FINAL PANEL REPORT
NCCOS HAB AND HYPOXIA PROGRAM REVIEW
November 2023

REPORT GUIDE

FINAL PANEL REPORT
NCCOS HAB AND HYPOXIA PROGRAM REVIEW
November 2023

INTRODUCTION

In November 2023, the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service (NOS) undertook the 2023 Harmful Algal Bloom (HAB) and Hypoxia Review. This well-organized effort explored the research, products, and services provided by the National Centers for Coastal Ocean Science (NCCOS) and allowed Stakeholder input during the evaluation process.

This review details successes that were achieved in the interim since the completion of the 2018 review. The Panel was struck by the scholarly and professional expertise displayed through the presentations and excellent discussions on recent work and research. It is hoped that our input will help guide future expansion of products and services to coastal communities, vulnerable communities, and the research community.

The Panel has offered significant recommendations and observations that are intended to facilitate improvements in current activities and expansion for future developments. While this report details themes and selected recommendations from the individual Panelists, it is not exhaustive. Therefore, it is highly recommended that each individual report be reviewed for clarity and further illumination.

Finally, all of the Review Panelists expressed gratitude for the opportunity to participate in this review. We jointly congratulate the NCCOS for the execution of the entire pre-planning, materials development, and presentations. We are assured that the NCCOS will continue to produce high quality, impactful contributions to the Weather, Water, Climate enterprise.

2023 Review Panel

GENERAL SUMMARY OF PANEL REVIEW AND RECURRING THEMES

Pre-Planning, Materials, and Presentation Formats

- The entire panel expressed gratitude for the attention to detail that was exhibited by the NCCOS - through thorough pre-planning, excellent communications, anticipatory presenter preparations, detailed review panel materials, and the well-delivered presentations and panel discussions. The Review Team found that the process was very well planned, staffed, and executed. Excellent job, NCCOS!
- The background information provided on the formation of HAB events and hypoxia provided vital insights that allowed the panelists to coalesce around the observations and recommendations that appear in this report.
- The use of case studies is an outstanding way to convey the tremendous amount of work being done but it also makes it a bit more difficult to see how the entire program fits together. It was mentioned that there were HAB strategic plans developed/in development and perhaps making the links to those strategic plans within the presentations would have been helpful.
- Overall outstanding work has been performed by NCCOS. Yet, while NCCOS is collecting feedback in individual programs, there does not appear to be a centralized feedback mechanism, a standardized format, or a repository of the feedback. If there were a feedback repository, recommendations could be synthesized and acted upon in a more coherent fashion.

NCCOS Overview of Feedback from 2018 HAB and Hypoxia Program Review

- Tremendous progress has been made since the last review. NCCOS has done a great job in focusing on relevant HAB and hypoxia issues, as customer demands have expanded and become more diverse.
- The NOAA NCCOS HAB and Hypoxia portfolio consists of several core groups with interconnected projects that fall along a range of maturity. Comprehensive overviews of the NCCOS HAB and Hypoxia research portfolio highlighted successes, challenges, and opportunities based on the last five years and substantive response to the prior review.

HAB Observing and Monitoring Presentation

- As technology advances, the need to evolve can be difficult to realize in the face of funding cycles, operational efforts, as well as routine and emergency situations. NCCOS should consider expansion of the observational networks, through models similar to NWS' networks - radar; satellite and surface observations, etc.
- Stakeholder identification could be enhanced, with better definitions of who constitutes a "Stakeholder". Efforts should be made to identify opportunities to expand to indigenous,

marginalized, vulnerable, and underserved residents, partners, subsistence residents, tourists, and organizations within coastal communities.
- Feedback should be actively solicited on activities, research and product development.
- Consideration should be given to developing more highly resolved observation networks, in light of temporal and spatial resolution of algal blooms.
- More regionally-specific activities should be developed.
- More work should be done with satellite data for hazard/risk aversion communications.
- Better ingestion and utilization of real-time data should be explored to provide situational awareness.
- Temporal and spatial resolution for algal blooms might be better supported if regionally specific activities and products were developed versus activities based upon global data catchments.
- Algal bloom monitoring should provide zoom options for the satellite products and regional data integration. This might require developing set "regions" for the displays.
- The National HAB Observing and Monitoring Program is being built from the regions up in partnership with the IOOS RAs. NCCOS needs to provide standardized and centralized guidance to ensure a cohesive National system comes to fruition.

