IPHAB TASK TEAM ON FISH-KILLING MICROALGAE AND ECOSYSTEM EFFECTS

IPHAB XVII Status Report and Links to UN Ocean Decade Initiatives

Decision IPHAB-XV.7 at IPHAB-XVI, at FAO, Rome endorsed continuation as the Task Team on Fish Killing Microalgae and Ecosystem Effects (FKMEE)

Co-chairs: A. Cembella (Germany) and K. Wakita (IOC/WESTPAC-HAB), with members L. Guzmán (Chile), P. Hess (France), B. Karlson (Sweden), P.T. Lim (Malaysia, GlobalHAB-SSC), C. McKenzie (Canada), L.-J. Naustvoll (Norway), M. Wells (PICES), and A. Yñiguez (Philippines)

The Task Team is supplemented by international advisors and experts: E. García-Mendoza (Mexico), G. Hallegraeff (Australia), H. Hégaret (France), M. Iwataki (Japan) and J. Mardones (Chile)

Fish in freshwater ponds and river basins

Wild fish in coastal ecosytems

Mass mortality of flat-fish by a red tide of *Cochlodinium polykrikoides*

***Salmon farms* (*e.g., in Norway, Scotland, Ireland, New Zealand, Chile, and Atlantic Canada, NE Pacific*)**

Major Themes

Develop an improved understanding of long term changes in fish killing HABs driven by climate and other environmental factors by assembling and analysing time-series of HABs and related events in the global context, in coordination with international organizations (e.g. ICES, PICES, FAO)

Identify central unresolved issues that limit advances in scientific progress in the monitoring and mitigation of fish-killing blooms, and **mechanisms of fish mortalities**, including biotic and anthropogenic stressors, in collaboration with international scientific experts, global research networks (e.g. GlobalHAB) and by convening advanced technical workshops

Foster communication and joint interaction of HAB scientists with participation of the fisheries and aquaculture industry, stakeholders, and members of the general public socioeconomically impacted by fish kill events

Task Team focusses on:

i) ecology, oceanography and bloom dynamics of fish-killing microalgae as they relate to wild fish and aquaculture operations, causing enhanced mortality and morbidity events;

ii) aetiology and specific mechanisms of fish morbidity and mortality;

iii) management and mitigation of fish-killing algal events;

iv) global synthesis of the status of fish-killing blooms leading to conceptual models and scenarios of expected shifts in biogeographical distribution, frequency, diversity and magnitude in response to climate change and anthropogenic stressors in coastal zones

Major intersessional achievements of involving or coordinated by the Task Team in the intersession

- Completed the IOC White Paper on Fish-Killing Marine Algal Blooms
- Updated and annotated HAEDAT/HAIS maps and reviewed of fish-killing HAB events in the ICES and PICES regions
- Completed peer-reviewed manuscripts on fish-killing taxa, biogeography of events, mode of action and toxicity mechanisms and mitigation strategies ("state-of-the-art") for Asia-Pacific, Latin America (focus: Chile), Canada and northern European coastal waters
- Participated in and/or co-organized conference Special Sessions (e.g., ICHA 2023, Hiroshima) and Symposia on ichthyotoxins and fish-killing algae, including workshops and round table discussions with aquaculture and fisheries stakeholders

Task Team Relevant Activities of WESTPAC-HAB

Scientific sessions organized and conducted

WESTPAC HAB Session conducted at ICHA 2023 in Hiroshima, Japan, 5-10 November 2023

Outputs & Outcomes: Emerging issues shared, i.e., new species and its first social damage to fisheries in Hokkaido, Japan reported; Collaborative effort to respond to the incident among national, local government officers and academics and regional cooperation among WESTPAC HAB members shared among WESTAC and international scientists and practitioners.

Regional/National trainings for capacity development organized/conducted

Activity 1: UM and IOCAS Joint seminar on Mitigation of HABs, 16-19 August 2023

Joint Symposium and Seminars on Mitigation of Harmful Algal Blooms (HABs)

We are pleased to announce that experts from the Institute of Oceanology, Chinese Academy of Science (IOCAS), Prof. Zhiming Yu and his research team will be in Malaysia as part of the effort to strengthen research collaboration among HAB researchers in the region.

A joint symposium and two seminars will be organized during the visit.

The joint symposium between IOCAS and IOES will be held in Bachok Marine Research Station (BMRS), the Institute of Ocean and Earth Sciences, University of Malaya, Bachok, Kelantan.

Tentative program for **Joint Symposium**:
Venue: BMRS Seminar Room, BMRS, IOES, UM, Bachok, Kelantan
Date: 16th August 2023
Time: 1000 - 1700

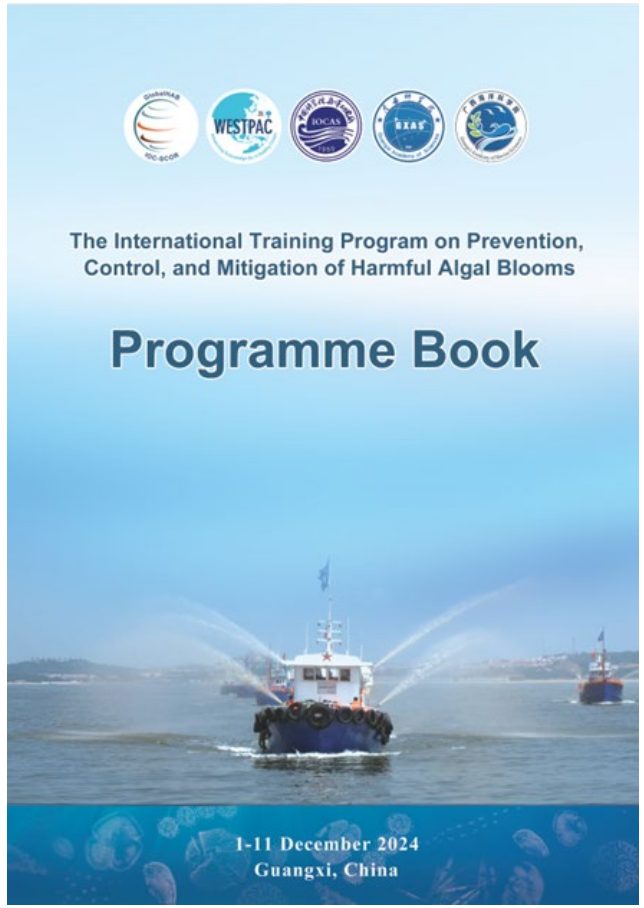
The in-person seminar will be held in the Institute of Ocean and Earth Sciences (IOES), University of Malaya, Kuala Lumpur, and followed by an online webinar jointly organized with WESTPAC HAB program. The seat is limited for the in-person meeting at IOES, UM.

