

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)

**Fourteenth Session of the IOC Intergovernmental Panel
on Harmful Algal Blooms**

SCOR-IOC GlobalHAB program
Progress Report 2017-2019



GlobalHAB Scientific Steering Committee members

Elisa Berdalet, Institute of Marine Sciences, CSIC, Spain, Chair
Raphael Kudela, University of California, Santa Cruz, USA, Vice-chair

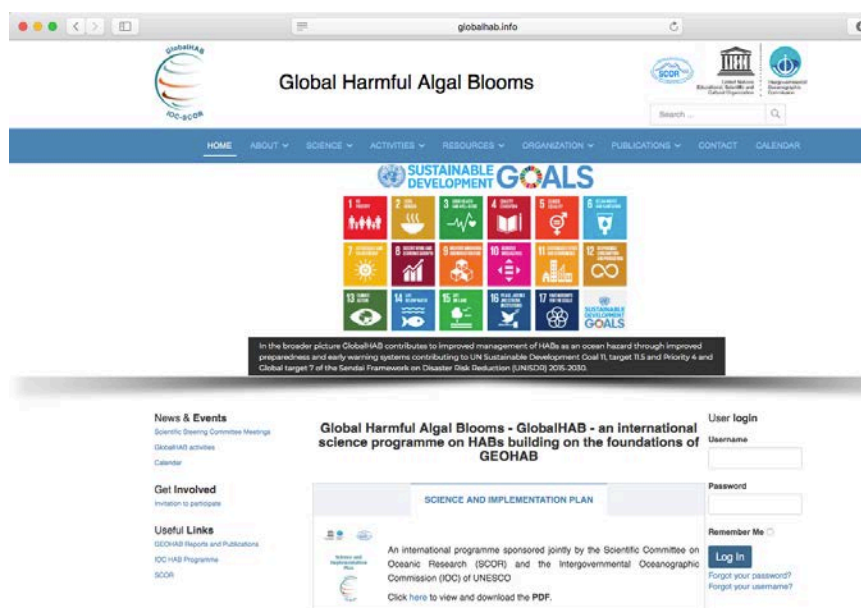
Neil S. Banas, University of Strathclyde, United Kingdom
Michele Burford, Griffith University, Australia
Christopher J. Gobler, Stony Brook University, USA
Bengt Karlson, Swedish Meteorological and Hydrological Institute, Sweden
Po Teen Lim, University of Malaya, Kuala Lumpur, Malaysia
Lincoln Mackenzie, Cawthron Institute, New Zealand
Marina Montresor, Stazione Zoologica Anton Dohrn, Italy
Kedong Yin, Sun Yat-Sen (Zhongshan) University, China

Eileen Bresnan, Marine Scotland Science, United Kingdom, ICES representative
Keith Davidson, The Scottish Association for Marine Science, United Kingdom, Ex-officio
Vera L. Trainer, National Oceanic and Atmospheric Administration, USA, ISSHA and PICES representative
Gires Usup, Universiti Kebangsaan Malaysia, Malaysia, IPHAB representative

Henrik Enevoldsen, IOC UNESCO/ University of Copenhagen, Denmark
Ed Urban, Scientific Committee on Oceanic Research, USA

I. Finalization of the GlobalHAB Science and Implementation Plan

In response to Decision IPHAB-XII.1. "HABs in a Changing World: A Global Approach to HAB Research to Meet Societal Needs, GlobalHAB", the new programme GlobalHAB was launched in January 2016. The *GlobalHAB Science and Implementation Plan* was developed by the GlobalHAB Scientific Steering Committee (SSC) incorporating the suggestions of the international community at the 17th International Conference on Harmful Algae (ICHA) (<http://icha2016.com/about/>) and the evaluation of 11 external reviewers. In November 2017, the final Plan was edited and made free available at the GlobalHAB webpage (www.globalhab.info), which was active in January 2018.



Home page of the GlobalHAB website. This image illustrates in particular that, in the broader picture, GlobalHAB contributes to improved management of HABs as an ocean hazard through improved preparedness and early warning systems thus contributing to UN Sustainable Development Goal 11, target 11.5 and Priority 4 and to Global target 7 of the Sendai Framework on Disaster Risk Reduction (UNISDR) 2015-2020.

II. April 10-11, 2018. Third meeting of the GlobalHAB Scientific Steering Committee.

The GlobalHAB SSC held his third meeting since its launch at the Laboratoire d'Océanographie de Villefranche (LOV) in Villefranche-sur-mer (France) on April 10 and 11, 2018 hosted by Dr. Rodolphe Lemée. His students, Anne-Sophie Marron, and Kévin Drouet offered a brief presentation of their PhD thesis and a tour through the LOV facilities was conducted with Dr. Lars Stemman. Dr. Lemée also presented the artificial substrate method for sampling benthic microalgae, which he had also introduced during the concurrent Regional Workshop on Monitoring and Management Strategies for Benthic HABs in Monaco, April 9-12, 2018. GlobalHAB acknowledges the LOV for its kind support.



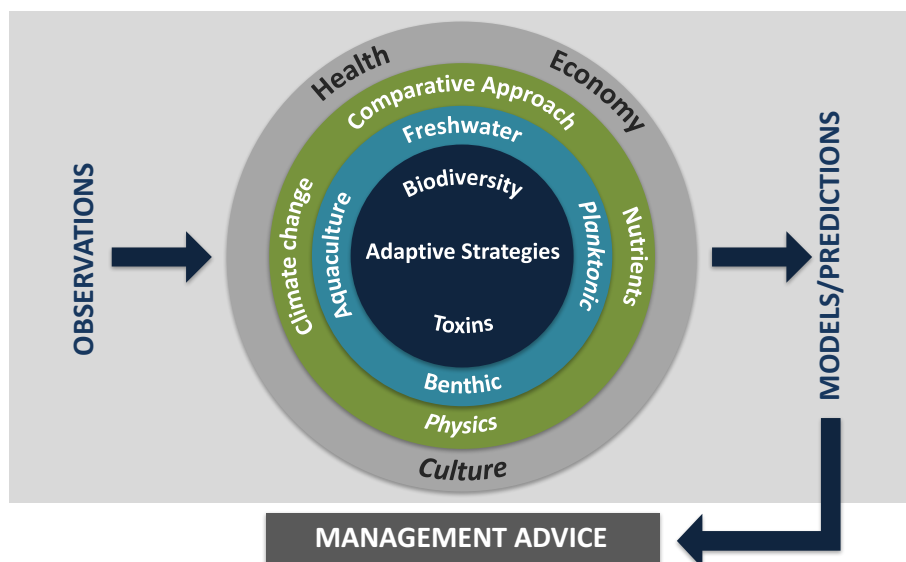
GlobalHAB SSC members at the entrance of the LOV, April 2018. Participants (left to right): Henrik Enevoldsen, Ed Urban, Bengt Karlson, Vera Trainer, Chris Gobler, Elisa Berdalet, Raphe Kudela, Marina Montresor, Po Teen Lim, Neil Banas, and Kedong Yin.

