EXTERNAL PEER REVIEW: NCCOS HARMFUL ALGAL BLOOMS AND HYPOXIA
SUMMARY AND INDIVIDUAL REVIEWS

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Review Panel Members

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- Dan Ayres, Washington Department of Fish & Wildlife
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  - Executive Director
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Purpose of the Review

The panel members were convened to provide an external review that NOAA requires of its research and development (R&D) programs on a periodic basis. These reviews may play a role in program planning, management, and oversight by providing feedback on program design and execution. Specifically, NOAA's National Centers for Coastal Ocean Science (NCCOS) was interested in an evaluation of its information products, the delivery of those products to users, and engagement with stakeholders. Specifically, the review was intended to achieve the following:

1. assess NCCOS' role as a federal entity to improve scientific understanding of harmful algal blooms (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; and

   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 engage stakeholders, and transitioning its R&D to widely utilized applications; and
4. offer observations and make recommendations to better position NCCOS for implementing its HAB and hypoxia portfolio.

Scope of the Review

The review covered all aspects of intramural and extramural HAB and hypoxia related research, assessment, monitoring, and other activities conducted by NCCOS over the past five years. The review focused 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. The review considered the underlying assumptions, statutes, and organizational drivers that led to the current HAB and hypoxia portfolio.

Program Evaluation Criteria

Through Administrative Order (NAO 216-115A, dated 3 October 2016), NOAA adopted the following core program evaluation criteria: quality, relevance, and performance. The criteria and brief descriptions of each were provided to the panel members in advance of the review. **Quality** was described as a measure of soundness, accuracy, and reproducibility of a specific body of research. Quality 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. Quality also requires evidence of established procedures for competitive, merit-based procedures for research funding and assuring scientific integrity. **Relevance** is a measure of impact. For example, "what would not have happened if NCCOS did not exist, and how much would society have missed?" This criterion addresses the benefits of the program. **Performance** is a measure that refers to the ability to manage in a manner that produces identifiable results, both effectively and efficiently. Performance can be assessed by evaluating the program management structure and whether it produces the desired results, guidance, or framework for tracking progress toward the agency's strategic goals and objectives, having the flexibility to address events or changing priorities, interacting with stakeholders, and collaborating with extramural partners. Accordingly, the reviewers focused and organized evaluations and recommendations using these three core criteria.

Reviewers' Responsibilities

The panel members reviewed data and information provided and presented by NCCOS that were relevant to its HAB and hypoxia research portfolio. The information was provided primarily in the form of (1) a briefing book distributed in advance of the in-person panel review and (2) presentations and ensuing discussion during a 2 ½ day in-person panel review. Additional documentation and references were provided to panel members following the in-person panel review in response to follow-up questions. Each panel member used the provided and presented information to develop independent observations, evaluation, and recommendations on NCCOS' HAB and hypoxia portfolio. Panel members were charged with emphasizing relevance as the most important criterion in the evaluation. NCCOS anticipated products from the panel members included a presentation of preliminary findings on the last day of the in-person panel review and individual reviewer reports to be submitted 60 days following the review. At the end of the in-person panel review on 28 February 2018, the panel chair presented an overview of common observations and recommendations shared by each reviewer. The review panel employed a SWOT (strengths, weaknesses, opportunities, and threats) analysis as the tool for presenting common findings. Additionally, each panel member presented individual preliminary findings related to quality, relevance, and performance of the HAB and hypoxia portfolio. This report serves to fulfill the reviews' responsibility of providing individual reviewer reports. To further aid the NCCOS director and program managers, this report also includes a summary of observations and recommendations shared by all panel members.

Summary of Observations

During the in-person panel review, executive sessions were held for panel member discussions. Primarily these were private sessions with only the panel members present; however, an extra executive session was added and the panel members invited NCCOS program managers of extramural programs to ask follow-up questions. During the private executive sessions, the panel members discussed and noted observations of the NCCOS HAB and hypoxia research portfolio that were shared by all of the panel members.

The shared observations were captured and presented on the last day of the in-person panel review in the form of a SWOT analysis (Fig. 1). Of the many strengths identified, it was notable that NCCOS accomplishes an impressive and comprehensive research program on HABs and hypoxia, especially given the unique, limited, and varying funding for such programs. Specifically, NCCOS administration appears extremely adaptable at taking advantage of the ebb and flow of research funding and its continuous cyclic nature. One of the greatest assets of the program is the caliber of scientists employed and funded by NCCOS. The scientists involved in both the HAB and hypoxia programs are highly respected in their field, produce voluminous peer reviewed publications, and participate in the research community on national and international levels. Among other strengths listed in the SWOT analysis, NCCOS' ability to respond to emergencies demonstrates one of the best examples of efficiency observed.

While some of the weaknesses observed may be out of NCCOS' control, they are noteworthy given the negative impacts these weaknesses can have on the overall HAB and hypoxia program. Primarily, the budget is extremely limited and unstable for such an important area of research that is needed by a wide range of stakeholders. The panel members also found it palpable that the NCCOS organizational chart showed a high percentage (28%) of vacant or acting positions. This lack of consistent leadership has negative impacts on research quality, relevance, and in particular performance. It is clear that NCCOS strives to engage with stakeholders to inform research decisions, yet the last formal, in-person community engagement activity (i.e., National Plan for Algal Toxins and Harmful Algal Blooms: HARRNESS) is outdated and in need of revisiting. Similarly, there is an obvious lack of socio-economic understanding of whether/how NCCOS HAB and hypoxia research adequately addresses the most critical needs. Several other weaknesses are listed in Figure 1 and, if improved upon, could further strengthen the HAB and hypoxia program.

The panel members identified opportunities that NCCOS could explore to advance the HAB and hypoxia research portfolio. One opportunity is to take advantage of other NOAA priority endeavors to address NCCOS HAB and hypoxia needs. For example, it was noted during the first day of the panel review that Blue Ocean is a high priority for NOAA. However, as stated above, the lack of socio-economic understanding of HABs and hypoxia is a major shortcoming of the program. Aligning with the overall NOAA Blue Ocean project may be an opportunity to resolve the challenges faced to date related to understanding socio-economics for this topic specifically. Additional opportunities include increasing collaboration with regional Integrated Ocean Observing Systems (IOOS), improving strategic planning (e.g., incorporating institutional knowledge and connected the research drivers with how they support the mission), and ensuring complete transition of research to its end goal/use.

As major threats to the successes of NCCOS HAB and hypoxia research, the panel members agreed on four. The limited, ever-fluctuating budgetary environment rose to the top of the list as likely threats. Challenges with ensuring high-quality, consistent staffing, especially leadership positions, was a close second. Duplication of activities with other agencies was also identified as a threat. Engaging in collaboration and leveraging opportunities with other agencies would be enhanced and avoid duplication with more attention to clearly defining roles and responsibilities with partners in advance of conducting research. Lastly, the panel found that NCCOS intramural and extramural scientists were unable to successfully measure and articulate the real impacts that the program makes. Attention to and training in this element would not only strengthen the credibility and importance of the program, but it would lead to addressing other shortcomings such as the lack of understanding of the socio-economic knowledge base.

Figure 1. SWOT analysis of the NCCOS HAB and hypoxia research portfolio. These observations of strengths, weaknesses, opportunities, and threats were shared by all panel members.

Summary of Recommendations

The following recommendations were consistent among all panel members:

1. **HABs - Update the National Plan for Algal Toxins and Harmful Algal Blooms (i.e., HARRNESS) by gaining the input of a wide range of stakeholders; and**
2. **Hypoxia - Seek innovative, alternative approaches (e.g., user fees, use of other platforms, use of citizen science) to sustain long-term monitoring surveys such as Gulf of Mexico hypoxic zone monitoring.**

Individual Reviewer Reports

Independent individual reviewer observations, evaluations, and recommendations represent the majority of this report and are provided separately and anonymously below.

Individual Review Report #1

Introduction

As a state fishery manager I am honored and more than a little humbled to have had the chance to participate in this review. I approach this review with some trepidation. I have the utmost respect and admiration for all of the scientists involved with the organization and execution of the science conducted at NCCOS. I do not consider myself a scientist, but rather a bit of a gate keeper who stands between the work scientists like those reviewed here and many of stakeholders and fishery user groups who benefit from the science. So, as you read my comments please remember this is the view from which they were written. Also, remember that I know I am not alone, but only one of many other fishery managers, human health managers, recreation managers, water quality managers, etc. who all manage around the problems presented by harmful algae. Throughout this review I asked myself "What would happen if NCCOS did not exist and what would have society have missed?" My answers to those questions will be the basis of my reviews.

Harmful Algal Blooms - Intramural

Forecast Branch

Overview: As had their colleagues, the NCCOS staff in this group provided the review panel with several excellent presentations. Their work is well-known within the national HAB community and well regarded.

Quality: As I expect many on the panel will agree, the work conducted here is of very high quality, and ever improving as technology evolves.

Relevance: "What would happen if NCCOS/Forecast Branch did not exist and what would society have missed?"

- It is clear that in many regions around the U.S., the ability to predict HABs even in the very short term would be severely reduced if NCCOS staff were not conducting this work. There are many very well documented examples in many regions with numerous HABs that prove this to be true. I am also very impressed with the innovative way this group and their partners have incorporated citizen scientists to expand and improve their forecasts. The best example of this is using Florida lifeguards to rate air quality through the "every beach every day" respiratory warning system.

Performance: The overall performance of this group and the work they are doing is excellent. I do have concerns with future continuity as many of the key players are nearing the end of their careers.

Conclusions/Recommendations: **NCCOS and their federal partners (at the National Security Agency [NSA] and National Weather Service [NWS], etc.) must continue to work hard to improve satellite HAB detection technology. Then, as the technology associated with satellite imagery improves, NCCOS should continue to look for ways to expand this work to other marine coastlines and freshwater bodies around the nation. In addition, some of that effort needs to be focused on how these images and the forecasts they are able to provide can best be verified and "ground-truthed." Also, as was discussed in the review presentations, I recommend NCCOS continue to consider how the day-to-day portion of this group's work that is built around the analysis of satellite imagery might be transferred to NOAA's Weather Service or perhaps to NSA. In addition, the expertise required to analyze these images should be passed onto individuals and groups (via training) across, and perhaps beyond, NOAA.**

I feel a need to end with a personal note (forgive me if this is not appropriate). However, included in testimony I was invited to present in a March 2003 Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA) hearing before a subcommittee of the U.S. House Science Committee was the following statement, "However, the promise of larger scale technologies like offshore moorings equipped to provide real-time monitoring of key HAB predictors and satellite telemetry that could monitor oceanographic conditions that may lead to HAB events is truly exciting." Now 15-years later I remain excited to see how far the fine scientists of NCCOS have brought these technologies. I can't wait for what the future holds.

<u>Monitoring and Reference Branch</u>

Overview: I was impressed how this group of great NCOSS scientists made efforts to present the work of their various activities in a consistent manner, using a standard format. This greatly enhanced my ability to review their work. From the information provided to the panel and from my exposure to their work over the years, it is clear the NCCOS HAB Monitoring and Reference Branch has a strong track record in successfully addressing a wide variety HAB issues all around the U.S.

Quality: I am again impressed with how this highly qualified staff has and is bringing quality science to the many places where it is needed; development and deployment all around the nation of the environmental sample processor (ESP); support of the exciting Alaska paralytic shellfish poisoning (PSP) monitoring network; work to develop new and improve existing toxin analytical methods (receptor binding assay [RBA]; liquid chromatography mass spectroscopy

[LC-MS]); continuing to expand and grow the impressive phytoplankton monitoring network (PMN); and work to better understand the long-term effects of poisoning by harmful algal toxins.

Relevance: "What would happen if NCCOS/HAB Monitoring and Reference did not exist and what would society have missed?"

- Clearly, much of the ground-breaking work on HABs around the nation would not have occurred. My list above is just a small sampling. However, this group has always been a ready source of "help in times of need." HAB events by nature occur suddenly and often without much warning. They can also quickly grow from rather small localized impacts to massive coast-wide events that impact very wide areas and many more people in a very short amount of time. This branch of NCCOS has a strong history to being quick to respond and assist local managers, or existing state or local HAB monitoring programs, etc. with their knowledge and expertise. Without this group, national response to HAB events would be greatly hindered.

Performance: As I have indicated above and in the presentations and documents I have reviewed, I believe this group's work performance to be very strong.

Conclusions/Recommendations: **While I remain excited and very impressed with many of the new technologies developed by the branch, I am concerned that not all tools are repeatable and operable outside of NOAA (with the ESP as an example) simply because of the cost and expertise to operate them. While they have great potential for improving early warning of HAB events, without the on-going and long-term operational support of NOAA these technologies will likely sit on the shelf. Rather harsh words, but it boils down to the financial inability for relatively small state and local programs to make such investments. I commend this group's work to modify technologies to help make them less expensive, as in the case of the ESP mountable on a glider platform that does not require expensive "big ship" time to deploy. I recommend more work in this direction and a focus of technologies that are transferable to non-NOAA funding sources. I also recommend continued focus on projects that engage citizen scientists around the nation as the group has so effectively demonstrated they are capable of.**

Harmful Algal Blooms - Extramural

<u>Ecology of Harmful Algal Blooms (ECOHAB)</u>

Overview: It is clear in all the documentation and presentations provided to the review panel that ECOHAB has been a very successful extramural program. With the a stated intent of

developing new information and tools, predictive models and forecasts and prevention strategies to aid coastal managers ECOHAB is not about science for the sake of science. ECOHAB managers and the scientists they fund are working to make a difference in society.

