program 1991-2016, Marine Environmental Science Program 2000-2016.

FEDERAL SERVICE

National Oceanic and Atmospheric Administration, NOAA Faculty Appointee/Program Manager NOAA Marine Biotoxins Program, 1992-95, Division Chief, Seafood Safety 1995-1977, Branch Chief, Coastal Research, 1997-2008, Branch Chief, Harmful Algal Bloom & Analytical Response, 2008-2016, Branch Chief HAB Monitoring and Reference Branch-2016-present.

AWARDS

U.S. Department of Commerce Honor Award -Silver Medal for Leadership, 2003.

U.S. Department of Commerce Honor Award -Gold Medal for Scientific Achievement, 2011.

NATIONAL MEDIA

NPR Science Friday "Toxin Triggers Epilepsy in Sea Lions and Humans" live before the Annual Meeting of the American Society for the Advancement of Science, February 19, 2010.

CONTRIBUTIONS TO NATIONAL HAB PLANNING AND PRIORITIZATION

Congressional Testimony to U.S. House Committee on Government Reform and Oversight and U.S. House Committee on Natural Resources to direct national funding in 1998 for Harmful Algal Bloom research.

Executive Editor, HARRNESS, Harmful Algal Research and Response: A National Environmental Science Strategy 2005-2015, Ecological Society of America, Washington DC. A 10-year plan for US HAB research.

ORIGINAL CONTRIBUTIONS TO HAB RESEARCH

Demonstrate domoic acid poisoning progresses to epilepsy through experimental animal model.

Characterize brain pathways for epilepsy and aggressive behavior in response to domoic acid and identify origin for domoic acid at dendritic spines of olfactory granule cells.

Published case definition: "Domoic acid epileptic disease is characterized by spontaneous recurrent seizures weeks to months after domoic acid poisoning and unusual behaviors in animal subjects, notably conspecific aggression".

Multiple publications defining toxicokinetic parameters for prenatal and adult exposures of rats, mice and finfish to domoic acid, brevetoxin and ciguatoxins using multiple routes of exposure.

Identification of ciguatoxin in the critically endangered Hawaiian monk seal. The first detection of ciguatoxin in a marine mammal, confirmed by mass spectrometry and testing of >150 seals across the Hawaiian Archipelago. Findings determined common occurrence in failing populations of monk seals on Midway Island. Impact assessed through laboratory novelty suppressed feeding test to implicate the effect of ciguatoxin to reduce foraging under apex predator stress.

CONTRIBUTIONS TO INTERNATIONAL AGENCIES

NOAA lead for MOU between the International Atomic Energy Agency and NOAA (2010-2020) to apply nuclear technology to measure toxins such as saxitoxin and to transfer this capability to developing Member States in Africa, Southeast Asia, Latin America and the Arabian Gulf.

U.S. Civilian Research & Development Foundation to mentor Russian scientist to investigate harmful algal blooms in the White Sea and Black Sea and NATO Program for Security through Science to develop a monitoring program in the Black Sea.

R. Wayne Litaker, Ph.D.
NOAA National Ocean Service,
National Centers for Coastal Ocean Science
Beaufort, NC 28516 USA
Wayne.Litaker@noaa.gov

Education

Ph.D.	Duke University, Botany - Phytoplankton Ecology
M.S.	University of Michigan, Resource Ecology
B.S.	Duke University, Zoology and Botany

Experience

2014-present	Supervisory Ecologist, Center for Coastal Fisheries and Habitat Research. National Ocean Service, National Oceanic & Atmospheric Administration
2002-2014	Research Fisheries Biologist, Center for Coastal Fisheries and Habitat Research. National Ocean Service, National Oceanic & Atmospheric Administration
1991-2002	Director, Carolina Workshops, Program in Molecular Biology & Biotechnology, School of Medicine, University of North Carolina at Chapel Hill, & Research Associate Professor, Department of Biology CB# 3280 - Fordham Hall, Chapel Hill, NC 27599-3280.
1989-1991	Research Associate, Department of Microbiology and Immunology, University of North Carolina at Chapel Hill.
1986-1991	Postdoctoral Fellow, Department of Microbiology and Immunology, University of North Carolina at Chapel Hill.

Dr. Litaker has over thirty years of experience investigating the ecology, taxonomy, molecular biology and toxicity of harmful algal bloom species (HABs). His research focuses methods for predicting and mitigating the adverse impacts of HABs.

External Funding:
North Pacific Research Board, Implementation of Community-based PSP Testing for Subsistence and Recreational Shellfish Harvesting in Southcentral and Southwestern Alaska, lead PI. ($97,237) 2017-2020
Ecology and Oceanography of Harmful Algal Blooms, Strain Differences in the Toxicity of Caribbean *Gambierdiscus* species: Implications for ciguatera fish poisoning in the Caribbean. ($249,758) 2011- 2015
North Pacific Research Board, Tools for Detecting PSP Causing Organisms, Co-PI. ($72,504) 20107-2014
US State Department, Lionfish and Ciguatera Fish Poisoning (CFP), CO-PI ($50,000) 2011 - 2014
North Carolina Biotechnology Center, Development of a new molecular training facility in eastern NC, CO-PI ($40,000) 2012 - 2013

Selected Key Publications on Harmful Algae (out of 149;
https://www.researchgate.net/profile/Richard_Litaker)

Litaker, R. W., Holland, W.C., Hardison, D.R., Pisapia, F., Hess P., Kibler, S.R., Tester, P.A. (2017). Ciguatoxicity of *Gambierdiscus* and *Fukuyoa* species from the Caribbean and Gulf of Mexico. PLoS ONE. https://doi.org/10.1371/journal.pone.0185776.

