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**Sixteenth Session of the IOC-FAO Intergovernmental Panel**

**on Harmful Algal Blooms**

Rome, 27-29 March 2023

Item 4.7.1 of the Provisional Agenda

**REPORT OF THE IPHAB TASK TEAM ON DETECTION, WARNING AND FORECASTING OF HAB EVENTS**

**The report is structured according to the decision taken in 2021** (Decision IPHAB-XV.2) **reproduced below:**

**Decides**, with reference to the HAB Programme Plan, objective 6.3.2 (IOC/IPHAB-IX.3, Annex VII), to establish a Task Team on the Early Detection, Warning and Forecasting of HAB Events with the following terms of reference:

1. Serve as a strategic and advisory group for the establishment of guidelines, recommendations, and advancement of Early Warning Systems,

* Members of the TT co-authored several chapters of the **Technical Guidance Document for the Development of Early Warning Systems for Marine Harmful Algal Bloom Events** that include Bentic HABs (BHABs), fish killing HABs, pelagic toxin producing HABs and cyanobacteria (CyanoHABs). The document was published in 2023 as a joint publication of the three agencies (i.e., FAO, IOC-UNESCO, IAEA). DOI: <https://doi.org/10.4060/cc4794en> | PDF URL: <http://www.fao.org/3/cc4794en/cc4794en.pdf> | Card page: <http://www.fao.org/documents/card/en/c/cc4794en>
* During 2021-2022 there was the implementation of an IOC project on ’Detection and Early Warning Systems for Harmful Algal Blooms’, supported through funding from the Government of Norway (NORAD). The project included the development of a survey to assess national capacities in HAB and biotoxin management (including general knowledge and monitoring capacity for HAbs and biotoxins, monitoring governance, and data) in African countries upon which two countries, Namibia and Morocco were identified as two pilot countries for implementing HAB/ESW guided through the step by step process of the Technical guidance document. Members of the TT joined a strategic and advisory group that held the Namibia workshop\_EWS (5-6th October 2022) in Swakopmund, housed by the Ministry of Fisheries and Marine Resources, and the Morocco workshop (5-8th December 2022) in Casablanca, hosted by L'Institut National de Recherche Halieutique.

1. Initiating sessions on near real time HAB Observing and Early Warning Systems at forthcoming international and national science meetings such as the ISSHA International Conference on Harmful Algae, the ICES Annual Science Conference, US HAB Symposium and other relevant opportunities,

* Results of the *19th International Conference on Harmful Algal Blooms* will be held from the 10th to the 15th of October 2021 in the Conference Center of La Paz, B.C.S., Mexico. There will be a topic in particular dedicated to “HAB prediction: Modeling, observing systems, data collection and processing”. <http://icha2021.com/Secciones/contenido/33>. Side event - The program will include relevant talks on early warning systems for HABs with a food security and food safety focus and present the Draft Joint FAO-IOC-IAEA Technical Guidance for the Development of Early Warning Systems for HABs. Presentation of case studies
* The 11th *US HABs Symposium on early warning HABs systems* was held on October 23-28, 2022, in Albany, New York

1. Invite the scientific community and stakeholders to contribute by identifying early warning research topics, promoting strategies for engagement, and communicating scientific information to policy makers, managers and other end-users,