HAB and Hypoxia Forecasts Presentation

- The current robust model operates with involvement of NWS Weather Forecast Office and River Forecast Centers, along with the Environmental Protection Agency (EPS). This prototype should be used to expand the HAB and hypoxia forecasting capabilities over other parts of the nation.
- NCCOS should consider incorporating kits and techniques utilized by other agencies. This would be accomplished through collaboration and training.
- Transitioning the models into operations should be expanded.
- Focus on quantitative evaluation of the models. Start with key metrics, using skill assessment to help inform what additional data the models need.
- NCCOS should further expand HAB and hypoxia observing networks, using advanced methodologies for design, including Observing System Simulation Experiments (OSSEs).

HAB Toxin Detection and Control Presentations

- NCCOS should empower other entities, stakeholders, Tribal Nations, and local groups to validate and detect HAB toxins.
- Training should be offered to participants on detection, data collection, and data processing.
- Recognizing that HAB issues are different across the country, NCCOS should develop priorities based upon needs around prevention, mitigation, and control, with quantitative measures of success.

- NCCOS has a path to expand client and customer understanding and knowledge through a national education program geared towards instrumentation, as well as the science of HAB and hypoxia.

R2X Stakeholder Panelist Discussion

- The closed sessions with stakeholders and externally-funded scientists allowed the Review Panel to hear both positive and negative aspects of current research and practices with NCCOS. This was beneficial and highlighted areas where NCCOS can concentrate efforts to improve the funding process and the R2X process.
- Efforts should be made to provide an educational and certification process to ensure that citizen scientists maintain a specific level of knowledge and proficiency in testing samples.
- NCCOS should explore expanded funding opportunities to speed the development of applications directed toward HAB control and/or mitigation.

Public Communication and Societal Acceptance Stakeholder Panelist Discussion

- The US HAB Control Technologies Incubator and Clearinghouse waits for incoming requests for assistance. Consideration should be given to proactive dissemination of information.
- Continue to support the Clearinghouse, industry/technology sessions at annual HAB meetings, and webinars on technology gaps/needs to continue to aggregate the demand for industrial partners.
- NCCOS should consider connecting the US HAB-CTI Clearinghouse with SBIR and the Tech Transfer Program (NOAA TPO).
- The Clearinghouse could expand proactive prevention work through broader advertising.
- ICSS partnerships should be evaluated for future advancements.
- NCCOS should investigate providing a Clearinghouse to things like: (1) successful engagement and impact efforts and/or products; (2) partners to engage in each region to help with engagement; and (3) best practices.
- Control Science should adapt to community needs. Coordination efforts should be made with governmental organizations, academia, and industry to reduce duplication of requests and services and to facilitate collaboration.
- NCCOS should clarify the IWP message.
- NCCOS should expand advertising of products and services. NCCOS should brag more.

Partnerships and Capacity Building for NCCOS

- NCCOS should use scientific associations more broadly to promote its work, research, and communications. Workshops should be conducted with appropriate organizations

to explore validation of measurements and forecasts, explore technique development, and provide wider education.

- NCCOS should investigate locating staff at a facility on the contiguous US West Coast. Expansion along the Eastern Seaboard is still warranted and should be continued.
- NCCOS should investigate partnerships within NOAA, particularly the National Weather Service (NWS) and the National Environmental Satellite, Data, and Information Service(NESDIS). NCCOS should investigate partnership with the Federal Aviation Administration (FAA) to utilize modeling expertise.
- NCCOS should determine what capacities are needed to increase communications for all products and services. The NCCOS staffing profile might require appropriate levels of additional staffing for expanded programs and services.
- Wider participation and partnerships with other Federal agencies that focus on wetlands, coastal issues, sustainable food supplies, marine ecosystems and conservation, as well as coastal anthropological concerns would be beneficial for reducing the vulnerability of marginalized, minority, and underserved communities.
- NCCOS should consider expansion of research opportunities with Minority Serving Institutions (MSIs), as designated by the U. S. Department of Education, including those colleges and universities that specifically have larger populations of Alaska Natives and other indigenous peoples.
- International partnerships should be considered, such as with Canada.