Gobler, C.J, Doherty, O., Hattenrath-Lehmann, T., Griffith, A., Kang, Y., Litaker, R.W. (2017). Ocean warming since1982 has expanded the niche of toxic algal blooms in the North Atlantic and North Pacific Oceans. Proceedings National Academy of Science, USA. 114(19):4975–4980, doi: 10.1073/pnas.1619575114.

John, U., Litaker, W., Montresor, M., Murray, S., Broshanan, M., Anderson, D. (2014). Formal revision of the *Alexandrium tamarense* species complex (Dinophyceae) taxonomy: The introduction of five species with emphasis on molecular-based (rDNA) classification. Protist. 63: 932-933.

Litaker, R.W., M. W. Vandersea, M. A. Faust, S. R. Kibler, A. W. Nau, M. Chinain, M. J. Holmes, W. C. Holland and P. A. Tester. (2010). Global Distribution of Ciguatera Causing Dinoflagellates in the Genus *Gambierdiscus*. Toxicon 56: 711-730.

Litaker, R. W., Vandersea, M.W., Faust, M.A., Kibler, S.R., Chinain, M., Holmes, M.J., Holland, W.C, Tester, P.A. (2009). Taxonomy of *Gambierdiscus*: Including four new species, *Gambierdiscus caribaeus* sp. nov., *Gambierdiscus carolinianus* sp. nov., *Gambierdiscus carpenteri* sp. nov. and *Gambierdiscus ruetzleri* sp. nov. (Gonyaulacales, Dinophyceae). Phycologia. 48:344-390.

ALAN JAY LEWITUS

Director, Competitive Research Program (CRP)
National Centers for Coastal Ocean Science (NCCOS) - National Ocean Service (NOS)/NOAA
1305 East West Highway, Silver Spring, MD 20910, e-mail: Alan.Lewitus@NOAA.gov

Education

1990 Ph.D., Massachusetts Institute of Technology/Woods Hole Oceanographic Institution. Biological Oceanography. Advisor: David A. Caron.

Physiology of Phototrophy and Heterotrophy in Algae with Contrasting Nutritional Characteristics, Pyrenomonas salina (Cryptophyceae) and Poterioochromonas malhamensis (Chrysophyceae).

1984 M.S., San Jose State University/Moss Landing Marine Laboratories. Marine Sciences; Physical Oceanography discipline. Advisor: William W. Broenkow.

The Distribution of In Situ Fluorescence, Bioluminescence, and Light Attenuation in the North Pacific.

1975 B.A., Rutgers University, New Brunswick. NJ. Biological Sciences.

Professional Background

2017-present Director, CRP, NOAA/NOS/NCCOS, Silver Spring, MD

2007-2017 Branch Chief, Ecosystem Stressors Research Branch, Center for Sponsored Coastal Ocean Research (CSCOR), NOAA/NOS/NCCOS, Silver Spring, MD

2006-2007 Program Manager, CSCOR, NOAA/NOS/NCCOS, Silver Spring, MD

2000-2006 Joint Position as 1) Research Associate Professor, University of South Carolina, and 2) Associate Marine Scientist, SC Department of Natural Resources. Director, SC Algal Ecology Laboratory/SC Harmful Algal Bloom Program, Charleston, SC.

1993-2000 Research Assistant Professor, Belle W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Georgetown, SC.

1990-1993 Research Associate, Univ. Maryland Center for Environmental and Estuarine Studies, Cambridge, MD.

Experience

Research background prior to NOAA: Phytoplankton ecology and physiology; harmful algal blooms; microbial food web dynamics; response of estuarine and marine ecosystems to eutrophication.

NOAA: Responsible for the oversight of a multimillion dollar competitive grant portfolio, requiring engagement of diverse stakeholder groups to advance coastal ecosystem research and management. Focus on application of sponsored research to inform management strategies to mitigate the impacts of environmental stressors (e.g. hypoxia, harmful algal blooms, sea level rise, ocean acidification) on coastal ecosystems.

Publications (out of 95 peer-reviewed) - Five most recent

Allen, A.L., C.W. Brown, A.J. Lewitus, P.A. Sandifer. 2015. The roles of emerging technology and modeling techniques in operational ecological forecasting at NOAA. Marine Technology Society Journal, March/April 2015, Volume 49, Number 2, pp. 194–203.

Lewitus, A.J. et al. 2012. Harmful algal blooms along the North American West Coast region: History, trends, causes, and impacts. Harmful Algae 19:133-159.

Glibert, P.M., A.J. Lewitus, et al. 2010. Modeling of HABs and eutrophication: Status, advances, challenges. Journal of Marine Systems 83:262–275.

Kidwell, D.M., A.J. Lewitus, S.B. Brandt, E.B. Jewett, and D.M. Mason. 2009. Ecological impacts of hypoxia on living resources. J. Exper. Mar. Biol. Ecol. 381:S1-S3.

Heisler, J., P. Glibert, J. Burkholder, D. Anderson, W. Cochlan, W. Dennison, Q. Dortch, C. Gobler, C. Heil, E. Humphries, A. Lewitus, R. Magnien, H. Marshall, K. Sellner, D. Stockwel, D. Stoecker, M. Suddleson. 2008. Eutrophication and Harmful Algal Blooms: A Scientific Consensus. Harmful Algae 8:3-13.

Five other selected

Lewitus, A.J., L.M. Brock, M.K. Burke, K.A. DeMattio and S.B. Wilde. 2008. Lagoonal stormwater detention ponds as promoters of harmful algal blooms and eutrophication along the South Carolina coast. Harmful Algae 8:60-65.

