S-HAB contributions to FUTURE

by Vera L. Trainer, Mark L. Wells, and Charles G. Trick

Harmful Algal Blooms (HABs) are events that reflect undesirable disruption of plankton systems that negatively impact ecological structure, productivity, and human health, namely factors that are integral to the assessment of the coastal goals of FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems), PICES' integrative science program. While PICES' Section on *Ecology of Harmful Algal Blooms in the North Pacific* (S-HAB) has been actively contributing to the PICES mission for over a decade, the specific goals and activities of S-HAB have paralleled FUTURE research themes in key areas:

1) What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?

Specifically S-HAB is interested in understanding the features of climate change that may affect the frequency, occurrence, and changing global distribution of HABs. In fact, harmful species and their toxins respectively provide "eco-indicators" and "physiological tracers" of ecosystem stress and the disruption of plankton systems that provide the carbon and energy foundation for marine food webs. These compositional changes can substantially affect the trajectory, vulnerability and resilience of upper trophic levels.

2) How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?

S-HAB is participating in research and monitoring to determine the role of climate impacts such as ocean acidification, increasing temperature, changing stratification, altered light fields, changes in grazing pressures, and altered nutrients on harmful species.

3) How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

HABs are a societal-based definition reflecting negative changes in ecosystems, some of which are a direct result of human activities. S-HAB will co-convene a Topic Session with the Section on *Human Dynamics of Marine Systems* at PICES-2015 in Qingdao, China, that will address more closely this linkage between disruptive plankton systems and a range of human wellness issues. In addition, members are participating in the Marine Ecosystem Health and Well-Being (MarWeB) project, sponsored by the Government of Japan's Ministry of Agriculture, Forestry and Fisheries (MAFF) to study the health and happiness of coastal communities in Indonesia and Guatemala that depend on aquaculture.

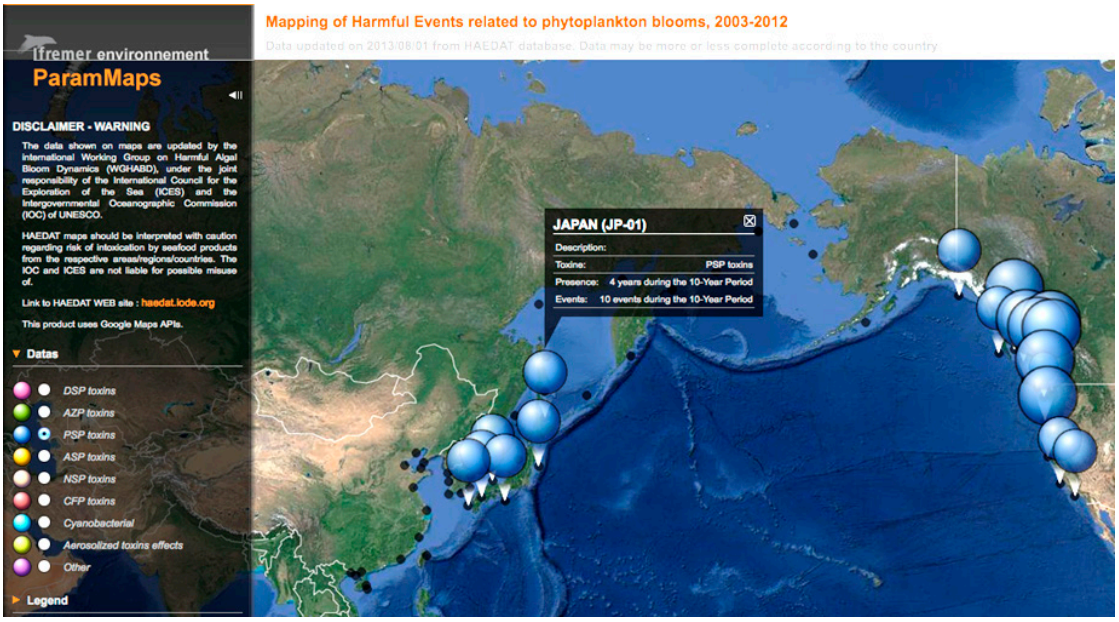
A goal of FUTURE is to provide meaningful "early warnings" of disruptive ecosystem states in a changing ocean. Fundamentally, major shifts in marine biochemistry and higher trophic levels reflect a largely "bottom up" control, driven by the interactive relationship between environmental conditions and the nature of primary production. Developing early recognition, and perhaps forecasting skill, of any ecosystem changes will critically depend on better understanding of several key disruptive plankton systems, including:

- High biomass, monospecific blooms (phytoplankton, macroalgae, grazers (red tides), hypoxia),
- Toxic blooms (toxic diatoms, fish-killing species, toxic dinoflagellates),
- Food-web disruptive blooms (*e.g.*, ecological conditions that facilitate jellyfish blooms),
- Nutritionally inadequate blooms (physiological or species-driven changes in production of essential fatty acids).

S-HAB recognizes the need to go beyond the current focus on carbon processing/climate linkages to better assessment of ecological/climate linkages. This shift will require an entirely new approach to understand how climate variables interact to create "windows" of opportunity for ecosystem disruptive planktonic systems. At this stage, we cannot predict these disruptive systems, but can only establish how they may change temporally or geographically. These changes can be envisioned as providing an "environmental market report", similar to a stock market index – the presence of HABs serves both as an "indicator" and a "driver" in the decision-making process.

The Section is well positioned to provide key input to help define the edges of these "windows" that, when linked with appropriate physical and human dimension models, can provide "market forecast" outcomes. Specifically, S-HAB has collaborated on a number of efforts to achieve the goals described above via S-HAB workshop and topic session outputs (characterizing the ecophysiology of key HAB species in the PICES region; the economics of HABs events) during PICES Annual Meetings, and its participation in the IOC/UNESCO harmful algal event database (HAEDAT), the global database on HAB events.

To illustrate knowledge exchange–knowledge transfer activities of S-HAB, members have been participating in several stages of a more rigorous assessment of purported links between anticipated climate-driven changes and HABs. Phase 1 was a 5-day jointly sponsored PICES, NOAA, and SCOR/GEOHAB international workshop on "*HABs in a changing world*" held March 18–22, 2013, at the University of Washington Friday Harbor Labs in Washington State, USA, and co-organized by Mark Wells



PICES S-HAB entries into HAEDAT showing paralytic shellfish poisoning events from 2003–2012. An example "pop-up window" shows detailed information from the JP-01 area code of Japan (www.haedat.iode.org).

(PICES S-HAB) and Bengt Karlson (ICES/IOC-WGHABD). A focused group of internationally recognized HAB scientists with different expertise reviewed what is known and unknown about HAB/climate linkages (summarized in an article "*Harmful Algal Blooms in a Changing World*" in PICES Press, Vol. 21, No. 2, Summer 2013). A seminal review paper identifying the keystone parameters and research infrastructure needed to test these purported linkages will be published in the journal *Harmful Algae* in late summer 2015. This paper titled "*Harmful algal blooms and Climate change: What do we know and where do we go from here?*" is authored by Mark L. Wells[1], Vera L. Trainer[1], Theodore J. Smayda, Bengt S. O. Karlson, Charles G. Trick[1], Raphael M. Kudela, Akira Ishikawa, Stewart Bernard, Angela Wulff, Donald M. Anderson, and William P. Cochlan.[1]