* In the framework of the NORAD IOC-UNESCO project on ’Detection and Early Warning Systems for Harmful Algal Blooms’ two workshops were organized to assess stakeholder needs for establishing EWS. In Swakopmund Namibia, 5-6 October 2022, and in Casablanca Morocco, 5-8 December 2022, the workshop gathered 32 and 45 participants, respectively, from government ministries, the private sector, academic institutions, and official laboratories. Each workshop consisted of a series of presentations, interactive discussions, surveys and polls to with the objective of capturing the needs and requirements of participating stakeholders, the current capacity, pre-existing and missing knowledge and data gaps, as well as identifying the current limiting factors and resources in establishing an EWS in the country. Participating stakeholders, national counterparts and the expert that guided the workshop raised the need to pursue this effort and seek further funding to implement concrete action toward developing EWS for HABs in Africa, and in particular in Namibia and Morocco.
* The scientific community and stakeholders collaborate within several research projects that address different topics and approaches to early warning of HABs. The needs of stakeholders are usually accessed through online surveys and meetings/workshops. List of ongoing projects related with HAB’s monitoring, early warning, management strategies, enhancing capacity and HAB literacy:
  + SHAREMED – “Sharing and enhancing capabilities to address environmental threats in the Mediterranean Sea” (<https://sharemed.interreg-med.eu/>). The main objective of the strategic project Interreg Med is to enhance the capabilities of regional, sub-regional and local authorities in the Mediterranean region, as well as the research community, to assess and address hazards related to pollution and environmental threats, including HABs, in the transnational waters of the Mediterranean Sea. Regarding HABs, the most appropriate molecular practices for monitoring selected organisms will be surveyed and optimized among partners. The transference of tools, knowledge and procedures developed and implemented during the project will be achieved through specific lessons with attendees from the MED area (Sharemed Summer School- SS).
  + SNMB-MONITOR – <http://www.ipma.pt/pt/bivalves/index.jsp>, This is a long-run project co-funded by the Operational Fisheries Program-PROMAR in Portugal and the European Fisheries Fund (EFF), to support shellfish monitoring in harvesting and production areas in Portugal. The outcome is a public service, with results being published near real time for multiple related variables (<http://www.ipma.pt/pt/bivalves/fito/index-map-dia-chart.jsp> ) and stakeholders engaging is regular trough meetings, surveys on quality service and needs and upon request.
  + Great Lakes Observing System - <https://www.glos.us/projects/habs/>This effort aims to create a system that will keep people informed when portions of Lake Erie develop cyanobacterial HABs. This is possible by bringing together live data from forecasts and a network of in-water sensors (including autonomous toxin sensors on robotic ESP instruments) and other monitoring equipment, processing that data, and sending actionable text message alerts when conditions worsen. By making high quality, live information readily available, decision makers in the western basin can better anticipate HABs and react more effectively.
  + HABON-NE - This project will create HABON-NE (HAB Observing Network - New England), a framework for aligned academic, industry, state, and federal scientists to deploy - adaptively and continually - a fleet of advanced sensors and sensor platforms. The project would dramatically improve HAB surveillance and early warning, help direct state biotoxin testing, and support resource management decision-making. A multi-institutional team of scientists will oversee year-round deployments of sensors and sensor platforms, relocating assets as necessary to meet changing seasonal threats and respond to unexpected ones. Data and analytical products will be shared as they are created through the WHOI HAB Hub (WHHub), an open source, containerized web server platform for region-scale integration and sharing of rich and diversely sourced HAB observations, model outputs, contextual data, and management actions. The WHHub will enable comparison of diverse data and model estimates from specific areas, time periods, and/or times of year. Resource managers and stakeholders will be engaged throughout the project to share observations, new capabilities, and to solicit input on upcoming deployments, event response actions, and WHHub development. Transfer of WHHub operation to the Northeast Regional Association for Ocean Observing Systems (NERACOOS) will also be explored and used as a mechanism for documenting code and sharing broadly with researchers and resource managers nationwide.
  + US NANOOS Real Time HABS - <http://www.nanoos.org/products/habs/real-time/home.php>; Real-Time HABs provides timely information on harmful algae in the US Pacific Northwest (PNW). The [PNW HAB Bulletin](http://www.nanoos.org/products/habs/forecasts/bulletins.php) provides an early warning of HABs to coastal shellfish managers. An integrated component of the PNW HAB Bulletin, measurements are made remotely and autonomously by an underwater robot, the ESP, and are available in near-real time in the ESP Now section. By detecting both the potentially harmful phytoplankton species as well as the toxin they produce, the ESP gives us early warning of these potentially toxic events.