Lewitus, A.J. 2006. Osmotrophy in marine microalgae. In “Algal cultures, analogues and blooms”, D.V. Subba Rao (ed.), pp. 343-383.

Lewitus, A.J., D.L. White, R.G. Tymowski, M.E. Geesey, S.N. Hymel and P.A. Noble. 2005. Adapting the CHEMTAX method for assessing phytoplankton taxonomic composition in southeastern U.S. estuaries. Estuaries 28:158-170.

Lewitus, A.J., H.B. Glasgow and J.M. Burkholder. 1999. Kleptoplastidy in the toxic dinoflagellate, Pfiesteria piscicida (Dinophyceae). J. Phycol. 35:303-12.

Lewitus, A.J., E.T. Koepfler and J.T. Morris. 1998. Seasonal variation in the regulation of phytoplankton by nitrogen and grazing in a salt marsh estuary. Limnol. Oceanogr. 43:636-46.

FRANCES QUAY DORTCH

EDUCATIONAL BACKGROUND:

B.A. with Honors, 1970, Chemistry, Randolph-Macon Woman's College, Lynchburg, VA

M.S., 1973, Biochemistry, Indiana University, Bloomington, IN

Ph.D., 1980, Biological and Chemical Oceanography, University of Washington, Seattle, WA

PROFESSIONAL EMPLOYMENT:

Oceanographer NOAA NOS NCCOS 2003 to present

Coordinator, Ecology and Oceanography of Harmful Algal Bloom Program, 2003-present,

Program Manager, Prevention, Control and Mitigation of Harmful Algal Blooms Program, 2010 to present

Co-manage Event Response Program, 2003-present

Associate Professor, Louisiana Universities Marine Consortium; 1991 to 2003, Assistant Professor, 1986 to 1991

Research Scientist, Bigelow Laboratory for Ocean Sciences; 1981-1986

SELECTED ACCOMPLISHMENTS at NOAA

Active in Interstate Shellfish Sanitary Conference in order to align NOAA HAB research with needs of shellfish managers

Member Laboratory Committee

Chair Sub-committee on Engagement Committee on Laboratory. Led effort to develop research priorities for improving management of biotoxins in bivalve mollusks

Served as NOAA Representative on Task Force 1 Growing Waters 2017 Biennial Meeting

Serve on IWG HABHRCA

Established new research program for Prevention, Control and Mitigation of Harmful Algal Blooms based on HABHRCA reports

Served as NOAA point person on the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA) reauthorization in 2004, 2008-2014, and currently. Provide analysis and information to NOAA and Congress.

Alternate member of Joint Sub-committee on Ocean Science and Technology (JSOST) Interagency Working Group on Harmful Algal Blooms, Hypoxia and Human Health (IWG-4H) and Co-chair of Sub-committee on Harmful Algal Booms

Led NOAA effort to Fulfill HABHRCA requirements for 6 scientific assessments and research plans on HABs (see list below)

AWARDS (with many others):

May 2007 NOAA Bronze Award. For quick action and exceptional initiative helping shellfish managers protects human health in the face of the 2005 New England Harmful Algal Bloom

April 2010 NOAA Bronze Award. For leadership in producing five congressionally-mandated HABHRCA reports to advance the research and management of harmful algal bloom and hypoxia issues.

May 2016 NOAA Bronze Award. For Response Activities for the Lake Erie Harmful Algal Bloom that Impacted Drinking Water Supplies in Ohio and Michigan

August 2016 NOAA Administrator's Award. For providing timely and essential event response support and coordination leadership during the historic 2015 West Coast harmful algal bloom event.

November 2017 NOAA Technology Transfer Award. For leading the development and successful transition to commercial application of an automated sensor, the Imaging Flow Cytobot that provides early warning of harmful algal blooms

November 2017 Federal Laboratory Consortium for Technology Transfer (FLC) Mid-Atlantic Regional Excellence in Technology Transfer Award. For efforts to transition a sensor, the Imaging Flow Cytobot, to commercial availability for automated early warning of harmful algal blooms.

PUBLICATIONS

HABHRCA Reports Submitted to Congress

National Assessment of Efforts to Predict and Respond to Harmful algal Blooms in U.S. Waters. Interim Report. 2007. Jewett, E.B., Lopez, C.B., Dortch, Q., Etheridge, S.M. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, D.C.

Scientific Assessment of Freshwater HABs, 2008. Lopez, C.B., Jewett, E.B., Dortch, Q., Walton, B.T., Hudnell, H.K. Interagency Working Group on Harmful Algal Blooms, Hypoxia and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC, 65 pp.

Harmful Algal Bloom Management and Response: Assessment and Plan, 2008, Jewett, E.B., Lopez, C.B., Dortch, Q., Etheridge, S.M., Backer, L.C. Interagency Working Group on Harmful Algal Blooms, Hypoxia and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC, 76 pp.

Scientific Assessment of Marine HABs, 2008, Lopez, C.B., E.B. Jewett, Q. Dortch, D. Garrison. Interagency Working Group on Harmful Algal Blooms, Hypoxia and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC., 62 pp.

Workshop Reports Leading to HABHRCA Reports

Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs, 2008, edited by H.K. Hudnell, Advances in Experimental Medicine and Biology, vol. 619, Springer. (Dortch co-author on multiple chapters)

Harmful Algal Bloom Research, Development, Demonstration and Technology Transfer: A National Workshop Report, 2008, Ed. by Q. Dortch, D. Anderson, D. Ayres, P. Glibert. Woods Hole Oceanographic Institute, Woods Hole, MA.