Tentative program for **in-person seminar**:
Venue: Anggerik Meeting Room, Institute of Advanced Studies Building (IAS Building), UM, Kuala Lumpur
Date: 18th August 2023
Time: 1430 - 1730

Tentative program for **webinar**:
Venue: MS TEAMs
Date: 19th August 2023
Time: 1430 - 1630

Prof Yu and his team will share their success story using modified clays to mitigate the occurrence of algal blooms in China. A dialogue session will be arranged with stakeholders from aquacultures industries and relevant authorities at the end of the

Activity: The international training program on prevention, control, and mitigation of Harmful Algal Blooms December 1-11, 2024; Guangxi, China



Advisory Committee

Donald Anderson

Professor, former Chairman of Ad Hoc Group of Experts on HABs, IOC

Aileen Tan Shau Hwai

Professor, Vice Chairman of UNESCO-IOC-WestPAC

Pichai Sonchaeng

Professor of Burapha University, Former Vice Minister, Office of the Prime Minister, Government of Thailand

Eduardo Yong Motta

Chair of CEDECIPEC, Former Minister of the Health Ministry of Peru

Keith Davidson

Professor and Vice President of Scottish Association for Marine Science

Delu Pan

Academician, Second Institute of Oceanography, MNR

Xingwei Jiang

Academician, National Satellite Ocean Application Service

Si Zhang

Academician, South China Sea Institute of Oceanology, CAS

Yuzao Qi

Professor, Jinan University

Mingjiang Zhou

Professor, Institute of Oceanology, CAS

International Steering Committee

Prof. Zhiming Yu (Chair)

Institute of Oceanology, CAS

Prof. Lim Po Teen (Co-Chair)

Vice President, International Society for the Study of Harmful Algae (ISSHA)

Prof. Mark Wells

The University of Maine/Member of PICES Marine Environmental Quality Section-Harmful Algal Blooms

Prof. Kazumi Wakita

Tokai University /IOC-WestPAC HAB

Prof. Aletta Yniguez

University of the Philippines/IOC-WestPAC HAB

Prof. Nguyen Ngoc Lam

Institute of Oceanography, Vietnam Academy of Sciences/ IPHAB

Prof. Zainal Arifin

National Research and Innovation Agency(BRIN)

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Jinan University/UNESCO-IOC-GEOHAB

Prof. Aifeng Li

Ocean University of China /UNESCO-IOC-GlobalHAB

Prof. Xiaoyong Shi

Marine Disaster Mitigation Center, MNR

Prof. Haifeng Gu

Second Institute of Oceanography, MNR

Prof. Rencheng Yu

Institute of Oceanology, CAS

Dr. Pengbin Wang

International Union for Conservation of Nature

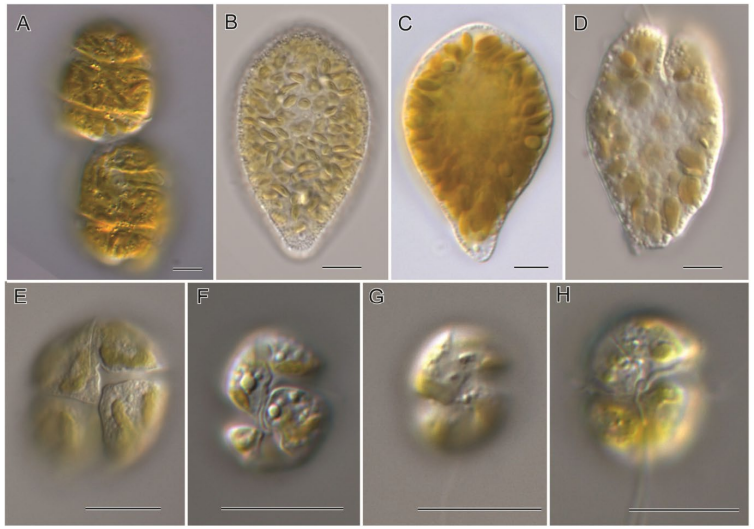


Figure 1. Common harmful fish-killing microalgal species in Southeast Asia. (**A**) *Margalefidinium polykrikoides*; (**B**), *Chattonella marina*; (**C**), *Chattonella subsalsa*; (**D**), *Chattonella malayana*; (**E**), *Karenia mikimotoi*; (**F**), *Karlodinium australe*; (**G**), *Karlodinium veneficum*; (**H**), *Takayama acrotrocha*. Scales, 10 µm.

Table 1. Marine microalgae associated with major fish-kill events in Southeast Asian countries.

