The Next Decade of GlobalHAB: 2026-2035

GlobalHAB

Global Harmful Algal Blooms

Science and Implementation Plan

An International Programme Sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO

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Appendix A. Past themes and accomplishments 2017-2025*

**provided as a separate attachment*

Appendix B. List of Acronyms

Appendix C. GlobalHAB community involvement

What is GlobalHAB?

> The overall **Goal of GlobalHAB is** to improve understanding and prediction of Harmful Algal Blooms (HABs) in aquatic ecosystems, and management and mitigation of their impacts.
>
> The **Mission of** GlobalHAB includes the following elements:
>
> a) Foster international coordination and cooperative research to address the scientific and societal challenges of HABs, including the environmental, human health and economic impacts, in a rapidly changing world.
>
> b) Consolidate linkages with broader scientific fields and other regional and international initiatives relevant to HABs.
>
> c) Foster the development and adoption of advanced and cost-effective technologies.
>
> d) Promote training, capacity building and communication of HAB research to society.
>
> d) Serve as a liaison and promoter between the scientific community, stakeholders and policy makers, informing science-based decision-making.

GlobalHAB addresses the contemporary scientific and societal challenges of HABs by adopting a multidisciplinary approach through the evaluation and application of new advanced technologies, training and capacity building, and information and dissemination requirements. The program has become synonymous with cutting-edge science co-designed for local, regional, national, and global decision-making on all topics pertaining to HABs.

This document, the ***The Next Ten Years of GlobalHAB (2026-2035) Science and Implementation Plan****,* is structured with six goals that are a direct extension of the themes identified at the initiation of GlobalHAB in 2016: “Biodiversity and Biogeography”, “Adaptive Strategies”, “Toxins”, “Freshwater HABs and cyanobacteria HABs”, “Benthic HABs”, “Nutrients and Eutrophication”, “Aquaculture and HABs”, “Climate Change”, “Comparative Approach”, “Health”, “Economy”, “Observations, Models and Predictions.” A new *Sargassum* theme was also incorporated in 2022 as a response to an emerging HAB and its associated societal needs.

The widest **international participation** of the research community and stakeholders will be essential to ensure the success of another ten years of GlobalHAB programme.

Scientists working in physics, chemistry and biology, as well as other disciplines related to harmful algae research—including toxicology, aquaculture, development of relevant instrumentation, modeling—are encouraged to contribute to this programme. Furthermore, special invitation is made to climate science, medicine, socioeconomics, and social science professionals and policy makers, whose expertise will be fundamental to find efficient and effective strategies to reduce the impacts of HABs in the coming years. This document provides a formal invitation to participate and to continue to grow the successful GlobalHAB programme, accompanied by a description of the procedure for application, and associated responsibilities and benefits. Scientists are invited to participate in GlobalHAB by designing and implementing scientific activities aligned with the goals and objectives of GlobalHAB science plan, by applying for endorsement of such activities, and by participating in framework activities. The primary criterion for endorsement of activities or proposals is their applicability to any of the GlobalHAB Science Plan objectives with an international collaboration perspective.

GlobalHAB has found its niche within the international community, evidenced by the incredibly diverse Scientific Steering Committee, and has worked hard to form strategic partnerships that produce reciprocal benefits with other relevant organizations and projects. New partnerships and synergies will continue to be built or established in the future.

In summary, GlobalHAB constitutes a platform to connect science-to-science and science-to-society to prevent and manage the impacts of HABs.

Executive Summary

Over the last decade of global research on harmful algal blooms (HABs), it has become increasingly clear that the “wicked problem” of HABs is not going away (Hallegraeff et al. 2021). Instead, new phenomena are emerging while others are worsening. The GlobalHAB Scientific Steering Committee (SSC) has been tracking research initiatives around the world over the last decade in response to the plan laid out in the 2017 ***GlobalHAB Science and Implementation Plan*** (Berdalet et al., 2017). There were 13 themes identified in 2017 that were considered of immediate significance to the broad community of scientists studying HABs:

1) Biodiversity and Biogeography;
2) Adaptive Strategies;
3) Toxins;
4) Nutrients and Eutrophication;
5) Freshwater and Cyanobacterial HABs from Marine to Freshwater Systems;
6) Benthic HABs;
7) HABs and Marine Aquaculture;
8) The Comparative Approach;
9) Observation; Modeling and Prediction;
10) HABs and Human and Animal Health;
11) Economy;
12 Climate Change and HABs;
13) *Sargassum* beachings.

All of these have remained prominent topics to the SSC given the challenges presented in studying and understanding a rapidly changing seascape of organisms, toxins, and socioeconomic impacts. Environmental stressors that interact with the underlying causal conditions of HABs are themselves evolving and strengthening, leading to an entirely new field of “Multi-Stressor” investigations that was rarely discussed seven years ago. Here, we have identified special need for integrative studies on:

- emerging HABs,
- global climate variability and change,
- multiple interacting stressors with synergistic influence on microalgal physiology,
- expanding cyanobacterial blooms, and
- the often unpredictable human dimension driven by local/regional community responses to HABs harbinger of a new era of global HAB research, coordination, and critical resource leveraging if we are to develop solutions.

The successes of the Global Ocean Observing System (GOOS) in concert with the introduction of UN Sustainable Development Goals (SDGs) and the UN Decade of the Ocean have highlighted HAB science and prediction and reframed traditional concepts of applied science to encourage integrated, outcome-oriented solutions for all mankind. The cross-cutting nature of HABs relative to food security, fisheries, aquaculture, safe oceans, and safe drinking water has revitalized engagement around this important topic, with 11 of the 14 SDGs applicable and relevant in some way to the HAB problem. GOOS efforts to standardize and develop Best Practices around Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs) are widely recognized and have been applied by many governments to ensure interoperable datasets from diverse observing platforms and systems. Importantly, the common language proposed by SDGs, along with the implementation of global programmes dedicated to society-relevant ocean initiatives, aligns extremely well with the long-held goals of the HAB science community. The growing and highly relevant concept of OneHealth bridges many disciplines interested in examining the connectivity of ecosystem and human health. The highly interdisciplinary field of HAB research is ripe for a concerted OneHealth approach.

This influx of complementary global programmes offers the SSC an ideal launching-off point for the next era of GlobalHAB activities that builds off the previous Implementation Plan. The newly proposed plan reimagines past themes within the context of the present-day investment in “Ocean Decade” projects and proposed ocean solutions, e.g. the HAB-Solutions endorsed programme. As with previous plans, we provide goals, tasks, and outcomes developed at virtual and in-person SSC meetings over the last year (2024-2025). A critical core tenet linking the **six high-level goals** proposed in this document is that the “wicked problem” of HABs essentially cuts across many of the themes discussed above. Key questions buttressing specific goals and tasks are:

1) *How does global change cascade through or overlie the immediate science questions?*
2) *How do we forecast HABs in a changing climate when baselines are also changing and interacting with multiple stressor trends?*
3) *What techniques will improve our ability to predict both blooms and impacts throughout food webs or directly on human health?*
4) *Can we identify possible tipping points or nonlinear change points in relevant ecosystems?*
5) *How will new research findings be linked to broad societal drivers surrounding geoengineering solutions to climate change, e.g., marine carbon dioxide removal and renewable offshore wind energy?*

The Science and Implementation Plan that follows will fundamentally address the above key questions while providing a roadmap for exploring specific areas of scientific inquiry critical to better understanding the global expansion of HABs and the apparent changes in toxicity of potentially toxic taxa in many regions of the world.