Other Publications: https://www.researchgate.net/profile/Quay_Dortch

Marc E. Suddleson. NOAA Ocean Service, National Centers for Coastal Ocean Science 1305 East-West Highway, Silver Spring, MD 20910; Tel. 240-533-0305, Email: marc.suddleson@noaa.gov.

Relevant Professional Experience:

2002–Present. Oceanographer\Program Manager, NOAA National Centers for Coastal Ocean Science, Competitive Research Program. Silver Spring, MD.

Promoting the development of new coastal monitoring and ocean observation technologies and fostering sustainable monitoring, alert, and prediction systems for ocean phenomena, like harmful algal blooms. Building effective statewide and regional partnerships between federal labs, research universities, and state agencies to deliver peer-reviewed science in support of decisions to manage the use of coastal resources. Managing multidisciplinary oceanographic research programs. Co-wrote national and regional strategic research guidance reports (e.g. Harmful Algal Research and Response: A National Environmental Science Strategy 2005–2015 (HARRNESS). Managing the Monitoring and Event Response for Harmful Algal Blooms (MERHAB) program and HAB Event Response program.

1999–2002. Program Analyst, NOAA National Centers for Coastal Ocean Science, Coastal Ocean Program. Silver Spring, MD.

Assisted in preparing Ecology and Oceanography of Harmful Algal Bloom (ECOHAB) financial awards to ensure continuation of office HAB research projects. Created and co-hosted web-based seminar on current and emerging HAB technologies. Assisted development of a competitive coral research program. Analyzed office budget data and represented office in the budget planning process. Developed performance measures for Coastal Ocean Program (COP) projects and prepared quarterly and year-end progress and accomplishment reports. Helped define and plan for long-term office database improvements and provided oversight of administrative contractors. Managed and enhanced the utility of office FileMaker Pro database and provided training for COP Grants staff and program managers. Developed and maintained office communications products including publications, factsheets, presentations, and office website.

1996–1999. Marine Policy Analyst, NOAA Office of Ocean and Coastal Resource Management, Office of the Director, Silver Spring, MD.

Represented NOAA on federal committee working to implement Clean Water Action Plan - facilitated communications with state, county and Native American representatives. Analyzed federal policy for impact on NOAA programs. Led team that produced the 1996-1997 Biennial Report to Congress to document NOAA and state progress in implementing the Coastal Zone Management Act. Lead manager for 1997 Walter B. Jones Memorial and NOAA Excellence Awards to honor NOAA constituent accomplishments. Achieved best Congressional attendance for any NOAA event that year.

1995. Government Relations Assistant Consortium for Oceanographic Research and Education. Washington, District of Columbia

Analyzed ocean legislative actions during the 104th United States Congress and updated university and federal agency constituents. Tracked bills and reported weekly on hearings of Senate and House of Representative authorization and appropriation committees to inform over 30 member universities and institutions. Prepared testimony for the Consortium President, Admiral James D. Watkins.

Education:

1997 - Master of Marine Policy, University of Delaware, College of Marine Studies, Newark, Delaware.

1992 – Bachelor of Science in Marine Science and Biology, University of Miami, Coral Gables, Florida.

Professional Memberships:

Federal Laboratory Consortium, Washington, DC. Executive Board Member for NOAA (FY18-19).

International Society for the Study of Harmful Algae

Awards:

2017 – NOAA Technology Transfer Award for leading development and successful transition to commercial application of an automated sensor that provides early warning of harmful algal blooms

2016 NOAA Administrator's Award for providing timely and essential event response support and coordination leadership during the historic 2015 West Coast harmful algal bloom event.

2016 – Department of Commerce Bronze Medal for superior performance in agency response to a Lake Erie harmful algal bloom that impacted drinking water supplies in Ohio and Michigan.

2007 – NOAA Technology Transfer Award for development and commercialization of rapid, cost effective kits to detect harmful algal toxins in shellfish.

2007 – Department of Commerce Bronze Medal for response to 2005 New England

Harmful Algal Bloom.

2006 – United States Food and Drug Administration award recognizing participation on the

Paralytic Shellfish Management Group.

1998 – Clean Water Action Plan Principals Award.

Publications:

Heisler, J., Glibert, P., Burkholder, J., Anderson, D., Cochlan, W., Dennison, W., Gobler, C., Dortch, Q., Heil, C., Humphries, E., Lewitus, A., Magnien, R., Marshall, H., Sellner, K., Stockwell, D., Stoecker, D., Suddleson, M., 2008. Eutrophication and harmful algal blooms: a scientific consensus. Harmful Algae 8, 3–13.

Valette Silver, N., Q. Dortch, R. P. Stumpf, R.W. Litaker, M. E. Suddleson and G. C. Matlock, NOAA. 2008. Development and implementation of a forecasting and warning system for harmful algal blooms by the US National Oceanic and Atmospheric Administration (NOAA). pp.151154. In: Risk Wise, Eds. S. Nicklin, B. Cornwell, J. Dodd, J. Griffiths and S. Townsend. Tutor Rose, Leicester, United Kingdom.

Trainer V. and Suddleson M. "Monitoring Approaches for Early Warning of Domoic Acid

Events in Washington State. Oceanography. Vol 18: 228237. June 2005.

M. JAWED HAMEEDI

Ph.D. in Oceanography, University of Washington, Seattle
M.S. in Oceanography, University of Washington, Seattle

Dr. Hameedi is Lead Research Scientist at the National Centers for Coastal Ocean Science. As such, he provides expert advice, scientific reviews, and strategic priorities to NOAA and interagency working groups on program initiatives, policy directives, and research and development portfolio management.