Quality: ECOHAB has not only been a source of excellent science but also a great training ground for the next generation of scientist to come. ECOHAB has added large volumes of information to the HAB scientific literature with over 185 peer reviewed articles.

Relevance: "What would happen if NCCOS/ECOHAB did not exist and what would society have missed?"

- There are excellent examples of societal benefits from ECOHAB; below is just a sampling.
- The geographical scope around the nation has been strong with key research on a wide range of HAB species in most every HAB hot-spot, including the coastal waters off Washington, California, Texas, Florida and Maine; the inland waters of Chesapeake Bay, Puget Sound, the Great lakes; and the Caribbean Sea. This huge volume of work has led to many key questions about HAB species being answered. These answers are building blocks to future advances in protecting our coastal communities from the effects of HABs. This could not have happened if NCCOS did not exist.
- The development of methods for shipboard and dockside testing of PSP that opened the lucrative Georges Bank clam fisheries benefiting commercial fishers and seafood processing companies.
- Development of models to track and predict *Karenia* blooms have helped develop systems to protect beach goers from aerosolized blooms in Florida. These same models that have also been used to track oil spills helping to mitigate impacts.
- The large amount of work (partially funded by ECOHAB) focusing on the understanding of PSP blooms in the Gulf of Maine that has resulted in a large forecasting system that protects shellfish users.
- Important work conducted in the Pacific Northwest that has greatly expanded the understanding of how the diatom *Pseudonitzschia*, moves from initiation sites to coastal shellfish beds threatening users with amnesic shellfish poisoning (ASP).

Performance: As has been demonstrated in all that I have reviewed, I believe this work conducted via ECOHAB to be quite strong.

Conclusions/Recommendations: **Much has changed in the world of harmful algae since the initial reports that provided guidance for the program was produced. Much of this change is due to the success of ECOHAB adding to the knowledge base. Also, Congressional guidance**

(through the latest versions of HABHRCA) placing more emphasis on the prevention and control of HABs. In additional, the HAB research and stakeholder groups have changed with new people joining their ranks. It is my strong recommendation that new version of the 2005 HARRNESS Plan be developed. In addition, I offer the following recommendations:

- **Some regions of the U.S. have received a lopsided portion of the limited funding available, not only from ECOHAB, but also from other of the NCCOS competitive programs. For example, while information learned studying *Alexandrium* in the Gulf of Maine will be applicable in other parts of the U.S. and perhaps the world, the limited funding source needs to be shared in more areas around the nation.**
- **In order for much of the science that is developed by many of the expensive research projects funded by ECOHAB to be truly beneficial to society is the successful transition of this science to management. The identification of operational fund sources is key to transition. The more expansive the program, the more sophisticated the tools, the more people required, all makes successful transition more difficult. More work needs to be conducted at the beginning of projects to put serious thought into the design of implementable monitoring tools and programs that can be sustained by a non-federal fund source. For monitoring tools and forecasting programs that simply cannot be transitioned outside of a federal agency, a dedicated operational fund source is badly needed. This is especially true for HABs that affect multi-state areas and stakeholders over wide regions. NOAA does not ask individual states or local governments to fund weather forecasts and the same should be true for harmful algae forecasts.**
- **Future ECOHAB calls for proposals should focus more attention on the science that will lead to successful prevention and mitigation of HABs. This is the bottom-line concern and need for most all stakeholders, including members of Congress. While the Prevention Control and Mitigation (PCM) Program within NCCOS is relatively new, it would benefit greatly by focusing ECOHAB projects to answering some of the key questions that have stalled advances to this important arena. No, it won't be easy and the risks can be great. But there are no better groups of scientists in the world capable of tacking these issues that those found at NCCOS and the many outside research groups they are able to fund.**

<u>Monitoring and Event Response of Harmful Algal Blooms (MERHAB)</u>

Overview: This unique program has a strong history of providing needed tools and training to fishery managers tasked with managing fisheries around HAB events. I have long been a strong supporter of the stated goals of MERHAB.

Quality: The work done through MERHAB has been well represented in the scientific literature with over 50 publications. Those conducting the work funded by MERHAB may not all be the high powered scientists who work on larger scale NCCOS projects; however, the quality of the work presented and that I am aware of is still of high quality.

Relevance: "What would happen if NCCOS/MERHAB did not exist and what would society have missed?"

- The MERHAB's relevance is quite clear to this fishery manager. By providing an emphasis on the adoption of faster and less expensive detection methods for HAB cells and toxins; developing operational monitoring capabilities for early warning and forecasting of HABs; ensuring that trained and equipped personnel are able to respond appropriately and quickly during a HAB event; MERHAB funded work has been effective all across the nation.
- Examples are many and include:
    - An early warning system that builds on an earlier MERHAB funded project (ORHAB) to produce a HAB bulletin providing managers forecasts of where HABs are likely to occur along the WA and OR coasts.
    - The first ever training course on the identification of HAB species in the U.S. that is now in year three. This effective program is building a new class of U.S. HAB taxonomists for the future.
    - In California a program to provide improved tools for monitoring multiple HAB toxins at the land-sea Interface.
    - A program aimed at monitoring and management of lipophilic shellfish toxins in Washington State that includes assisting state managers to develop methods for finding lipophilic toxins in existing monitoring programs.
    - In Maine a program to develop and validate new HAB detection instrumentation and transition that work to state agencies.

Performance: Both through this review process and through many years of watching successful MERHAB projects address HAB related needs around the nation I have seen MERHAB's strong performance. The dedication of NCCOS staff, the rigorous proposal review process and the host of excellent funded projects and their principal investigators (PIs) is impressive.

Conclusions/Recommendations:

1. **My one critique of MERHAB projects is the general lack of successful transition to operational funding sources that are not NOAA related. One answer would be to have NCCOS set aside dedicated operational funds. However, with the variability of funding levels that ebb and flow into NCCOS this funding would likely decrease the**

amount of overall funding that should be reserved for important new projects. It is well understood that this is not a new issue and that NCCOS has taken steps to try to solve. For example, requiring MERHAB projects to have pertinent state or local managers as part of the PI team or on project advisory groups certainly helps engage folks who should be seeking the operational funds. In addition, the appointment of a transition manager or a transition team is an excellent step in the right direction. However, in practice many of those folks are state or local agency employees who deal with HAB issues, but are not placed correctly to be lobbying for non-NOAA funding. I have a couple of suggestions, but keep in mind they are coming from a fishery manager, not a successful lobbyist.

2. **Once a project has been identified for funding, but prior to the final funding award, the project PIs should arrange for a meeting between state agency budget decision makers (perhaps as high as an agency Director or assistant Director) and the appropriate NCCOS program manager (and this should be an in-person meeting if possible). At this meeting the NCCOS representative should discuss with that state decision maker that this federal funding award is contingent on the eventual transition to state funding and that short of some failure of the project, NOAA fully expects the state to find a way to make the monitoring or response program operational. The PI and NCCOS should be able at that time to articulate in general the value of the project to the state agency's mission and provide a general cost of eventual operations. Such a meeting occurred during the early stages of WA ORHAB project (funded from 2000-2005 by MERHAB) and the agency assistant director later played a key role in finding a state legislator to put forward a bill to provide sustainable funding.**
3. **And/or, NCCOS should provide specific training to successful project PI teams on how to seek funding from a legislative body. This would likely best be done by a contractor who has the right experience and successful track record to provide such training. One example might be Effective State Lobbying Seminars (http:/www.learn-to-lobby.com/). Also, in the project proposal the proponents should be required to identify one team member who has the specific role (from the onset of the project) of seeking support for transitional funding. This may be a key stakeholder (managers, or others supportive of the proposal – or even a key legislator or legislative staffer).**

Prevention Control and Mitigation of Harmful Algal Blooms (PCMHAB)

Overview: I applaud NCCOS for a job well done in the design of this relatively new competitive research program that not only meets the direction provided in HABHRCA (to "identify research and development and demonstration needs and priorities related to monitoring, prevention, control, mitigation and response…"), but also responds directly to the needs expressed by the

HAB community workshop (i.e., HAB RDDTT - National Workshop Report: A Plan for Reducing HABs and HAB Impacts).

Quality: The caliber of the science that has so far been funded by PCMHAB, or at least were presented to the committee as examples, is high and well conducted.

Relevance: "What would happen if NCCOS/PCMHAB did not exist and what would society have missed?"

- The entire concept of PCMHAB is very relevant to the entire issue of harmful algae in the U.S. In fact, to natural resource managers it can easily be described as perhaps the most significant and potentially the most relevant of the NCOSS HAB portfolio. The HAB community (through the RDDTT workshop and report) envisioned a program that that was the "apex" of the research and development work conducted in ECOHAB and MERHAB. I commend NCCOS for designing that program that is making real head-way to develop, demonstrate and transfer that good science to effectively address the problems created by HABs. Even as a fairly new program, without PCMHAB the future of HABs in the U.S. could be "stuck" in just monitoring and closing fisheries and other affected areas and the impacts of those HABs would continue to mount.

Performance: The examples provided to the review committee certainly tell the story of strong performance. Examples include: investigating the use of biological control agents as a potential control of some dinoflagellates; work to make the ESP less expensive, more robust and improve user interface.

Conclusions/Recommendations:

1. **PCMHAB has great promise to address the problem of HABs well into the future. However, I was disappointed to hear during the course of the presentations to the panel that NCCOS has backed away from HAB control – at least in regard to a statement that biological control proposals are no longer being considered for funding.**
2. **Any resource manager will tell you that effective monitoring helps them make better decisions about harvest and better protects human health. However, once a bloom occurs that harvest (or other activity) comes to quick end and the resulting socio-economic impacts quickly mount. Those same managers essentially stand between the resource users and NCCOS science and the question we most often hear is "what can be done to stop these blooms?" In addition, in the three occasions that I have personally had the opportunity to testify in Congressional hearings on HABHRCA re-authorizations, one of the consistent questions coming from Congressional**

representatives has been focused on the *control and prevention* of HAB blooms. I recently re-listened to the recording of the July 2008 sub-committee hearing that can be found on YouTube and heard again U.S. Rep. Brian Baird (now retired) ask "what can we do about these blooms?" (to hear the questions and responses from HAB community leaders, see https://science.house.gov/legislation/hearings/subcommittee-energy-and-environment-hearing-harmful-algal-blooms-challenges starting at about the 56 minute mark). It was an amendment by the same Congressman that added the specific language addressing control and mitigation into HABHRCA that resulted in PCMHAB. If my participation in the review panel has any value I hope it can be to focus more of NCCOS attention in this direction. Perhaps this focus can occur best within the PCMHAB program, but truly it should also be considered throughout the NCCOS HAB portfolio. While investigations into HAB control and prevention will likely be controversial and difficult, the public and Congress wants AND needs NCCOS to step up to this challenge. If the excellent scientists at NCCOS and NOAA as well as throughout the HAB community cannot find solutions to these issues – I do not know who can.

Event Response

Overview: Very few if any federal programs are designed as successfully as this small but significant program. While it needs expansion with more funding, I believe it has been a true NCCOS success story.

Quality: Because the NCCOS staff has successfully fostered close relationships with so many people around the nation who study HABs or manage resources affected by HABS they have the ability to quickly approve funds to worthy HAB event related needs.

Relevance: "What would happen if NCCOS/Event Response did not exist and what would society have missed?"

- If ever there was a time to use a colloquial phrase, it is in reviewing this program. The NCCOS HAB Event Response Program truly is a "lot of bang for the buck," AND those funds are provided in such a rapid fashion that they arrive in the midst of an event to make a real difference. The many examples provided in the materials and presentations provided to this review process are the proof. From $8K to develop an *Aureoumbra* genetic probe in New York; to improving the recovery of Florida Manatees exposed to brevetoxin for $5K; to help Ohio analyze a variety of freshwater toxins in Toledo drinking water for just $6K; and allow west coast states and tribes to purchase domoic

acid test kits and ship-time to inform fishery managers of the magnitude of a huge HAB event for $9K. As a fishery manager who has benefited from this program, I cannot think of a more relevant way that NCCOS can spend their limited funds. All of these benefits and many more would be lost without the exceptional support of NCCOS staff.

Performance: HABHRCA's most recent re-authorization requires that NOAA "shall identify ways to reduce the duration and intensity of harmful algal blooms and hypoxia including deployment of response technologies in a timely fashion" [Section 603A (3) (b) (3)]. With this congressional guidance as a guide, the Event Response program has been very successful.