SERVICE DELIVERY (SD)

I. Quality (Q) Recommendations

SD-Q1: NCCOS should find ways to track how well all Principal Investigators continue to engage stakeholders in all science activities (conducted via funding from discretionary, extramural, and external sources) – early and often.

SD-Q2: NCCOS should assess current and future NCCOS products and services through a peer-review process, incorporating Federal agencies, states, and stakeholder communities. NCCOS should look to expand its role in providing real-time and archived HAB and hypoxia data for researchers, impacted communities, and responders.

SD-Q3: As the IOOS implementation is done by the IOOS RAs and there are varying degrees of capabilities within the IOOS RAs, it will be incumbent on NCCOS to work with IOOS leadership to determine appropriate levels and expectations of what NOAA requires for a successful HABON.

SD-Q4: Rapid evolution in the prevention, control, and mitigation (PCM) sectors has involved NCCOS as a leader in helping to advance the types of projects funded including the HAB Incubator. NCCOS has also worked at improving and supporting knowledge of permitting and approval processes. A multi-agency Community of Development and/or Practice could be beneficial in these processes to ensure that appropriate testing is conducted before environmental introduction of compounds and solutions.

SD-Q5: It was noted during the stakeholder panels how important NCCOS support has been for training, technical assistance, and expanding the toxin testing capabilities of the Native American-run laboratory in Sitka, Alaska. Also, NCCOS has been providing research funding to better understand the changing HAB patterns in Alaska due to climate change. PSP in particular is occurring in areas where it has not previously and also the timing and seasonality of PSP events appear to be shifting, making traditional knowledge that has protected people for hundreds of years no longer protective of public health. It is imperative that this work continues and be allowed to expand. It was also noted during the stakeholder panel that multiple remote communities depend on these resources and additional regional laboratories are needed.

II. Relevance (R) Recommendations

SD-R1: Moving to provide a sustained forecasting capability is a fundamental shift in NCCOS' mission and is likely going to require a discussion on organizational change that reflects this new mandate. If this mandate is not clear in the HABHRCA legislation, it should be reflected in the language to codify these forecasts as essential services akin to forecasts and warnings provided by the NWS.

SD-R2: NCCOS should continue to focus attention and funding on new technologies, advanced modeling, and other efforts to improve HAB and hypoxia forecasting around the nation. This should include conditioned support for the ongoing efforts to establish a National HAB Forecast Framework.

SD-R3: NCCOS should develop a holistic strategic plan to deliver a national capability for delivering a sustained warning system for HABs that includes both observing and forecasting. As new projects are funded, they should be linked to this strategic plan. A single plan will also assist with communications across the entire community and provide for quantification of how far along you are in achieving the national capability.

SD-R4: Given the occurrence of emergent and particularly severe events, increased event response capacity is important and should be planned for through internal strategic planning at the appropriate scales (while often referred to as ad hoc, a single event response can require significant federal, state, county, etc. involvement and investment). Event response can often translate to an increased need for routine sampling that may take time to finance and plan.

SD-R5: Examples of underserved communities in need of assistance with the management of seafood toxins include tropical areas that are endemic to Ciguatera Poisoning, such as those in Hawaii and Puerto Rico. Reference materials for these toxins are restricted to a few compounds found in the Pacific and even these are of limited quantity and very expensive. Corresponding reference and research materials for the toxins found in the Caribbean Sea do not exist. An expanded role for NCCOS scientists in the area of Ciguatera Poisoning management is recommended.

SD-R6: NCCOS should investigate partnerships within NOAA, particularly the NWS, to expand service delivery and communications. Further utilizing NOAA satellite data, developing full forecasting and observing programs, and expanding coastal community outreach benefit the NCCOS, marginalized and under-served communities, and the greater scientific community. An end goal could be merging into the NWS' Advanced Weather Interactive Processing System (AWIPS).

SD-R7: HAB issues and priorities are different across the Great Lakes and various coastal ocean systems. NCCOS should assess and evaluate if there exists a need to prioritize funding of ECO, MER, PCM, SEA across regions differently.

III. Performance (P) Recommendations

SD-P1: NCCOS managers should focus on "building their bench" by continuing to add younger scientists and program management staff who can learn from their veteran colleagues before the treasure trove of institutional knowledge is lost.