Dr. Hameedi served as research coordinator, deputy director, and director of a multi-faceted, and long-term Outer Continental Shelf Environmental Assessment Program (OCSEAP), which in its halcyon days, was the largest environmental studies program ever undertaken. The program provided research findings, quality-assured scientific data, information products, disciplinary and synthesis reports, and engagement with stakeholders to help guide safe and prudent development of offshore oil and gas resources in Alaska. It resulted in numerous scientific breakthroughs and pioneering information products that still define state of the art in the region. He was manager of NOAA's National Status and Trends (NS&T) Program, a comprehensive monitoring and assessment program to observe and report on coastal contamination and its associated biological effects in US coastal waters and estuaries. . The program also developed ecological indicators, guidelines and other diagnostic tools to infer the severity of contamination and to evaluate the performance of governmental programs to abate degradation of coastal ecosystems. He was an original member of the Group of Experts that developed and implemented the international Arctic Monitoring and Assessment Program, which coordinated and produced comprehensive assessment reports on environmental pollution in the Arctic, including petroleum hydrocarbons, radionuclides, persistent organic pollutants, and heavy and trace metals. He has also served on international committees and US delegations that developed bilateral and multinational marine research, assessment and monitoring programs in the Arctic, Yellow Sea, Vietnam, Japan, China, and Pakistan.

Dr. Hameedi has authored more than 90 peer-reviewed publications on a number of subjects, including general and regional oceanography, statistical and analytical models, coastal pollution and monitoring, transport and weathering of spilled crude oil, human health risk from exposure to radionuclides, management use of scientific data, and applications to national defense. He also co-edited a book on different aspects environmental management of Port Valdez, where a mammoth ballast water treatment facility operated to transfer crude oil from Alaska to the conterminous United States. In addition, he has written, as principal author or contributor, dozens of strategic plans, technical development plans, policy papers, and agency policy and procedures related to research and development, and applications of new technologies. Recent examples include an interagency report on National Earth Observation Assessment submitted to Congress, an initiative for national environmental indicators but forth by the National Academy of Public Administration, Implementation Plan for the National Ocean Policy, and the next decadal Ocean Research and Technology Plan for the United States.

Dr. Hameedi has provided extensive expert advice to state governments, inter-state commissions, non-governmental organizations, international programs, and the public at large on issues related to environmental pollution, integrated coastal zone management, and interpreting and synthesizing scientific data in light of federal statutes and regulations.

Richard P. Stumpf, Ph.D.
NOAA National Ocean Service,
National Centers for Coastal Ocean Science
Silver Spring MD 20910 USA
Richard.stumpf@noaa.gov

Education

Ph.D. University of Delaware, Marine Studies

M.S. University of Delaware, Marine Studies

B.A. University of Virginia, Environmental Sciences with high honors

Experience

2008-2009 Visiting Scientist, NASA Ocean Biology Processing Group, Goddard, MD

1998-present Oceanographer, National Oceanic and Atmospheric Administration. National Centers for Coastal Ocean Science. MD

1996 Guest Scientist, British Geological Survey, Coastal Geology Group, Notts. UK

1989-1999 Physical Scientist, U.S. Geological Survey, Center for Coastal Geology, FL

1985-1989 Physical Scientist, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, DC

Dr. Stumpf has over thirty years of experience in coastal oceanography with particular emphasis on algal blooms. He develops methods to apply satellite data and modeling to address eutrophication impacts, habitat change, and algal bloom monitoring and forecasting, with work on most of the US coast. He leads NOAA's efforts to translate forecasts of harmful algal blooms from research to operations.

External Funding:

NASA Decision Support, Earth Science Applications, lead PI, Improved Forecasts of Respiratory Illness Hazard from Gulf of Mexico Red Tide. ($422,853 of $1,019,880) 2015-2018

NASA Ocean Biology and Biochemistry, Co-PI, Cyanobacteria Assessment Network (CyAN) for freshwater systems: an early warning indicator for toxic and nuisance blooms using ocean color satellites. ($513,107 of $1,621,136) 2015-2019

NASA Decision Support through Earth Science Results. "Monitoring and Forecasting Cyanobacterial Blooms for Public Health Protection and Response. ($1,217,252) 2009-2014

Selected Key Publications on Harmful Algae

Stumpf, R.P., T.W. Davis, T.T. Wynne, J.L. Graham, K.A. Loftin, T.H. Johengen, D. Gossiaux, D. P, (2016). Challenges for mapping cyanotoxin patterns from remote sensing of cyanobacteria. Harmful Algae, 54:160-173.

Bullerjahn, G.S., + 20 authors (alphabetic) , R.P. Stumpf, (2016). Global solutions to regional problems: collecting global expertise to address the problem of harmful algal blooms—A Lake Erie case study. Harmful Algae. (contributed remote sensing and forecasting sections), 54:223-238.

Stumpf, R.P., T.T. Wynne, D.B. Baker, G.L. Fahnenstiel, (2012). Interannual variability of cyanobacterial blooms in Lake Erie. PLoSONE. 7(8): doi:10.1371/journal.pone.0042444

Stumpf, R.P. , M.E. Culver, P.A. Tester, G.J. Kirkpatrick, B.A. Pederson, M. Tomlinson, E. Truby, V. Ransibrahmanakul, K. Hughes, M. Soracco. (2003). Monitoring Karenia brevis blooms in the Gulf of Mexico Using Satellite Ocean Color Imagery and Other Data. Harmful Algae, v. 2(2):147-160.