Figure 1. Sargassum White Paper recently published. “Addressing the influxes of the holopelagic *Sargassum* spp. in the equatorial and subtropical Atlantic: recent scientific insights in their dynamics.”

Proposed Science and Implementation Plan

Goal 1. Emerging threats: Characterize invasion ecology and changing biogeography of potential HAB species

Introduced and invasive species are studied in many contexts outside of the HAB context. Introduced species generally pose a problem for their new habitat in that previously nonexistent competitive relationships emerge within communities, sometimes leading to nonlinear, unpredictable outcomes. One line of research that is still greatly lacking involves understanding the extent of this problem and impacts in order to inform effective HAB management on what is essentially a moving target. Goal #1 aims to use modern/emerging technology and approaches to accurately characterize and even predict the dynamic seascape of HAB biogeography. Over the last 5-10 years, a suite of emerging HABs and toxins have been documented globally. In order to accurately detect and quantify as well as set up early warning systems for sometimes detrimental events of HABs, we need to use the latest and most efficient techniques available and make the knowledge as available as possible to global communities.

Here we have identified a number of emerging issues:

1) 2016 (June): A massive *Dinophysis acuminata* complex bloom in the southern Brazilian coast (Santa Catarina and Paraná) causing damage to the local mariculture along its trajectory. During its peak the bloom covered an area of 201 km^2 attaining unprecedented cell densities along the shallow continental shelf, and multi-species okadaic acid contamination and human poisoning was evidenced (Mafra et al., 2019 https://doi.org/10.1016/j.hal.2019.101662).
2) 2016/2017 and 2020/2021: Haff disease outbreaks related to freshwater and marine fish consumption in Bahia and Pernambuco, Brazil (Cardoso et al., 2021 10.1016/j.lana.2021.100092 and Perezan et al., 2024 https://doi.org/10.1016/j.foodres.2024.114585). The etiology of Haff disease remains unknown, but palytoxin analogues are suspected to cause the disease.
3) 2019 (May and June): *Chrysochromulina leadbeateri* event in Norway caused salmon kills with associated multi-million € losses.
4) 2020 (Nov) + 2021 (Nov): *Vulcanodinium rugosum* events in Senegal leading to acute dermatitis in more than 1300 artisanal drift net fishermen (so called “Mysterious Senegalese fishermen’s disease”). Portimine A was identified as the main involved toxin causing severe inflammation via NLRP1 inflammasome (https://doi.org/10.1038/s44321-025-00197-4). This extent had never been seen before and not in the open ocean; a previous event in 2015 in Cienfuegos Bay, Cuba caused dermatitis in 60 bathing people.

5) 2020 (Fall). Massive bloom of *Karenia* species (Dinophyceae) off the Kamchatka coast, Russia (https://doi.org/10.1016/j.hal.2022.102337).
6) 2020 (Spring). Unprecedented bloom of *Lingulodinium polyedra* in southern California (https://online.ucpress.edu/elementa/pages/red-tide).
7) 2020 - 2021: Bloom of the fish killing algae *Fibrocapsa japonica* in a coastal lagoon in southern Brazil (Santa Catarina State). The bloom was followed by intense fish and crustacean mortality. This is the first time that a bloom of *Fibrocapsa* with fish kills was registered in Brazil.
8) 2021 (Summer): Emergence of *Ostreopsis* cf. *ovata* in the Bay of Biscay (Spanish and French Basque countries). This was the northern-most spread of *Ostreopsis* spp. Blooms. Previously, they had been limited to Mediterranean coasts. Tropical *Ostreopsis* spp. are expanding their range in temperate areas since the late 80s and can be, in some cases, considered as non-indigenous invasive species (Chomerat et al., 2022 https://doi.org/10.3390/md20070461; Marampouti et al., 2021).
9) 2021 (Summer): An unprecedented bloom of *Lingulodinium polyedra* on the French Atlantic coast (https://doi.org/10.1016/j.hal.2023.102426).
10) 2021 (December): Unprecedented multispecies bloom in Rio de Janeiro city and nearby, with 12 species of dinoflagellates, among them *Karlodinium veneficum, Prorocentrum* spp., *Scrippsiella* spp*., Tetraselmis* sp. (coming from Guanabara Bay) and *Mesodinuim rubrum*. Seawater along more than 150 km between Rio de Janeiro and Arraial do Cabo (Brazil) were dark brown with scums (Harmful Algae News 70, 2022).
11) 2022 (March): First cases of Ciguatera Fish Poisoning registered in Brazil, at the Fernando de Noronha Archipelago. *Gambierdiscus* species are known to occur in the island since at least 2017, when its presence was first investigated there.
12) 2022 (Summer): *Prymnesium parvum* event in the river Oder (between Germany and Poland) leading to massive mortality of sturgeon.http://dx.doi.org/10.1038/s41598-024-66943-9
13) 2022: A massive bloom of the toxic dinoflagellate *Alexandrium catenella* was detected as it moved through the Bering Strait region. This bloom was exceptional in scale, density, and toxicity, far exceeding any events reported previously in Arctic waters.https://doi.org/10.1002/lol2.10421
14) 2023: First observation of a *Pyrodinium bahamense* bloom in the Gulf of Aden, Djibouti causing massive fish kills (https://doi.org/10.1080/09670262.2024.2447871).
15) 2024 (March): First massive bloom of *Takayama acrotrocha* causing fish kills in Santa Catarina state, South Brazil.
16) 2024 (July): Massive bloom of *Noctiluca scintillans* in the South Coast of Brazil, that later reached the Southeast coast of the country.

17) 2016 (Austral summer): Blooms in Chile, extreme events, *Alexandrium catenella*, *Pseudochatenella* cf. *verruculosa* (Trainer et al. 2019, https://doi.org/10.1016/j.hal.2019.03.009).
18) Increased incidences of blooms and fish kills due to unarmored dinoflagellates such as *Takayama* sp. in Bolinao-Anda, Philippines (McGlone et al. 2024).
19) For over a decade, countries and territories in the Gulf of Mexico, South Florida, Wider Caribbean and West Africa have experienced an unprecedented Transatlantic Triple Threat, the influxes of holopelagic *Sargassum* spp., resulting in significant social, economic and environmental impacts. These impacts have caused challenges to already strained climate-sensitive socio-economic and environmental sectors. Emerging impacts recently reported in the energy and water sectors further highlight the need for adaptive management strategies to address this triple threat (Cox, Speede, and Alleyne, 2024).