SD-P2: Using FAA and NWS models for guidance, NCCOS should develop products that are industry targeted (entertainment, shipping, fishing, etc.), community targeted (utilities, planning, etc.) and readiness targeted (emergency management, environmental, etc.).

SD-P3: Expand the communication about control to state tourism, economic development agencies, and health associations. In the coastal states, the governor has appointed a coastal zone manager, who may be the right point of contact within the state to identify other important groups. Many areas have both state and local convention, visitor, and tourist bureaus that could serve as central points of contact. For example, in Florida, Visit Florida and Visit Orlando are associations closely tied to tourism.

SD-P4: Work with NOAA's Chief Economists office to develop a market study on the needs for HAB observing and control technology. Market studies done by NOAA can be used by start-ups to seek venture funding. (Finding of the MTS/GOOS/NOAA *Dialogue with Industries* series).

SD-P5: NCCOS needs to ensure funding is made available to allow researchers to sufficiently engage with stakeholders. This should include funding to allow stakeholders to attend in-person meetings.

SD-P6: NCCOS managers should begin to expose the younger members of their workforce to the various national and international collaborations and partnerships to allow for smooth future transitions. Just like science and products, relationships also need to be transitioned.

SD-P7: Wider participation and partnerships with other Federal agencies that focus on wetlands, coastal issues, sustainable food supplies, climate change, marine ecosystems and conservation, as well as coastal anthropological concerns would be beneficial for reducing the vulnerability of rural, marginalized, minority, and underserved communities. Further expansion of the Social Sciences into NCCOS research and activities will allow scientists to better address the tenets and goals of Executive Order 13985.

SD-P8: NCCOS should consider expansion of research opportunities with Minority Serving Institutions (MSIs), as designated by the U. S. Department of Education, including those colleges and universities that specifically have larger populations of Alaska Natives and other indigenous peoples.

SD-P9: NCCOS should increase and target communications. This includes an assessment of what staffing capacity is required to connect NCCOS efforts with Federal and academic partners, particularly those participating in HABs research and monitoring.

SD-P10: NCCOS should outwardly and internally provide more detail related to engagement with IWG and Sea Grant.

SD-P11: NCCOS will likely need to take on efforts and tools with no market pull (e.g., gliders, ESPs, data storage). "Take on" would mean support logistically and financially.

SD-P12: NCCOS should consider ways to quantify the impacts and cost benefits of the Agency's efforts and products. Cost benefit analysis should examine the cost and/or savings associated with recalls of produce, costs of chemicals to treat drinking water, and other definitive actions that impact coastal communities, partners, Stakeholders, industries, and the Agency.

RESEARCH TRANSITIONS (RT)

NOAA/NCCOS should develop an integrated observing and modeling plan for HAB and hypoxia problems. The integrated plan will encompass sensing capabilities, as well as frameworks for quantitative and qualitative skill assessment. The integrated plan should include frameworks for: sampling, collection and evaluation of toxins and cell concentrations; HAB control processes; enhancement of nationally-relevant satellite applications for algal bloom monitoring; forecast modeling; nowcast development; data coordination and integration systems; and dissemination procedures.

I. Quality (Q) Recommendations

RT-Q1: For future forecasts, develop a matrix and criteria to determine whether forecasts should be done internally or with partners. If the determination is that the forecasts be done with partners, define the expectations for sustained forecasting. NCCOS may need to consider the application of Federal tort liability as it pertains to operational forecasting. The IOOS RAs have been certified concerning data provisioning that extends Federal tort liability to the RAs, however, it will need to be investigated if this applies to forecasting. NCCOS should work with IOOS and determine the best structure for the NHABON so it is done with the end in mind.

RT-Q2: More formal assessment tools for performance, impacts, and quality–assessed via economic, social science, feasibility metrics – would be useful for guiding decision-making related to all programmatic elements, including internal and external projects. Qualitative and quantitative metrics are needed; metrics are invaluable in communication to legislators, public, and others. Performance metrics provided were largely qualitative. Those qualitative metrics are extremely important and appropriate but should not supplant quantitative ones as both are needed to guide service delivery.

RT-Q3: With only some forecasts considered operational, it is recommended that NOAA continue to take steps toward expanding towards a national forecasting system that accommodates regional autonomy to address relevant HAB issues at the appropriate scales. This involves other agencies and perhaps could be addressed through focused national/international workshops, and could be a priority area for NHABON to focus on. This is also an area to consider advancing to better capture HAB events at the national scale. Validation needs to occur with the observations and models/forecasts. Advances in probabilistic forecasting suggests that this approach could have major benefits for providing simple risk-based forecasts.