The second phase of assessment of the links between climate change and HABs was a broader-scope Symposium on "*Harmful algal blooms and climate change*" that was held from May 19–22, 2015 in Göteburg, Sweden, jointly sponsored by PICES, the Swedish Research Council (FORMAS), SCOR/GEOHAB, NOAA, the Swedish Meteorological and Hydrological Institute, and the University of Göteburg, and endorsed by IOC and ICES. This workshop brought together 58 participants from across the globe to delineate the bounds of our understanding, to identify the major impediments that block knowledge advance, and to derive from these a list of more productive research strategies. Participants considered a wide range of climate change and other factors (*e.g.*, nutrient fluxes, ocean acidification, temperature, stratification, improved modeling skill, new methodologies and observation systems, and the need for a best practices manual to unify HAB research methods). The central ecological questions focused on how climate change will influence the character and prevalence of future HABs within the context of broader changes in planktonic systems. Participants also worked to identify the key steps to improve understanding of HAB effects on fisheries productivity and to develop the requisite forecasting abilities for HABs and other disruptive plankton systems.

There are key knowledge gaps in the underpinning of the intrinsic resilience and vulnerability of marine ecosystems to natural and anthropogenic forcing, how ecosystems of today will respond to natural and anthropogenic forcing in the future, and ultimately how societies will be affected by these altered ecosystems. It is reasonable to argue that the most uncertain of these gaps is constraining how planktonic systems shift from strongly sustaining to disruptive modes. To this end, S-HAB is continuing its efforts to coordinate observations and trend analysis of plankton data among PICES member countries, and link these to climate change science, and to contribute to the developing UNESCO-IOC Global HAB Status Report. The Scientific Steering Committee of the newly formed replacement for GEOHAB, GlobalHAB, will include expertise on freshwater HABs, benthic HABs, satellite observation systems, ecology, oceanography, toxins, human health links, and economic links and will have representation from all regions. Early discussions with IOC delegates have emphasized that PICES needs representation on the executive committee. This will ensure a collaborative functioning with global organizations that share similar aims to PICES, such as IOC, ICES, SCOR, IOCCG, and IAEA.

[1] PICES authors

Participants of the "HABs and climate change" symposium in Göteborg, Sweden, from May 19–22, 2015.

In this way, PICES will become a major partner in contributing to the strategic focus of this international effort. Other collaborators include IPHAB, OSPAR, HELCOM, GOOS and national and local programs including seafood safety monitoring and phytoplankton monitoring programs. The rationale behind more coordinated HAB/climate science research and monitoring include protection of public health and coastal economies including fisheries, aquaculture, ecosystem services and tourism.

In summary, the key strategies that S-HAB uses to contribute to FUTURE's research themes are: (1) to publish workshop and symposium reports that integrate "State of the Science" climate change with the character, distribution and intensity of future HAB scenarios, (2) to identify and prioritize future research needs that improve our forecasting abilities, (3) to continue to lead, organize, and participate in workshops and open science meetings that address HABs in the context of disruptive plankton systems, and (4) to help organize and develop the GlobalHAB research strategies and UNESCO-IOC Global HAB Status Report. S-HAB will continue to be a leader in global HAB research but the primary goal is to serve the PICES community by fostering a fundamental understanding of the drivers of change from productive to disruptive planktonic systems – critical knowledge that underpins the activities of FUTURE.

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Dr. Mark Wells (mlwells@maine.edu) is a Professor of Oceanography in the School of Marine Sciences, University of Maine, USA. His current work spans the study of toxin production associated with harmful algal blooms, the interaction of trace metal chemistry with phytoplankton production in coastal and offshore seawaters, and the implementation of nanoscience and engineering concepts into the next generation sensor development for bioactive metals, phytoplankton community composition, and other indicators of ecosystem health. He is a member of the PICES Section on Ecology of Harmful Algal Blooms in the North Pacific.

Dr. Charles Trick (trick@uwo.ca) is a Distinguished Research Professor for Ecosystem Health at Western University, London, Canada, a position that emphasizes the merging of science, health/medicine, social and psychological aspects of environmental programs. Since receiving his Ph.D. in Oceanography, Charlie has worked in a variety of different coastal and open ocean projects. He has recently completed a sustainability assessment of the Persian Gulf and continues his research in marine and freshwater harmful algal blooms. In PICES, he is a member of the Section on Ecology of Harmful Algal Blooms in the North Pacific.