Conclusions/Recommendations: **Regardless of my praises in the last several paragraphs, if I were a NCOSS manager I would be embarrassed to have to sit before a Congressional committee and admit how little funding is directed into this program. As presented to the committee, over the last 5 years 23 projects were funded for a total of just $171,000. In a nation as large as the U.S. with HAB issues in most – if not all – 50 states, this amount of money borders on the ridiculous. However, with NCCOS staff already stretched thin, more money – while terribly important – is not the only solution. A new way of responding to imminent or occurring HAB events is needed. This is one of three topic areas considered at a 2007 NCCOS sponsored HAB community RDDTT workshop. The result was a proposal and a specific plan to "improve access to existing resources for response through better information sharing, communication, and coordination and provide essential new resources"…with a new "regionally based, federal HAB Event Response Program linked to a network of Regional HAB Coordinators." The bones of the program are there and it is time for NOAA to dust off that report and put some life to it.**

Hypoxia - Extramural

It was clear during the presentations and questions from the panel that NCCOS's hypoxia work was new to many – or at the very least certainly new to this panelist. The confusion stems not in any way from NCCOS or their work, but more from a very basic question. Why did Congress choose to provide guidance to federal agencies on harmful algal bloom research that is combined with guidance on hypoxia research in the one document as we all know and love, the Harmful Algal Bloom and Hypoxia Research and Control Act? I suppose one can work to make the argument that the two are somewhat related, but I think most would agree this is generally not the case for either. What seems obvious to this reviewer is that in the process, the work on hypoxia has played "second fiddle" to work on HABs. I do not believe this has been NCCOS' intent, but more the levels that these two marine (and freshwater) phenomena impact the environment. So, to any readers of this review who have any sway over the decisions made by

the U.S. Congress, **I strongly recommend the uncoupling of the research conducted on hypoxia from the research conducted on harmful algae.**

Coastal Hypoxia Research Program (CHRP)

Overview: In the information provided during the review process, and the additional very helpful information provided after some the review panel's initial comments, I have come to better understand the need for this program and the work that it accomplishes. While I do not have the experience to provide extensive comments on this program please consider the following as my best effort to objectively review what we have been provided.

Quality: I do not have enough experience in this field to accurately comment on the quality of this work. However, I do personally know some of the scientists involved in CHRP work and have no reason to question the quality of the work they are doing.

Relevance: "What would happen if NCCOS/CHRP did not exist and what would society have missed?" In the most recent information provided to the review panel, I have come to a much clearer understanding of the importance of this program and the work that has been accomplished.

- The CHRP is well designed to provide an understanding of the effects of both natural and man-caused factors that precipitate hypoxic events and the timing and extent of these events. This is evident in several examples of CHRP funded projects that were provided to this review process, all of which would not have occurred had CHRP not been available, including:
    - The modelling of hypoxia in Narragansett Bay, RI that allows state managers to best manage nutrient loads to prevent fish kills and overall biological primary production.
    - In Green Bay Lake Michigan the development of an interactive web site that allows state managers to determine the effectiveness of nutrient reductions while considering the cost-benefits.
    - In Lake Erie where a multi-model approach was developed to set loading targets and strategies and to inform fishery managers of necessary changes they would need to make to fisheries policies for the management of key yellow perch commercial and recreational fisheries.
    - In Chesapeake Bay a project that used monitoring and modelling programs to predict impacts of nutrient levels to assist state resource managers. In addition to increase public awareness, the development of a well done on-line educational curriculum that focuses on hypoxia.

Performance: I do not have the experience to fully comment on CHRP performance, but I have no reason to say I do not believe it to be a solid program.

Conclusions/Recommendations: **I greatly appreciate the extra work that went into providing specific questions the review panel had about the relevance of the hypoxia research conducted by NCCOS. I have no specific recommendations.**

Northern Gulf of Mexico Ecosystems and Hypoxia Assessment Program (NGOMEX)

Overview: One reoccurring question that I had at the end of the review process was what was the need for NCCOS funds to be spent continuing to monitor the size of the hypoxic (dead-zone) in the northern Gulf of Mexico. However, in the information provided during the review process, and the additional very helpful information provided after some the review panel's initial comments, I have come to better understand the need for this program and the work that it accomplishes.

Quality: I do not have enough experience in this field to accurately comment on the quality of this work. However, I have no reason to question the quality of the work that is being conducted.

Relevance: "What would happen if NCCOS/NGOMEX did not exist and what would society have missed?"

- While I can understand the need to maintain a long-term data base that documents the size of the dead-zone in this area and the use of that relative change in size as a bench-mark for the success of nutrient reductions programs in the adjacent massive watersheds, I had a hard time understanding the impacts to society if that work did not occur. I was also concerned with the report that there had been a "wholesale shift in the roles states have been willing to play in the mitigation of nutrient pollution." Is the lack of clear impacts of the hypoxic zone also not evident to state authorities, as it was to this review panelist? However, in the most recent information provided to the review panel, I now understand the steps NCCOS is taking by including in what is described as NGOMEX Objective 3 the goal of developing quantitative models to determine the sub-lethal impacts of the hypoxic zone on ecologically and economically important living resources. I applaud NGOMEX for supporting the first studies to make a direct link between hypoxic events in this region on commercially and ecosystem relevant species in the region. This is a very relevant objective by addressing interest and concern Gulf of Mexico fisheries managers and federal fisheries councils.

Performance: I do not have the experience to fully comment on NGOMEX performance, but I have no reason to say it is not a solid program.

Conclusions/Recommendations: **In regard to the funding of the annual monitoring of Gulf of Mexico hypoxic zone size, as I understand the situation, state university scientists had been conducting this work, with NCCOS/NGOMEX competitive funds. However, for reasons that I do not fully understand that work has now been transitioned to NCCOS operational funds. If in doing so, NCCOS is reducing funding for other competitive HABHRCA mandated competitive programs, I recommend NCCOS revisit this practice. We are told this work is very important to the work of the Interagency Mississippi River/Gulf of Mexico Watershed Nutrient Task Force's (HTF) as a bench-mark to track their nutrient reduction progress. If that is indeed the case, the many state and federal agencies listed on the web-site (found on the web link provided to the panel) should find a way to fund this work jointly. NCCOS/NGOMEX should then focus more attention and effort to better defining the true impacts of this "dead-zone" and developing ways to assist fishery resource managers to better address the issues produced by those impacts.**

Concluding Remarks

- Overall, I am happy to be a fishery manager who is dealing with HABs in the U.S. and know that NCCOS programs and scientists are available to assist me when called upon.
- However, one very specific area I want to highly commend NCCOS on is the excellent relationships it has fostered over many years with folks in the harmful algal bloom community. In my opinion it is because of NCCOS that these folks all across the nation can consider themselves a "community." I don't have enough history to know when this all started but I can say that my participation in the formulation of the HARRNESS report began my initiation into this community. Soon after the formation and funding of the National HAB Office housed at the Woods Hole Oceanographic Institution, the National HAB Committee both continued to re-enforce these relationships. In addition, I believe NCCOS's consistent support of the national HAB symposiums, including travel funds for both students and resource and health managers has played a key role. Finally, by NCCOS calling on community members to join them in Congressional hearings and briefings have allowed the resulting legislation to be well received by this community – who can rightfully claim ownership. I wholeheartedly believe that other science communities around the nation could take some lessons from the folks with in NCCOS's HAB groups and programs about how to build a community of colleagues – rather than adversaries.

- Thank you for allowing me the opportunity to offer these comments and recommendations.

Individual Reviewer Report #2

Harmful Algal Blooms - Intramural

Overall

I disagree with the statement that 'internal' investments allow direct engagement between the users and the researchers (in Hameedi brief). As someone who lives in a frequently impacted HAB community, it is the local researchers who can easily engage with the users- the folks who are being impacted by the problem.

I would suggest that the internal programs be seen as a resource or backbone – such as the HAB forecast group. I would also suggest that the IOOS Regional Associations be more heavily engaged as they have a track record for sustained stakeholder engagement.

The reorganization appears to be much sharper/streamlined than the prior organization. With only 2 branches, I would assume communication has improved. However, I think of monitoring and forecasting as going hand in hand - every modeler/forecaster I have met always needs/wants more observations so I am curious why the PMN and sensor group were put with the reference folks. It seems like a strange fit to me - Maybe an attempt to keep a similar number of full-time equivalents (FTEs) in both branches?

The internal staffers are mainly senior folks with a lot of experience. I would express concerns over retirement/succession plans and if there are junior folks in the pipeline.

<u>HAB Forecasting Branch- Litaker (17 FTEs)</u>

Overview: This is an incredibly relevant and productive branch providing services across the U.S.

Quality: Outstanding, developing new forecasts at the same time improving established ones. Appear to work very well with the local research community and end users.

Relevance: To avoid HAB impacts, we have to know where they are and where they are moving to. This group is providing critical information to a variety of communities for just that. They appear to be really digging in to what a community needs and making all attempts to assist.

I am a huge fan of any type of rapid field test kit and citizen science programs. We have both spatial and temporal sampling issues with HABs, and complicated and cumbersome sampling approaches (such as the ESP, see comments below) are not the long term solution.

Performance: Again, nationwide reach from marine environments to freshwater. I believe this is key capability that should be well supported in the future as we see new HABs or old HABs in new places as our climate changes.

Conclusions/Recommendations: **Continue to grow the relationship with the IOOS Regional Associations (RAs) and Program Office. The RAs can be an effective conduit (in person, websites, e newsletters and congressional engagement) to the local community on HAB achievements. As more forecast systems go operational, I highly recommend they go to the IOOS RAs nationwide. It appears there is a bit of variation across the country about who is going to maintain the operational forecast (CO-Ops, Coast Watch, etc). I believe a single organization such as IOOS is the answer.**

<u>HAB Monitoring and Reference Branch- Ramsdell (15 FTEs)</u>

Again, because these appear to be very disparate programs, I believe I need to discuss them one by one instead of as a branch.

Phytoplankton Monitoring Network

Overview: As I mentioned above, I believe citizen science programs are the answer to our spatial and temporal monitoring of HABs. This is a sustained, low cost program that had National relevance and impact and has received numerous NOAA and other national awards. The work done in conjunction with the Environmental Protection Agency (EPA) is an excellent model- would love to see more Federal agencies working together!

Quality: Excellent as an outreach program, Fair to poor as a science program.

Relevance: Excellent as an outreach program. Engaging communities nationally and a wide swath of folks are engaged- from school groups to retirees.

Performance: Fair. I am surprised that only 12 confirmed toxic events have been detected over the 16 years with the national coverage. I don't see anywhere in the brief about how often people are asked to sample and wonder if the frequency is low (i.e., once a week) if that could

be reason for low numbers of events detected. The Alaska Tribal story is an excellent outreach example.

Conclusions/Recommendations: **I think this program should be supported in the future. Would recommend that new technology (i.e., phone apps, etc.) be constantly improved on, and take it beyond an outreach program so it can make a real contribution to HAB monitoring.**

Robotic Underwater Sensor for HAB Toxins

Overview: The ESP- This is a highly sophisticated and complicated instrument that yields great specificity at a single fixed point. It appears that it is being engineered to be in the payload of a REMUS autonomous underwater vehicle (AUV) - again, another very expensive AUV with a short deployment duration compared to Slocums. Suspect they need the larger size of the payload bay and increased power.

Quality: Have to give it a variable as I have heard that when they are working- data is amazing, but a lot of down time.

Relevance: I have to question why the NOAA lab chose to focus on this one technology and render internal support to a commercially available product. It appears to me that McLane has received much financial support with Dr. Doucette and staff's efforts (as shown in photos-no specifics were given). Again, with my concern over spatial and temporal coverage, one instrument at a fixed point gives very specific information- for 1 point. I can see that it would be a very useful research tool, but I do not believe that the cost (as described in session at $175K 'dry' and another $175K for it to be 'wet' and O and M costs of $90K/year are in any way sustainable for an observing system. (and I note they have not been deployed in the Gulf of Mexico where they would be operational for 12 months, not the ~4 months in the Gulf of Maine). As an RA director, I can say that we have challenges with O and M for met buoys- something that multiple stakeholders use the data from. A HAB buoy is only of interest to a very small group of people.

Performance: Although Dr. Doucette gave a glowing report of performance, I have heard from colleagues over the years that they are "finicky" and "always breaking."

Conclusions/Recommendations: **I do not believe the support of the ESP, a commercially available product, should be supported by Internal NOAA funds without a competitive bid process with all commercially available HAB detection products. I believe a serious reality**

check needs to be done in thinking this instrument is a good fit for a sustained ocean observing system. Perhaps the Lake Erie folks- focusing on the intake inlet area will find this a key sampling strategy, but for large scale bloom issues, I do not see the advantage over the cost.

Analytical Response Team

Overview: This is a needed lab for standards and QA/QC- a true backbone national lab.

Quality: Excellent.

Relevance: This is not one of the 'sexy' services (until there is a UME) - most lay folks would not understand the need, but it is essential that there be one Lab that is the national standard.

Performance: Excellent.

Conclusions/Recommendations: **This is a vital piece of HAB bloom/response action that needs to be continued to be supported.**

Genomics

Where is Fran's work?

Harmful Algal Blooms - Extramural

Overall

Overall, these programs are incredibly productive with the small budget they have. I believe the program management staff needs to be applauded for setting a high standard of expectations with these programs. I am struggling with issue that some regions have some highly developed teams of researchers and resource managers who are extremely capable of writing excellent competitive proposals – and as a result have received numerous grants from these programs. My concern/question is how do other communities who have less experience/track record compete with these groups? I believe the regional rotation was an attempt at 'leveling the playing field' a bit.