  + US Olympic Region Harmful Algal Bloom (ORHAB) Partnership - <http://www.orhab.org/>; ORHAB shares knowledge with local communities on the Olympic Peninsula of the Washington State coast, empowering tribal and state managers to make scientifically-based decisions about managing and mitigating HAB impacts on coastal fishery resources. ORHAB provides weekly phytoplankton levels at several beach locations, to the Washington State Dept. of Health (WDOH), allowing the Dept. of Fish and Wildlife and tribal managers to reduce the number of razor clam samples to be tested prior to beach opening for harvest. This results in reduced cost and faster analysis, with testing of clams for toxins and posting results in two days.
  + US Alaska HAB Network - <https://aoos.org/alaska-hab-network/>; The Alaska Harmful Algal Bloom Network (AHAB) was formed in 2017 to provide a state-wide approach to HAB awareness, research, monitoring, and response in Alaska. AHAB coordinates a diverse group of coastal stakeholders to address human and wildlife health risks from toxic algal blooms. Objectives: Reduce health risks to humans from HABs; identify information needs, data gaps, and emerging HAB threats; expand and enhance state-wide HAB, wildlife and shellfish monitoring; improve effectiveness of and coordination for HAB event response; develop HAB event forecasting capabilities; improve HAB education and outreach to coastal Alaskans; unify and build on existing regional HAB networks in Alaska; facilitate a safe supply of seafood.
  + GCOOS-NCCOS Experimental Respiratory Forecast (for *Karenia brevis*) - This [Experimental Forecast](https://habforecast.gcoos.org/), based in part on cell counts provided by the [HABScope](https://habscope.gcoos.org/), provides information on when the red tide caused by *Karenia brevis* could be impacting area beaches so that people who are susceptible to its impacts will know the risks.
  + GCOOS Harmful Algal Bloom Integrated Observing System - <https://gcoos.org/wp-content/uploads/2020/01/HABIOS-Plan_final_9_3_15.pdf>; Vision: to establish a sustained observing system as part of the U.S. IOOS (Integrated Ocean Observing System) that will facilitate and enhance efforts to monitor, manage, and reduce detrimental effects of harmful algal blooms (HABs) on human health and living marine resources (non-human animals and plants) and to mitigate impacts of HABs on coastal communities.
  + PRIMROSE – Predicting Risk and Impact of Harmful Events on the Aquaculture Sector). The Interreg Atlantic Area funded project PRIMROSE is builds on the existing HAB forecasting systems. PRIMROSE will deliver improved forecasts of HABs, microbial risks and climate impacts in aquaculture locations the length of Europe’s Atlantic Arc from the Shetland Islands in the north to the Canary Islands in the South. The project will use a combination of technologies including the OLCI system flying on board the new Sentinel 3 satellites that provide increased remote sensing resolution for aquaculture production areas in Ireland, Scotland England, France, Spain and Portugal. The transnational cooperation within PRIMROSE will allow best practises and methodologies to be shared among the partners, with the development of a common web based gateway for risk assessment in the region including an easily understood “traffic light” risk index for industry.
  + SCCWRP - Southern California Coastal Water Research Project <https://www.sccwrp.org/news/statewide-habs-early-warning-system-being-developed/> - SCCWRP and its partners have launched a two-year pilot study to develop a statewide early-warning system for coastal harmful algal blooms (HABs) that relies on autonomous microscopes to alert water-quality managers that a bloom event could be imminent. The pilot network, which will be the first of its kind on the West Coast, marks the next phase of expansion for the statewide Harmful Algal Bloom Monitoring and Alert Program (HABMAP), which has been collecting coastal HABs data for more than a decade via weekly grab sampling at piers.
* MONITOR-CHILE. Since 2006, a periodic and timely data and information system has been available on harmful microalgae, marine biotoxins, phytoplankton, and meteorological and hydrographic variables, based on standardized sampling with wide spatial coverage, appropriate to the geographic complexity of the fjord system (41°-55°S). The data comes from 228 fixed sampling sites that are visited monthly, but 23 sites have an every 10 days sampling, located at the northern end of the fjords (MON.FJORDS). On the other hand, since 2018 between 36° and 44°S but on the coast exposed to the Pacific Ocean, similar activities are carried out in a total of 69 fixed sampling sites, located at 2, 5 and 10 miles in transects perpendicular to the coast. (MON.PACIFIC). In both programs, environmental monitoring and dissemination of key HAB topics to local communities are combined with research activities. Both programs are ongoing and employ traditional techniques, but since 2018 new tools have been incorporated for the identification and quantification of harmful microalgae and marine toxins from real-time qPCR, metabarcoding and HPLC MS/MS, respectively. Harmful microalgae relative abundance estimators serve as an early warning and are coupled to a particle tracking system on a hydrodynamic model.