Country	Microalgae
Brunei	Dinoflagellates (*Margalefidinium polykrikoides* [32], *Pyrodinium bahamense* [33])
Cambodia	Dinoflagellate (*Noctiluca scintillans* [34])
Indonesia	Dinoflagellates (*Alexandrium affine* [35], *Margalefidinium polykrikoides* [31], *Noctiluca scintillans* [36], *Pyrodinium bahamense* [37]), diatoms (*Chaetoceros* sp. [37], *Skeletonema* sp. [37]), cyanobacteria (*Trichodesmium* spp. [37])
Malaysia	Raphidophytes (*Chattonella malayana* [38], *Chattonella subsalsa* [39]), dinoflagellates (*Karlodinium australe* [21], *Margalefidinium fulvescens* [40], *Margalefidinium polykrikoides* [41], *Noctiluca scintillans* [42]), diatom (*Coscinodiscus* sp. [43])
Singapore	Dinoflagellates (*Karenia mikimotoi* [44], *Karlodinium australe* [44], *Karlodinium veneficum* [44], *Takayama* sp. [44])
Philippines	Raphidophyte (*Chattonella subsalsa* [45]), dinoflagellates (*Alexandrium minutum* [46], *Alexandrium* sp. [47], *Noctiluca scintillans* [48], *Prorocentrum cordatum* [49], *Margalefidinium polykrikoides* [50], *Karenia mikimotoi* [47], *Takayama* sp. [51]), diatoms (*Rhizosolenia* sp. [46], *Skeletonema* sp. [52])
Thailand	Raphidophyte (*Chattonella* sp. [53]), dinoflagellates (*Ceratium furca* [54], *Noctiluca scintillans* [54]), diatom (*Skeletonema* sp. [55]), ciliate (*Mesodinium* sp. [54]), cyanobacteria (*Trichodesmium erythraeum* [56])
Vietnam	Raphidophyte (*Chattonella antiqua* [57,58]), dinoflagellates (*Ceratium furca* [57], *Noctiluca scintillans* [59]), haptophyte (*Phaeocystis globosa* [57,60])

sustainability

MDPI

Review

Fish Kills Related to Harmful Algal Bloom Events in Southeast Asia

Maria Lourdes San Diego-McGlone [1,*], Aletta T. Yñiguez [1], Garry Benico [2], Wai Mun Lum [3], Kieng Soon Hii [4], Sandric Chee Yew Leong [5], Chui Pin Leaw [4], Mitsunori Iwataki [6] and Po Teen Lim [4]

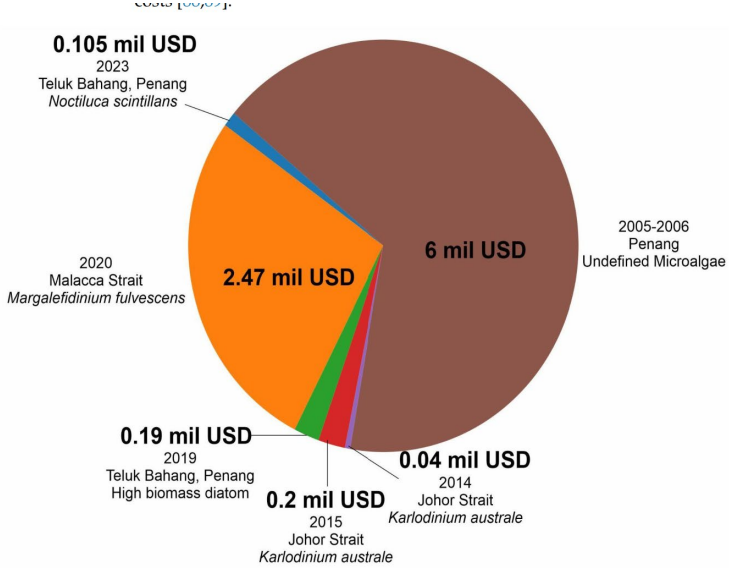


Figure 2. Fish-kill losses due to microalgae with monetary values reported from Malaysia.