Budget: I believe it is time to switch the ECOHAB and MERHAB budgets. Understand that at the beginning we had to know basics- hence ECOHAB. Believe we have made significant progress and now MERHAB should have the larger budget.

ECOHAB

Overview: Again, kudos to the program manager for establishing a highly productive and professional ethos across recipients of ECOHAB grantees.

Quality: Excellent.

Relevance: The relevance to the science community is what we need to know about the organism and the associated toxins is excellent. This is the one external program that is most difficult to translate to stakeholders. The need to know the life cycle of the organism is key if considering non-harmful prevention or control strategies. Unfortunately, I have heard too many times 'just get rid of it.'

Performance: Excellent from the number of peer reviewed publications.

Conclusions/Recommendations: **One topic that I didn't see a lot of on review was phytoplankton community structure- yet we all agree that with the changing climate, we will probably see increased HABs. If we don't know community structure now, will we be able to measure/detect change or will we be surprised? The Imaging FlowCytobot (ICFB) gets at community structure and Dr. Campbell reported they now have a 10 year time series. I actually see this as a bigger benchmark for Dr. Campbell's work than the detection of 8 HABs over the 10 years- that possibly could have been done with daily grab samples.**

MERHAB

Overview: Apologies for repetition, but I do not understand when, in the brief and written material provided, the words 'faster, less expensive and more reliable detection methods' are used and yet the ESP is the showcased instrument. I defer to my earlier comments.

Quality: Overall, very good. Applaud the strategy of engaging managers in the peer review process and the support of the infrastructure projects.

Relevance: Excellent track record for assisting forecast models to higher readiness levels.

Performance: Excellent. Excellent number of publications and progress toward improved monitoring.

Conclusions/Recommendations: **This program needs to be funded at a much higher level. (There was no discussion regarding how are the amounts between 3 programs set from year to year?)**

PCM

Overview: This is probably the most difficult program scientifically and the program most stakeholders want - How to stop, reduce, or otherwise lessen the impacts from HABs. Somehow the transition of HAB forecast has worked its way into all three programs - I think this needs to be revisited as I believe that, although I am in full support of operational forecast, the research teams that have been working for years together are 'snuffing out' the competition from new investigator and/or teams of investigators. The lack of economic data continues to haunt us and I advocate for funds to come out of competitive research to make this happen - again, perhaps regional. The IOOS program office is giving the RAs a small amount of money (~$25K) to hold regional workshops on particular issues - perhaps this could be a strategy. I note that between the 3 programs, the Gulf of Maine group has received over $20M – but do we have any measure on the economic savings that had occurred from this effort? Perhaps writing in an economic assessment component to the project would be of benefit? Maybe that would be the way to get economists engaged?

Quality: I would say proportional to the small amount of funding.

Relevance: Extremely. This is what folks want!

Performance: Again, I would say proportional to the small amount of funding.

Conclusions/Recommendations: **Fund an economic workshop or series of workshops. Work with IOOS RAs, Sea Grants or both. And what happened to the Human Dimensions work after the workshop and report came out in 2006?**

Event Response

This program is highly impactful and needs to be funded at a MUCH higher rate.

Hypoxia - Extramural

GOMEX; CHRP

Overview: I believe this came out in our closing briefs, but if THIS panel had a hard time understanding who the stakeholders are for these programs - we identified a major problem. Either there is a communication problem, or, I believe it is because overall hypoxia is an interesting ecosystem issue that needs to be followed.

Quality: Good especially considering small budget.

Relevance: Here is where I have concerns. Is it relevant? I noted during the Scavia brief that a question was asked about the downsides to false positive hypoxia forecasts and the response was that there were none. In that case, I have to ask who cares about these forecasts? In HABs, false positive forecasts are a HUGE concern.

Performance: Again, good based on small size of budget.

Conclusions/Recommendations: **I believe major work needs to be done to clearly articulate who the stakeholders are and identify the socioeconomic impacts. If these aren't addressed, it's an interesting scientific ecosystem problem but in these days of extremely tight budgets, may not be the best use of taxpayer dollars.**

Overall recommendations:

1. **Need stable budget- demonstrates outstanding program management to keep productivity high in poorly funded years. Yo-yo effects hurt progress. Need to come close to authorized amounts.**
2. **As climate change and increased occurrence of HABs are frequently linked, I would suggest that a major data mining project(s) be funded to collect all cell count and associated data funded by NOAA internal and external programs be placed in a central repository. Again, the IOOS RAs would be an excellent place for this as 9 of 11 RAs at the time of this writing are Regional Information Coordination Entities (RICEs). In addition, the program needs to then place data submission into these repositories as a new funding requirement - again, the RA data management teams can help PIs with this. With disparate data sets spread everywhere (and still many residing on individual PI hard drives) and potential incredible resource (that the taxpayers have funded) is not being captured. The FL Fish and Wildlife Conservation Commission (FWC)/Fish and Wildlife Research Institute (FWRI) is the only state database I am aware of that goes back to 1947. Although an imperfect data set as much of the sampling was opportunistic - it's still 'something.'**

3. **And again, I am concerned about the senior status of the program PIs and succession plans. I was sad to see that, apparently, Dr. Van Dolah's fine work over the years was simply ended when she retired.**

Individual Reviewer Report #3

Introduction

From the social science perspective, the HAB/hypoxia portfolio has generated (either directly or in collaboration) a vast amount of information for a variety of users and stakeholders. The impacts over the past five years have largely been specific to the projects and most often qualitative in nature. The benefits of the work conducted by NCCOS related to HABs and hypoxia were conveyed by staff as being of utmost importance – which is confirmed by the fact that "social science" is one of four Strategic Priorities for 2017-2021 and that it is also one of seven Milestones identified in the 2018 Annual Operating Plan. Suggestions and recommendations for addressing the human dimensions associated with this unit were also contained in the HARRNESS report completed prior to the evaluation period, which can continue to be consulted for ideas. The key to ensuring that program accomplishments are recognized and help to provide useful information moving forward, is to ensure that the results of the prevention, mitigation and control measures investigated under this program are effectively conveyed and not just assumed. The success of past projects in advancing the science is evidenced in the publication of peer-reviewed articles, the release of data that supports the development of commercial enterprise, and the development of novel technologies. The technical advisory committee is a good mechanism to help recommend strategic investments in projects that benefit the U.S. public (seafood safety and public health agencies, waterfront home owners, recreational fishermen, coastal park managers, fish/seafood consumers, etc.). The program has effectively cultivated strategic partnerships to meet objectives. The program is mature enough now that there is much information to be conveyed to the public and policy makers on the success of the program in tangible terms; the fact that Social Science has been prioritized is encouraging and should be emphasized to procure future funding. Not knowing how to measure success, assuming the benefits of the work are obvious, or glossing over the fact that economic effects have not been quantified, compromises the value of the entire portfolio; the need to connect the dots to provide evidence of benefits from the social sciences cannot be overstated.

Quality: We were asked to assess the quality of the research programs, output and personnel through a series of three questions. Each is paraphrased and addressed below. In summary, quality is evidenced by the (1) number of citations in high-ranking peer-reviewed journal articles associated with internal and funded scientists, and leadership displayed through (for example) engagement in, and organization of, scientific workshops; (2) development and/or support of new models and technological tools that have been launched to support HAB and/or

hypoxia research in strategic locations around the continental U.S.; and (3) use of systematically employed and used protocols for soliciting and reviewing research proposals with the potential to generate rigorous, science-based findings across disciplines.

Question 1. Leadership, recognition and output? The panel was provided with an extensive list of peer-reviewed publications and *Curriculum Vitae* (CVs) of relevant personnel. The documents clearly show that the personnel are active in their respective professions and recognized in their discipline through participation in scholarly activities. It was, however, challenging to assess the distribution of contributions by program or discipline.

Question 2. Developed analytical methods and advanced tools? The panel was provided with several presentations that highlighted the development and use of several novel methods and tools that are the direct result of HAB/hypoxia programs over the past five years. By the nature of project funding and the life cycle of new product development, some of these have yet to be adopted to other areas (or maybe should not if private costs are prohibitively high), but the projects have unequivocally advanced science and technology.

Question 3. Procedures for funding preeminent and impactful projects? The quality assurance procedures provided to the panel were impressive. Moreover, information provided to the panel on the running of specific requests for proposals (RFPs) and process of obtaining well-balanced panels to review proposals indicates that procedures do not only exist, but that staff are committed to their use as they have been followed as intended.

Relevance: The review committee was asked to spend most efforts in evaluating the relevance of NCCOS' HAB and hypoxia-related activities over the past five years. Each of the four specific questions is paraphrased and addressed below. In short, the work on HAB/hypoxia events within NCCOS is both broad and deep in key areas of expertise. Not only has the agency served stakeholders specifically interested in HABs and hypoxia events, as an agency and topic with a multitude of impacts on natural systems and society, the reach of the agency has been extended through key collaborations and opportunities.

Question 1. Advanced understanding of causes that has improved management? All projects appeared to have been driven by – and focused on – providing relevant information to "users" and "stakeholders;" the need to provide such information was a recurrent theme expressed by all speakers during the review. Given the broad applicability of results to help a diversity of audiences, it will be important to clarify the messaging on the specific audiences served by each project, which can help facilitate metrics for social science impacts (e.g., "states," the "American public," "stakeholders," "managers" and "scientists" are not compelling

beneficiaries as broad groups; more specifics would strengthen the case benefiting targeted programs).

Question 2. Informing regulatory guidance in upland states? The relevance of programs in the Great Lakes region was repeatedly verified and confirmed by other reviewers on the panel. This program is generating data quickly enough to be of use for states in the region. This role is a notable strength and service to the public.

Question 3. Evidence of improved preparedness/response, and prevention/mitigation of damages? One practical example was the ability to respond to a request for assistance in examining ciguatera. There was an important issue to be addressed, and helpful societal outcome (i.e., a new tool); however, sampling occurred in a remote area and in a reserve, which is of little benefit to the U.S. public.

Question 4. Effective at generating applied outcomes? Yes, especially for specific projects. Key will now be to ensure that data can be made available for broader use. The cost-effectiveness of programs was also mentioned repeatedly; however, the level of rigor was not shown and in some cases the cost savings were assumed or implied instead of calculated or estimated.

Performance: The final core evaluation criteria relates to performance of programs in (1) meeting the requirements of HABHRCA, (2) executing external funding agreements, (3) utilizing collaborators/partnerships, and (4) organizing events that affect management. Each is described in turn with an emphasis on the period of evaluation. In short, the HAB/hypoxia programs have been very active and productive. Responding to immediate needs has been a key strength, and relying on external linkages to extend the scope of work is good strategy (but also means that your research agenda is driven in part by external entities, which may have different missions).

Question 1. Meeting the requirements of HABHRCA? The Act provided a "mandate for NOAA to advance the scientific understanding and ability to detect, monitor, assess, and predict HAB and hypoxia events." Establishing a technical advisory committee was a great idea to obtain ongoing feedback on whether programs are meeting goals in a systematic manner. At this time, it appears that all mandates have been addressed to some extent.

Question 2. Executing external funding agreements? By any measure, these programs (HAB/hypoxia) have been diligent (and competent) in funding external collaborators via competitive programs. The rotational regional scheduling of funding (MERHAB, ECOHAB,

PCMHAB) was a clever solution to ensuring a well-balanced portfolio (at least until the funding was an issue).

Question 3. Utilizing collaborators/partnerships? Several excellent examples were provided that showed the effectiveness of joint efforts, especially regarding fish stock assessments, food safety and communications. Such efforts have surely extended the impacts of NCCOS programs, but engaging in such efforts should be evaluated closely such that organizational priorities do not shift.

Question 4. Taking action that affects management? As with the previous question, one of the most notable examples of a change in management or potential for such involved human health such as the new guidance for harvesting areas in Alaska, a ciguatera study, and public announcements/ communication of HABs with the EPA. The contributions to fisheries management were also a positive step toward linking hypoxia research with broader impacts (although (1) shrimp are not managed by quotas and there is a distinction between state and federal management that can limit the extent that products can have broader use, and (2) showing the hypoxia or HAB events reduce stocks and, as a result, managers should lower quotas, will be a more challenging outcome to assess benefits, but it highlights the diversity of socio-economic methods needed to value projects that should be considered at the onset).

Recommendations:

1) **Several funded programs have successfully developed advanced models and tools, and the HAB/hypoxia program has been able to opportunistically participate with (or benefit from), related programs; in looking ahead, whether to continue investing in specific projects should consider the costs and benefits of adoption/transfer of such technologies and the extent to which programs might be dependent on specific individuals (what's at risk if succession planning has yet to begin?).**
2) **Better articulate that the business model is one of collaborations due to the need for external support/investigators, and opportunities with other government agencies. Theme could be around success in "leveraging" by showing estimated cost share; what is the value of in-kind contributions? Such information would show efficiencies in meeting the mission. While it is not possible to easily query all federal agencies or state partners to identify complementary programs, it is in the best interest of this program to do so.**
3) **There continues to be at least some misunderstanding of the use of economics to help evaluate HABs and hypoxia, which is evidenced in part on the webpage describing HABHRCA. Current emphasis seems entirely (and solely) on the need for estimation of *economic impacts*, which is a specific type of methodology (tool) that is only suited for measuring the effect of a time-limited event that changes the flow of money into or**

out of an economy (such as a county or state); when using an economic impact methodology, the broader the geographic scope of consideration, the smaller will be the impact as there are more substitutes available within the region. Alternatively, there are tools that can measure changes in *economic value* (i.e., consumer and/or producer surplus) that have been successfully used for evaluating events such as oil spills (e.g., the travel cost method and contingent valuation). Could also solicit, even internally within NOAA, for the use of the "benefits transfer" approach for changing property values, affected threatened/endangered species, impacted recreational trips, etc.).