* MACH (Monitoring in Chile). The study “Development of Harmful Algal Bloom Monitoring Methods and Forecast System for Sustainable Aquaculture and Coastal Fisheries in Chile” initiated in April 2018 and today in its final fase, was carried out by Chilean and Japanese Agencies, with aiming to contribute to develop an early prediction system for Harmful Algal Blooms (HABs). It is expected to predict HAB with a scientific basis based on the results of environmental monitoring, to link this to concrete measures such as the dissemination of warning information by relevant Chilean agencies, and to provide the knowledge necessary for relevant agencies to formulate policies for marine environmental conservation. The holobiome concept in the HAB forecast, metabarcoding technology, and suitcase lab, and strengthening the relationship among academic, government, and private institutions through are significant accomplishments of the project. Environmental monitoring activities were implemented at 8 places in southern Chile, plus 5 sites in the northern coastline. Por each site a Holobiome analyses including metabarcoding analyses were implemented to identify microbiological factors, and a metabarcoding (MB) analysis pipeline called NorSaSa was developed. Thousands of samples have been sequenced, including for bacterial analysis and eukaryotic analysis. A total of hundreds strains of holobiome constituent microbes, mainly bacteria were isolated. The bacterial genomes of total 26 species that potentially determine HAB dynamics were identified. Beside 26 bacterial genomes, there are many other bacteria isolated in the project whose genomes have already been identified. Experiments to determine the optimum growth conditions for HAB-associating algae and/or other microbes were conducted for total 42 species (37 bacteria and 5 microalgae). The suit case lab was enabled with LAMP (Loop-mediated amplification) kit which can detect 10 HAB species plus 5 bacteria species. A HAB early warning system using abundance and particle tracking simulations on top of a hydrodynamic model was developed. Artificial Intelligence models based on the monitoring data are developed to verify which HAB species are predictable. Also an Empirical Dynamic Model (EDM), to estimate probability of appearance of HAB species using cell density and frequency of appearance data, using long-term microscopic specimen data have been developed.
  + Philippine HAB management and early-warning system. Harmful algal blooms are monitored and managed by the Bureau of Fisheries and Aquatic Resources and some partner local government units in the Philippines. This consists of regular shellfish and water sample collections in different coastal waters all around the country that have had history of HABs. Advisories and shellfish bulletins are deployed locally and nationally to communicate the monitoring results. This monitoring and management scheme has helped to increase awareness and limit illnesses and fatalities due to Paralytic Shellfish Poisoning. Currently, BFAR, other government units, and local communities in pilot sites are collaborating with the academe, namely the Marine Science Institute, University of the Philippines Diliman in establishing an early-warning system. The framework for this system is based on the Sendai Disaster Risk Reduction framework and is composed of four components: 1) HAB Risk Knowledge; 2) Monitoring and Warning Service; 3) Dissemination and Communication; and 4) Response Capability. As part of the first component, activities included collation and analysis of historical HAB data, and participatory risk assessment with the local communities including marginalized shellfish farmers and their families. For the second component, the development and deployment of low-cost real-time environmental sensors is being explored, and data from these assimilated in forecast models. The data from the sensors are fed and stored into the second component – the database and informatics system that also houses historical data from various laboratories and the program partners. Currently, a model for a severely affected site Bolinao-Anda, Pangasinan, northwest of the Philippines has been developed. This makes use of random forest algorithm, a machine learning approach, that forecasts the probability of a shellfish toxicity and a fish kill. The model is linked to real-time sensor data from Bolinao. In May 2022, the fish kill model predicted high possibility of a fish kill. This was communicated to BFAR who in turn informed the local government units and fish farmers. There is still a need though to determine how to obtain and assimilate real-time information on phytoplankton and/or toxicity. The coarser-scale remote sensing model SeAHABS is also a part of this EWS. The data and models have been made available at the HABHub web site for dissemination and communication primarily to management and regulators. For the last component, apart from the already existing closures as response to HAB events, the participatory risk assessment activity also identified some avenues to help mitigate HAB impacts on the stakeholders through changes in policies and governance aspects. This system is still very much in its infancy and many challenges have been encountered and still need to be addressed.