Tasks:

1) Establish global diversity baselines to evaluate changes in species biogeography over time by using paleogenetic approaches and ancient dDNA analyses in order to study the multisecular dynamics of species and identify the drivers of their expansion through time. In some cases, this may include applying new methods to old archives to build new, longer time series.
2) Promote exchange of passive sampling and metabolomics methods, particularly metabolomic libraries for HAB species.
3) Explore and improve methods for collecting and analyzing aerosolized compounds, some of them still not characterized, such as those produced during cyanobacteria (in freshwater reservoirs) and *Ostreopsis* spp. in shallow rocky coasts in temperate and tropical latitudes.
4) Implement global baselines/recommendations for cyanobacterial blooms and their toxins in drinking and recreational waters.
5) Call attention to microscopy vs. genetics and microscopy vs.‘omics approaches - what do the comparisons tell us about. What we miss and what we do not with different methods?
6) Promote IOC training courses emphasizing classical taxonomic identification to preserve taxonomic expertise, addressing the decline in skilled taxonomists.
7) Identify causes and drivers fostering the different HAB events, allowing the design and implementation of management and policies aimed to minimizing anthropogenic forcings while favoring habitat protection policies.
8) Promote the use of the eDNA-based methods to: i. detect rare HAB species in various regions, sites, world zones to prevent future problems that could arise as a consequence of ecosystem change and/or global change; ii. integrate existing

HAB observatories across the world in order to improve the detection of HAB species that are unidentifiable with conventional methods (e.g. light microscopy); iii. produce distribution maps of HAB species in order to establish new sites eDNA-based observatories to monitor species expansion; iv. foster standardized identification of HAB species across the world by developing eDNA method formation, especially in countries where these approaches are not yet applied.

Outcomes:

1) Consolidation of a baseline of HAB species distributions based on morphological and new genomic information at local, regional, and global scales.
2) Improved knowledge on the information that can be delivered by eDNA-based methods relative to light microscopy.
3) A larger, coordinated community of experts on microalgal taxonomy, supporting HAB monitoring efforts worldwide.
4) Effective implementation of policies protecting the environment and preventing expansion of HABs.

Goal 2. Food Security and Human Health:

a. ***Codify methodologies to understand the threat and impacts to fisheries and aquaculture posed by HABs***

HABs threaten the food supply when they contaminate shellfish and fin fish, leading to compromised fisheries. Marine HAB threats to food include contaminated seafood where consumption might lead to foodborne illnesses with symptoms like vomiting, diarrhea, or in worst case neurological damage or death. The toxins can also accumulate in the food web and affect not only seafood but animals eating seafood and accumulating the toxins which may then be consumed. Fisheries and aquaculture industries can suffer large economic losses due to HABs, particularly in circumstances when food is contaminated and can no longer be sold or when areas must be closed to harvest or fishing. This in turn represents a threat to global food security since, according to the FAO, the ocean contributes 20% of the animal protein consumption for every 3 billion people (FAO 2020). According to the UN rationale for SDG 2 “Zero Hunger,” climate change is one factor contributing to the alarming trend in increasing hunger worldwide since 2015. Both SDG 12 *Ensure Sustainable Consumption and Production* and SDG 14 *Life below Water* invoke best practices around safe and sustainable seafood production, supply, and processing as well as the role of tourism in supporting vibrant economies. Taken together, these statistics and SDG emphases suggest a strong need to preserve as much ocean protein in the next decade as possible and to create predictive and mitigative tools related to the impacts of HABs on recreational and commercial fisheries or marine wildlife harvesting. The following identified tasks stem from the recommendations and future actions highlighted in the PICES Report on the GlobalHAB workshop on Economic impacts of HABs (Trainer et al. 2020).

Tasks:

1) Promote communities of practice directed at understanding how recurring and emerging HABs threaten aquaculture (shellfish, finfish, seaweed) sustainability, with a renewed focus on socio economic valuations of these impacts.
2) Establish and promote best practices for monitoring and mitigating fish-killing blooms.
3) Assess the socioeconomic impacts of all types of HABs on commercial, subsistence and recreational fisheries.
4) Develop and promote targeted engagement strategies with industry and fisheries managers to implement HAB monitoring and mitigation measures.
5) Promote risk assessments for HAB-related seafood contamination and its effect on regional to global economic supply chains.

Outcomes:

1) Strengthened HAB monitoring frameworks in aquaculture and fisheries sectors.
2) Recommendations to reduce economic losses due to HAB-related impacts.
3) Enhanced communication channels between scientists, regulators, industries and communities.

b. Freshwater HAB Impacts on Human, Animal, and Ecosystem Health

Harmful algae can impact human and animal health through exposure to toxins via drinking water, food, and recreational activities. Some freshwater harmful algae, including many cyanobacteria genera and some *Euglena* species, can produce toxins (including microcystins, anatoxins, cylindrospermopsins, saxitoxins, guanitoxins, anabaenopeptins, and euglophycin) that can contaminate drinking water, impact recreational areas, and accumulate in animal and plant tissues. These toxins can cause a range of health issues like liver damage, gastrointestinal problems, respiratory failure, and even, in the worst cases, death. Conventional drinking water treatment is often ineffective in removing those toxins, which pose major challenges for providing safe drinking water. Additional exposure pathways include accidental ingestion and inhalation of aerosolized toxins from HAB impacted recreational waters and ingestion of toxin-containing nutritional supplements, drinks, and foods (fish, shellfish, produce) that were sourced from or irrigated with HAB impacted waters.

Some examples of recent freshwater HAB impacts include:

1) Freshwater HAB advisories in the United states increased annually for the past ten years, with over 2500 advisories issued in 2024.
2) 2015: Recreational exposure to freshwater microcystin-producing HAB in Uruguay resulted in acute liver failure of an exposed 20-month old child, necessitating liver transplant.
3) Increased awareness and/or incidences of freshwater HABs in Philippine lakes and reservoirs and concern regarding drinking water safety.
4) Cyanotoxins have been detected in drinking water in the United States, Canada, Australia, and China, with advisories affecting millions.
5) Annual economic impacts related to freshwater HABs in the U.S. estimated at $2.2-4.6 billion annually.
6) 2016: Ranchers and farmers in the United States advised to discontinue irrigation and livestock watering with water sourced from freshwater HAB impacted Utah Lake. Recent studies have confirmed uptake of cyanotoxins in edible plant tissues and death of livestock following cyanotoxin exposure.
7) 2018 & 2020. The U.S. Food and Drug Administration issued recalls for dietary supplements and beverages that were found to contain microcystins at concentrations of human health concern.