4) **Re-consider the role of social science research, either how where or how it is managed; as is, it is touted as one of four "Strategic Science Priorities" for 2017-2021, but currently the "Social Science" Priority is subcategorized under "Marine Spatial Ecology." One approach would be to generate a mapping of the organizational structure to these four priorities to ensure consistency in addressing all four if they are equally weighted. Think of it this way, how would estimating the change in lake front home property values (and lost tax revenue) due to recurrent HABs be appropriately estimated within the Marine Spatial Ecology unit? Or the value of closed shellfish beds that reduce fishermen income or consumption by the public?**
5) **Evaluate the opportunity to assess licensing fees for development of products that use information (including data) generated from public funding. Commercialization is an indicator that the program is providing economic value; is there an opportunity for cost recovery? If not from past projects, can this be considered as a goal in future projects (i.e., shared intellectual property)?**
6) **As you begin the next five years, look to identifying how success and accomplishment will be measured over the evaluation period, particularly by priority area (e.g., impact statements for each project developed using structured guidelines, publications grouped by priority area, mapping of all projects geographically). It is notable that much value of these programs stems from preventing future damage, if so, then look to organizations that need to make similar cases to justify their costs (e.g., programs examining invasive species). And, when funding external projects, perhaps require all of them provide impact statements and/or investigate the socio-economic impacts as part of the project (versus standalone or subsequent social science studies).**
7) **To increase the visibility of NCCOS activities related to HABs and hypoxia research, consider developing standard templates for PowerPoint presentations, fact sheets, funding recognition, and impact statements. There are several good, generic, guidance documents available from other federal agencies for use by PIs or a staff member charged with conveying impacts to stakeholders.**
8) **Consider re-visiting the HARRNESS report and recommendations included therein. It is likely that many remain relevant and applicable.**
9) **Work aggressively to fill open positions; many of these recommendations are likely to go unaddressed unless previously identified positions are filled. Leaving positions**

unfilled also prevents succession planning and knowledge transfer, which is an issue with this group as the current expertise is nearly irreplaceable.

Individual Reviewer Report #4

Harmful Algal Blooms - Intramural

HAB Modeling and Forecasting Branch

Overview: The modeling and forecasting branch provides critical HAB forecasting information targeted to address stakeholder priorities. There is a clear path from development to operations, and operational forecasts continue to be improved based on availability of new sensors and data and evolving stakeholder needs. These products support local economies by demonstrating that there are safe areas to recreate even during a HAB, saving water utilities money by targeting HAB treatment when it poses a threat, helping charter boat captains know where to fish and avoid HABs, and assisting with the timely opening and closing of economically important shellfish beds.

Quality: High quality models and forecasts are seamlessly translated to the public in a user-friendly format. Staff members are well regarded as experts in their respective fields.

Relevance: Water quality managers, public water systems, beach managers and others use the timely data provided by this branch to make informed decisions to better protect public health. This branch produces applied products, that the public is confident in, that make use of the best available science and technology. Key examples include:

- Lake Erie HAB Bulletin. The Lake Erie HAB Bulletins provide wide-ranging benefits to an array of stakeholders. The bulletins have been integrated into weather forecasts on local media outlets, providing timely and useful information to the public. The state of Ohio includes the Lake Erie HAB Bulletin in weekly updates to the governor's office and Emergency Management Agency (EMA), to help ensure the state is prepared to respond to a worsening HAB. The bulletins are utilized by local public water systems to help make operational decisions and reduce the potential for drinking water impacts. The 2014 Lake Erie HAB that affected Toledo's drinking water supply had an estimated $65-71 million economic impact. Beach managers use the bulletins to help focus cyanotoxin sampling. The state of Ohio has also begun to use the bulletins as a means of evaluating open water recreational impairment under the Clean Water Act. NCCOS data was most recently used to list the open waters of Lake Erie as impaired (see Ohio EPA draft 2018 Integrated Water Quality Monitoring and Assessment Report). The bulletins will also provide the data needed to measure improvements to Lake Erie and help determine if

the open waters can be delisted in the future. The state of Ohio depends on the HAB bulletins, and continued support of these products is critical.

- CyAN Project. One of the goals of the CyAN project is to apply the algorithms validated in Lake Erie to other HAB impacted inland lakes. Ohio benefited by being one of the pilot states for this project. The satellite data helped identify cyanotoxin producing HABs that were not visibly detectable by lake managers and helped resource managers more effectively focus their monitoring efforts. This led to both cost savings and improved public health protection. In addition, public water systems used the information to assist with proactive reservoir management strategies and implemented HAB avoidance strategies based on the inland lake satellite data. This resulted in drinking water protection and additional public health benefits. Finally, the value of both the spatial coverage and frequency of data from this project cannot be overstated. Most states do not monitor for HABs during the fall-spring time-period, yet some Ohio lakes have experienced cyanotoxin-producing winter blooms. The satellite data will help ensure off-season blooms are detected and drinking water sources are protected, at a minimal cost compared to traditional HAB monitoring. Overall, the project has the potential to have wide-reaching economic and public health protection benefits once available nation-wide.
- Florida HAB Bulletins. These innovative citizen-science supported "every beach every day" bulletins provide a valuable tool to both protect public health and ensure HAB impacts to local beach-based economies are minimized. The bulletins enable advisories to be posted and removed in an extremely timely fashion.
- Other Projects. The reviewer was equally impressed by the other projects and forecasts supported by this branch. Innovative collaborative projects related to PSP and ciguatera fish poisoning (CFP) events in Alaska and the Caribbean resulted in development of novel molecular detection and rapid toxin screening methods. These projects will help reduce the risk of PSP and CFP poisonings. In addition, lessons learned from both the Lake Erie and Florida bulletins were efficiently and effectively translated to other areas with emerging HAB concerns, including the Chesapeake and Albemarle regions.

Performance: NCCOS does a fabulous job engaging stakeholders to ensure products meet their needs and are adapted as needs evolve. NCCOS staff members are adept at appropriately messaging their products as useful tools for managing risk (versus a trigger for public hysteria). NCCOS also effectively collaborates with local and regional governments and University researchers to achieve shared goals. The projects are well aligned with HABHRCA priorities. The quality and scope of the projects covered by this branch are incredible given the limited staffing.

Conclusions/Recommendations:

1. **NCCOS should be the CyAN project lead in terms of inland lake OLCI HAB satellite data processing and applications. NCCOS has the expertise to lead this effort, and it is better equipped than USEPA to take on this vital role. This transition may require additional NCCOS staff support, but with the tools and expertise that reside in NOAA this would be a smaller lift than transitioning the inland lake program to USEPA (where it would have minimal support based on existing capacity). Inland lakes provide economically important recreational opportunities, support local fisheries, and are the source of drinking water for millions. The same quality data and interpretation should be available for these vital resources as is currently relied upon for Lake Erie.**
2. **The services provided by this branch, especially the Lake Erie HAB Bulletins and Florida Beach HAB Bulletins, have direct links to public health protection and are vital to local economies. These services should be maintained at the expense of all other NCCOS programs, if budgets are limited.**

HAB Monitoring and Reference Branch

Overview: The HAB Monitoring and Reference Branch provides valuable analytical method development and support for HAB programs in both the U.S. and abroad and helps advance innovations in HAB monitoring technology. The applied research conducted by this branch has direct benefits to stakeholders. This branch also plays a critical role in timely HAB event response and helps to fill knowledge gaps on emerging HAB contaminants of concern.

Quality: Expert staff members utilize multiple analytical methods to support scientifically defensible hazard assessments. Staff members are also leaders in the development of novel methods and detection technologies that have in several instances been advanced and adopted as standard methodologies.

Relevance: Technology is effectively transitioned from the research and development phases into broader applied uses, resulting in the protection of human health. Some relevant examples include:

- Receptor Binding Assay (RBA). The RBA is a great example of developing a lower cost, easier to implement, validated, and accepted analytical method that can be utilized broadly to improve public health protection. The RBA also has potential freshwater saxitoxins applications. Since the current saxitoxin enzyme linked immunosorbent assays (ELISAs) have poor reactivity for all saxitoxin analogs the RBA would be a great improvement to existing methods, resulting in improved drinking water protection.

- Environmental Sample Processor (ESP). The ESP is a promising tool for real-time remote HAB monitoring of both marine and freshwater HABs. These sentinel systems have the potential to provide early warning to resource managers and public water systems. The technology is currently cost-prohibitive, but advances continue to be made to help ensure the technology can be more widely adopted in the future. The AUV ESP is a profound advancement in monitoring capability and again has the potential to revolutionize how waters are monitored. The AUV technology also has the potential to reduce monitoring costs if expensive boat time can be reduced. ESPs may also be deployable in conditions inhospitable to traditional vessel-based monitoring, allowing important data to be gathered when not possible by other means. Finally, the ESP collaboration led to a partnership to develop a portable cartridge based multi-plex freshwater cyanotoxin detection platform. This innovative technology has broad potential utility for fast, efficient, and low-cost cyanotoxin monitoring.
- Marine Biotoxins. The public expects a response to charismatic marine mammal poisonings, and this branch provides that valuable service. The foundational analytical method development work supported by this branch also ruled out biotoxins as the cause for marine mammal poisonings following the Deepwater Horizon spill, which facilitated a more timely and appropriate natural resources damage assessment for the spill. The advanced LC-MS/MS based methods for lipophilic toxins can also be used as a more cost-effective alternative to the traditional mouse/rat bioassay methods.
- Phytoplankton Monitoring Network (PMN). If there ever was a great example of bang for your buck, the PMN is it. Through an effective citizen-science based monitoring network useful data is obtained at very modest cost, providing early warning of HABs, public health protection, excellent educational opportunities for project partners, and increased public awareness of HAB issues. This program deserves the awards it has won.

Performance: This branch is nimble and adaptable, accomplishing a lot with limited resources while maintaining the flexibility to address emerging HAB issues and effectively respond to HAB events, including marine mammal poisonings.

Conclusions/Recommendations:

1. **Collaboration between this NCCOS branch and USEPA-ORD and USEPA Office of Water Technical Support Center is necessary to ensure limited resources are focused effectively, technical expertise is best utilized, and duplication of effort is avoided. This is especially critical for freshwater HAB monitoring, response, and remediation.**
2. **Support for molecular methods and genomic approaches is needed and should be reinstated. Advances in molecular biology have exceeded Moore's law and continued**

federal support for applied research in these areas is necessary. Molecular methods show huge promise in advancing our understanding of triggers for toxin production (with potential management implications) and can provide more cost-effective monitoring options compared to traditional chemical analytical methods. This branch should reprioritize funding in this area.

3. **The PMN should be more strategic in program expansion, targeting high priority HAB impacted regions of the country where HAB data is limited. This is especially critical for expansion of the network to include additional freshwater monitoring sites (should partner with USEPA and states on focusing site selection).**
4. **This branch would benefit from additional dedicated funding. Staff could spend more time on applied research and less on searching for extramural funding to support critical programs.**

Harmful Algal Blooms - Extramural (ECOHAB, MERHAB, PCM HAB, Event Response)

Overview: The extramural applied research is responsive to stakeholder needs while addressing HABHRCA priorities. The research funded through these programs contributes to forecasts by enhancing models, transitioning novel monitoring methods to applications, and improving existing models.

Quality: The review process is appropriate and ensures quality projects, tied to applied research objectives, are funded. There is a tight collaboration between projects and forecasting needs, when appropriate. Funded projects have resulted in numerous peer-reviewed publications.

Relevance: For all projects, stakeholder involvement is a requirement and has been a key to project success. Funded projects often provide data critical to model development and forecasts. Many projects are iterative, and successfully build upon each other moving the state of the science from more basic to directly applied research.

- Event Response Funds. The event response funding is amazingly nimble and should be a model for other Agency event response funding. The application process is easy to navigate and funds are quickly provided, enabling timely data collection during a crisis.
- ECOHAB/PCMHAB/MERHAB. The model of having funds available for foundational applied research (ECOHAB), cost effective monitoring and response (MERHAB) and finally technology transfer and HAB mitigation (PCMHAB) is exceptional. New HAB threats continue to be identified and continued funding of all three programs is necessary. The scope these projects cover is immense, and NCCOS staff clearly

documented the applied benefits of project outcomes in the limited time that was available to them.

Performance: For a relatively small amount of funding, a lot of varied HABHRCA priorities are addressed through these extramural funding programs. It is a credit to NCCOS management that during severe funding reductions, the program was managed with minimal disruption to previously funded projects. These programs could have immense benefits if ever fully funded.