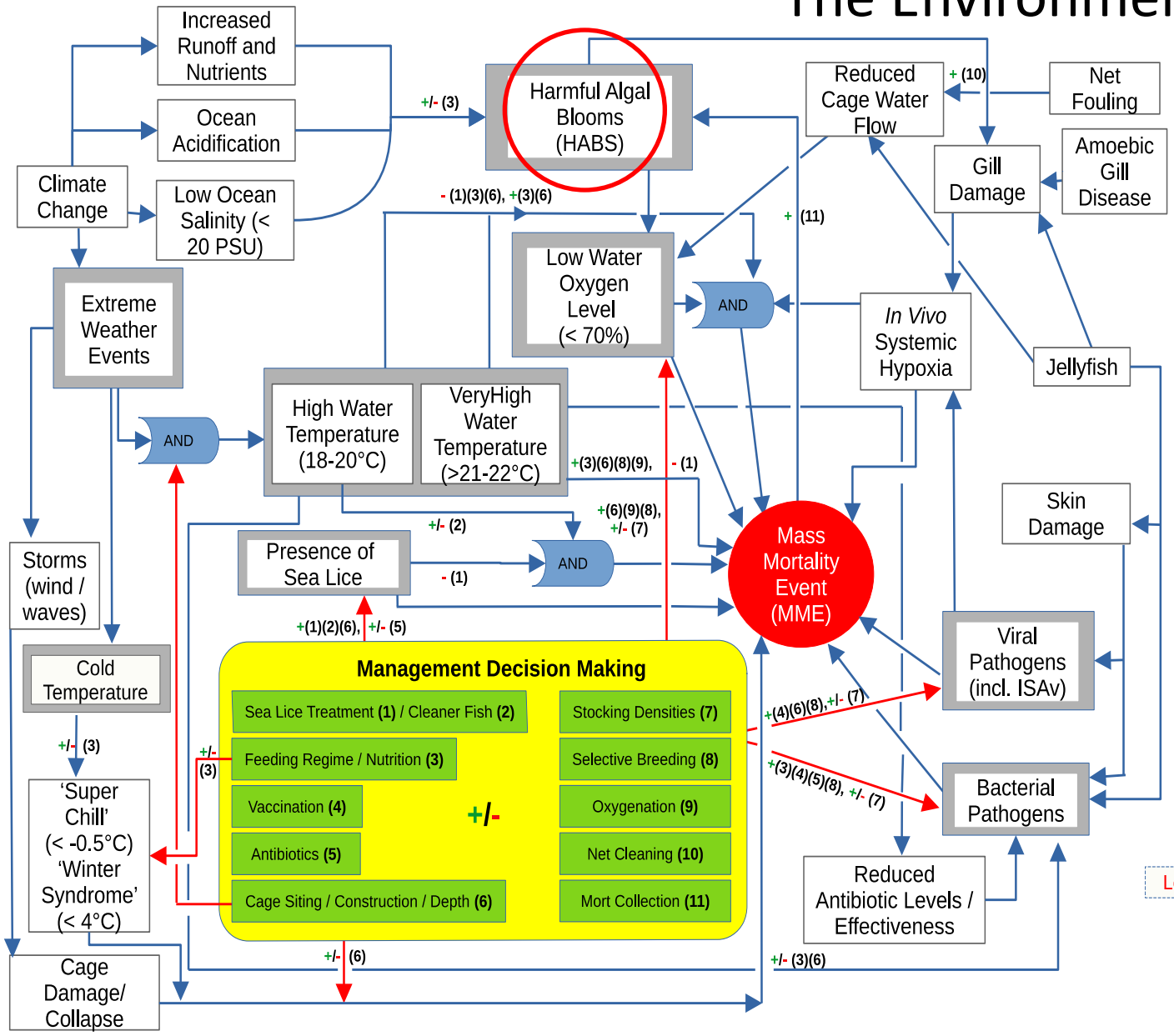
Ocean Hazards to Salmon Aquaculture

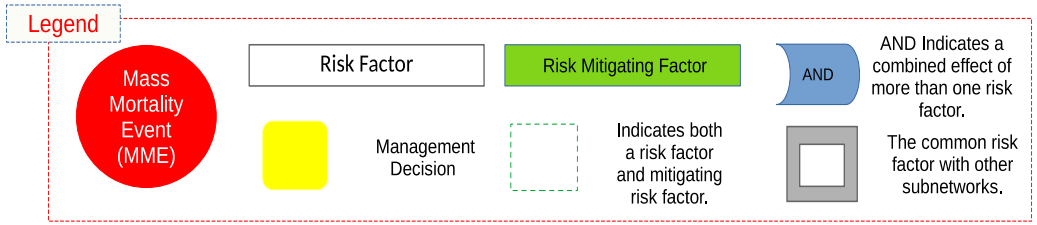
REVIEWS IN Aquaculture

An Aquaculture Risk Model to Understand the Causes and Consequences of Atlantic Salmon Mass Mortality Events (MMEs): a Review

Zaman Sajid*, Kurt Gamperl, Albert Caballero-Solares, Allan Cembella, Barbara Neis, Charles Mather, Christopher C Parrish, Christine Knott, Cory Ochs, Cyr Couturier, Cynthia H. McKenzie, Harry M. Murray, Ian Fleming, Ingunn Marie Holmen, Javier Santander, João F. Romero, Joel Finnis, Jonathan Grant, Lissandra Souto Cavalli, María Andrée López Gómez, Mark Fast, Mark Wells, Matthew Rise, Mohamed Jeebhay, Ramon Filgueira, Sarah Lehnert, Stefanie Colombo, Wenzhao Gao, Gerald Singh

The Environmental Model





McKenzie, C.H., Locke, A., Michaud, S., Peña, M.A., Bates, S.S., Martin, J.L., Poulin, M., Comeau, L., Devred, E., Haigh, N., Howland, K., Moore-Gibbons, C., Perry, R.I., Rochon, A., Scarratt, M.G., Starr, M., and Wells, T. 2025. **Harmful Algal Events in Canadian Marine Ecosystems: Current Status, Impacts, Consequences and Knowledge Gaps.** DFO Can. Sci. Advis. Sec. Res. Doc. 2023/090. v + 85 p.

Aussi disponible en français :
McKenzie, C.H., Locke, A., Michaud, S., Peña, M.A., Bates, S.S., Martin, J.L., Poulin, M., Comeau, L., Devred, E., Haigh, N., Howland, K., Moore-Gibbons, C., Perry, R.I., Rochon, A., Scarratt, M.G., Starr, M., et Wells, T. 2025. **Proliférations d’algues nuisibles dans les écosystèmes marins canadiens : état actuel, effets, conséquences et lacunes dans les connaissances.** Secr. can. des avis sci. du MPO. Doc. de rech. 2023/090. v + 96 p.

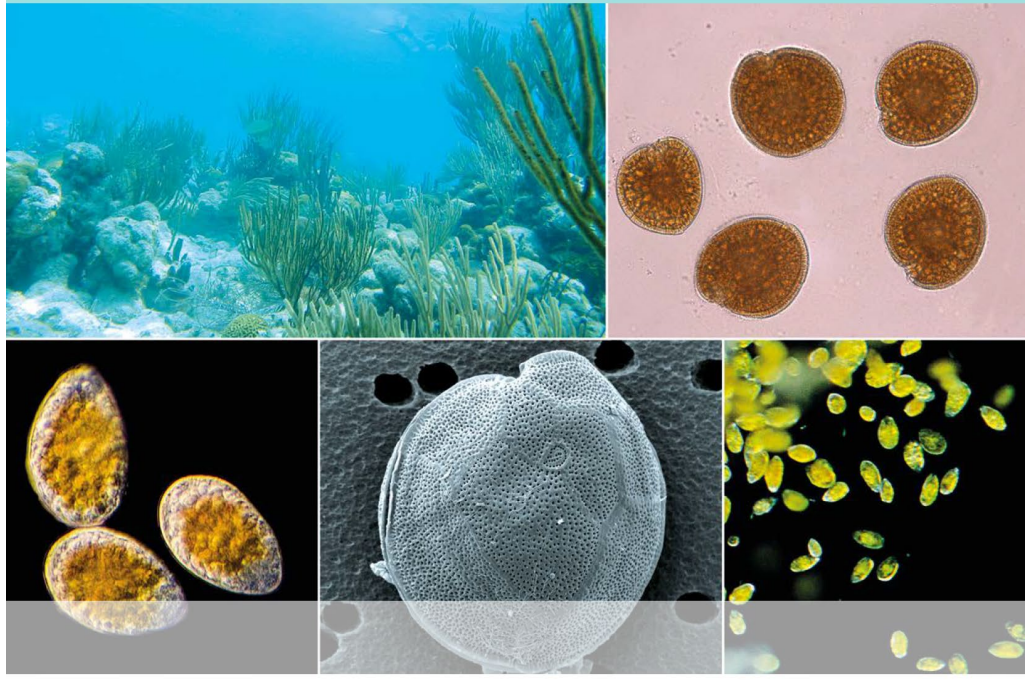
Food and Agriculture Organization of the United Nations

FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER

690

ISSN 2070-6065

Joint FAO-IOC-IAEA technical guidance for the implementation of early warning systems for harmful algal blooms



With the technical support of

unesco Intergovernmental Oceanographic Commission

IAEA International Atomic Energy Agency
Atoms for Peace and Development

5 High biomass blooms causing fish kills and other environmental impacts

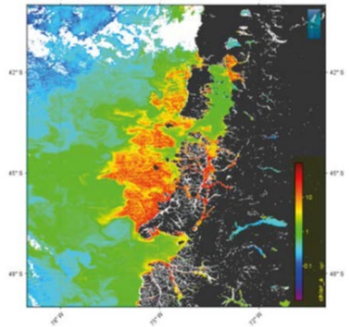
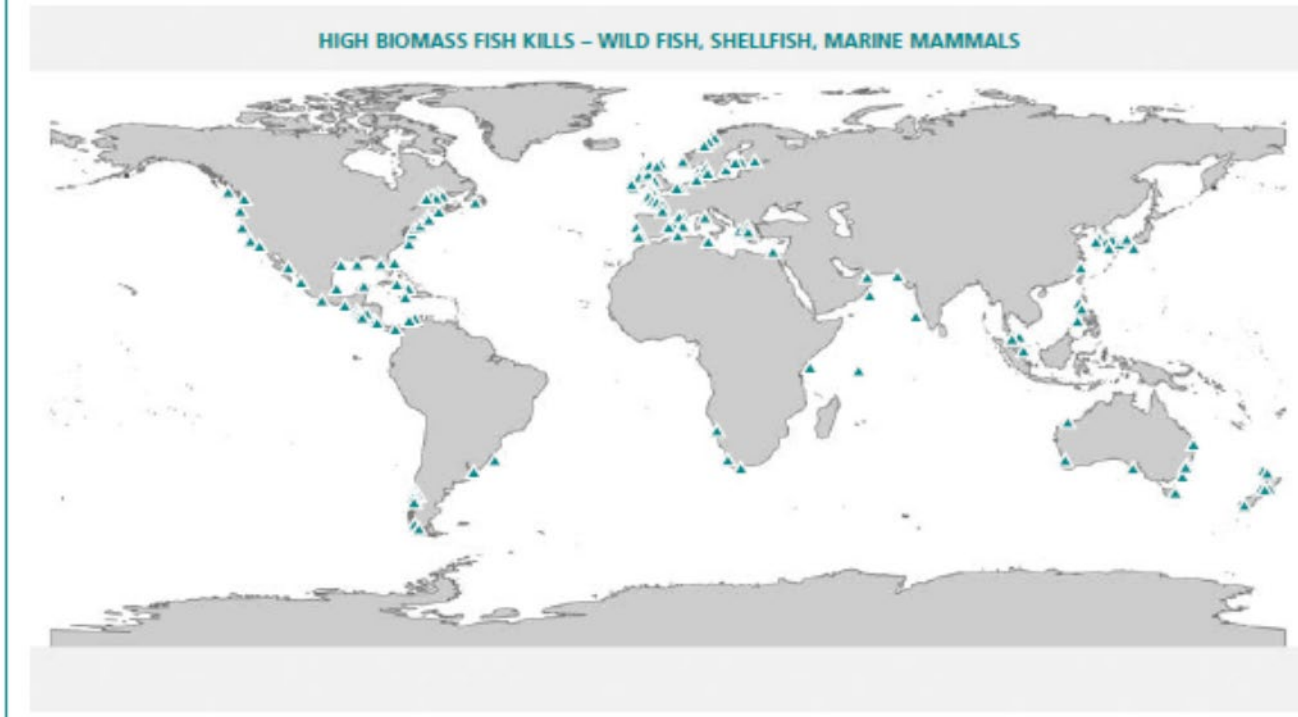


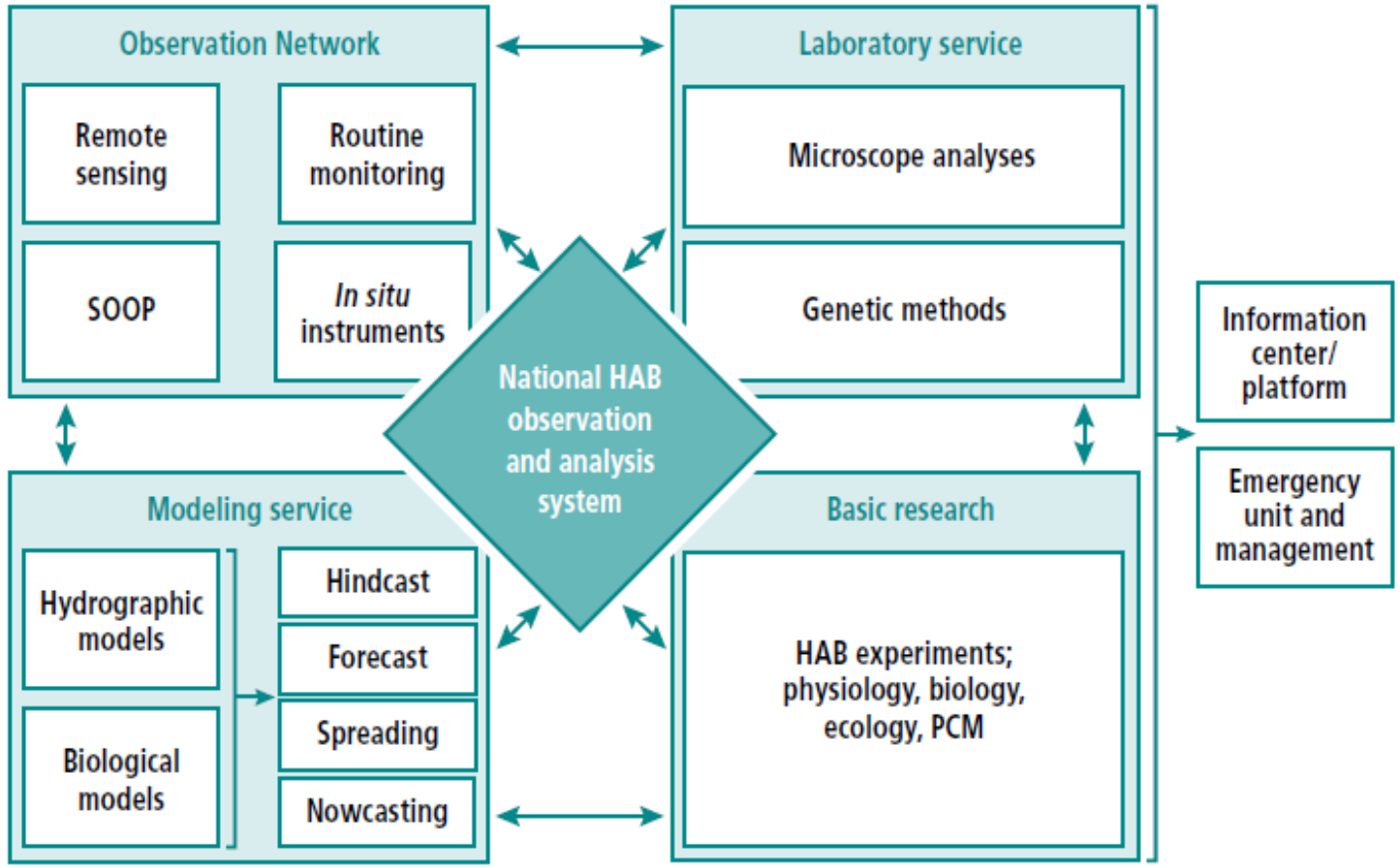
FIGURE 5.2
World distribution of reported mass mortality fish kill events impacting wild fish, shellfish and marine mammals; last updated in April 2022