II. Relevance (R) Recommendations

RT-R1: During the 2018 review, it was suggested that NCCOS focus on developing observational and monitoring technologies that are easily transferable to, and affordable by, non-federal entities. While good progress with this has certainly occurred in the last five years, NCCOS staff is strongly encouraged to continue working in this direction.

RT-R2: The stakeholder and end-user communities that are utilizing and impacted by the products and outputs from NCCOS appear to be diversifying, as HAB issues and related products continue to be developed and improved upon. While common training and structure might be beneficial to ensure effective communication and coordination, the organic and deliberate structure benefits from that region-specific focus, since HAB issues vary across regions.

RT-R3: Management end-users should be included in coordination, implementation, and assessment plans, and should help develop communication strategies and share forecasts in different formats. This flexibility invariably helps products reach a greater demographic of end-users.

RT-R4: The operational forecasting program has been very successful. Additional resources and personnel appear to be warranted. In the satellite based HAB monitoring presentation, it was indicated that this group had reached the capacity of what services they could provide given the resources they have. This is clearly an area that could be expanded upon given additional resources. It was pointed out that there is currently no equivalent to CYAN for distributing data for coastal systems. At the same time, new satellites are coming on-line that will greatly increase the availability of data. Yet, there is currently not enough operational support to deliver this data in a national way. There should be consideration for expansion and additional resources to accommodate the increased demand.

RT-R5: Work with organizations such as the MTS who can work with the government and industry to have structured conversations on how to accelerate the industrial base in a sustained manner to provide the necessary technologies for HAB monitoring. MTS was recently awarded a grant from NOAA based on the MTS/GOOS/NOAA series titled *Dialogues with Industry* to support the maturing of the Ocean Enterprise.

Reference: https://www.mtsociety.org/ocean-enterprise-initiative-learn-more

RT-R6: HAB toxin research should expand to include more than the direct impacts on humans, mainly through food seafood consumption. HAB toxin research should expand to consider the many additional bioactive compounds that are impacting their surroundings in other ways. There has been a general lack of resources dedicated to the understanding of the mechanisms of ichthyotoxic HAB events. In many cases the toxins or other bioactive compounds responsible for massive fish kills world-wide are not even known. This topic has been gaining interest globally, as it is one of the greatest impediments to the development of aquaculture. Recent NCCOS investments researching the apparent link between yessotoxin producing dinoflagellates and shellfish aquaculture mortalities on the west coast is a good example, but additional work remains to be done in this topic area and is worthy of future investment.

RT-R7: While it is the states' responsibility to assure the safety of seafood landed in their waters, it is the responsibility of NOAA and the FDA to assure the safety of seafood products

harvested from Federal waters. The National Shellfish Sanitation Program mandates a thorough assessment of HAB toxin risks for a particular harvest area to determine if active management is required. The threshold between requiring management, and whether this is in the form of a contingency or full control plan depends greatly on historical knowledge of the presence of HAB species and toxins in a given harvesting area. While this knowledge exists in many state-controlled harvesting areas there is far less knowledge in federally controlled waters. Future efforts are needed to gather baseline data on the presence and dynamics of HAB species and toxins in federally controlled waters, with an emphasis on areas where there is interest in establishing offshore aquaculture. These efforts should be coordinated with the Interagency Federal Waters Shellfish Biotoxin Advisory Board.

Performance (P) Recommendations

RT-P1: In working with congressional staff to prepare for future hearings related to the Harmful Algal Bloom and Hypoxia Research and Control Amendment Act (HABHRCA) of 2004 and 2014, NCCOS should encourage the inclusion of key non-federal stakeholders on hearing panels. Giving Congress the opportunity to hear from entities and "boots on the ground" is important to the continued success of future reauthorizations of this important legislation.

RT-P2: To help highlight and utilize HABHRCA, which also has a massive congressional component, efforts should continue to prioritize and promote greater harmonization across Federal and other management agencies and consider how this can further mobilize financial support for ongoing and new initiatives.