Conclusions/Recommendations:

1. **Encourage University collaboration, not competition. This could help with technology and knowledge transfer, development of junior PIs, and possibly help initiate work in HAB affected regions with limited existing HAB monitoring or assessment support.**
2. **Collaborate with other Agencies on overlapping funding priorities to help ensure complementary, not duplicative, RFPs. This could be formalized in Memoranda of Understanding (MOUs), if possible.**
3. **Work with partner agencies to reevaluate the NEPA FOSI assumptions for biological HAB controls. Biological controls are an important HAB remediation tool, especially in freshwater systems. Currently these controls are being utilized based upon research conducted primarily by manufacturers, and labels have broad application ranges. There is a need for independent research on efficacy of these products and appropriate application rates for targeted HAB control.**
4. **NCCOS staff should continue to be eligible to receive competitive research funding. NCCOS staff are well regarded as experts in their respective fields and are often the best partner or PI for a given research priority.**
5. **The minimal event response funds should be continued at the expense of other extramural funding in tight budget years. If funding increases, consider increasing event response funding allocation.**
6. **All funded projects should be required to input data collected as part of the project into a regional or national publicly accessible database. We need to learn from past projects. Big data is sometimes needed to make more holistic observations and revelations. This would be a start.**

Hypoxia - Extramural

<u>Coastal Hypoxia Research Program (CHRP)</u>

Overview: The CHRP provides funding to support applied hypoxia research and forecasting in regions other than the Northern Gulf of Mexico.

Quality: As with other NOAA products, the quality is very good. Models are developed and validated providing valuable tools for estimating changes in hypoxic conditions.

Relevance:

- Lake Erie. The Lake Erie CHRP project appeared to have the broadest potential public health and resource protection benefits compared to other hypoxia projects. Lake Erie is the source of drinking water to millions, and hypoxic conditions can create "yellow water" events that cause both aesthetic impacts (including turning laundry yellow/orange, causing citizen outrage) and emerging potential health effects resulting from new USEPA health advisory levels established for manganese (which can be elevated during hypoxic events). Drinking water advisories due to elevated manganese, could have a major economic impact. Having a better understanding of when hypoxic events can occur (based on NCCOS models) would enable water systems to proactively treat for manganese removal and reduce the potential for a drinking water advisory. Treating the water for iron and manganese on a continual basis is often cost-prohibitive for water systems. In addition, Lake Erie hypoxia events have been linked to impacts on the economically important perch fishery. Finally, the existing hypoxia models were used to help develop load response curves and help support internationally accepted (International Joint Commission; IJC) 40% phosphorus load reduction goals for the basin.
- Chesapeake Bay. The gulf coast model was successfully spun off to the Chesapeake and was utilized to test total maximum daily load (TMDL) impacts on main stem hypoxia. The model results drove policy attention. Hypoxic events were linked to impacts on economically important fishery.

Performance: The CHRP program helps address HABHRCA hypoxia priorities. It is not clear how priority hypoxic regions of the U.S. are selected for further research and funding.

Conclusions/Recommendations:

1. **Evaluate hypoxia nationwide and identify critical areas based on public health and resource impacts and stakeholder engagement. Any new or continued funding should focus on projects within critical areas.**

Gulf of Mexico Ecosystems and Hypoxia Assessment (NGOMEX)

Overview: Of all the NOAA-NCCOS programs this one had the least local stakeholder involvement and no direct impact on human health. The program is driven by an overarching goal to decrease the size of the Gulf of Mexico hypoxic zone, but it is unclear how that goal was

derived or how a hypoxic zone reduction will benefit local stakeholders or provide public health protection. Reducing the hypoxic zone would require substantial reduction to nutrient inputs tied to approximately 40% of the continental U.S. Meeting such a substantial nutrient reduction goal would require a significant financial investment and could affect crop productivity. Further, if nutrient reduction goals were achieved it could negatively impact local fisheries, based on potential loss of productivity and increased difficulty in catch (target species not concentrated in hypoxic zone margins). The local fishery survey response rate was abysmal (1%), demonstrating a lack of local engagement. Midsummer cruises are expensive and may not be best use of limited funds. There were a few studies that showed potential impact of the hypoxic zone on fish reproduction, which could have management implications.

Quality: As with other NOAA products, the quality is very good. The models have been validated and provide an appropriate tool for estimating changes in hypoxic conditions.

Relevance: The potential impact of hypoxia on fish reproduction was of most relevance, although the fishing community did not seem engaged in this program. The reviewer struggled to find broader relevance for this program.

Performance: The Gulf of Mexico hypoxic zone is large and difficult to monitor. The data gathered to date was useful in developing and validating appropriate models, but funding continued monitoring is not sustainable unless alternate sources are identified and linked to stakeholder support for continuation of program.

Conclusions/Recommendations:

1. **Focus efforts on better quantifying potential and realized impacts of the hypoxic zone. Engage local stakeholders. If hypoxic zone impacts cannot be quantified and local stakeholders do not support program, efforts should be focused elsewhere.**
2. **Continue exploration of novel ways to acquire data needed to help validate models. The glider research was important, and NCCOS should continue to evaluate more cost-effective monitoring options (which could also be applied in other regions). This should include evaluating other autonomous vehicle options and partnering with the fishing fleet on data acquisition. This is a lower priority compared to the first recommendation (pursue if impacts are better quantified and local support is obtained).**

Overall NCCOS Program Comments and Recommendations:

1. **Funding. NCCOS program linkages to HABHRCA are strong, but NCCOS cannot address all HABHRCA priorities with existing funding. Primary focus of efforts has**

been on marine hypoxia and HABs, and there are insufficient funds to effectively expand programming to adequately address freshwater HAB and hypoxia issues and emerging marine issues. Intramural programs should be funded at the expense of extramural programs to, at a minimum, ensure some continuity in core programming.

2. **Prioritization (projects and regions). Although the NCCOS projects are of exceptional quality and address HABHRCA priorities, the reviewer struggled with how (or if) regions of the U.S. and specific topics were prioritized for funding. NCCOS should consider updating the HARRNESS report to ensure research and funding is appropriately targeted towards stakeholders needs. The program may also benefit from more targeted RFPs to address critical areas and data gaps, instead of topic-based RFPs where PIs more experienced with quality proposal writing may outcompete junior PIs working in perhaps more critical areas.**
3. **Accessibility of data. A national HAB database is needed (freshwater and marine). Regional HAB databases could be a start, but they need to be developed in such a way that future integration is possible. Big data is sometimes necessary to make more holistic observations and revelations (especially true for molecular data). In addition, if data is more widely available that can lead to increased stakeholder involvement and support. This should be a joint federal (USEPA/NOAA/USACE/USGS) priority.**
4. **Support for National HABs Symposium. NCCOS should continue providing support for this valuable meeting. This is the main opportunity for the HABs community to transfer knowledge and develop new effective collaborations. The meeting also provides a very effective way for state agencies and resource managers to stay current on the state of the science and provide their input on applied research needs. One recommendation would be to shorten the length of the meeting to 2.5 or 3 days instead of 5 (plus extra 1-1.5 days for optional workshops, as in past). The same amount of information could be covered in this time-period if topic-based afternoon break-out sessions were utilized. It is often difficult for managers to take an entire week off for this type of meeting and a shorter meeting would provide a cost-savings for everyone.**

Individual Reviewer Report #5

Introduction

I am a long-term observer of NCCOS HAB and hypoxia programs, starting with multiple NECOP grants in the early 1990s. I also had a GOMEX grant in the earlier 2000s and ECOHAB grant as a co-PI from 2009-2013. I also closely followed the funding challenges of recent years, both as a Sea Grant Director and an interested scientist. I was interested in serving on this review team not only because of past research funding from this program but because I believe that it has led the important national research effort in these areas and will likely continue to do so.

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)?

NCCOS scientists (both intramural and extramural) and program managers include a large fraction of the leaders in the field in the U.S. Their contributions include all of the items mentioned (peer-reviewed publications, congressional briefings, invited lectures, awards, and leadership positions). That said, many of these scientists and program managers are baby boomers and will either be retiring or working well into their senior years. There are already numerous vacancies in NCCOS and little evidence for succession planning. In addition, though young scientists are training in the field, the funding irregularities of NCCOS, including the lack of any new HAB or Hypoxia projects started from 2012-2014, have discouraged new investigators. Additionally, the major HAB regional projects are excellent opportunities to entrain young scientists into HAB studies and are also viewed by program managers as the best source of information on causes and impacts of HABs. However, funding constraints have prevented the start of any new regional projects since 2011.

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 PCM technologies?

HAB cell and toxin detection methods. Advanced scientific instruments like the ESP and Flow Cytobot whose development was aided by NCCOS are great scientific research and monitoring tools and can have important management uses. However, with a few exceptions they are unlikely to be affordable or useable by state or local managers alone without continuing outside technical and monetary support. Even relatively simple instruments like fluorometers are challenging to use and maintain when moored or incorporated into an AUV. Therefore,

increased partnerships with the regional IOOS programs, already important collaborators, should be further encouraged. These and subsequently developed instruments will likely continue to be important research tools, however, they would be need to be much simpler and cheaper to be of wide use outside the scientific community.

HAB forecast models, both for coastal regions and inland lakes, can be very useful to water managers. Good examples include the Texas and Florida HAB models, and the western Lake Erie HAB forecast model. They are at various stages from research to operational, with the Florida models targeting predictions for individual beaches when coupled with volunteer monitors. They are likely to become increasingly specific and reliable, and therefore important to managers, but will require continued support from NCCOS.

The interagency CYAN Program (EPA, NASA, NOAA, USGS) uses satellite imagery to find cyanobacterial blooms. It has had success in at least 5 different states but apparently lacks long-term support. Given the rapidly increasing incidence of toxic cyanobacteria blooms which is exacerbated by increased temperatures due to climate change, this program should be made a greater priority.

Simpler laboratory methods, especially the ELISA, antibody and perhaps qPCR methods as well as surface plasmon resonance (SPR) and peptide nucleic acid (PNA)-based detection methods are more likely to be adopted and used by less expert personnel. This is especially true when they can be incorporated into hand-held or other portable instruments. The RBA methods for toxin detection has been used and widely disseminated around the world by NCCOS for toxin detection.

PCM technology is still in development with some methods more successful than others. NCCOS could perhaps make an impact by focusing more effort in the area, particularly with cyanobacteria. The Europeans seem to be leading in the area so far. The prohibition on biological control methods should be reconsidered.

3. How does NCCOS assure and does it have procedures for funding preeminent research and impactful science?

NCCOS uses a rigorous peer-review system for its Competitive Research Program (CRP) which funds both extramural and intramural research teams. (Intramural researchers are eligible for CRP funding, which is fine, but it was unclear what are the NCCOS limits or guidelines for such funding.) While the success rate of proposals varies widely with the program and the year, it is generally less than 50% and often much less. Other intramural funding relies on internal evaluation processes which presumably use many of the same criteria as the competitive research program but was not detailed.

Relevance:

1. How well has the portfolio supported noteworthy achievements in improving scientific understanding of causes of HABs that have led to improvements in HAB management and

response?

The NCCOS HAB portfolio has supported many important research papers which have improved the understanding of HABs, though there is still much that we don't know, including the likely impacts of climate change on future HABs. The oceanography related to the recent increases in HABs and hypoxia on the West Coast, including the coast-wide *Pseudo-nitzschia* bloom in 2015, and the possible involvement of climate change, represents important remaining research questions. HAB management and response are less well understood than the causes and would also benefit from additional investment in the PCM program.

2. How effective are the hypoxia modeling and related studies in informing Federal guidance on nutrient management strategies in upland states?

I believe that the hypoxia modeling and related studies have provided useful targets for nutrient management in upland states for a variety of locations, including Chesapeake Bay, Lake Erie, and the Gulf of Mexico. Many of the recommended reductions are significant, on the order of 50%. Additionally, many of the nutrient inputs to Lake Erie and the Gulf of Mexico are primarily non-point source inputs from agriculture which are largely unregulated. Therefore, despite the modeled nutrient concentrations, attainment of the needed reductions is problematic because of the policies and politics, not the science. That said, the better the science informs nutrient management, the more likely progress is to be made.

The Gulf hypoxia monitoring program, particularly the annual monitoring cruise, should be made more cost effective, so hopefully additional monitoring can be done. I know there has been some effort with gliders in this environment, but it is challenging with shallow depths and steep gradients. Additional efforts should be made with either gliders or other new technology. There will be turnover in the monitoring teams in the next few years and hopefully this transition will be an opportunity to improve cooperation among the different monitoring teams that has not always been evident in the past.

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?

Some of the most important HAB outreach and technology transfer to state, local, and tribal governments is through the smaller less well-known Citizens Science programs, such as the PMN and the EPA program which collaborates with it. SEATOR, the collaborative program with the Alaska tribes, is an excellent example and should be replicated elsewhere. In addition, the HAB Event Response program provides a big bang for a small buck, and all these programs could benefit from better communications of their impact to decision makers and the public.

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?