The meeting addressed the following items:

- 1) Revision of the Implementation Activities identified in the second SSC meeting in Naples (see IOC/IPHAB-XIII/Inf.11. at http://hab.iocunesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=15021) to address the objectives of the twelve GlobalHAB Themes and planed for the 2017-2019 period. Before the meeting each SSC member was invited to elaborate a presentation addressing what had been done, what will be done, what are the needs (funds, maturity of the action) for implementation actions, limitations, change of plans, etc.
- 2) Information on HAB related activities fostered by IOC/UNESCO and other entities (ISSHA, IPHAB, ICES, PICES, UNEP).
- 3) Communication strategies (Endorsement procedure, website maintenance), budget, SSC membership renovation system.

III. Progress on the activities identified in the GlobalHAB Science and Implementation Plan

GlobalHAB Themes



Themes integrated in GlobalHAB. Note that the terms "Physics", "Planktonic" and "Culture" refer to general aspects developed within the different Themes, and are included in the scheme to emphasize the multidisciplinary aspects integrated in GlobalHAB. Figure in the GlobalHAB Science and Implementation Plan, free download at (www.globalhab.info).

The main conducted, ongoing and planned activities corresponding to each GlobalHAB Theme, and other key issues are presented next.

Theme 1. Biogeography and Biodiversity. Responsible: Marina Montresor

Activity 1.1. October 2018. HABs biogeography session within the 18th ICHA. **E. Berdalet** contacted the ICHA organizers, biogeography was included in two sessions.

Activity 1.2. November 2018. Workshop on dinoflagellates barcoding. **M. Montresor** and **E. Berdalet** fostered a workshop on this topic co-organized by EukRef of UniEuk (<http://www.unieuk.org>). *EukRef* is a standardized, open-source bioinformatics pipeline that allows taxonomic curation of publicly available phylogenetic marker sequences (starting with 18S rDNA), generating homogeneous sets of curated, aligned sequences and phylogenetic trees. *EukRef* is one of the modules of *UniEuk* (www.unieuk.org), an open, community-based and expert-driven international initiative to build a flexible, adaptive universal taxonomic framework for eukaryotes, focused primarily on protists. The workshop was organized by the EukRef team, it was sponsored by GlobalHAB and it was held in Roscoff, (France) on 5-9 Nov 2018 (<http://eukref.org/roscoff-workshop/>). Marina Montresor was funded by UniEuk to attend the workshop in quality of advisor.

The workshop was focused on Diatoms, Dinoflagellates, and Green Algae. During the workshop, the working group integrated the curation efforts on individual eukaryotic groups into a biological data warehouse consisting of curated sequences, flexible taxonomy, and phylogenetic trees and their underlying sequence alignment. EukRef will integrate with PR2, a reference database for protists, with plans to push forward and expand ongoing curation efforts that are crucial for the interpretation of metabarcoding datasets (<http://eukref.org/eukref-pr2-integration/>).

Activity 1.3. August 2019. A session on HABs is planned within the 7th European Phycological Conference (<http://epcseven.biol.pmf.hr/>) that will be held in Zagreb (Croatia) from 25-30 August 2019). The session will be led by E. Berdalet and P.M. Visser

Activity 1.4. - In progress. GlobalHAB Status Report coordinated by **Henrik Enevoldsen**. In order to develop and launch the first Global HAB Status Report a network of data providers for OBIS-HAB and HAEDAT has been established (or reconfirmed) and an Editorial Team for the First Global HAB Status Report was established together with a data flow structure.

The network of data providers in ICES and PICES regions for OBIS-HAB and HAEDAT has been expanded in cooperation with IAEA in the South Pacific, SE Asia, the Caribbean and Africa. One joint workshop was held in South Pacific, one in the Caribbean, one for Africa. Additionally, a training workshop for data editors across regions was held in Ostend (Belgium), 25-28 September 2017. Reviewing the literature and other sources for HAB species occurrences for entry into OBIS and compilation of data on HAB events for HAEDAT is ongoing. A data compilation template for HAB data in OBIS has been developed and reviewed and is in use (https://github.com/iobis/habtemplate/blob/master/habtemplate_a_v4.xlsx). This will allow to complement, and add value to, data already in OBIS with baseline observations recorded in the literature.

Establishment of a data flow with global coverage has taken longer than expected, but major progress has been achieved and all key regions are now covered with only South East Asia pending full coverage. This is except regions/countries which are already regularly submitting HAB event data to HAEDAT (North Atlantic, North Pacific, China etc.).

During second half of 2016 until the end of 2017 focus continued to be on data compilation and upgrades and adjustments to the data systems (HAEDAT as well as the OBIS-HAB data entry template). Additionally, the Editorial Team for the GHRS has developed the outline of the GHRS and chapters are drafted. Regional summaries on HAB based on OBIS, HAEDAT and the literature will constitute a paper in the Elsevier Journal Harmful Algae special issue in 2019.

The planned online tools to create information products have yet to be developed and will focus on creating the products for the GHRS. Currently, a new data portal for HAEDAT is in development (<http://dev.iobis.org/haedat/>). The GHRS is foreseen to be complete by end 2018 and to be launched early 2019.

Theme 2. Adaptive Strategies. Responsible: Michele Burford.

There was nothing to be reported on this theme, which is crosscutting other Themes. The SSC will follow on the content and implementation of this Theme through the other activities.