Margaret H. Broadwater

NOAA · National Ocean Service · National Centers for Coastal Ocean Science
Stressor Detection and Impacts Division · Charleston, SC
843.460.9684 (desk) · 843.670.8994 (cell)
maggie.broadwater@noaa.gov

Education

Ph.D.	Medical University of South Carolina, *Biochemistry – Bioinformatics*	2012
M.S.	Medical University of South Carolina, *Biomedical Sciences – Bioinformatics*	2006
B.S.	College of Charleston, *Biochemistry*	1997

Professional Experience

2006-Present	Research Chemist, NOAA National Ocean Service, National Centers for Coastal Ocean Science, Stressor Detection and Impacts Division, Charleston, SC
2003-2006	Research Chemist, NOAA National Ocean Service, National Centers for Coastal Ocean Science, Marine Forensics Program, Charleston, SC
1999-2003	Chemist, NOAA National Ocean Service, National Centers for Coastal Ocean Science, Marine Forensics Program, Charleston, SC
1998-1999	Chemist, STL-Savannah Laboratories, Inc., Savannah, GA

Awards

NCCOS Peer Recognition Special Achievement Award	2017
NOAA Administrator's Award	2016
NCCOS Peer Recognition EEO/Diversity Award	2016
Outstanding Student Achievement Award, Society for Wildlife Forensic Science	2010
Fellow, National Library of Medicine, *Toolmakers for Bioinformatics*	2006
Outstanding Student Volunteer Award, Medical University of South Carolina	2003

Professional Organizations and Activities

2016-Present	Interstate Shellfish Sanitation Conference, NOAA Advisor
2015-Present	Gulf of Mexico Alliance, Water Resources and Wildlife & Fisheries Teams
2015-2017	Alaska/British Columbia Large Whale Unusual Mortality Event Investigative Team
2000-2009	American Oil Chemists' Society

Teaching Experience

2011-Present	College of Charleston, Adjunct Professor, Master of Science in Environmental Studies Program
2013-2017	*Theory and laboratory implementation of the receptor binding assay for paralytic shellfish toxins*, NOAA Marine Biotoxins Program, Charleston, SC Training provided to the following agencies/entities: · Centers for Disease Control, Atlanta, GA · Sitka Tribe of Alaska, Sitka, AK · Queens University, Belfast, Ireland · US FDA Northeast Regional Laboratory, Jamaica, NY · Marine Animal Rehabilitation Centre, Figueira da Foz, Portugal

· Resource Access International, LLC, Brunswick, ME

2017 *Effects and toxicity of oil to marine mammals*, NOAA Science of Oil Spills Course, Charleston, SC

2016 *Harmful algal blooms: science and support*, NOAA Science of Coastal Natural Disasters Course, Mobile, AL

2008 Medical University of South Carolina, Teaching Assistant, College of Graduate Studies

1995-1996 College of Charleston, Teaching Assistant, Chemistry & Biochemistry Department

Selected Publications

Turner AT, Broadwater MH, Van Dolah V. (2018) Use of the receptor binding assay for determination of paralytic shellfish poisoning toxins in bivalve molluscs from Great Britain and the assessment of method performance in oysters. Submitted to *Toxicon*; 22 January 2018.

Broadwater MH, Fire S, VanDolah F. (2018) Vulnerabilities of Marine Mammals to Harmful Algal Blooms. In: Harmful Algal Blooms and Their Management: A compendium desk reference.

Walker JS, Shaver DJ, Stacy BA, Flewelling LJ, Broadwater MH, Wang Z. (2018) Brevetoxin exposure in sea turtles in south Texas during *Karenia brevis* red tide. *Diseases of Aquatic Organisms*, 127:145-150.

Hattenrath-Lehmann TK, Lusty MW, Wallace RW, Haynes B, Wang Z, Broadwater M, Deeds JR, Morton SL, Hastback W, Porter L, Chytalo K, Gobler CJ. (2018) Evaluation of rapid, early warning approaches to track shellfish toxins associated with *Dinophysis* and *Alexandrium* blooms. *Marine Drugs*, 16(1):28.

Fire SE, Adkesson MJ, Wang Z, Jankowski G, Cárdenas-Alayza S, Broadwater MH. (2016) Peruvian fur seals (*Arctocephalus australis*) and South American sea lions (*Otaria flavescens*) in Peru are exposed to the harmful algal toxins domoic acid and okadaic acid. *Marine Mammal Science*, 33(2): 630-644.

Wilson C, Sastre AV, Hoffmeyer M, Rowntree VJ, Fire SE, Santinelli NH, Ovejero SD, D'Agostino V, Marón CF, Doucette G, Broadwater MH, Wang Z, Montoya N, Seger J, Adler FR, Sironi M, Uhart MM. (2016) Southern right whale (*Eubalaena australis*) calf mortality at Península Valdés, Argentina: are harmful algal blooms to blame? *Marine Mammal Science*, 32(2): 423-451.

Wang Z, Broadwater MH, Ramsdell JS. (2015) Analysis of diarrhetic shellfish poisoning toxins and pectenotoxin-2 in the bottlenose dolphin (*Tursiops truncatus*) by liquid chromatography–tandem mass spectrometry. *Journal of Chromatography A*, 1416: 22-30.

Broadwater MH, Seaborn GT, Schwacke JH. (2013) Forensic identification of seal oils using lipid profiles and statistical models. *Journal of Forensic Sciences* 58(2): 336-343.