RT-P3: The lack of availability of strains and DNA from HAB species has historically been an impediment to answering some of the biggest questions in the HAB science field. Not every lab has the resources to collect and the expertise to isolate and maintain cultures, yet they do have the expertise to perform meaningful research if they had access to these materials. Access to toxin producing strains for HAB species has inhibited the availability of toxin reference materials which has impacted our ability to understand mechanisms of action, confirm structures, develop methods of detection, and produce certified standards required for the widespread use of these new methods. While public repositories for HAB isolates do exist in the US, there is currently no equivalent public repository or even best practices for the production, storage, and distribution of genetic reference materials. NCCOS should consider making it a requirement for funding that any strains or DNA not otherwise available be placed in a public repository for maximum impact of the investment. Future NCCOS investments in this area are recommended and would be in line with needs identified in the new HARRNESS report.

RT-P4: The wide-scale application of some NCCOS developed technologies has been hindered by the permitting or other permissions required by local, state, or federal authorities, sometimes by more than one entity. These regulations have prevented the large-scale testing of bio-controls, such as the Dino Shield presented during the review. This is an area where NCOSS

could be of assistance in working with other state and federal agencies and providing this information as an on-line resource.

RT-P5: According to the Stakeholder Panels, intellectual property issues have held back the commercialization or continued availability of some of the technologies that originated from NCCOS-funded projects. NCCOS should develop a requirement of NCCOSS funding that certain aspects of these technologies are open source, such that operations can continue even if a critical component becomes discontinued or is no longer fit for a purpose due to manufacturing changes.

RT-P6: Ensure sufficient funding is made available for NCCOS scientists and program managers to continue to attend national and international HAB and hypoxia conferences, and to conduct onsite visits with stakeholders where HAB and hypoxia issues occur.

GENERAL COMMENTS (GC)

I. Recommendations (R)

GC-R1: For future reviews, consider using an off-site location. Having a larger room that has no security requirements would allow for easier access. Choosing a location that allows staff to be away from their offices would promote better engagement for all of the attendees.

GC-R2: NCCOS should investigate locating staff at a facility on the contiguous US West Coast. During the final session of the review, there was a discussion regarding the location of NCCOS facilities. Until recently, the only NOAA staff engaged in west coast HAB issues were located within NOAA Fisheries based in Seattle. Other than a small field station near Homer, AK, (Kasitsna Bay Laboratory), there are no facilities on the US West Coast. This particular facility is arguably farther from the continental west coast than the west coast is from the US east coast. While there are significant HAB issues on the west coast, which include impacts on very large fisheries in California, Oregon and Washington, there are no federal HAB or Hypoxia staff located there.

GC-R3: As NOAA and NCCOS wrestle with the definition of "operational" versus "research," consider adopting the terms "sustained" and "experimental" as defined by the 2014 National Plan for Civil Earth Observations (https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/NSTC/2014_national_plan_for_civil_earth_observations.pdf

GC-R4: For the next five years, it would be beneficial to provide case studies or examples where integrated projects and efforts that span the key themes of observation, forecasting, and prevention, control, and mitigation (PCM) can be highlighted as being more impactful together (e.g., for observations of persistent saxitoxin concentrations in Alaska now and in future with climate change; consideration of how observation changes practices related to measuring, predicting and mitigating human health threats; given operational and varied forecasts in Florida, how and where should PCM be utilized to minimize ecosystem and economic threats, etc).

GC-R5: While keeping themes separate has some advantages, uniting themes under regional umbrellas might ensure that the appropriate components are sustained. This might aid in maintaining the necessary connections that keep mission-critical projects moving forward, in terms of service delivery and assimilation through varied research transition steps.

GC-R6: NOAA should work with other agencies to avoid duplication of effort and foster synergies. NOAA may wish to consider enhancing connections with the National Science Foundation (NSF)/National Institute of Environmental Health Services (NIEHS) Centers for Oceans and Human Health.

GS-R7: Prevention and mitigation need to continue to be prioritized as strategies to help with HABs, as well as control. Crossover with restoration management authorities would be one area to prioritize. Here impactful results may be measurable, achievable, and provide lessons learned that can be applied on regional to national scales.

GC-R8: Develop a plan for the funding to (a) develop new satellite sensors, and (2) for the processing and distribution of coastal remote sensing data applied to the coast HABs.