Theme 3. Toxins. Responsible: Po Teen Lim.

Activity 3.1. A workshop was organized by IOC WESTPAC-HAB at Chulalongkorn University from 25-27 February 2019 to review the status of fish-killing Raphidophytes species in Western Pacific region. A review paper on Raphidophyte species and its impacts in the region is expected from this activity.

Activity 3.2. *In progress.* A fish-killing HABs workshop is planned on summer-fall 2019, funded by GlobalHAB and the Chile government. The activity is coordinated by Leonardo Guzmán in coordination with the IPHAB Task Team on Fish-killing algae. This activity contributes to the implementation of Theme 7 (HABs and Aquaculture).

Activity 3.3. *In progress.* Develop plans for a Workshop and Summer school on analysis and interpretation of genetic data on HABs. The activity is followed by **Po Teen Lim**, who hosted regional workshops/training courses on HABs species and detection for Southeast Asia in year 2017 and 2018 in detection of harmful species using molecular techniques. More details of these activities are available in Harmful Algae News. National and regional workshop will be planned in collaboration with other international and regional agencies interested in HABs.

Theme 4. Nutrients. Responsible: Kedong Yin.

There was nothing to be reported on this theme. **Kedong Yin** and the SSC will follow on the content and implementation of this Theme.

Theme 5. Freshwater HABs and CyanoHABs. Responsible: Chris Gobler and Michele Burford.



Activity 5.1. First draft complete. Manual for water managers on mitigation of cyanobacterial HABs. The goal is an aesthetically appealing, easy to understand document for drinking and recreational water managers on managing cyanobacterial HABs available in print and on web.

- **Outline:**
 - Background on cyanoHABs
 - Risks and standards for drinking water and recreational water
 - Options for mitigating cyanoHABs
 - Watershed management
 - Whole ecosystem management
 - Drinking water treatment
 - Recreational water treatment
- **Materials:** Existing information from peer-reviewed literature and reputable governmental documents
- **Status:**
 - A summary document has been circulated to GlobalHAB steering committee.
 - Document has been outlined and partly written; will be circulated to scientific community as well as managers for review.
- **Support:** GlobalHAB will provide financial support for document design and layout (maybe similar to the GEOHAB policy maker document).

Activity 5.2. In progress: Webinar series on cyanoHABs for water managers, informational, one-hour duration, on cyanoHABs with a focus on management.

- **Topics:**
 - Background on cyanoHABs
 - CyanoHABs ecology
 - Risks and standards for drinking water and recreational water
 - Monitoring techniques, cells and biomass microscopic and molecular methods
 - Monitoring techniques, toxin analysis
 - Mitigating cyanoHABs: Watershed management
 - Mitigating cyanoHABs: In water treatment
 - Mitigating cyanoHABs: Drinking water treatment
 - Webinars could be housed on GlobalHAB YouTube channel with links on GlobalHAB web site
- **Support:** The webinar series needs financial support the set-up logistics.

Activity 5.3. Complete: Global maps of cyanoHABs. Michele, with assistance from a postdoc and Henrik Enevoldsen, had collated and incorporated data on blooms and toxins into the HAEDAT map. Map of key problem cyanobacteria blooms and toxins globally to be placed on GlobalHAB website.

- **Support:** GlobalHAB provided logistical and financial support to gather information for other cyanoHAB maps, to make them, and make them interactive with downloadable data and information. The maps could be added or linked to IOC-UNESCO Taxonomic Reference List of Harmful Microalgae.

Theme 6. BHABs. Responsible: Elisa Berdalet

Activity 6.1. In progress. GlobalHAB is collaborating in the coordination and implementation of the multiagency "IOC - IAEA - FAO - WHO Global Ciguatera Strategy". In particular, GlobalHAB participated in the workshop held during the Monaco's Ocean Week 9-12 April 2018, at the Oceanographic Museum of Monaco. The aims of the Workshop was to identify the main gaps that limit monitoring of BHAB species and their toxins in the most affected areas and define the best approaches to prevent and manage their impacts.

The workshop was structured on three major topics:

- * Methods for Sampling benthic species, and to design an intercomparison experiment involving participants from about 30 countries. Artificial substrates were distributed among the participants to test the method in different habitats.
- * Methods for monitoring toxins, with cost effective and reliable methods in the affected areas
- * Epidemiology studies on BHABs health impacts



Other activities that were planed at the launch of GlobalHAB are expected to be implemented in 2019-2021 period. These include a PCR/qPCR *Gambierdiscus* identification workshop, the 2nd International Conference on *Ostreopsis* Development, and a meeting on BHABs, health and economy in coordination with Themes 10 and 11.

Theme 7. Aquaculture. Responsible: Lincoln Mackenzie.

Activity 7.1. In progress. The GlobalHAB endorsed project *"International Collaborative Study for the Validation of a HILIC-MS/MS Method for Analysis of Paralytic Shellfish Toxins and Tetrodotoxin in Live Bivalve Molluscs"* is in the final stages of report preparation and publication. This marks a very important milestone in the global adoption of instrumental method of analysis of marine biotoxins. The project is jointly led by Dr Andrew Turner (Centre for Environment Fisheries and Aquaculture Science -CEFAS-, Weymouth, United Kingdom) and Dr Tim Harwood (Cawthron Institute, Nelson, New Zealand). Twenty-four labs were involved in the inter-laboratory validation study and there were three independent advisors: Dr Paul McNabb (NZ), Dr Ana Gago Martinez (EURLMB Spain) and Dr Jim Hungerford (FDA USA). Chromatography columns were donated by a private company. The final report is currently being assessed by reviewers and it is expected that a full report on the results of the study will be available on the GlobalHAB web site later in 2019. The validation study will be published in the Journal of Official Analytical Chemists (JAOAC) after which it can be formally accepted as the official standard method for the analysis of paralytic shellfish toxins and tetrodotoxins in New Zealand and other jurisdictions that may wish to adopt this method. It is planned present the results of the validation study (and perhaps hold workshops) at the International Conference on Molluscan Shellfish Safety in Mexico in 2019 and the International Conference on Harmful Algae, also in Mexico in 2020.