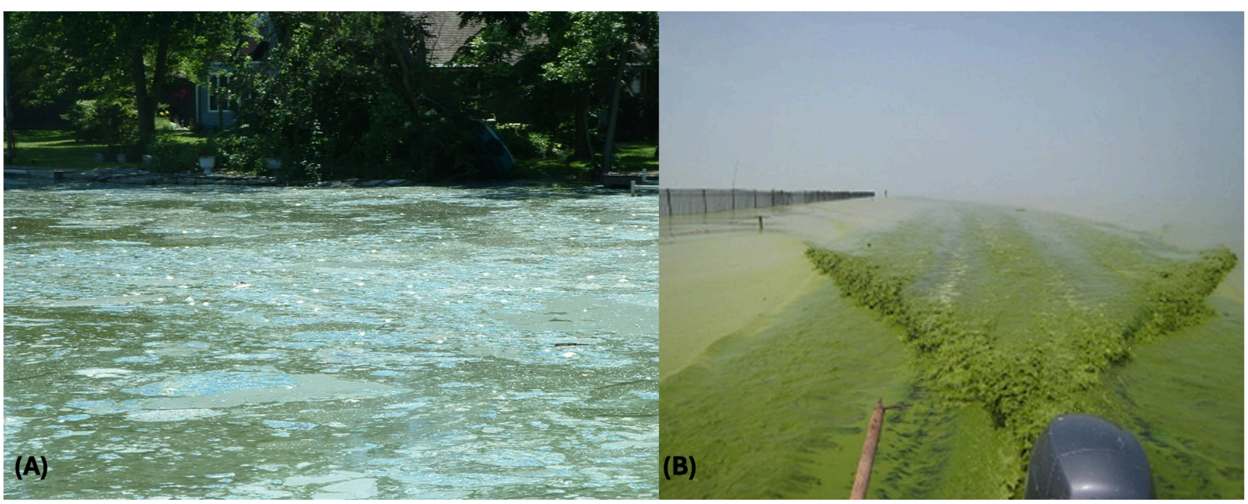

Figure 2. **(A)** Harmful algal bloom and resulting fish kill on Grand Lake St. Marys, Ohio, USA. The lake has four public beaches and is a community source of drinking water. The blooms on this lake have produced microcystins (multiple variants), saxitoxins, cylindrospermopsins, anatoxin-a, and euglenophycin. Beaches are often closed due to elevated cyanotoxins (microcystins have exceeded 100 ug/L) and the public water system upgraded conventional treatment to include dissolved air flotation,

2-stage ozonation, and granular activated carbon to remove cyanotoxins from drinking water. The community and state have spent millions of dollars on in-lake treatments and efforts to reduce the nutrient inputs that help fuel recurring HABs. Photo credit: Ohio Environmental Protection Agency. **(B)** Recurrent harmful algal bloom on the third largest lake in China, Taihu. In 2007, elevated microcystins from the bloom resulted in the loss of drinking water for over two million people. The country spent millions diverting water from the Yangtze River in an attempt to flush the bloom out of the lake, but that only worsened the problem. Photo credit: UNC Institute of Marine Sciences.

Given the wide-ranging and increasing impacts of freshwater HABs, GlobalHAB identified several tasks at the 2024 Steering Committee meeting to focus on over the next decade.

Tasks:

1) Coordinate the development of a global freshwater HAB satellite data processing center and data repository. The information will help provide an early warning to local lake managers for increased public health protection and enhance our understanding of global freshwater HAB occurrence and trends (potentially model after U.S. Cyanobacteria Assessment Network, CyAN program).
2) Promote exposure studies for development of LD50s, TDI, and NOAELs for emerging cyanotoxins of concern to enable governing agencies (WHO, affected nations, regions, and local governments) to establish new and update existing health advisory levels. Long-term exposure studies and mixed exposure studies are needed for multiple classes of cyanotoxins, and improved short term drinking water exposure studies are needed for microcystins, cylindrospermopsins, saxitoxins, guanitoxins, and anatoxin-a.
3) Promote evaluation of different types of toxin exposure from food, water, or aerosols.
4) Promote development of standardized sampling methodologies for freshwater benthic HABs and information sharing.
5) Promote information sharing of effective source water HAB control technologies and drinking water treatment techniques for removal and destruction of different classes of cyanotoxins.
6) Inform and train medical professionals to identify effects on human health by food poisoning, contaminated drinking water or aerosol exposure (e.g. Testai et al. 2016).
7) Develop global guidelines for cyanobacterial toxin accumulation in shellfish, mussels, oysters, near freshwater outlets and in brackish systems, such as the Baltic Sea, Chesapeake Bay, and Puget Sound (e.g. Testai et al. 2016).

Outcomes:

1) Increased access to processed satellite data showing the occurrence and distribution of freshwater HABs to help inform local decision making (potentially trigger additional sampling, help inform lake management decisions, drinking water treatment optimization, and consideration for recreational advisories).
2) Information on the global trends of freshwater HABs (and associated toxins) driven by eutrophication and climate change.
3) Increased understanding of occurrence of freshwater benthic HABs and risks they may pose to human and animal health.
4) Information for policy makers, such as a list of priorities for understanding and managing freshwater HABs, and a manual for freshwater HAB mitigation strategies.
5) Suggested recommendation guidelines for cyanobacterial toxins for safe food consumption.
6) Improved public health protection.

Goal 3. Food Web Complexity influencing HAB Dynamics

a. ***Use new methodologies in genomics to define the role of tropho-dynamics in structuring HAB occurrence, frequency, intensity, and food web impacts***

Inter- and Intra-species interactions in phytoplankton communities structure competitive relationships with consequences on plankton physiological ecology and life history traits, which includes toxin production. A significant gap in scientific knowledge that is currently preventing accurate prediction of bloom initiation, termination, and food web transfer of toxins to higher trophic levels is a sophisticated and mechanistic understanding of 1) food web connectivity, 2) variability in toxin vectors in space and time, and 3) controls on bioaccumulation or biomagnification. This goal outlines the emerging approaches, methods, and questions pertaining to food web complexity and its relevance to HAB outcomes and impacts.

Tasks:

1) Facilitate the synthesis of tools and models used to study physiology of mixotrophs, food web dynamics, and pathways. This would involve at least one community workshop that results in such guidelines.
2) Promote the importance of understanding microalgal community interactions - macro/micro/myco/pico/nano organisms – for predicting and modeling HABs.

3) Improve understanding of benthic-plankton interactions, e.g. are microalgal community models accurately capturing the role of HABs, and what are the current knowledge gaps?
4) Document the diversity of toxin accumulation, biomagnification, and trophic transfer and transformation of toxins in food webs to identify ways to improve prediction of impacts.
5) Guide the development of scientific projects to address food web complexity via modeling, laboratory, mesocosm, and depuration experiments.
6) Expand studies that document interactions between algal species and associated bacteria and viruses to increase our understanding of factors contributing to growth, toxin production, and termination of HABs.
7) Support for the emerging field that capitalizes on metagenomic advances (e.g. Fei et al. 2025).

Outcomes:

1) Improved experimental guidelines and predictive models for HAB formation, persistence, and food web impacts.
2) Improved information on toxin transfer pathways across ecosystems and their ecological consequences.
3) Stronger integration of field, laboratory, and modeling approaches for assessing HAB/food web interactions.
4) Workshop to share findings, discuss methods, foster a community of practice around metagenomic advances.

b. Apply improved detection techniques and experimental approaches to move towards a predictive understanding of regulations on toxin production phases, mechanisms of harm, and reverberating effects in food webs.