Source: Created by Fisheries and Oceans Canada (DFO) with data from IOC-UNESCO. 2023. Harmful Algae Information System. Harmful Algal Bloom (HAB) portal (ioc-unesco.org)

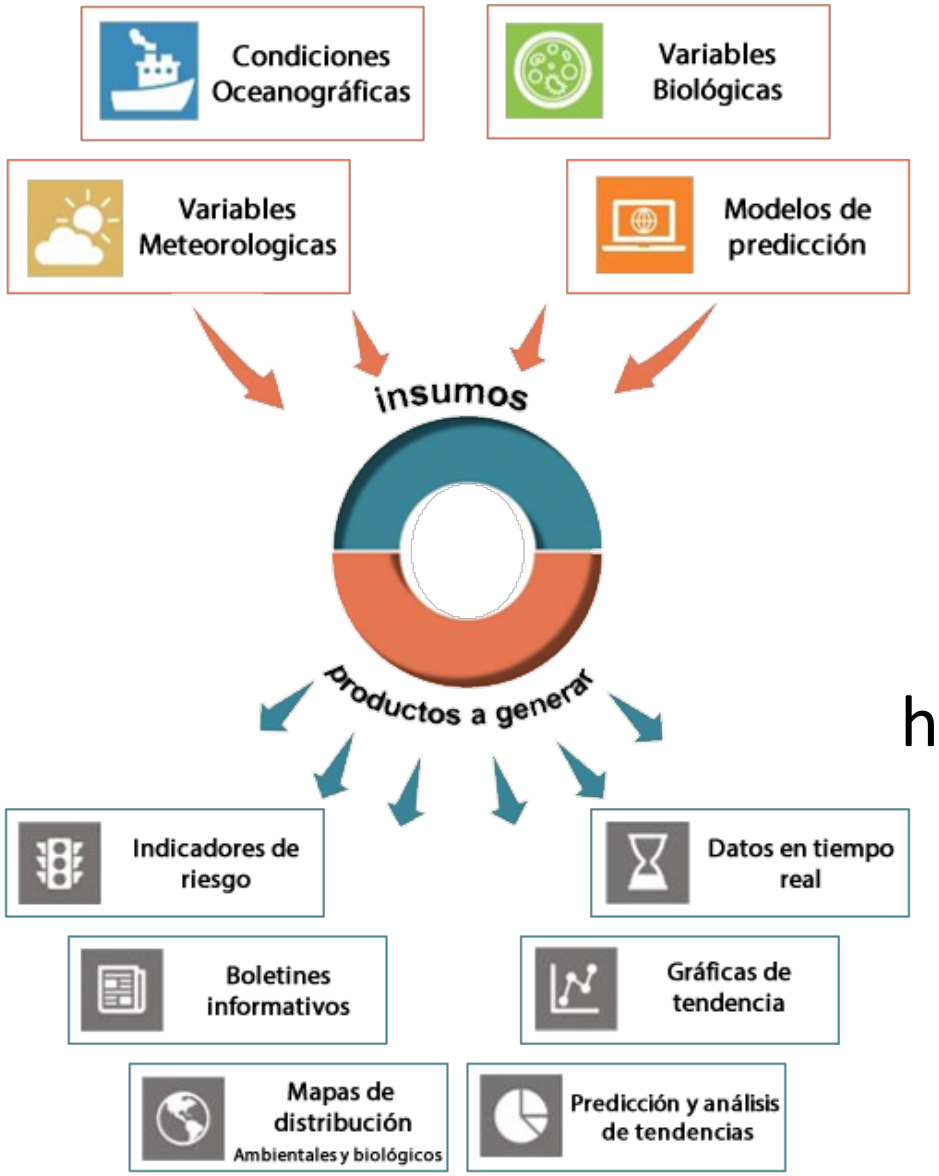
FIGURE 5.7

Schematic overview of the monitoring and early warning system (EWS) under development for Norwegian waters, with focus on fish-killing harmful algal blooms (HAB-Fish). The new program is designed to include existing monitoring of other HAB events, hellfish toxicity (HAB-Mussel) and general high-biomass blooms and effects (HAB-high biomass) to form one large HAB EWS.