Activity 7.2 Completed The GlobalHAB endorsed project *"Assessment of the risk of benthic life stages of toxic dinoflagellates to the Seafood Sector of New Zealand and France"*



Participants in the workshop on morphological and molecular methods for HAB cyst identification at the Cawthron Institute, 12-14 February 2018

This was a two-year project to enable New Zealand scientists to establish a collaborative relationship with French scientists at Ifremer and MARBEC who are experts in HAB cysts. The specific aim of this project was to identify benthic life stages of three high priority toxic dinoflagellate groups, *Alexandrium*, *Azadinium* and *Vulcanodinium*. The project was led by Dr Kirsty Smith (Cawthron Institute, Nelson New Zealand) and Dr Kenneth Mertens Ifremer, Concarneau, France)

Cysts were isolated from sediments around New Zealand and France. Cyst morphology, molecular genetic composition and toxicity were determined. By identifying and establishing the abundance of benthic cysts beds predictions of the risk of harmful blooms that impact on aquaculture can be made.

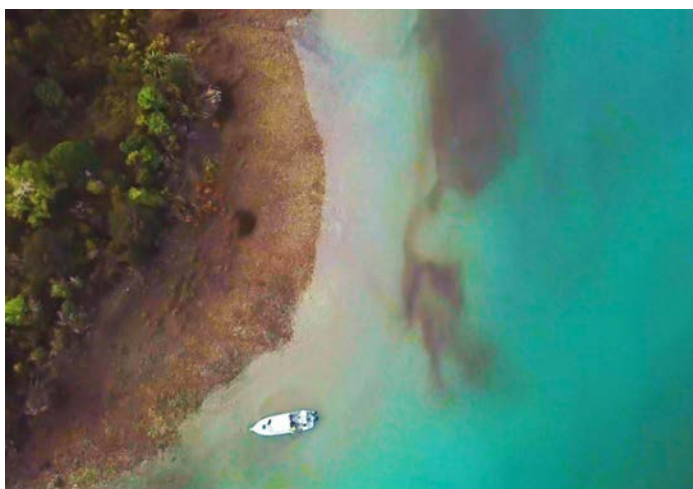
A workshop led by Drs Mertens and Smith, was held in New Zealand (12-14 February 2018) to demonstrate morphological and novel molecular methods for cyst identification and provided training for those involved with monitoring programmes.

A follow-up workshop led by Dr Mertens (Morphological and molecular identification of micro-algae) coincided with ICHA 2018 in Nantes (France; 21-26 October 2018) to enable the transfer of expertise and uptake of these methods internationally.

Activity 7.3 In progress “Innovative technologies for the early detection of Harmful Algal Bloom threats”

This project is led by Dr Lincoln MacKenzie Cawthron n Institute, New Zealand. Other participants include: Drs Kirsty Smith and Jonathan Banks (Cawthron), Dr Raphael Kudela (University of California Santa Cruz, USA), Mr Mark Vanasten (Diagnostic Technologies, Australia), and Dr Jason Acker (Diagnostic Systems Inc. Edmonton, Canada).

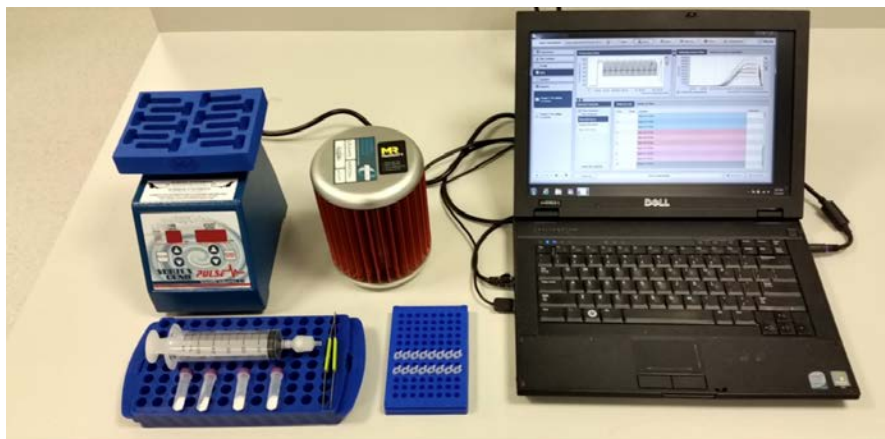
The project aims to apply innovative technologies for detecting harmful phytoplankton species in near real time, thereby enabling rapid response of the aquaculture industry and other stakeholders to the onset of HABs and where possible mitigate their impacts.



Drone footage of a ‘red-tide’ of *Alexandrium pacificum* in the Marlborough Sounds, New Zealand.

Specifically, the project involves field and laboratory trials of three complementary technologies: the HydrogelTM qPCR assay, the DinoDTec Saxitoxin gene qPCR assay and the Imaging FlowCytoBot (IFCB) instrument for the detection and monitoring of harmful planktonic micro-algae. This project is applied research aimed at improving the effectiveness, and lowering the cost, of current harmful algae monitoring methods for aquaculture.

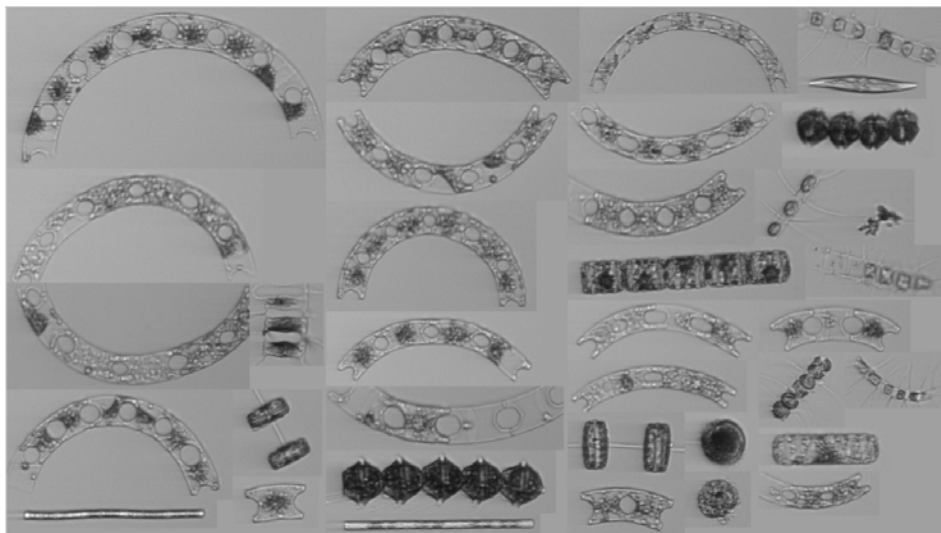
The Hydrogel™ assay is a field deployable qPCR assay developed by Aquila Diagnostic Systems, that can provide a fast and effective screening tool competitive with the current microscopy methods for



detecting problem algae species. The assay is sensitive, simple and robust and able to be carried out in a basic laboratory at sea or in an on-shore sea-food processing facility.