In recent years, there has been an explosion of breakthroughs identifying the genes underlying toxin production in various HAB taxa (Brunson et al. 2018, Litchman, 2022). These critical discoveries have allowed for a new era of transcriptomics, metabolomics, and other ‘omics approaches to finally develop a mechanistic understanding of environmental and internal cellular controls on toxin production in nature, not just in the laboratory. Examples of identified genes include the domoic acid (DA) biosynthesis genes identified in the diatom *Pseudo-nitzschia multiseries* (Brunson et al., 2018), the co-expression of the *dabA* and silicon transporters (*sit1*) genes which could be used as a robust predictor of DA one week in advance, potentially enabling the forecasting of DA-producing HABs (Brunson et al., 2024), the PKZILLA-1 and -2 encoding giant polyketide synthase enzymes in the harmful haptophyte microalga *Prymnesium parvum*, regulating the biosynthesis of prymnesins (Fallon et al., 2024), cysteine synthase (CysK) elucidated as a key enzyme regulating the biosynthesis of *β*-*N*-methylamino-*L*-alanine (BMAA) in marine diatoms which should be also a useful biomarker for investigation of BMAA-producing diatoms and forecasting BMAA-producing HABs. Biosynthetic pathways for many freshwater cyanotoxins have already been elucidated, leading to significant improvements in monitoring and toxin predictions. With this ability in hand, further upstream and downstream discoveries and applications will be facilitated pertaining to bottom up and top down controls of toxins and their fate in food webs. Community genomics approaches are a new frontier and pertinent to any GlobalHAB scientific campaigns, workshops, or initiatives.

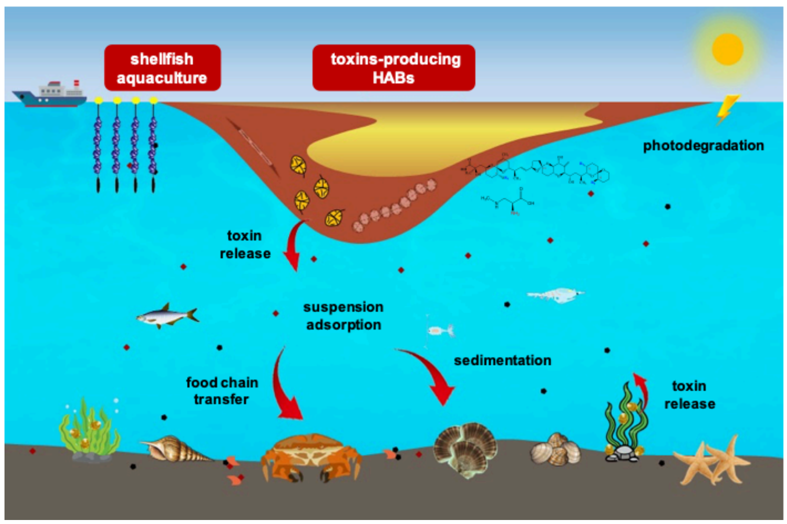

Figure 3. Diagrammatic sketch for the release diffusion of extracellular toxins in marine environments (drawn by Dr. Guixiang Wang).

In the last decade, dissolved toxins such as brevetoxins (BTXs), DA, okadaic acid (OA), dinophysistoxin-1 (DTX1), pectenotoxin-2 (PTX2), and saxitoxin-group toxins have been worldwide detected in seawater samples (Pierce et al., 2011; Geuer et al., 2019; Wu et al., 2024; Li et al., 2024; Wang et al., 2024). These toxins permeate seawater environments and threaten marine organisms *via* direct or indirect exposure, of which the cascading impacts on marine ecosystems possibly exceed our understanding scope and ability. The cascading effects on marine ecosystems caused by the environmental extracellular toxins via chemical ecology mechanisms should be paid attention to in future studies. In addition, the dissolved toxins such as OA and DTX1 could enter air environments from seawater through sea spray aerosols (Acker et al., 2021). *Ostreopsis* proliferations in the Mediterranean have been related to symptoms of respiratory and cutaneous irritation in humans via inhalation of aerosols containing unknown irritative chemicals produced under certain circumstances during the blooms

(Berdalet et al., 2022). Therefore, the airborne exposure of toxins sprayed from seawater and their effects on human health should be studied and understood in the future.

Tasks:

1) Promote the investigation of dissolved and aerosolized toxins, and deeply explore their environmental behaviors in seawater and air media.
2) Develop sensitive and quick detection methods of toxins in seawater for early warning of toxins-producing HABs.
3) Conduct workshops to facilitate the development of sensitive and quick monitoring methods of toxins in water for early warning of the contamination of seafood or other organisms in the food web.This includes the purification and availability of more reference standard materials for phycotoxins for further toxicity studies and use as analytical controls
4) Promote studies that Identify fish and shellfish-harmful compounds from HAB species and exploration of their toxicological mechanisms and target organisms.
5) Promote comprehensive exploration of the chemical ecology effects of dissolved toxins on marine organisms to understand their impacts on ecosystems.
6) Establish the genetic basis for toxin production and omics approaches to disclose toxin biosynthesis mechanisms and predict toxigenic microalgae.
7) Encourage retention of efforts to purify and obtain more reference standard materials of toxins, especially some emerging phycotoxins.
8) Facilitate shared knowledge and advancement of studies establishing the genetic basis for toxin production and ‘omics approaches to elucidate the biosynthesis mechanisms of toxins to predict toxigenic microalgae.

Outcomes:

1) Enhanced detection methods for tracking toxin impacts on fisheries and marine organisms
2) Enhanced early-warning systems for HABs through rapid detection techniques
3) Establishment of databases for dissolved toxins in coastal regions with frequent occurrence of HABs.
4) Development of portable and quick detection methods for dissolved toxins in seawater.
5) Elucidation of the compounds that kill fish and shellfish in the events of HABs.
6) Understanding of the cascading impacts of dissolved toxins on regional or global ecosystems.
7) Promotion for application of multi-omics approaches to disclose the biosynthesis pathways of toxins in microalgae.

8) Advancements in molecular and genetic understanding of toxin biosynthesis in HAB species.
9) Enrichment for the types of certified reference materials of toxins that could be commercialized or shared in the GlobalHAB community.

Goal 4. Benthic HABs: Ecological studies including species ecophysiology, biotic interactions, responses to nutrient enrichment, to a changing climate, and to habitat destruction, besides bloom impacts on ecosystem and human health.

Benthic harmful dinoflagellates are linked to different historical and emerging threats to ecosystems and human health. On the one hand, *Gambierdiscus* spp. and *Fukuyoa* spp. are historically problematic in tropical areas, involved in the endemic Ciguatera poisoning. *Ostreopsis* spp. and *Vulcanodinium rugosum* have emerged in the 21st century, causing mainly respiratory and cutaneous irritation, respectively. Some benthic species of the genus *Prorocentrum* accompany the other taxa and produce diarrhetic toxins. Overall, these taxa are expanding their biogeographic range in tropical and temperate latitudes since the 1980s, and their proliferations are becoming a global phenomenon, both in the Northern and Southern hemispheres. Due to the peculiarity of benthic species, tightly tied to biotic communities of macroorganisms, research on their ecology and physiology must be approached with particular techniques and tools, different from those commonly used for plankton HABs. Concerning Ciguatera, there is a need to improve the understanding on how small-scale biotic (interactions with benthic communities) and physico-chemical stressors as well as climate change influence *Gambierdiscus* proliferation in affected areas. Furthermore, it is necessary to investigate local species toxicity, toxin bioaccumulation, and biotransformation in fish and other vectors.