Much of NCCOS research has been effectively transitioned to a variety of applications, using the NOAA Readiness Levels. However, funding gaps or other challenges have delayed or derailed transitioning of a number of research products. There is not a specific NOAA process or funds for transitioning, though transition plans are recommended for projects beyond a Readiness Level 4. Some of the products transitioned to NOAA operations are maintained with intramural research funds, an unsustainable course of action. Greater priority should be focused on especially promising research products in order to fast-track their transitioning to applications.

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).

NCCOS fulfills its HABHRCA responsibilities satisfactorily but may have additional opportunities to increase its impact. As mentioned elsewhere, it would be useful to involve other interested agencies, both state and federal, in developing and coordinating a national research strategy. I imagine that this has already been tried to some extent, but it could improve efficiency and minimize overlap. Clearly NCCOS should retain its lead role in this area and expand it if possible.

2. How well does NCCOS execute its research and related studies in an efficient and effective manner given the resources?

NCCOS does an effective job executing its research and related efforts with it current resources. However, the variability and unpredictability of its funding can decrease its efficiency, which would likely improve if it became more stable, such as slow but steady regular increases.

3. How effectively does NCCOS utilize collaboration and partnerships to achieve desired outcomes, and how well are stakeholders engaged in transitioning research to applications?

Past ECOHAB RFPs were interagency, with at least EPA and NSF participation as well as NCCOS. It seemed to be an effective strategy but did not last. NCCOS should encourage more interagency RFPs in the future in order to increase collaboration and decrease overlap.

NCCOS could consider partnerships with NOAA Sea Grant programs which support coastal and Great Lakes research and conduct outreach. Many of their coastal concerns involve HABs or hypoxia. Another possible partnership could be with the EPA National Estuary Programs (NEPs) which have similar concerns. These programs recently met with the Congressional Estuary Caucus on the subject of HABs. Some of the larger NEPs and related programs like Long Island Sound, Puget Sound, and the Great Lakes have significant resources.

Most NCCOS projects involve stakeholders from the beginning; a good example is citizen scientists in Florida who provide information on *Karenia* impacts on specific beaches to couple with the satellite data. That said, one can almost always increase stakeholder involvement, particularly of fishermen and other marine trades people who benefit from NCCOS products but are not paid to participate in meetings or other interactions. They often have to be sought out, but they can also provide some of the best testimonials to policy makers if successfully involved.

4. How effective are NCCOS roles in leading workshops, symposia and training that result in outputs that drive management outcomes?

There are numerous examples of such NCCOS efforts detailed below. An active MERHAB targeted project has developed and established a sustainable model for an annual United States training course in marine harmful algae identificaiton at Bigelow Laboratory for Ocean Sciences. Several outside experts are leading the training with support from NCCOS scientists. The course meets training requirements critcal to maintaining effective national HAB monitoring programs.

An operational outcome of a past MERHAB Lower Great Lakes regional project, the algal toxins laboratory at the Environmental Science and Forestry of the State University of New York is an integral part of the New York Citizens Statewide Lake Assessment Program (CSLAP) and also provides toxin analysis for outside groups.

NCCOS has a long-time collaboration with the International Atomic Energy Agency (IAEA) to provide instruction on the use of RBA methods for toxin measurement around the world. It is not clear that any of these outreach examples has received the notice and credit for NCCOS that they deserve. It also seems like the two MERHAB projects above have transitioned to more permanent programs but their funding support is unclear.

Overall, I believe NCCOS is highly relevant and doing a good job and mostly needs to do more of the same but I have several specific concerns:

1. **The vacancy and succession issue mentioned previously.**
2. **Intramural moleular capability. While molecular capabilities are now widespread among extramural researchers, a question remains as to whether there is a need for such capabilities within the NCCOS intramural program. The methods are now so powerful they are essential for any biological research.**
3. **Intramural vs. extramural research. The NCCOS HAB programs are a mix of both while hypoxia is largely extramural. The HAB programs also have a higher visibility and a larger share of the funding, some of which is due to the funding mix but also includes the greater visibility of HAB issues. In the future NCCOS might consider running the**

more routine monitoring programs in house, perhaps including even the Gulf hypoxia monitoring, but only if it can be done more efficiently that way. Intramural efforts should also be focused on particular problems which must be addressed but do not attract proposals. Proposal-driven programs are always ultimately dependent on the proposals received, though pressure can be applied to direct them. The panel had concerns that some regions of the country may have received larger fractions of the funding than perhaps the issues warranted, however, with proposal-driven programs talented proposal writers and research groups will often garner an extra share of the funding.

4. **The balance between low tech programs like the PMN and high tech devices like the ESP. Both capabilities are important to the program but serve different needs. The ESP and Flow Cytobot are cutting edge research instruments which also have important management uses but will continue to require significant technical support and funding. The PMN is an important outreach effort which can benefit from the observations of such instruments, but does not rely on them, the basic observational tools of the PMN and related programs are much simpler and can be used with by citizen scientists after appropriate training. Ideally NCCOS will be in position to expand both efforts but should also look to potential example collaborators (there are also others) like Sea Grant for outreach, and marine technology programs like NSF OTIC, as possible opportunties for leveraging funding.**

Individual Reviewer Report #6

Harmful Algal Blooms – Intramural & Extramural

Overview: The internal and external HABs work at NCCOS appears to be of high quality; it appears to be in good alignment with HABHRCA, and well-aligned with appropriate stakeholders.

Quality: The HAB work at NCCOS is conducted by talented staff, as evidenced by their expertise, CVs, presentations, reputations, quality of collaborations, and number of articles in well-respected journals with high impact. Articles are published in a relatively wide variety of journals, which is commendable. During the review and through the materials, I observed that there is strong leadership and coordination for the HAB work in NCCOS.

There appear to be several key positions within the program that are either vacant, filled with acting staff, or filled with staff near retirement, so it will be good for NCCOS to have a staffing plan for filling these vacancies. I understand from discussion during the review that this is an area of focus for the current leadership.

The extramural program appears to be well-run and appropriately managed. There appears to be open competition and appropriate peer review for the grants, and appropriate oversight and tracking of the projects selected for funding.

The extramural programs have clearly been able to adapt to changes in funding and to emerging issues, while maintaining continuity and delivering desired results. However, consistent funding would reduce uncertainty and support best results.

Relevance: There is a good alignment of the work with HABHRCA as the enabling legislation. The presenters demonstrated clear ties to mandates in HABHRCA, where appropriate, and it appears that NCCOS is carrying out the actions intended for their agency in the legislation. The HABs work also appears to be well aligned within the structure of the Agency.

- A notable strength is that strong partnerships have been developed and maintained in many areas of the research portfolio, including technical advisory committees. NCCOS recognizes the importance of engaging stakeholders, which is an important aspect of HABHRCA. For example, MERHAB includes managers as reviewers and as part of the PI team.

- The Events Response grant program clearly provides a large impact for a relatively small amount of money. Even though it was not specifically designed for wide coverage, the result is excellent coverage in space and HAB type. There was discussion of how to cap individual responses. A possible new direction was given in the presentation, which would focus on "Events of National Significance" – this seems reasonable.
- I think that NCCOS has an excellent and relevant mission and vision, which clearly bind and specify the work. I understand that we were only presented a part of the overall NCCOS picture, but I think it would be useful if there was an overall conceptual model, map, and/or framework to show how all of the different activities (e.g., those listed in Appendix III of the "Advancing Coastal Science" publication) fit together to collectively achieve the NCCOS mission. With that, it would be easier to show how the HABs programs fill gaps and lead to coordinated solutions for coastal management.
- The NOAA's Ecological Forecasting Roadmap was a useful example of how HAB forecasts are integrated with other ecological forecasts for delivery to stakeholders.
- There was some mention of working with the National Estuarine Research Reserve System (NERRS), and this seems like an important and fruitful area for partnership and coordination. The NERRS science coordinator attended the review, and it appears that work with NERRS is underway in some areas (e.g., Tijuana River NERR).
- Great outreach to stakeholders, including the public, was demonstrated throughout the program, with many good mechanisms for getting results out. There was emphasis on a quick turn around on forecasts. CYAN was a particularly good example of identifiable results.
- The HAB Forecasting Branch demonstrated a variety of significant studies and results. A particular strength of this Branch is that it appears to be identifying gaps within the forecasting science, and directing research to fill these.
- The HAB Monitoring and Reference Branch is comprised of successful and relevant programs. The IAEA collaboration appears to be a significant success story for this Branch – such training and technology transfer takes significant time and effort, and it is good to see that leverage and legacy opportunities were sought as part of the effort.
- I found the program of Transition and Readiness levels to be impressive, with the nine readiness levels well defined. In our experience, the social aspect of transition (e.g., acceptability) is often overlooked, so it is good to see that it is recognized by NCCOS. The presentations also stressed a progression of outcomes from changes in management knowledge, to changes in management behavior, to societal benefits. The focus on societal benefits provides the opportunity to connect to a larger body of work on benefits and ecosystem services. It would be useful to align the readiness levels and technology transfer with the progression of outcomes, to create a complete picture of how outputs are made relevant to stakeholders.

- The PMN is an innovative and strong citizen science program that seems to have many benefits. It appears that there is strong and growing participation, notably in Alaska. Good coordination is evidenced by the use of PMN data in the FY18 Northeast Fisheries Service Center State of the Ecosystem report. This is a significant step when citizen science data can be used in Agency reporting.

Performance: There is a clear and coordinated progressive structure across the grant programs in support of HABHRCA, where ECOHAB determines causes and impacts, MERHAB builds national capacity to improve monitoring and response, and PCMHAB develops methods and transitions then to end user operations. In multiple cases, it appeared that a grantee conducted work through these programs in series; this provides beneficial continuity for long-term solutions.

Each of the programs, and the ECOHAB program in particular, has a good spatial range, and covers a broad range of types of toxins.

A value of the PCMHAB program is that it is using a socioeconomic approach and values the acceptability of approaches, not just the technology. In my experience, it is difficult to hire social scientists and to conduct social science surveys in the federal government, so the effort through this program is notable.

NCCOS and partners are commended for their use of cutting-edge technology, such as the ESP in Great Lakes and Gulf of Maine, and Flow Cytobot in Texas. As was recognized by the presenters, these technologies pose challenges in terms of cost for operational status. The presenters were clear and knowledgeable about the challenges that are involved, with cost being a primary challenge. It appears that both grantees and the Agency are addressing the challenges; however, there are no clear or easy solutions to making these complex and expensive technologies operational.

It appeared that high standards were used in methods development within NCCOS to ensure quality and reproducibility.

A presenter suggested that there was not enough coordination among federal agencies. I would also suggest that this is an area of opportunity. In-person meetings are ideal for fostering the coordination; however, many federal agencies are often faced with limitations in travel budgets. Cross-agency coordination may be pursued through virtual workgroups, at scientific meetings (e.g., CERF), and possibly through special programs (e.g., USGS Powell

Center). Also, how could the current HABHRCA infrastructure be used to promote this coordination?

Recommendations:

1. **Provide continuity through stable funding and permanent federal staff.**
2. **Consider formalizing a conceptual model and/or framework for NCCOS to show how all of the different activities fit together to collectively achieve the mission.**
3. **Continue to work with partners to address recognized challenges in making complex technology operational.**
4. **Pursue cross-agency coordination through workgroups, scientific meetings, special programs, and the HABHRCA infrastructure.**

Hypoxia - Extramural

Overview: The NGOMEX and CHRP programs are populated by very high quality work conducted by qualified and talented researchers. The programs have clear goals and appear well-aligned with stakeholder needs. Innovative approaches are being used to measure and forecast hypoxia and its effects on living resources.

Quality: The quality of the Hypoxia work at NCCOS is excellent, as evidenced by 1) talented, well-respected staff with strong expertise and excellent CVs; 2) productivity, in terms of number of articles in a wide variety of well-respected journals with high impact; 3) quality of collaborations and partnerships; and 4) strong leadership and coordination within NCCOS.

There are key positions within the program that are either vacant, filled with acting staff, or filled with staff near retirement, so it will be good for NCCOS to have a staffing plan for filling these vacancies. I understand from discussion during the review that this is an area of focus for the current leadership.

The extramural program appears to be well-run and appropriately managed. There appears to be open competition and appropriate peer review for the grants, and appropriate oversight and tracking of the projects selected for funding.

As with HABs, the extramural programs have clearly been able to adapt to changes in funding and to emerging issues, while maintaining continuity and delivering desired results. However, consistent funding would reduce uncertainty and support best results.

Relevance: For NGOMEX, there is good alignment with NCCOS mission, HABHRCA, and the rest of Agency; a clear client in the Hypoxia Task Force; clear and reasonable goals and objectives; and good interagency cooperation and coordination. There seems to be a coordinated effort to get the information (forecasts) out to the general public effectively. This seems like a successful model for place-based, long-term research.

The NGOMEX program is supporting the production of an important and valuable long-term record of data for characterizing gulf hypoxia. It is clear that the larger research community is working on a cooperative effort for how to make the monitoring program sustainable, which the presenters identified as an issue. Also, it seems that a data repository needed for accessibility and reuse. It would be useful to facilitate integration of modeling and data streams.