Portable equipment required for DNA extraction and the Hydrogel qPCR assay of seawater samples

The research involves the transfer of developed qPCR assays to the Hydrogel™ format targeting HAB species most important to the aquaculture industry in New Zealand. The assays specifically target DNA sequences unique to the ichthyotoxic species *Pseudochattonella verruculosa*, *Heterosigma akashiwo* and *Karenia brevisulcata*, and the paralytic shellfish toxin producers *Alexandrium pacificum* and *A. minutum*. Parallel trials of the commercially available DinoTec STX gene assay are being carried out alongside the Hydrogel™ assay when screening for toxic *Alexandrium* spp.



IFCB *in situ* imaging of phytoplankton showing two chain forming *Alexandrium* species (*A. pacificum* and *A. fraterculus*) in the assemblage.

The Imaging FlowCytobot (IFCB) is an-autonomous submersible, *in situ* imaging flow cytometer, manufactured by McLane Labs, USA (<http://mclanelabs.com/imaging-flowcytobot/>). It combines flow cytometry and video technology to capture images of individual cells. After training the software, the images can be automatically classified to provide, identification, abundance and bio-volume estimates. Through a collaboration with Dr Raphael Kudela the instrument is being evaluated for the detection and quantification of HAB species in aquaculture regions in New Zealand. The IFCB is currently being deployed from various aquaculture installations (e.g. salmon farms) and on monitoring vessels and its capabilities demonstrated the aquaculture industry.

Theme 8. Comparative ecosystems. Responsible: Bengt Karlson.

Activity 8.1. The IOC Trends PO activity is related to this Theme 8 and it is also linked to Theme 1. Comparative work on different environments and harmful events has also been conducted by PICES and NOAA. As part of the TrendsPO meeting (12-16 November 2018), there was a discussion about linking GlobalHAB and TrendsPO to analyse occurrence of HABs in response to climate change and global change. This was endorsed by TrendsPO, and efforts are underway to conduct a comparative analysis across multiple ecosystems of trends in HAB organisms. Following from this analysis would be exploration of the underlying drivers (i.e. if a trend exists, is it clearly linked to climate change?).

Theme 9. Observation, Modelling and Prediction. Cross cutting activities. Responsible: Raphael Kudela.

Activity 9.1. In progress. As already initiated within GEOHAB (lead by Grant Pitcher and Raphe Kudela) GlobalHAB included fostering research on the potential links between ocean deoxygenation and HABs through interaction with IOC GO2NE (Global Ocean Oxygen Network, <http://www.unesco.org/new/en/natural-sciences/ioc-oceans/sections-and-programmes/ocean-sciences/global-ocean-oxygen-network/>). A joint GO2NE - GlobalHAB workshop is being organized to identify potential research on this topic in 2019, to be held in Paris immediately prior to the next GO2NE workshop, 11-12 June 2019.

Activity 9.2. In progress. GOOS Panel on Biology and Ecosystems. – The Essential Ocean Variable (EOV) for Phytoplankton Biomass and Diversity is [online](#) and it includes HABs. The information has been summarized in the paper "Essential ocean variables for global sustained observations of biodiversity and ecosystem changes", by Miloslawick et al. (2018), Global Change Biology, DOI: 10.1111/gcb.14108, coauthored by **Raphe Kudela**. A workshop was conducted in June 2018 to begin implementing the EOV for phytoplankton and zooplankton measuring everything as recommended in the EOV, including the HAB component (genus and species information), perhaps on a GO-SHIP cruise. GOOS and GlobalHAB members have also submitted several white papers to OceanObs19 (Hawaii, USA, 2019) describing the need and capabilities for regional and global HAB and plankton observation.

Activity 9.3. **Raphe Kudela** participated in the [Alliance for Coastal Technologies](#) workshop in Jan 2017 on detection of HABs (see [report](#)). A second workshop and technology demonstration on toxin detection will be conducted soon. This organization is supported by U.S. companies, but is open to any vendor. There are a series of field sites, including Monterey, Lake Erie, and Long Island. Data from the technology demonstrations are currently being collated and will be made available as an ACT report.

Activity 9.4. Summer 2020. Symposium on automated in situ observations of plankton.

In recent years novel in situ instrumentation has been developed for automated high frequency HAB detection in near real time. Also instruments for observing grazers, e.g. microzooplankton and multicellular zooplankton are becoming available commercially. These instruments are now being adopted in research and also in monitoring programmes. The aim of the mini-symposium is to bring together experts on, and users of, in automated in situ imaging systems, novel sampling equipment etc. to present methods, recent results and to share experiences. Another aim is to carry out a comparison of results when analysing plankton communities quantitatively. Young scientists is one target group of the symposium. After the main symposium a young scientist's data workshop for data processing and report/article writing is planned. The symposium is planned on summer 2020, pending the results of several applications for funds, besides some potential support from GlobalHAB.

Theme 10. Health. Responsible: Elisa Berdalet

Activity 10.1. April 2018. Participation in the implementation of the coordinated IOC-IAEA-FAO-WHO "Global Ciguatera Strategy" and in particular in the Regional Workshop on Monitoring and Management Strategies for Benthic HABs, Monaco, 9-12 April, 2018. This activity corresponds to Activity 6.1, here focused in the health aspects. **E. Berdalet** contributed to the organization of the questionnaires designed to better assess the existing capacity in benthic HABs management in relation to human poisonings surveillance programs, regulations, outreach campaigns, investigation procedures in case of epidemics, etc. The objective was, through relevant case studies, to discuss, during the workshop, about current programs, good practices, but also identify gaps, needs and propose adapted solutions. The workshop was aimed to provide guidance for improved mitigation of HAB health effects on ciguatera and prevention of respiratory impacts related to *Ostreopsis* blooms. Accommodation of E. Berdalet was funded by Accord RAMOGE that co-sponsored the workshop with IAEA that covered invitation of ca. 30 participants, logistics, etc.