Steve L. Morton, Ph.D.
National Oceanic and Atmospheric Administration
NOS/NCCOS
Harmful Algal Blooms Monitoring and Reference Branch
219 Fort Johnson Road
Charleston, SC 29412 USA

EDUCATION

Ph.D., 1994, Plant Biology/Marine Phycology, Southern Illinois University

M.Sc., 1990, Biological Oceanography, Florida Institute of Technology

B.Sc., 1988, Biological Oceanography, Florida Institute of Technology

PROFESSIONAL APPOINTMENTS

1998- Research Oceanographer, NOAA/Marine Biotoxins Program

1996-1998: Curator, Provasoli-Guillard National Center for Culture of Marine Phytoplankton

1995-1996: Post-Doctoral Research Scientist, Southern Illinois University

1994-1995: Laboratory Director, MariTech, Inc., Carbondale, IL

FACULTY APPOINTMENTS

2000-present: Adjunct Research Professor, Medical University of South Carolina

2001-present: Adjunct Professor, Environmental Sciences, College of Charleston

2001-present: Adjunct Professor, Environmental Sciences, Florida A&M University

2003-present: Adjunct Professor, Marine Science Department, University of South Carolina

2013-present: Adjunct Professor, Biology Department, Jackson State University

PROFESSIONAL AWARDS

2017 National Oceanographic and Atmospheric Administration Center Champions Working Group Recognition Award

2017 National Centers for Coastal Ocean Science's Special Achievement Award

2016 National Oceanographic and Atmospheric Administration Administrator's Award

2015 United States Department of Commerce Bronze Medal Award for Research

2008 United States Department of Commerce Bronze Medal Award for Research

2007 United States Department of Commerce Bronze Medal Award for Research

Graduate students over past 5 years:

Sonia Munir, Ph.D. student, University of Karachi (2014), Matt Brim M.S. student, University of Nebraska (2014), Kim Tucker, Ph.D. student Florida A&M University (2017), Jeanna Dampier Ph.D.

student Jackson State University (current), Shareena Cannonier Ph.D. student Florida A&M University (current), Kevin Williams M.S. student Florida A&M (current), Nia Rene, M.S. student City University of New York (current)

Synergistic activities

Editorial Advisory Board, Journal of Harmful Algae 2000-present; Editorial Board Asian Journal of Marine Sciences; Editorial Board, Journal of Coastal Life Medicine; Scientific Board of Directors and Co-founder, The Living Black Sea, 2004-2010; Research Fellow, Smithsonian Institution Caribbean Coral Reef Ecosystem Program, 1997-2001

SELECT PUBLICATIONS (5 of 120)

Knaack, J.S., Km Porter, J.T. Jacob, K. Suillivan, M. Forester, R.Y. Wang, V.L. Trainer, S.L. Morton, G. Eckert, E. McGahee, J. Thomas, J. McLaughlin, R.C. Johnson. 2016. Diagnosing Saxitoxin-Induced Paralytic Shellfish Poisoning: Case Series of Alaskan Patients with Manifestations of Paralytic Shellfish Poisoning. Harmful Algae 57: 45-50.

Hattenrath-Lehmann, T.K., M.A. Marcoval, H. Mittlesdorf, J.A. Goleski, Z. Wang, B. Haynes, S.L. Morton, and C.J. Gobler. 2015. Nitrogenous nutrients promote the growth and toxicity of Dinophysis acuminate populations during estuarine bloom events. PLoS ONE 10(4): e0124148:doi10.1371.

Trainer, V.L., K. Sullivan, B-T Eberhart, A. Shuler, E. Hignutt, J. Kiser, G.L. Eckert, S.E. Shumway, and S.L. Morton. 2014. Enhancing shellfish safety in Alaska through monitoring of Harmful Algae and their toxins. Journal of Shellfish Research, 33(2) 531-539.

Skinner, M.P. R.J. Lewis and S.L. Morton. 2013. Ecology of the ciguatera causing dinoflagellates from the Northern Great Barrier Reef: changes in community distribution and coastal eutrophication. Marine Pollution Bulletin 77: 210-219.

Shuler, A.J., J. Paternoster, M. Brim, K. Nowocin, T. Tisdale, K. Neller, J.A. Cahill, T.A. Leighfield, S. Fire, Z. Wang and S.L. Morton. 2012. Spatial and temporal trends of the toxic diatom Pseudo-nitzschia in the Southeastern Atlantic United States: The use of volunteers to monitor HABs. Harmful Algae 17: 6-13.

Gregory John Doucette, Research Oceanographer

National Centers for Coastal Ocean Science, NOAA/NOS, 219 Fort Johnson Rd., Charleston, SC 29412; telephone: 843-460-9687; e-mail: greg.doucette@noaa.gov

EDUCATION/TRAINING: INSTITUTION	DEGREE	Completion Date MM/YYYY	FIELD OF STUDY
Bowling Green State University	B.S.	05/1979	Biology
Texas A&M University	M.S.	08/1982	Oceanography
University of British Columbia	Ph.D.	05/1989	Botany
Woods Hole Oceanographic Institution	Postdoctoral	06/1992	Algal Ecophysiology
National Marine Fisheries Service	Postdoctoral	12/1995	Marine Biotoxins & HABs

A. Personal Statement

Dr. Doucette is a Research Oceanographer in the HAB Monitoring and Reference Branch of NCCOS' Stressor Detection and Impacts Division, and is Co-Lead for the HAB Priority Area of NOAA's Ecological Forecasting Roadmap. Dr. Doucette has been at the forefront of developing sensors for the autonomous, in-situ detection of algal biotoxins for nearly two decades. His NCCOS research group led the design, development, and successful deployment of the first autonomous, sub-surface sensor for an algal biotoxin (domoic acid), and produced and deployed sensors for saxitoxins and microcystins, on the robotic Environmental Sample Processor platform. In partnership with the Monterey Bay Aquarium Res. Inst., WHOI, NMFS/NWFSC, and OAR/GLERL, deployments of this sensor technology enabled generation of near-real time algal toxin data off the U.S. east/west coasts and in the Great Lakes.