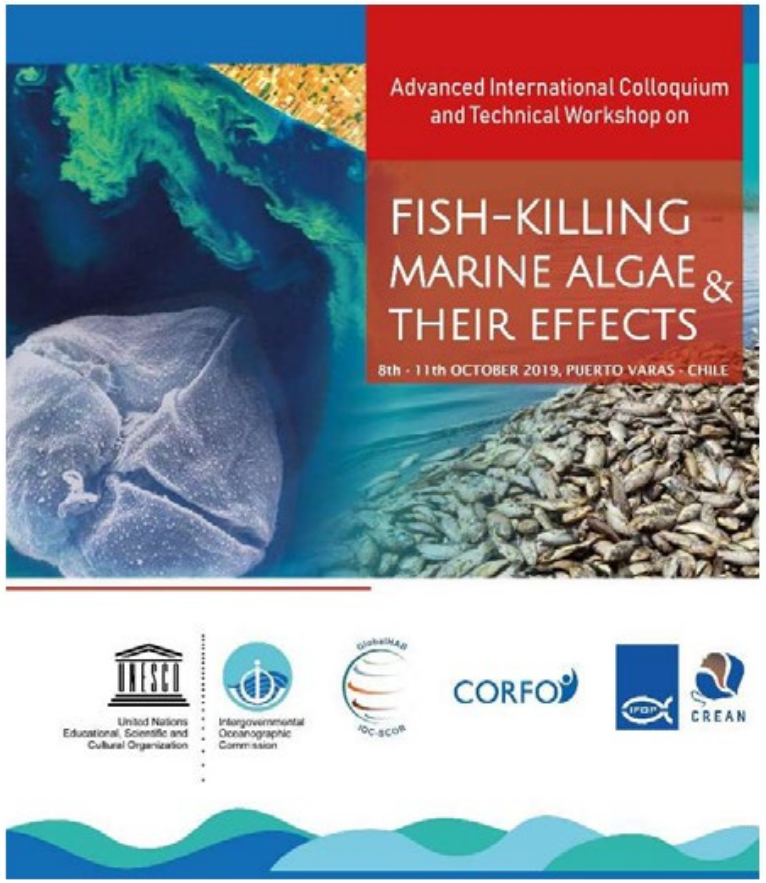


Source: Elaborated by Lars Naustvoll, Institute of Marine Research.

Magistral 2 | Dr. Ernesto García Mendoza
Florecimientos algales en México desde la perspectiva de un sistema de alerta temprana. Una revisión



https://siat-cicese.mx/#que-es-siat

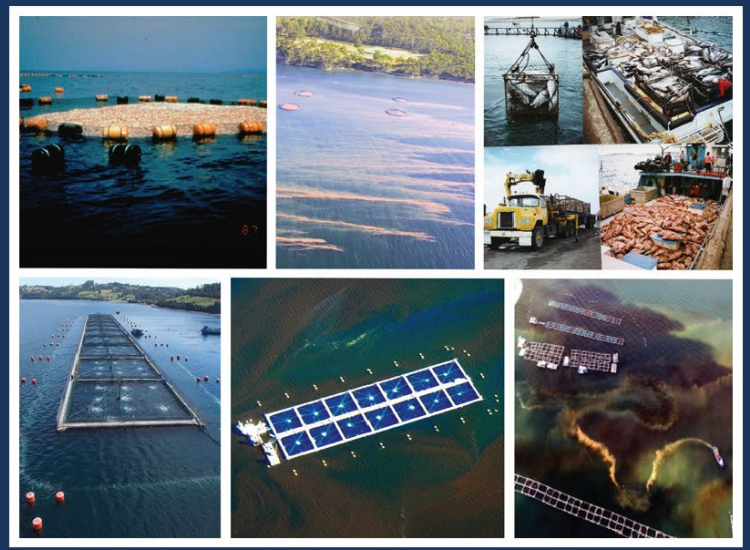


Venue: Puerto Varas, Chile
Dates: 8th – 11th October, 2019

FISH-KILLING MARINE ALGAL BLOOMS: Causative Organisms, Ichthyotoxic Mechanisms, Impacts and Mitigation

G.M. Hallegraeff, D.M. Anderson, K. Davidson, F. Gianella, P.J. Hansen, H. Hegaret, M. Iwataki, T.O. Larsen, J. Mardones, L. MacKenzie, J.E. Rensel

Contributors: A.D. Cembella, O. Espinosa, L. Guzman, B. Krock, P.T. Lim, A.R. Place



GlobalHAB IOC-SCOR

unesco Intergovernmental Oceanographic Commission

International Science Council SCOR Scientific Committee on Oceanic Research

Notable Fish-Killing HABS publications

RS Shahmohamadloo, T Frenken, SM Rudman, BW Ibelings, VL Trainer (2023) Diseases and disorders in fish due to harmful algal blooms. In PTK Woo and RP Subasinghe (eds). *Climate Change on Diseases and Disorders of Finfish in Cage Culture*, pp. 387-429

MM Allaf, CG Trick 2024. Influence of multi-stressor combinations of pCO_2, temperature, and salinity on the toxicity of *Heterosigma akashiwo* (Raphidophyceae), a fish-killing flagellate. *Journal of Phycology* 60 (4), 1001-1020

Place, A.R., Ramos-Franco, J., Waters, A.L. *et al.* (2024) Sterolysin from a 1950s culture of *Karlodinium veneficum* (aka *Gymnodinium veneficum* Ballantine) forms lethal sterol dependent membrane pores. *Sci Rep* **14**, 17998 https://doi.org/10.1038/s41598-024-68669-0

K Möller, U Tillmann, M Pöchhacker, E Varga, B Krock, F Porreca, F Koch, TM Harris, CL Meunier (2024) Toxic effects of the emerging *Alexandrium pseudogonyaulax* (Dinophyceae) on multiple trophic levels of the pelagic food web. *Harmful Algae* 138, 102705

E Varga, HC Prause, M Riepl, N Hochmayr, D Berk, E Attakpah, E Kiss, N Medic, G Del Favero, RO Lartsen, PJ Hansen, D Marko (2024). Cytotoxicity of *Prymnesium parvum* extracts and prymnesin analogs on epithelial fish gill cells RTgill-W1 and the human colon cell line HCEC-1CT. *Archives of Toxicology* 98 (3), 999-1014