Activity 10.2. March 2018 to October 2019. **E. Berdalet** represented GlobalHAB at the CLEFSA workshop: Emerging threats on human health in Europe due to climate change. CLEFSA is a project of the European Food Safety Agency (EFSA) that explores the risks of food intoxication in future climate change scenarios. CLEFSA included aquatic biotoxins in the European landscape. The event was held in Parma at the EFSA headquarters in March 2018. E. Berdalet is collaborating in the elaboration of Reports and documents through online communication and particular meetings.



Activity 10.3, April 2018. **Elisa Berdalet** was invited as External Expert in the SOPHIE project, a Coordination and Support Action (CSA) of the European Commission aimed to develop a programme on Oceans and Human Health in Europe. Elisa represents GlobalHAB and the HABs and Health Theme. A first workshop was held in Dublin, April 24-25, 2018, funded by SOPHIE.

Theme 11. Economy. Responsible: Vera Trainer and Keith Davidson.

As an Introduction to the Theme, **Vera Trainer** reviewed U.S. National HAB activities to estimate the economic cost of HABs and the existence of some fundamental problems with such a national estimate based on minimal data.

Activity 11.1. An international workshop, “Evaluating, reducing and mitigating the cost of harmful algal blooms: a compendium of case studies”, which will be held in Victoria, British Columbia, Canada from October 17-19, 2019 as part of the Annual Meeting of the North Pacific Marine Science Organization (PICES). The workshop co-convenors are Drs Vera Trainer (USA), Keith Davidson (UK) and Kazumi Wakita (Japan) and it is jointly sponsored by GlobalHAB (SCOR and IOC), PICES, NOWPAP, ISSHA, NOAA, FAO and private companies. The goal of the 2.5-day workshop is to bring together international experts in economics, social sciences, and the study of harmful algal blooms (HABs) to develop a compendium of case studies to guide future research on the economic and social costs of HABs. The intent is that this compendium will identify priorities and unify methods for future collaborative assessments of HAB impacts. More information can be found at <https://meetings.pices.int/meetings/annual/2019/PICES/Program>

Theme 12. Climate Change. Responsible: Neil Banas.

Activity 12.1. Special issue on the journal Harmful Algae focused on "Climate Change and HABs". The editors of the special issue, Chris Gobler and Mark Wells have solicited 14 articles. Papers were submitted in summer 2018 and are under revision; papers in bold are in press as of April 2019. GlobalHAB will support some open access. The main key messages from the special issue will be used to elaborate a Scientific Summary for Policy Makers (SSPM) on HABs and Climate Change. The SSPM could be linked to the two IPCC 1.5C special reports that are coming out this year and next year.

1. The Future of HAB Science: Directions and Challenges. *HAB-Climate Change Symposium Organizers and Breakout Discussion Leads.*
2. Projected Latitudinal Changes in Environmental Conditions Influencing HABs. *Fei Chai, Enrique Curchitser, Phil Boyd et al.*
3. Modelling HABs in a changing climate. *Kevin Flynn, Inga Hense, Neil Banas, Dennis McGillicuddy, Stephanie Dutkiewicz.*
4. **Dynamic CO₂ and pH levels in coastal, estuarine, and inland waters: theoretical and observed effects on harmful algal blooms.** *John Raven, Chris Gobler, Per Juel Hansen.*
5. **Progress and promise of omics for predicting the impacts of climate change on harmful algal blooms.** *Gwenn Hennon, Sonya Dhyrman.*
6. **Advancing the research agenda for improving understanding of cyanobacteria in a future of global change.** *M.A. Burford, C.C. Carey, D.P. Hamilton, J. Huisman, H.W., Paerl, S.A. Wood, A. Wulff.*

7. Pelagic harmful algal blooms and climate change: lessons from nature experiments with extremes. *Vera L. Trainer, Stephanie K. Moore, Gustaaf Hallegraeff, Raphael M. Kudela, Alejandro Clement, Jorge Mardones.*

8. Climate change and benthic harmful algae. *Pat Tester, Elisa Berdalet, Wayne Litaker.*

9. Fish-killing HAB and Climate change. *Charles Trick, Gustaaf Hallegraeff, Alan Cembella.*

10. High biomass HAB and Climate change. *Bill Sunda, Grant Pitcher, Chris Gobler.*

11. Future observing systems. *Bengt Karlson, Raphe Kudela, Stewart Bernard*

12. HABs: a climate change co-stressor in marine and freshwater ecosystems. *Andrew Griffith, Chris Gobler*

13. Zooplankton grazing and HABs. *Hans Dam, Susan Menden-Deuer, Diane Stoeker, Matt Johnson.*

14. Harmful algae at the complex nexus of eutrophication and climate change. *Pat Glibert.*

Activity 12.2. Best-practices Manual. Information from Marina Montresor.

The editorial team, constituted by Mark Wells (chair), Michele Burford, Anke Kremp, Marina Montresor, Grant Pitcher and Gires Usup met at the Stazione Zoologica di Napoli (Feb 26th - Mar 1, 2018) to work on the "Best Practice Guidelines for the Study of HABs and Climate Change". The outline of the chapters was defined and the guideline for the authors was prepared.

The initiative of the Best Practices Manual for HAB and Climate Change is in line with the activities of SCOR WG149 that is focusing on Changing Ocean Biological Systems (COBS) and particularly on "How will biota respond to a changing ocean?" (<https://scor149-ocean.com/>)



The editorial board of the "Best Practice Guidelines for the Study of HABs and Climate Change" in their meeting at the Stazione Zoologica Anton Dohrn.