B. Five Relevant Peer-reviewed Publications (total of 111 peer-reviewed publications)

1. Doucette, G.J., Mikulski, C.M., Jones, K.L., King, K.L., Greenfield, D.I., Marin III, R., Jensen, S., Roman, B., Elliott, C.T., Scholin, C.A. 2009. Remote, subsurface detection of the algal toxin domoic acid onboard the Environmental Sample Processor: assay development and field trials. Harmful Algae 8:880-888.
2. Scholin, C., Doucette, G., Jensen, S., (16 co-authors). 2009. Remote detection of marine microbes, small invertebrates, harmful algae and biotoxins using the Environmental Sample Processor (ESP). Oceanography 22:158-167.
3. Ryan, J., Greenfield, D., Marin III, R., Preston, C., Roman, B., Jensen, S., Pargett, D., Birch, J., Mikulski, C., Doucette, G., Scholin, C. 2011. Harmful phytoplankton ecology studies using an autonomous molecular analytical and ocean observing network. Limnology & Oceanography 56:1255–1272.
4. Bullerjahn, G.S., McKay, R.M., Davis, T.W., Baker, D.B., Boyer, G.L., D'Anglada, L.V., Doucette, G.J., (14 co-authors). 2016. Global solutions to regional problems: Collecting global expertise to address the problem of harmful cyanobacterial blooms. A Lake Erie case study. Harmful Algae 54:223-238.
5. Ryan, J.P, Kudela, R.M., Birch, J.M., Blum, M., Bowers, H.A., Chavez, F.P., Doucette, G.J., Marin III, R., Mikulski, C.M., Negrey, K., Pennington, J.T., Scholin, C.A., Smith, G.J., Zhang, Y. 2017. Causality of an extreme harmful algal bloom in the central California Current System during the 2014 – 2015 northeast Pacific warm anomaly. Geophysical Research Letters 44. doi:10.1002/2017GL072637.

C. Selected Book Chapters & White Papers (total of 13 book chapters)

1. Scholin, C.A., Doucette, G.J., Cembella, A.D. 2008. Prospects for developing automated systems for in situ detection of harmful algae and their toxins. In: Babin, M., Cullen, J., Roessler, C. (eds.), Real time coastal observing systems for ecosystem dynamics and harmful algal blooms. Monographs on

Oceanographic Methodologies, Vol. 10. Paris: Intergovernmental Oceanographic Commission of UNESCO. pp. 413-462.
2. Anderson, D.M., Doucette, G.J., Kirkpatrick, G., Scholin, C.A., Paul, J., Trainer, V.L., Campbell, L., Kudela, R.M., Stumpf, R.P., Morrison, J.R. 2013. Harmful algal bloom (HAB) sensors in ocean observing systems. In: Interagency Ocean Observation Committee (Ed.) U.S. IOOS Summit Report: A New Decade for the Integrated Ocean Observing System; Community White Papers, pp. 1-5.
3. Doucette, G.J., Kudela, R.M. 2017. In-situ and real time identification of toxins and toxin-producing microorganisms in the environment. In: Campàs, M., Diogène, J. (Eds.). CAC: Recent Advances on the Analysis of Marine Toxins. Elsevier, B.V. 78:411-443. http://dx.doi.org/10.1016/bs.coac.2017.06.006.
4. Doucette, G.J., Medlin, L.K., McCarron, P., Hess, P. 2017. Detection and surveillance of harmful algal bloom species and toxins. In: Shumway, S.E., Burkholder, J.M, Morton, S (Eds.) *Harmful Algal Blooms: A Compendium Desk Reference*. Elsevier, New York. In press.

D. Positions and Honors

Positions and Employment

1992 –	Adjunct Graduate Faculty of the University, Marine Biology Program, Univ. of Charleston
1996 – 1999	Project Leader, Marine Biotoxins Program, Charleston Lab, NMFS
1996 – 2012	Associate Graduate Faculty, Marine Biomedical and Environmental Sciences Program/College of Graduate Studies, Medical University of South Carolina
1999 –	Research Oceanographer/Principal Investigator, Marine Biotoxins Program, NOAA/NOS, Center for Coastal Environmental Health & Biomolecular Research
2009 – 2012	Visiting Senior Research Fellow; Queen's University Belfast, Belfast, N. Ireland

National & International Experience

1996 – 2006	Member, ICES Working Group on Phytoplankton Ecology
2002 – 2005	Member, Steering Comm., EC ASTOX Project on Azaspiracid Isolation, Purification, Toxicology
2002 – 2006	Technical Cooperation Expert, United Nations International Atomic Energy Agency (IAEA)
2004 – 2008	Member, Council of the International Society for the Study of Harmful Algae
2005 – 2010	Chair, International Advisory Board, EC BioCop Project on “New Technologies to Screen Multiple Contaminants in Foods”
2006	Convener/Organizer, workshop on Research and Management of *Cochlodinium* Blooms, Cheju National University, Cheju, South Korea
2007 – 2010	Member, U.S. National HAB Committee
2008	Course Director, IAEA African Interregional Training Course – saxitoxin receptor binding assay
2008, 2012	Member, Organizing Comm. for 13th (2008) 15th (2012) International Conf. on HABs
2010 – 2012	Member, International Advisory Board, EC CONffIDENCE Project on “CONtaminants in Food and Feed: Inexpensive DetectioN for Control of Exposure”
2010 –	Member, IAEA Scientific Advisory Committee on Harmful Algal Blooms
2011, 2013	Member, Steering Comm. for 6th (2011) and 7th (2013) Symposium on Harmful Algae in the U.S.

Federal Service Honors

2002	NOAA Technology Transfer Award
2010	NOAA Administrator’s Award
2016	NOAA Administrator’s Award