Wang X, Fon M, Andersen AJC, Solhaug A, Ingebrigtsen RA, Samdal IA, Uhlig S, Miles CO, Edvardsen B, Larsen TO. (2024) Insights into the nature of ichthyotoxins from the *Chrysochromulina leadbeateri* blooms in Northern Norwegian fjords. *Harmful Algae.* 137:102681. doi: 10.1016/j.hal.2024.102681.

frontiers

Global Change and the Future Ocean

Manuscript to be submitted to Frontiers in Marine Science,
Special issue for Global Changes Theme

Fish-killing algal blooms and mechanisms of harmful consequences in northern European and Arctic gateway waters

Allan Cembella[a*], Bengt Karlson[b], Per Andersen[c], Wenche Eikrem, Uwe John[a], Kerstin Klemm[a], Lars Naustvoll[c], Dave Clarke[d], Helene Hegaret[e], Keith Davidson[f]

SCIENCE ADVANCES | RESEARCH ARTICLE

EARTH, ENVIRONMENTAL, ECOLOGICAL, AND SPACE SCIENCES

High-resolution multi-omics links nutrients and mixotrophy to toxigenicity in a harmful bloom of the haptophyte *Chrysochromulina leadbeateri* - provisionally accepted pending revision

Antonia Otte[1], Sylke Wohlrab[1,2], Franco Moritz[3], Constanze Müller[3], Jan Janouškovec[4,5,6], Jan Michálek[5], Allan Cembella[1,7], Daniela Voss[8], Xinhui Wang[9], Jan Tebben[1], Thomas Ostenfeld Larsen[8], Bente Edvardsen[4], Philippe Schmitt-Kopplin[3,10], Uwe John[1,2] *

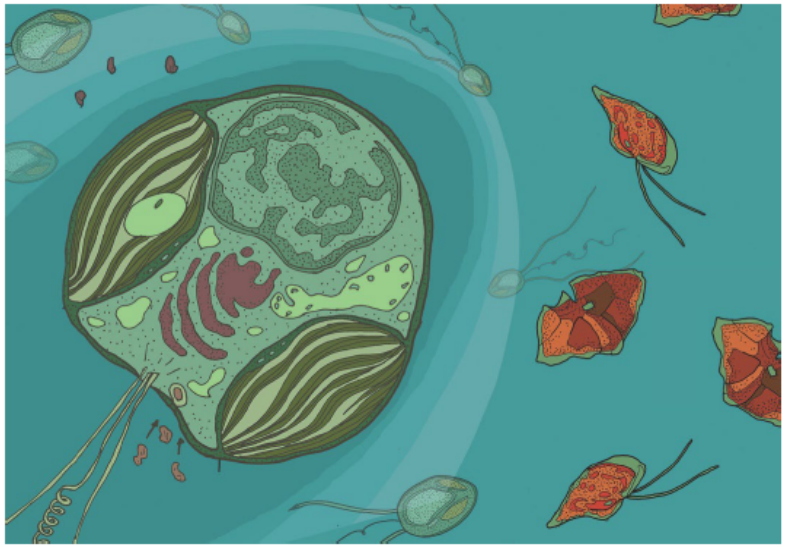


Fig. 6. Conceptual model of how the gene expression of cellular pathways contribute to a combined food acquisition and toxigenicity strategy during a hypothetical ichthyotoxic haptophyte (e.g., *C. leadbeateri*) bloom event. To compensate for incipient inorganic nutrient limitation, genes associated with mixotrophy are upregulated in the bloom, and thereby facilitate uptake of dissolved organics and engulfment of particulates (e.g., captured prey) as food (depicted as endocytosis at the base of the cell near flagellar insertion). Induction of PKS-genes yields allelochemicals ("toxins") for prey capture and to ward off predators and competitors.

ICES CIEM International Council for the Exploration of the Sea / Conseil international pour l'Exploration de la Mer

unesco Intergovernmental Oceanographic Commission

WGHABD

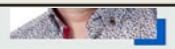
Working Group on Harmful

OUR OBJECTIVE

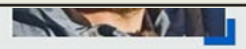
WGHABD is an important forum for ICES and IOC-UNESCO to review and discuss HAB events and to provide annual advice and updates on the state of HABs in the region. The aim of the working group is to outline the various physical, chemical and biological interactions associated with harmful algal blooms (HAB) and to define the main gaps in research.

ToR	Descriptor & Background
ToR (b)	**Identify and access the interactions of HAB dynamics with multidimensional environmental stressors on marine faunal mortalities and morbidity**
	Marine mortalities are a common factor linked to HAB events within the ICES region and thereby collectively reported within HAEDAT under ToR (c). Unfortunately, combining mass mortalities invariably associated with high biomass blooms (either toxigenic or not), tends of obscure the distinction of mechanisms of action causing mortalities. Within this ToR, fish-killing algal blooms will be considered in the functional content of caged-fish aquaculture, wild fish populations and other collateral damage to marine fauna and coastal ecosystems. Particular focus will be directed on defining the specific mode of action of dynamic ichthyotoxic blooms on salmonid aquaculture, the major fish aquaculture group impacting socioeconomic interests in the ICES region. Evidence that multifactorial environmental stressors, plausibly linked to climate change and/or anthropogenic factors, can amplify and attenuate the effects of HABs on fish mortalities and health status.

- Frequency of HAB distribution and impacts on plankton communities in a changing climate
- Produce protocols and guidelines for qPCR methodologies for the study and monitoring of HAB species using eDNA.



Dave Clarke



Lars Johan Naustvoll

Scan and learn more about our work

Major Themes of Current and Future Task Team

Linking Contributions to HAB-S and Oceans Decade Programme

- Development and implementation of early warning systems (EWS) linked to HAB dynamics and taxon/toxin-specific detection methods appropriate for fish farm temporal-spatial scales

- Critical importance of the human socioeconomic dimension:

- Strategies for risk assessment: networking science with aquaculture industry - financial support and manageable cost structures (e.g. HAB event insurance) and regulatory constraints on aquaculture development and expansion.

- Stakeholder participation and social acceptance on EWS, mitigation and management: encouraging development of measures to minimize impact to mariculture industries with due consideration on stakeholder participation and social acceptance of mitigation measures is essential