The tentative deadline for the submission of the draft chapters was the month of May 2019. The Manual includes the following chapters:

Overview (Editorial Board)

Chapter 1 - Rationale and Introduction (Editorial Board)

Chapter 2 - Observing changes in HABs over time — Long Term Observations (Richardson AJ, Eriksen R, Hallegraeff GM, Rochester W, Pitcher G, Burford M)

Chapter 3 - Understanding Responses of HAB Species to climate change through experimentation

A) General Recommendations (Michelle)

B) Culture Experiments (van der Waal D, Kremp A)

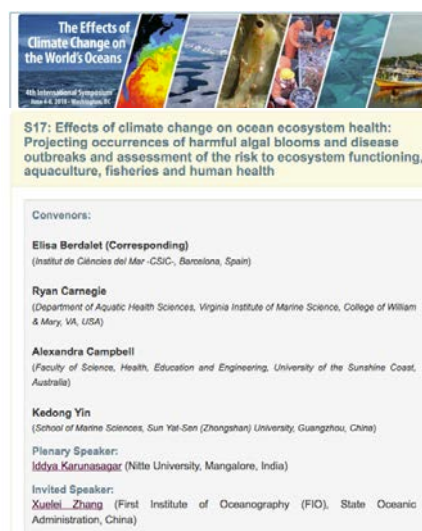
C) Acclimation and Adaptation (Dyhrman S, Godhe A, Hennon G, Seftom J)

D) Toxin Measurements (McCarron P, Deeds J)

Chapter 4 - Databases (Zingone A, O'Brien T, Enevoldsen H, Provoost P, Lorenzoni L, Yin K, Bresnan E, Richardson A, Kruck A, Hallegraeff G)

Chapter 5 - HAB modelling and forecasting chapter (Hense I)

Activity 12.3. June 2018. Symposium on Effects of Climate Change on Worlds Ocean. A session on HABs chaired by E. Berdalet and K. Yin was organized in this symposium: S17. Effects of climate change on ocean ecosystem health: Projecting occurrences of harmful algal blooms and disease outbreaks and assessment of the risk to ecosystem functioning, aquaculture, fisheries and human health (<https://meetings.pices.int/meetings/international/2018/climate-change/program#S1>). Raphe Kudela, Eileen Bresnan and Elisa Berdalet presented three oral communications and participated in the joint discussion of the session. GlobalHAB and IOC/UNESCO provided funds to cover the representation of GlobalHAB at the event.



Activity 12.4: Future activity, in progress. **Neil Banas** presented some possible workshops:

Planning is underway for a workshop on “Modelling and prediction of harmful algal blooms, from event response to multi-decadal projections” to be held in Glasgow, UK in May 2020. The organising committee consists of Neil Banas, David McKee, Bingzhang Chen, Paul Udom (University of Strathclyde), Bengt Karlson (Swedish Meteorological and Hydrological Institute), Keith Davidson, Dmitri Aleynik (Scottish Association of Marine Science) Clarissa Anderson (Scripps / SCCOOS),

Dennis McGillicuddy (Woods Hole Oceanographic Institution), Beatrix Siemering (Marine Institute, Galway), Marina Levy (CNRS) and is also coordinating with Katja Fennel and Marion Gehlen, chairs of the Marine Ecosystem Analysis and Prediction Task Team (MEAP-TT) of the GODAE OceanView programme.

Funding is likely to be from a mix of Scottish, European, US, French, and other sources. The hope is to secure enough funds to invite a substantial number of early-career and developing-world scientists. A programme of summer-school-like tutorials will be woven into conference-style presentations and discussions. The draft programme is organised into four parts:

- Exploring the diversity of HAB modelling approaches
- Emerging technologies and platforms to support HAB monitoring
- Linking models, observations, and stakeholder needs
- Scaling up: the global impact of global change on HABs

New Theme: *Sargassum* Blooms

The GlobalHAB Science and Implementation Plan noted that new emerging HAB related issues could be incorporated to the program after its launch. This was the case of the blooms of green macroalgae and *Sargassum*. **Elisa Berdalet** and **Henrik Enevoldsen** have been in touch with several researchers about this topic since 2016. GlobalHAB SSC will work during the coming months to progress in the organization of this theme.

IV. Presentation of GlobalHAB at different national and international events

Information about the program has been provided at:

* ICHA2018, Nantes, October 2018 - E. Berdalet, N. Banas, E. Bresnan, M. Burford, K. Davidson, C. Gobler, B. Karlson, R. Kudela, P. T. Lim, L. Mackenzie, M. Montresor, V. Trainer, G. Usup, K. Yin, H. Enevoldsen, E. Urban. *GlobalHAB (IOC-UNESCO and SCOR): International coordination for sound knowledge of HABs to manage their impacts.*

* ICHA2018, Nantes, October 2018 - L. Mackenzie, J. Banks, K. Smith. *Application of gel-formatted qPCR assays for rapid diagnosis of shellfish toxin producing and fish-killing micro-algae in seawater.* Communication of the GlobalHAB endorsed projects of the authors.

* The Effects of Climate Change on the World's Oceans, 4th International Symposium, Washington, DC, US, June 2018 - Raphael Kudela, E. Berdalet, C. Gobler, B. Karlson, N. Banas, E. Bresnan, M. Burford, K. Davidson, Po Teen Lim, L. Mackenzie, M. Montresor, V. Trainer, G. Usup, K. Yin, H. Enevoldsen and Ed Urban. *GlobalHAB: International coordination to ascertain the effects of Climate Change on the occurrence of Harmful Algal Blooms*

* Regional Workshop on Monitoring and Management Strategies for Benthic HABs, Monaco, April 2018 - E. Berdalet, H. Enevoldsen and the GlobalHAB SSC. *The IOC-UNESCO and SCOR programme GlobalHAB: International coordination to advance in the understanding and management of benthic harmful algal blooms impacts.*

* Global Ocean Observing System Bio/Eco Panel Meeting. St Peter's Beach, FL, USA, October 2018 - R.M. Kudela. *An update on development and implementation of the Phytoplankton EOY.*

* PICES2018, Yokohama, Japan October 2018 - V.L. Trainer *Progress of GlobalHAB including Best Practices Manual. PICES Annual Meeting, HAB Section report,*
<https://meetings.pices.int/publications/annual-reports/2018/2018-S-HAB.pdf>

* UN DOALAS, Multi-Stakeholder Dialogue and Capacity-Building Partnership Event, New York, January 24-25, 2019. Kedong Yin was invited to give the presentation *Science-Driven Management Decision Making in Formulating Sewage Treatment Strategy.*

* UN DOALAS, Regular Process For The Global Reporting and Assessment of the State of the Marine Environment, Including Socioeconomic Aspects. Kedong Yin also participates in writing *Chapter 10. Changes in inputs to the marine environment of nutrients.*

*** A brochure was produced on October 2018 and distributed at the ICHA2018 and at the *Marine Environmental Science Symposium (XMAS IV)* 6-9 Jan 2019, in the HABs session convened by Po Teen Lim and colleagues from Xiamen, China.**

The international community is invited to participate in the GlobalHAB program, through seeking endorsement of relevant research, monitoring, and modelling activities as well as by proposing and taking initiatives for integrating science workshops, publications and capacity building.