1. Promote the presence of HAB observations in the IOC Global Ocean Observing System and its regional components such as USA-IOOS and EuroGOOS, and the consolidation of integrated multi-hazard Early Warning Systems that employ scalable and affordable HAB technologies and methodologies for the continuous monitoring of coastal and ocean ecosystems,

* currently underway for US IOOS – “Framework for the National Harmful Algal Bloom Observing Network” listed under publications, <https://cdn.coastalscience.noaa.gov/page-attachments/news/NHABON_Framewk_WkshpReport_12-18-20_Final.pdf>. and the “Implementation Strategy for a National Harmful Algal Bloom Observing Network (NHABON)“.<https://ioosassociation.org/wp-content/uploads/2022/08/NHABON_StrategyDocWeb_FEB21.pdf>.
* US IOOS is hosting the US National HAB Observing Network (NHABON) website here, https://ioosassociation.org/nhabon/. The NHABON aims to effectively and efficiently integrate local, state, regional, and federal HAB observing capabilities and deliver products operationally. A NHABON Community of Practice (CoP; Terms of Reference are here, <https://docs.google.com/document/d/1HJHKRGPtYohTjCzjWkKsvrnWrFfG0XZYQy2rblARyo8/edit>) has been formed and hosts an ongoing webinar series.

1. Interact with HAB working groups and committees, e.g. ICES-IOC/WGHABD, PICES, IOC/FANSA, IOC/HANA, IOCARIBE/ANCA, IOC/WESTPAC-HAB in the development of regional EWS and in the standardization of alerts and harmonization of key messages,

* Participation on the ICES Annual Conference ICES Annual Science Conference 2022 (19–22 September 2022) in Aviva Stadium, Dublin, Ireland (<https://www.ices.dk/events/asc/ASC2022/Pages/default.aspx>)
* Participation on the ICES-IOC/WGHABD (14-17 June 2022) in Weymouth, UK. Presentations of national reports on HABs monitoring and of advances in research related to the ToR (<http://www.ices.dk/community/groups/Pages/WGHABD.aspx>).

1. Work with the desalination industry and its academic partners to communicate capabilities for HAB EWS through scientific presentations, workshops or other activities. These systems could include in-situ HAB sensors as well as models, forecasts and remote sensing of blooms,

* Design of a cohesive strategy with the *HABs and Desalination Task Team* regarding future ’Detection and Early Warning Systems for HABs’ workshops. The goal is to improve the articulation with stakeholders from this sector and between two distinct monitoring strategies (food safety and water quality) for the same hazard.

1. In 6 months develop a succinct list of challenges, objectives and actions with respect to the Task Team topic that will address the UN Decade of Ocean Science for Sustainable Development objectives and challenges and to present these at an IPHAB intersessional online consultation September 2021 with a view to formulate an IPHAB strategic framework for UN Decade initiatives,

* The Task Team Chair worked with Team members in the formulation of a document listing challenges, a future vision, and specific actions related to HAB EWSs. Defined actions congregate multiple Decade challenges, goals, specific projects/activities and interlink resources. The high-level objective is to provide solutions to mitigate the impacts of HABs and these solutions will be co-designed in consultation with stakeholders. Outcomes will increase the capacity and capability development in monitoring, predicting and mitigation of HABs and improve the communication to policy makers. The document was presented at a meeting of all IPHAB Task Team chairs in Helsingor Denmark in April 2022, where actions were incorporated into a common document that would form the basis for a submission to the UN Decade of Ocean Science for Sustainable Development. Regarding EWS outcomes, an Activity was defined, *HAB event Prevention, control and mitigation,* that considered i) Custom-designed EWS for Desalination plants and for Finfish and Shellfish Aquaculture and wild fisheries, ii) Tailored EWS Ciguatera hotspots, iii) Collect and curate meaningful time-series for the digital twin - development/contribute to information platforms, promote free and open-access use and re-use of data, iv) Fish and Shellfish safeguard strategies including the movement of affected stocks from impacted areas will be explored and v) Novel means of HAB suppression will be identified and pilot testing will be carried out