Concerning all benthic HABs, it is necessary to delve into the understanding of biotic factors and interactions facilitating/regulating their proliferation, with a special focus on the benthic communities and in particular macroalgae, the preferred habitat of harmful benthic species (Monserrat et al., 2022). Degraded states of benthic communities, such as those with increased dead corals, seem to be more prone to bHAB occurrence than well-structured ecosystems (healthy reefs). The calculation of tipping points of regime shifts from healthy to degraded ecosystems can provide an assessment of the likeliness of bHABs occurrence. The long-term stability of benthic communities (compared to the high dynamics of microalgae) allows the calculation of early warning signals (tipping points of regime shifts) over large spatial and temporal scales. Moreover, the biotic substrate determines the methods for detection and estimation of cell concentrations: benthic ecology tools can provide solutions for new methods allowing the comparison of blooms with absolute values as for planktonic blooms. Finally, the impacts caused by benthic HABs on human health and marine ecosystems, and potentially on human societies, need to be addressed using an integrative approach.

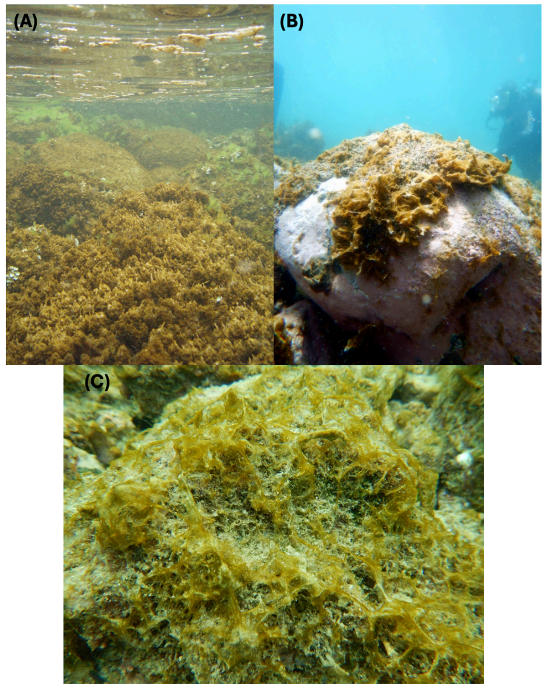

Figure 4. (A) *Ostreopsis* cf. *ovata* bloom developing on macroalgal communities in the Ligurian Sea. **(B)** *Ostreopsis siamensis* developing on algal turfs in the Pacific Ocean (New Zealand). **(C)** *Ostreopsis* cf. *ovata* bloom at Arraial do Cabo, Rio de Janeiro, Brazil in 2021.

Tasks:

1) Promote the development of standardized methodologies to precisely quantify benthic dinoflagellates under bloom and non bloom conditions and compare absolute values.Develop macro-organism community-based indicators (e.g. conservation status of coral reefs and presence of algal turfs) as early warning signals for benthic blooms in both tropical and temperate areas.
2) Conduct workshops to develop methods for the application of early warning signals of bHABs occurrence based on the benthic communities and discuss potential monitoring/regulations/mitigation actions that could be performed at the ecosystem level.
3) Develop and guide best practices on fast-application and cost-efficient tools to monitor benthic HAB species.
4) Promote the application of molecular techniques (e.g., qPCR) to monitor *Gambierdiscus* species in ciguatera endemic areas as an early warning system for ciguatera.

5) Establish baseline species composition datasets in order to address future distribution changes caused by invasions, accidental transport, or climate change.
6) Improve surveillance and monitoring programs for ciguatoxins in fish for consumption in ciguatera affected areas, improving the availability of accurate analytical methods validated according to international standards.
7) Promote awareness among medical doctors on intoxications derived from benthic species in ciguatera and *Ostreopsis*-affected areas.

Outcomes:

1) Improved quantification methods for benthic HAB species, and therefore risk assessment capabilities.
2) List of indicators based on tipping points of ecosystem change (both in tropical and temperate areas) to be used as early warning signals of bHABs occurrence.
3) Proposed monitoring/regulations/mitigation actions based on benthic communities to decrease the risk of intoxications.
4) A newly established baseline of knowledge on species distributions (preferably based on molecular methods) and impacts.
5) Improved understanding of factors that trigger benthic HABs in different systems worldwide.
6) A unified protocol of practices for medical doctors on how to treat the symptoms of ciguatera.

Goal 5. Automated HAB Detection and Prediction: Apply advanced remote sensing, machine-learning modeling techniques, and in situ observing to HAB detection, prediction, and operational forecasting for mitigation and spatial/temporal awareness of bloom transport.

Ocean color remote sensing is notoriously difficult due to the dark water target and ensuing requirements for very high signal-to-noise ratios across the entire visible electromagnetic spectrum. The last five years have seen an incredible advancement in remote sensing capacity for ocean color due to the launch of many highly sensitive hyperspectral sensors on low-earth orbiting, polar orbiting, and geostationary satellites by the National Aeronautics and Space Administration (NASA), European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA), and others. With these new technologies come new opportunities for developing taxon-specific detection algorithms that get us much closer to HAB detection from remote platforms (space, airborne, drone) than ever before (Rouleau et al. 2024). GlobalHAB has already contributed substantially to the modeling of HABs through efforts ranging from empirical to dynamical modeling frameworks to help resource managers foresee problematic events. The GlobalHAB Modeling Workshop held in Glasgow in 2022 showcased the global efforts in this arena and nurtured new multi-national collaborations for HAB prediction. The recommendations from that workshop were many (Karlson et al. 2021), but a high priority-item that led to an ASLO session dedicated to the topic is the blending of Artificial Intelligence/Machine Learning methods with deterministic understanding of coupled biological-physical models in order to better characterize non-linear or ill-defined relationships between environmental conditions, biological interactions, and toxic/HAB events. The assimilation of complex physical, chemical, and biological datasets is expected to continue advancing, particularly for biological observations. The modeling strategies described in Goal #5 apply to remote sensing applications, numerical models, and blended methods/products, all of which are poised for radical advancements over the next five to ten years with the explosion of supporting computational and observing technologies.

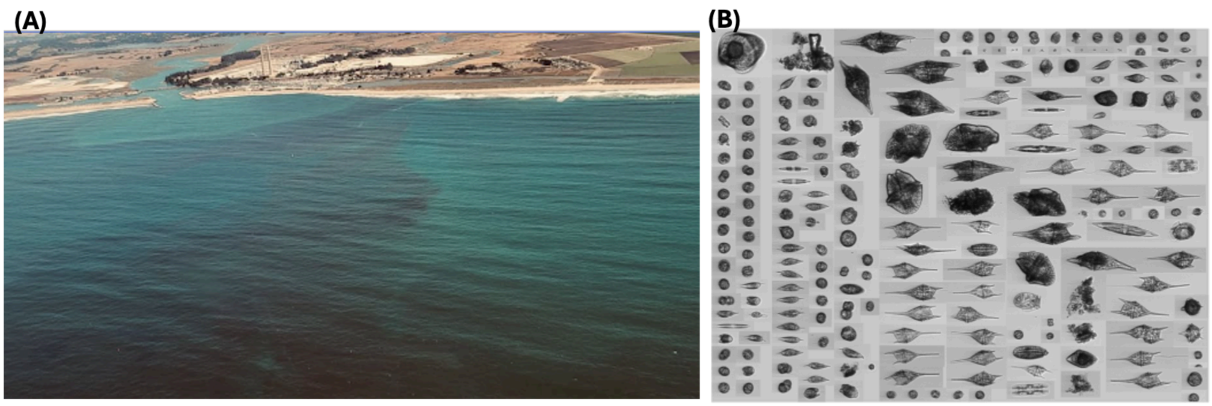

Figure 5. (A) Airborne image of a “red tide” dinoflagellate bloom in Monterey Bay captured by a CIRPAS Twin Otter during the NASA PACE-PAX airborne validation campaign for the PACE mission 25 September 2024; **(B)** Imaging FlowCytobot (IFCB) images of the in situ dinoflagellate community at the Santa Cruz Wharf on 25 September in Monterey Bay, corresponding to the airborne imagery in (A).