<http://www.globalhab.info/about-us/get-involved>






Goal

To improve the understanding and prediction of HABs in aquatic ecosystems, and management and mitigation of their impacts.

Mission

- To foster international coordination and cooperative research to address the scientific and societal challenges of HABs, including the environment, human health, and economic impacts, in a rapidly changing world.
- To serve as a liaison between the scientific community, stakeholders, and policy makers, informing science-based decision making.

GlobalHAB
An international program sponsored jointly by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO




An international science program on HABs building on the foundations of GEOHAB

GlobalHAB Endorsed Workshops & Projects


<http://www.globalhab.info/about-us/globalhab-endorsed-projects>

This list will be enhanced with your participation in GlobalHAB!

- EukRef: The 18S Annotation Initiative, 3rd Workshop, November 5-9, 2018
- International Collaborative Study for the Validation of a HILIC-MS/MS Method for Analysis of Paralytic Shellfish Toxins and Tetrodotoxin in Live Molluscs
- Effects of climate changes on harmful algal and cyanobacterial blooms along the South Atlantic Ocean
- Predicting Risk and Impact of Harmful Events on the Aquaculture Sector (PRIMROSE)
- Source and fate of ciguatera fish poisoning-toxins and its implication on coral reef ecosystem health and seafood safety. Training courses and Workshop
- AZTI - EEA Academy Summer School 2019: Does Human health and Wellbeing depend on a Healthy Ocean?
- Assessment of Risk of Benthic Life Stages of Toxic Dinoflagellates to the Seafood Sectors of New Zealand and France (CystRisk)
- Co-development of Climate services for adaptation to changing Marine Ecosystems (CoCIME)
- Innovative technologies for the early detection of Harmful Algal Bloom threats

GlobalHAB

Science and Implementation Plan 2018
<http://www.globalhab.info/files/Science-and-implementation-plan-final5.pdf>



The themes integrated in GlobalHAB range from cellular to ecosystem- and climate-based processes. GlobalHAB's perspective is multidisciplinary, integrating physics, chemistry, and biology and addressing the impacts of HABs on the environment and humans. Terms shown in *italics* are not established as individual GlobalHAB themes, but are intrinsically integrated into HAB research.

Coordination with International and Regional Programs on HABs, such as

- ISSHA, ICES, PICES, IAEA, CIESM, POGO, WHO, FAO, IWC, IOC-IPHAS, IOC Regional Groups, SCOR Working Groups
- GOOS Bio/Eco - HABs are a major component of the Phytoplankton EOY
- IOC-NOAA-FAO-WHO to implement the Global Ciguatera Strategy
- OceanObs19 - GlobalHAB will foster HAB multidisciplinary and innovative observation systems

Opportunities & Outcomes

- GEOHAB final product: Oceanography special issue (2017)
- Harmful Algae special issue "Harmful Algae and Climate Change" (2019)
M. Wells & C. Gobler, Editors
- Global Harmful Blooms Status Report
- "Best Practice Guidelines for the Study of HABs and Climate Change" (2019)
M. Wells, M. Burford, A. Kremp, M. Montresor, G. Pinhou, G. Uspu, Editors
- GlobalHAB participates as External Advisor in the EU H2020 SOPHIE project aimed at Linking Oceans and Human Health (2018-2020)
- Workshop on the economic impacts of HABs coordinated with PICES (2019)
- A Webinar series on cyanobacterial HABs for water managers and maps of cyanobacterial species occurrence
- Open Science Meeting on HABs and deoxygenation in coordination with IOC-GO2NE
- Open Science Meetings, Workshops and Summer Schools focused on HAB related topics

Acronyms

- HAB: Harmful Algal Bloom
- EOV: Essential Ocean Variable
- GO2NE: Global Ocean Oxygen Network
- PICES: North Pacific Marine Science Organization

V. September 3-7, 2018. Presentation of the GlobalHAB program at the SCOR Annual General Meeting in Plymouth, UK

Elisa Berdalet attended this meeting and acknowledged financial and logistic support from SCOR. In this meeting, a printed version of the completed *Science and Implementation Plan of GlobalHAB* was delivered, along with other GlobalHAB and GEOHAB products (i.e. the special issue in *Oceanography* and the book, section VI). The overall programme was very well received by the attendants at the SCOR Annual Meeting.

VI. Funding considerations/future funding plans/Donors

The scientific meetings of the SSC have been funded by IOC/UNESCO and SCOR (with funding from the U.S. National Science Foundation), and by in-kind contributions from ICES, PICES and IPHAB. Additional funds have been received from other institutions to conduct the specific activities as indicated previously.

VII. Follow up on GEOHAB Synthesis Products

At the official end of GEOHAB, some synthesis products were still in progress and GlobalHAB has taken responsibility to see them completed. These products include the following:

VII.1. A monograph on the application of Ocean Colour satellite techniques for the study of HABs.

It is planned for publication in the *IOCCG Report* series. This book is the result of the collaboration between GEOHAB and the International Ocean Colour Coordination Group (IOCCG), with Steward Bernard, Raphael Kudela and Grant Picher as editors. The document is been structured around several representative case studies of HABs.

VII.2. Book published by Elsevier, under their Ecological Studies series.

Editors: Pat Glibert, Elisa Berdalet, Michele Burford, Grant Pitcher and Mingjiang Zhou.

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ISSN 0070-8356

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