Per the presentation, CHRP is clearly separated from NGOMEX, and is focused on coastal managers as stakeholders, which aligns clearly with the NCCOS vision/mission and with HABHRCA. It is clear that CHRP-supported research is relevant to local stakeholders, such as in Narragansett Bay. In some cases, CHRP supports studies in areas that have place-based programs (e.g., Great Lakes, Chesapeake Bay), and the results are designed for use in-place. The Lake Erie work seems like a particularly successful project, in particular because of the links to the managing bodies (IJC, Great Lakes Fisheries Commission), and this is easier for a single place and bounded set of stakeholders. I think there is an opportunity to improve the coordination and outreach to sites beyond the place-based studies. An inherent challenge is the CHRP program's structure is that it can be difficult to integrate across projects, as was evidenced in the East Coast estuarine eutrophication projects. Is there a toolbox of empirical models and/or approaches that can be formulated and developed for transfer to additional sites? Also, it can be difficult to connect with coastal managers collectively - there is the potential for work with NERRS and National Estuary Programs (It seems like some work with NERRS is underway). Are there other coordinated groups of coastal managers than can be targeted with outputs of the work?

The hypoxia program is largely extramural, so it is not fully clear how the results get brought back in to NCCOS to support the mission. One avenue appears to be through NOAA's Ecological Forecasting Roadmap, where hypoxia forecasts are integrated with other ecological forecasts for delivery to stakeholders. As mentioned for HABs, an overall conceptual model, map, and/or framework could be useful to show how all of the different activities (e.g., those listed in Appendix III of the "Advancing Coastal Science" publication) fit together to collectively achieve the NCCOS vision and lead to coordinated solutions for coastal management.

The linkages presented to living resources are important, and represent good collaboration within NOAA, with relevance to fisheries management councils. The research is innovative, and in the leading edge of current ecological modeling field. The multi-stressor approach being used in this modeling is particularly relevant.

Performance: It appears that the hypoxia modeling in both programs uses rigorous methods and established best modeling practices, including ensemble modeling to address uncertainty. It is useful to see an ensemble modeling approach used, and encouraging that the models in the ensemble give relatively similar results. It seems reasonable to address both N and P, based on current scientific understanding. The models presented at the review are generally well supported with data. Exciting advances in the coupling of models were presented. It is impressive to see how the model results were transitioned to a coordinated forecast that is of great interest to stakeholders. This is an excellent example for other Agencies to follow.

I assume that the Task Force is providing a venue for coordination with other agencies on Gulf hypoxia, and providing coordination in particular on the topic of watershed modeling, which serves as input to water body models.

It would be useful to have federal scientists within NCCOS with the expertise to parameterize, run, calibrate and interpret results from the mechanistic model(s) that were mentioned and presented at the review (e.g., FVCOM, WASP), following the successful example of transitioning the four empirical gulf hypoxia models to operational status. It is important to have the perspective from 3D hydrodynamic models and from mechanistic water quality models, which can account for nonlinear/threshold/unexpected effects, lag times, and sediment processes. For places where the Agency has committed to long-term, place-based research (e.g., Gulf of Mexico), it seems like it would be more efficient to conduct this research internally, or at least to run the models once they have been developed and parameterized. Mechanistic models are also appropriate for use in assessing future scenarios, particularly those related to climate change – when climate change induces changes in physical factors (precipitation timing/amount/intensity, cloudiness, wind, temperature), hydrodynamics can change, and this will affect assumptions about water quality. Also, as was demonstrated in the fisheries presentation, hydrodynamics models can serve as the basis for broader NOAA efforts in the study site, including fisheries. With staffing limitations, it may be difficult to transition this work in-house. It may be possible to develop synergies with the HABs work, and use mechanistic modeling to support both.

Recommendations:

1. **Provide continuity through stable funding and permanent federal staff.**

2. **Work with partners to continue to address recognized challenges in sustaining long-term datasets. Facilitate integration of modeling and data streams.**
3. **Ensure continued coordination in the Gulf of Mexico with other agencies and with land/watershed work through the Hypoxia Task Force.**
4. **Develop in-house capabilities for complex mechanistic hydrodynamics and water quality models, perhaps in coordination with NMFS. Continue to pursue linkage of hypoxia and fisheries work.**
5. **Consider transferability in the CHRP program, e.g., the development of transferrable tools and approaches, and the identification of coordinated groups of stakeholders/coastal managers that can be targeted for technology transfer.**
6. **Continue to pursue NERRS as long-term, coordinated stakeholders.**

Individual Reviewer Report #7

Introduction

The briefing book, presentations, and supporting documentation provided a comprehensive overview of NCCOS R&D efforts related to HABs and hypoxia. Overall, the quality of the NCCOS HAB and hypoxia research portfolio is excellent as indicated from the extensive lists of peer-reviewed publications by and the recognition of the well-respected scientists conducting intramural and extramural research. A major weakness identified immediately in the briefing book materials is the striking number of vacancies in NCCOS senior management positions. Seven of twenty-five (28%) of the management positions are either designated as vacant or acting. This lack of consistent leadership can have detrimental impacts on research quality, relevance, and especially performance. Furthermore, the limited and inconsistent funding for the HAB and hypoxia programs hinders performance potential. Despite these challenges NCCOS has managed to maintain a high quality program and continues to demonstrate a positive trajectory with respect to the relevance of the R&D efforts undertaken.

Harmful Algal Blooms - Intramural

Quality: The quality of the NCCOS HAB research program is largely attributed to the prestigious scientists on staff. As demonstrated in the PI CVs provided, scientists have published copious peer-reviewed articles in a wide range of journals. The scientists are actively involved in the HAB research community, engage with stakeholders, and are well respected in the field.

Quality control measures have been developed for the PMN, which significantly improves the quality and use of data generated from this citizen science program. Such emphasis on quality control has been lacking in many citizen science endeavors. I have experience aiming to include data generated through a citizen science program where the lack of quality assurances rendered the data insufficient. It is important to maintain quality control in the program, but it is equally as important to share and articulate the quality control measures to users of the data. In doing so, the higher quality will positively influence the relevance. See more about the PMN below under Relevance.

The significant weakness in quality identified in the intramural program was related to the lack of standardization or criteria employed for toxin method validation to ensure the developed/optimized methods are fit for their intended purpose. Setting criteria for method validation would greatly improve the quality of R&D related to toxin methods and information

and data derived from the use of those methods. Not only would the quality of the research improve by having sufficiently validated methods, but transferring methods developed by NCCOS for external applications would be facilitated by having standardization of validation criteria instead of conducting method validation on a case by case and varying basis.

Relevance: It was clear that NCCOS engages with and strives to respond to stakeholders. Continuing to consider stakeholder perspectives and respond to their needs will further strengthen the relevance of NCCOS research.

A strength of the research portfolio that is related to relevance is the emphasis on "research to X," where X could be, for example, transition, operation or application. NCCOS, and NOAA in general, has clearly placed priority on research to transition, as demonstrated by the development and implementation of readiness levels. The goal of transitioning research to X is admirable and NOAA is to be commended for the attention given to the transition. For the range of projects presented during the panel review, the degree of success of going from research to X varies greatly. In fact, one of the weaknesses observed was the extremely long time periods some projects go through from research until the products are useful for implementation (e.g., ESP). However, there were some projects that were highly successful especially those that transferred the product/service to outside entities. One notable example of this was highlighted in the presentation about transferring laboratory capabilities to Tribes in Alaska. Another example is the expansiveness of the PMN. The expanded PMN ensures the collection of HAB data in a range of geographical locations over time, thereby generating a vast dataset that is incredibly useful and needed. The challenge is having a repository for the data, and one that utilizes a common format that could be easily accessed by others. The PMN is exemplary in terms of highlighting science and getting the community interested in participating in scientific endeavors. This program earns well-deserved respect nationwide and contributes to a substantive body of data while engaging the general public. The PMN has developed training tools and materials to ensure quality control of collected data. One of the challenges with citizen science is that credibility has not caught up with the need for and quality of such programs. The PMN has an opportunity to influence a paradigm shift in the use of citizen science. Training materials and quality control measures should be shared with other citizen science programs and should be highlighted as a part of the program to improve the reputation of such programs.

The major weakness with respect to relevance is that many of the PIs were unable to articulate the actual relevance of their science. There was also no measure of relevance considered. In most cases relevance was qualitative at best. The relevance of HAB research could be greatly enhanced with developing metrics for determining impact. For example, the presentations on

the RBA reported that the method is now being used for making regulatory decisions in the U.S. While the method has been adopted in 2014 by the Interstate Shellfish Sanitation Conference as an Approved Method for mussels for PSP determination under the National Shellfish Sanitation Program, no state has implemented the method. This demonstrates that the transition was not complete. Rather than checking the box that the method was approved, it is important to use this as an opportunity to understand why the method is not being implemented by the states and how can that be addressed in the future so that a method isn't just on a list but is utilized.

Performance: Despite the lack of permanent, consistent leadership in NCCOS management positions, research is being conducted at a productive rate. It is clear that a significant amount of research is performed with a limited and changing budget. NCCOS is to be commended for leveraging research opportunities with other scientists within and beyond the federal government. Identifying those collaborations and attributing successes of those collaborators would further strengthen relevance and positively influence possible collaborative and leveraging opportunities in the future.

I agree with other panel members that it is disappointing to see the genomics program end with the retirement of Dr. Van Dolah. However, I do not think the program should be reinstated for the sake of having one. NCCOS already has quite a diverse portfolio. I would caution reinstating the program if it means taking funds away from other areas that are performing well and/or if it means not having adequate staff or resources to support a genomics program that is of high quality, relevance, and performance.

Conclusions/Recommendations:

1. **Develop criteria for method validation to ensure developed methods are fit for their intended purpose.**
2. **Use the PMN as an example to improve the reputation and credibility of citizen science programs.**
3. **Develop metrics or others means for measuring and articulating the impact or relevance of research.**

Harmful Algal Blooms - Extramural

Quality: The quality of the research from NCCOS extramural HAB projects is also high, as evident from the extensive peer-reviewed publications that result. The process for evaluating proposals is robust and of high quality.

Relevance: The same comment about relevance above applies to the extramural program. For example, the presentation on the use of ESPs in the Gulf of Maine described the relevance to be that state managers are using the ESP data to make regulatory decisions. Such broad scale statements are not specific and in most cases not accurate. While the ESP data inform the state managers of the presence of toxic algae or toxins in a given location, it is still the testing of toxins in shellfish that must be performed in order for the state to make regulatory decisions (other than precautionary closures). In this case it seems that the ESP data then provides the state managers with information on when it is best to collect shellfish samples, perhaps reducing the number of samples that must be analyzed or providing an early warning system. This is only one example, but across the portfolio relevance could be improved by being specific on the real impact and doing so quantitatively when possible.

NCCOS clearly engages stakeholders in the process of determining extramural research. However, the last national plan development with stakeholder input is outdated. Further, the latest amendment to HABHRCA emphasizes inclusion of stakeholder engagement. As such, it is time to revisit the national plan by holding an in-person workshop akin to HARRNESS to ensure current stakeholder needs are considered and addressed, thereby improving the relevance of the program.

Performance: The performance of the Event Response Program is efficient. It is clear that funding in this area has gone to support an actual need and data generated during these events has enhanced the knowledge base and understanding of HABs. More funds should be dedicated to this area, especially as HABs appear to be increasing in frequency, range and duration.

One of the challenges with respect to the performance of extramural projects is the lack of transparency and potential for overlap with other agencies. Consider revisiting other agencies being involved in the extramural programs and/or continue pursuit of interagency discussions such as through the Interagency Working Group on HABHRCA to avoid duplication of effort and identify leveraging opportunities.

Conclusions/Recommendations:

1. **Update the National Plan for Algal Toxins and Harmful Algal Blooms (i.e., HARRNESS) by gaining the in-person input of a wide range of stakeholders.**
2. **Consider interagency involvement to improve transparency, align with agency missions, and reduce duplication of effort.**

Hypoxia - Extramural

Quality: Like the HAB program, the scientists representing the work on the hypoxia side of the portfolio have impressive accomplishments including extensive peer-reviewed publications and they are well-respected in the field. The main challenge identified with respect to quality has to do with the fact that this is an extramural program with varied approaches to address hypoxia. As such, there appears to be a lack of standardized practices being implemented to study or monitor hypoxia, which may ultimately severely limit the greater understanding and knowledge base from the work and the continuation of long-term datasets.

Relevance: A positive aspect of the hypoxia research is that the efforts undertaken to date have been driven by the Task Force, indicating a sense of direction and a collaboratively developed need for the research projects. A major weakness however is the lack of relevance demonstrated, with the exception, to a minor extent, of the Great Lakes activities.

Performance: NCCOS was able to ensure continuation for a period time of the long-term monitoring of hypoxia in the Gulf of Mexico. NCCOS transitioned to use operational funds to keep the monitoring efforts going. While this allowed the monitoring to continue, NCCOS is encouraged to seek innovative means to sustain long-term observations. Funding is becoming more difficult to support routine, long-term monitoring. Greater adaptability, leveraging opportunities, and innovation will be necessary to prevent interruption in the generation of valuable datasets.

Conclusions/Recommendations:

1. **Explore innovative opportunities to leverage or transition long-term activities without compromising the quality of the data and usefulness of the long-term datasets.**
2. **Consider the research relevance or impact of hypoxia research with respect to the overall research portfolio for NCCOS to balance funds accordingly.**