Tasks:

1) Promote the uptake and standardization of remote sensing techniques for HAB detection and prediction, emphasizing the democratic nature of satellite ocean color data sets where, for many regions, these are the only data available for monitoring HABs. This capacity building aspect will be highlighted through technical training of early career ocean professionals (ECOPs), workshops, and comparative studies.
2) Collaborate with the International Ocean Color Coordinating Group (IOCCG; https://ioccg.org/) and NASA/ESA on HAB-specific activities, tutorials, and guidelines. This will include advancing progress on the use of hyperspectral imagery for HAB observation and detection, e.g. with NASA PACE and NOAA GeoXO missions.

3) Develop guidelines for validation and ground truthing of satellite remote sensing imagery to encourage uptake and use around the world where expensive monitoring programs are not possible. These activities include increasing membership in communities of practice around imaging and other instruments/data solutions/and HAB classifiers.
4) Promote the sharing and open source treatment of algorithms developed for HAB detection, particularly for cyanobacteria detection, to promote broader use of satellite-based remote sensing for public health protection and enable global analyses of cyanoHAB distribution and trends. Successful examples of this include CyAN in the U.S. (https://www.epa.gov/water-research/cyanobacteria-assessment-network-cyan#:~:text=CyAN%20is%20a%20multi%2Dagency,protect%20aquatic%20and%20human%20health.) and CyanoAlert in the Baltic region (https://www.cyanoalert.com).
5) Organize and facilitate the exchange of knowledge on advanced numerical and statistical modeling techniques relevant for predicting and forecasting HABs, with focus on blended remote sensing and modeling approaches.
6) Co-design early warning products with the full suite of end-users, managers, and industry partners. `
7) Promote the awareness and market value of use and development of *in situ* remote sensing instrumentation biosensors, gliders, Imaging FlowCytobots (IFCBs) and other imaging or flow cytometer technology, autonomous, underwater vehicles (AUV's), Automated Surface Vehicles (ASV's), primary production optical instruments, Unmanned Aerial Vehicles (UAV's), such as drone mounted hyperspectral cameras etc. for ground truthing satellite imagery/hyperspectral signatures and for automated *in situ* HAB forecasting.
8) Build upon previous GlobalHAB-sponsored workshops on remote sensing imagery and *in-situ* instrumentation, focusing on the increased use of both advanced and open source technologies, such as the IFCB, PlanktoScope, Flowcam, and Cytosens instruments (Reguera and Bresnan, UNESCO, 2022).
9) Ensure that remote sensing and modeling approaches are focused on the mitigation of *Sargassum* beachings and downstream socioeconomic impacts. This task builds on the recommendations of the recent GlobalHAB sponsored publication: *"SARGASSUM WHITE PAPER: Turning the crisis into an opportunity" (https://www.unep.org/cep/resources/publication/sargassum-white-paper-turning-crisis-opportunity).*

Outcomes:

1) Improved understanding globally of the tools available for predicting and forecasting HABs.
2) A unified community of practice and global coordination surrounding remote sensing, autonomous observing, and modeling approaches relevant to HAB detection, prediction, and forecasting.
3) Improved capacity in developing countries surrounding the use and application of remote sensing and modeling tools for HAB monitoring and early warning to coastal communities.
4) An increased attention globally to techniques surrounding the monitoring and modeling of cyanobacteria in freshwater systems and *Sargassum* beachings at tropical to subtropical latitudes.
5) Global advances in the ability to develop early warning systems for all HAB taxa.

Goal 6: Marine HAB control and its interaction with environment – biofeedbacks from mitigation interventions.

Controlling HABs remains one of the most complex and least developed areas in HAB management. Nearly three decades ago, Anderson (1997) highlighted the significant challenges in marine HAB control, emphasizing the lack of research and field applications. A key difficulty lies in the fact that HAB species are often a minor component of diverse planktonic communities that support aquatic ecosystems, making selective suppression highly challenging. Additionally, marine HABs occur in dynamic hydrographic environments, where currents and tides facilitate their lateral and vertical movement, complicating treatment logistics. At the time, the prevailing view in the scientific community was that these challenges were too vast and complex to address directly, prioritizing further research on bloom dynamics over immediate control efforts. Recent reviews indicate that freshwater HAB control is significantly more developed compared to its application in marine systems. Despite advances in HAB detection, toxin quantification, forecasting, and impact management, large-scale control strategies in natural marine waters remain scarce. However, there is now increasing demand for effective, scalable control approaches, as stakeholders expect practical solutions from HAB science. A major obstacle in bridging this gap is the concern over balancing intervention benefits with potential environmental risks, as well as the difficulty of scaling up laboratory-proven technologies to manage blooms that span vast areas and move dynamically with water currents. There is a growing willingness among HAB researchers to explore control technologies, with many potential strategies moving toward field trials and implementation. However, in some countries, these later stages are often stalled or hampered by regulatory barriers.

Figure 6. Marine HAB control methods. A-C) Use of modified clays in China: A) Mixing of modified clays with seawater; B) Dispersion of modified clays using a suction pump and hose; C) Dispersion of clays using a remote-controlled drone (International Training program on Prevention, Control, and Mitigation of HABs (PCM-HAB) endorsed by IOC/SCOR programs GlobalHAB & WestPAC-HAB, Nanning, China December 2024; Photos: Jorge I. Mardones); D) Airlift upwelling and bubble curtains used as a control strategy against the 2016 *P. verruculosa* bloom event in Chile (Mardones et al., 2021); and E) Measurements of the effectiveness of ultraviolet radiation for HAB control in F) wellboats used for salmon transport in Chilean Patagonia (Photos: Ana Flores).

Tasks:

1) Conduct review papers focused on unintended consequences, trade offs, and advice on appropriate use for the different types of tools.
2) Promote the uptake of prevention practices, such as reduced nutrient runoff, wastewater treatment plants, urban stormwater management, monitoring and regulation of aquatic systems, public education and awareness, sustainable agricultural practices, research and innovation.