GC-R9: Work with stakeholders to develop a small set of repeatable metrics. Discuss with Sea Grant as to whether their system can be adapted to support NCCOS projects.

II. Observations (O)

GC-O1: There are ample examples of the work of NCCOS scientists and program managers to direct projects toward a transition to field operation and are using a systematic approach to service delivery to get science and products in the hands of stakeholders. While some presentations specifically included references to the Office of Research and Technology Applications (ORTA) R2X levels of readiness and others did not, it seemed clear that NCCOS management is moving the portfolio in this direction.

GC-O2: Discuss whether the Readiness levels are a guide or will be used as a metric to evaluate NCCOS' research portfolio with annual goals of reaching transition on a percentage of projects. NASA's Applied Sciences program uses Application Readiness Levels on all externally funded projects, https://appliedsciences.nasa.gov/sites/default/files/2021-02/ExpandedARLDefinitions4813.pdf). At the time of application, the requesting PI indicates the start and end readiness level and reports on this quarterly. NASA has set up an internal reporting system to track the readiness levels. For a briefing on this you can contact Dr. Emily Sylak-Glassman, Deputy Associate Director, Earth Action (eglassman@nasa.gov)

GC-O3: It was evident that NCCOS has worked hard to develop a good partnership with IOOS, yet at the same time, NCCOS is now dependent on IOOS to deliver a National HAB forecasting capability. During the presentations, a national HAB observing plan was mentioned but when questioned it appears that there is a separate HAB forecasting plan that is still being developed. It was not clear from the case studies that all the efforts are mapped into these strategic plans. NOAA and NCCOS should refine the concepts of "operational" and "sustained" which may be impacting how the forecast capabilities are defined as well as funding levels to introduce new forecasts and expanded use of remote sensing.

GC-O4: Visualization tools such as road-maps and/or blueprints that showed the connectivity and perpetuity of incorporating new observations and research into operations, either generally

or for specific projects were helpful for providing an overview. These varied somewhat in structure across projects and all were effective for different reasons. This evolution and ability to incorporate innovation needs to be integrated into path-related graphics across the board.

GC-O5: Terminology that may be confusing and imprecise should be clarified to assist with internal and external communication. Admittedly the definition of operational is difficult to constrain and differs across efforts, and may be used in different ways. While to some it sounds terminal, revision and updating of operational products occurs regularly and should be anticipated and expected.

GC-O6: Social Science can be a helpful tool for understanding stakeholder interactions and evaluating change over time to help better assess success quantitatively. Co-creation is important but should involve this social science element at the onset.

To facilitate this idea:

- It may be helpful to develop pathways for long-term research agreements or MOUs for external partners; this benefits working across different groups at NOAA as well.
- There is a clear need for sustained measurements, increased measurements, and ongoing mechanisms for assessing what is needed to adequately respond to stakeholder needs.
- Quantifying benefits to stakeholders is inherently challenging, but perhaps can be tracked in different ways.
- Assess all the types of engagement NCCOS is conducting and provide a program-wide engagement plan, understanding that a single method will not work across the portfolio as there will be engagement needs specific to a project and/or region.
- Develop an engagement lessons learned database.
- Develop key messages and work with stakeholders and partner associations (e.g IOOS Association, Sea Grant Association) to communicate with a clear, and united voice. For consideration, develop a set of timeline charts showing all partners that all can use to communicate the aspects of the portfolio.

INDIVIDUAL PANEL COMMENTS AND RECOMMENDATIONS

Review Focus Area Strength(s)	Name	Institution	Report
R2X/Operations, Service Delivery	Patricia Brown	NOAA/NWS/Office of Organizational Excellence (OOE)	Brown
R2X/Application	Dan Ayres	Washington (WA) Department of Fish and Wildlife (Retired)	Ayres
R2X/Commercialization	Zdenka Willis	Veraison Consulting, LLC)	Willis
R2X,Service Delivery	Christopher Winslow	Ohio (OH) Sea Grant	Winslow
R2X/Application	Kate Hubbard	Florida (FL) Fish and Wildlife Conservation Commission (FWC)/ Fish and Wildlife Research Institute (FWRI)	Hubbard
R2X/Operations	Dennis McGillicuddy	Woods Hole Oceanographic Institution (WHOI)	McGillicuddy
R2X/Application	Jonathan Deeds	US Food and Drug Administration (FDA)	Deeds