3) Identify and evaluate mitigation strategies for their efficacy and safety; includes Identifying regulatory barriers to implementing control efforts.
4) Promote the exchange of information on *in situ* testing of HAB control measures used by the private industry (e.g., bubble curtains, airlift upwelling systems, perimeter screens, etc.).
5) Foster collaboration between scientists and engineers working on HAB control methodologies through joint workshops and other initiatives. A recent example is a workshop on HAB prevention, control, and mitigation organized by IOCAS.
6) Promote efforts to scale up laboratory-tested technologies to effectively address blooms that can extend over hundreds of kilometers and dynamically shift with currents and tides in three dimensions.
7) Foster the development of phased approaches for the research and implementation of new HAB control strategies to ensure efficiency, safety, and regulatory compliance. This structured process will enable periodic assessments to prevent significant investments in technologies unlikely to reach field application or commercialization. Given that HAB control research can take decades to meet safety and efficacy standards, this approach will facilitate steady progress while addressing regulatory challenges, ultimately increasing the availability of viable marine HAB control solutions.

Outcomes:

1) Increased commitment from government agencies in certain countries to allocate more funding and resources for HAB control research, although these efforts remain limited in scope relative to the global scale of the HAB issue.
2) Improved understanding of impacts and efficacy in marine environments
3) Advancements in mitigation of real-time HAB events in both freshwater and marine environments.

Closing Remarks:

While this is not an exhaustive list of all the ways in which the study and mitigation of HABs should proceed in the coming decade, it is a highly prioritized roster of critical lines of inquiry identified by the GlobalHAB SSC. We have crafted this plan to be as clear and succinct as possible while also providing the necessary details for the committee to evaluate specific actions and potential outcomes. Obviously, investments by national and international agencies will determine the limits of success in implementing this plan and positively steering the direction of HAB research globally.

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Appendix A. Past themes and accomplishments 2017-2025 TBD
*provided as a separate attachment

Appendix B. List of Acronyms

ASLO: Association for the Sciences of Limnology and Oceanography
ASV's: Automated Surface Vehicles
AUV's: Autonomous Underwater Vehicles
UAV's: Unmanned Aerial Vehicles
BMAA: β-N-methylamino-L-alanine
BTXs: Brevetoxins
CIRPAS: Center for Interdisciplinary Remotely Piloted Aircraft Studies
CRISPR/Cas9: Clustered Regularly Interspaced Short Palindromic Repeats and associated protein 9
cyanoHAB: Cyanobacterial Harmful Algal Bloom
CyAN: Cyanobacteria Assessment Network
CysK: Cysteine Synthase
EBVs: Essential Biodiversity Variables
ECOPs: Early Career Ocean Professionals
eDNA: Environmental DNA
EFSA: European Food Safety Authority
EOVs: Essential Ocean Variables
ESA: European Space Agency
DTX1: Dinophysistoxin-1
DA: Domoic Acid
dabA: Domoic Acid Biosynthetic terpene cyclase
dabB: Domoic Acid Biosynthetic hypothetical protein
dabC: Domoic Acid Biosynthetic dioxygenase
dabD: Domoic Acid Biosynthetic cytochrome P450
DNA: Deoxyribonucleic Acid
FAO: Food and Agriculture Organization
GeoXO: Geostationary Extended Observations satellite system
GESAMP: is a group of independent scientific experts that provides advice to the UN system on scientific aspects of marine environmental protection.
GlobalHAB: Global Harmful Algal Bloom
GOOS: Global Ocean Observing System
HAEDAT: The Harmful Algal Event Database
HABs: Harmful Algal Blooms
IFCB: Imaging FlowCytobot

IOC: Intergovernmental Oceanographic Commission
IOCAS: Institute of Oceanology Chinese Academy of Sciences
IOCCG - International Ocean Color Coordinating Group
IPHAB: Intergovernmental Panel on Harmful Algae Blooms
JAXA: Japan Aerospace Exploration Agency
km: Kilometer
LD50: Lethal Dose 50
MDD: Major Depressive Disorder
NASA: National Aeronautics and Space Administration
NLRP1: Nucleotide-binding domain Leucine-rich Repeat Pyrin domain containing 1
NOAA: National Oceanic and Atmospheric Administration
NOAEL: No Observed Adverse Effect Level
NOS1 gene: Nitric Oxide Synthase 1 gene
OA: Okadaic Acid
‘Omics: a biological field that studies the molecules and processes that make up cells and tissues
PACE-PAX: Plankton, Aerosol, Cloud, ocean Ecosystem - Postlaunch Airborne eXperiment
PCM-HAB: Prevention, Control, and Mitigation of Harmful Algal Blooms
PTX2: Pectenotoxin-2
PICES: North Pacific Marine Science Organization
PKZILLA: the name of the largest protein ever identified in nature
qPCR: Quantitative Polymerase Chain Reaction
RAMOAGE: intergovernmental cooperation agreement between France, Italy and Monaco
S&IP: ??
SCCOOS: Southern California Coastal Ocean Observing System
SCOR: Scientific Committee on Oceanic Research
SDGs: Sustainable Development Goals
Sit1: silicon transporters
SSC: Scientific Steering Committee
TDI: Tolerable Daily Intake
µg/mL: Microgram per Millilitre
WESTPAC/HAB: Western Pacific HAB Network
WHO: World Health Organization

Appendix C:

Procedures and criterion for obtaining GlobalHAB endorsement of science activities

GlobalHAB provides an international structure for planning and coordination of international scientific activities related to HABs in aquatic environments and their effects on the ecosystems, human health and wellbeing. In addition, GlobalHAB helps provide a framework for national and regional projects to (1) coordinate their activities and, (2) participate in coordinated initiatives of research, observations, and modelling on HABs.

Scientists are invited to participate in GlobalHAB by designing scientific activities in alignment with the goals and objectives of GlobalHAB, and by applying for endorsement of such activities, and participation in framework activities.

The GlobalHAB SSC may endorse already funded projects, project proposals at the funding submission stage, or letters of intent. The primary criterion for endorsement is applicability to any of the GlobalHAB Science Plan objectives. Details of current endorsed projects are listed on the GlobalHAB website.

Requests for endorsement are initiated by submission of the accompanying ***application form***, emailed to the Chair of the GlobalHAB SSC (Contact). GlobalHAB SSC members and GlobalHAB chair (or vice-chair, if the chair is unavailable) will then assess the submission and make a decision about endorsement. The applicant will be notified no later than one month after submission of the request. Notification will be in the form of an official GlobalHAB letter (.pdf) sent via email. A printed version is available upon request.

Benefits of GlobalHAB endorsement

Individuals and research teams that participate in international GlobalHAB activities will receive the following benefits from their association with the programme:

- GlobalHAB will support the **communication and knowledge transfer** on HABs to the public, managers, and policymakers.
- GlobalHAB will facilitate **establishment of links with other relevant international programmes and bodies (e.g., GOOS, IPHAB, IOC WESTPAC, HAEDAT, ...) and related projects** also endorsed by GlobalHAB.
- GlobalHAB will facilitate **dissemination of project information** through newsletters, website and other communication mechanisms.

Responsibilities

- To communicate the progress of the project to GlobalHAB SSC once per year (or when necessary) between the endorsed project and the GlobalHAB SSC. Refer to the ***updated template.***
- Specify endorsement by GlobalHAB in scientific publications. Refer to the ***examples of acknowledgement.***
- Provide copies of scientific publications for listing as GlobalHAB Programme outputs.
- Contribute to the dissemination of GlobalHAB via seminar/Webinar.