Report of the Section on *Ecology of Harmful Algal Blooms in the North Pacific*

The Section on *Ecology of Harmful Algal Blooms in the North Pacific* (S-HAB) met under the chairpersonship of Drs. Vera Trainer and Shigeru Itakura on October 18, 2014, in Yeosu, Korea. The meeting was attended by members from Canada, China, Japan, Korea, and Russia. Other visiting scientists attended the meeting under their respective countries (*S-HAB Endnote 1*). The proposed agenda for the meeting (*S-HAB Endnote 2*) was reviewed and approved by the Section.

AGENDA ITEM 2
Country reports and HAE-DAT usage

Canada

Dr. Charles Trick reported that fish killing blooms occurring in May 2014 in Knight Inlet were mixed *Chrysochromulina* species, with *C. ericina* as the dominant species. Farmed Atlantic salmon were killed mainly at one site. *H. akashiwo* bloomed in September 2014. Approximately 1000 tons of farmed Atlantic salmon were lost at a site in Queen Charlotte Strait.

China

Dr. Doudling Lu reported that *Noctiluca* is a common genus causing red tides on the China coast. *Aureococcus anophagefferens* is becoming a recurrent problem in the northern China area. Most HABs in China occur in May and June. Large scale blooms, >100 km^2 in 2012, were *Noctiluca scintillans*, *Prorocentrum donghaiense*, *Karenia mikimotoi*, and *A. anophagefferens*. Most HABs in 2013 were in the East China Sea. *P. donghaiense* bloomed 16 times in East China Sea, sometimes at an abundance of > 10^7 cells/L. These blooms are believed to originate from offshore. *P. donghaiense* can cause mortality of *Calanus sinicus* (and also causes lower egg production rates).

Other HAB species causing problems in China were *H. akashiwo, Phaeocystis globosa, Cochlodinium geminatum,* and *Prorocentrum minimum*. *Alexandrium tamarense* exists in Chinese coastal waters. Microsatellites are being used to compare Chinese isolates with those from around the world. *Karlodinium veneficum* can co-occur with *P. donghaiense*. *Cochlodinium polykrikoides* has been found in the East China Sea and Yellow Sea (possibly Bohai Sea). This species is the East Asian ribotype. *Cochlodinium* is having an increasing trend in China coastal waters. *P. globosa* creates big blooms in the South China Sea and is toxic. *Azadinium popurum* exists in sediments. Blooms of the green tide (*Ulva prolifera*) are typical in March through August in the Yellow Sea. *H. akashiwo* can cause some damage in the East China Sea but this damage is limited, perhaps because it is in a well mixed area.

Japan

Dr. Shigeru Itakura reported that there were 232 red tide cases in 2013, a normal year. Species of HABs included *Chattonella* spp. and *Heterosigma akashiwo*, *Karenia mikimotoi*, and *Cochlodinium polykrikoides*. Blooms of these HABs are a problem in the southwestern part of Japan where fish aquaculture occurs. *Heterocapsa circularisquama* occurs in southwestern Japan as well, but causes shellfish kills. The number of HAB cases in 2013 included 64 cases in eastern Japan; 92 cases in Seto Inland Sea; 106 cases, with 27 cases of fishery damage, in Kyushu. For toxic blooms, there were 23 cases of PSP and 33 cases of DSP in 2013. In 2007 Harmful Algal Event Data (HAE-DAT), there were 22 cases of red tides, 37 cases of PSP and 8 cases of DSP recorded.

Korea

Dr. Changkyu Lee reported that in 2013, *Cochlodinium* blooms were the second most economically devastating in the history of monitoring. These blooms caused mass fish mortalities on the Tongyoung coast.

They initiated earlier in 2013 than many other years. Much lower rainfall was also observed, with salinity greater than 32 ppt. The wind direction was strong and from the south with no reversals, facilitating the accumulation of *Cochlodinium*, and a fast transport of cells from the south to the east. There was also an unusual *Cochlodinium fulvescens* bloom on the Korean west coast but its density was not very high.

A mitigation study was conducted in Korea to test several privately-available mitigation substances. It was found that a fine clay spray reduces the particle size and increases the longevity of clay in the water. Other methods were tested including a HAB alarm system, liquified oxygen, and a HAB shield curtain. Over 170 potential mitigation substances were developed by the private sector including chemicals, clay-like substances, synthetic materials, and others (*e.g*., Triton). The criterion for selection of effective mitigation substances include high removal efficiency, no significant impact on the ecosystem, cost effectiveness, and a secure supply. An expert committee has been assigned to select the best possible methods.

Russia

Dr. Tatiana Orlova reported on molecular genetic studies being conducted in Russia.I n 2013–2014, there was a total of 11 bloom-forming species including *Skeletonema marinoi*, *S. costatum*, and *S. japonicum*. A bloom of *H. akashiwo* was observed for the first time in June 2013 in Amurskii Bay and was observed again in 2014. There are no fish farms in the Amurskii Bay area; therefore, there was no apparent damage. Ice diatoms have been observed to bloom under ice. A brown bloom of Prymnesiophytes *Pseudohaptolina birgeri* was observed in March through April 2013. *Pseudo-nitzschia* species toxicity was determined in culture. The same species can demonstrate toxicity and lack of toxicity. Is there a connection with associated bacteria? The most toxic species of *Pseudo-nitzschia* in Russia is *P. calliantha*. Domoic acid (DA) has been measured in molluscs but at concentrations below the regulatory limit. Approximately 65% of the samples tested had some contamination with DA, but at low levels. Several mollusc species and an urchin were tested. Dinophysistoxin-3 was detected in edible and non-edible parts of *Crenomytilus grayanus*. Hydrolyzed and non-hydrolyzed samples showed the same concentrations, demonstrating the lack of DTX-3. Dr. Orlova reported on cyst concentrations in the benthos. She reported that *Ostreopsis* is a newly observed genus in Russian waters. *Prorocentrum foraminosum* (not a toxic species) has been observed in the spring and fall, but not in high numbers. Cultures have been established from epiphyte communities. Morphologically, *Ostreopsis* is similar to *P. lima* but different in the lack of a marginal row of pores. *Chattonella* is a winter-blooming raphidophyte and *Thecadinium koroidii* is found in sands and is not present in the plankton.

USA

Dr. Vera Trainer reported that 2013 was an average year for paralytic shellfish toxins. Of the 3249 shellfish samples analyzed, only 5 had values greater than 1000 μg/100g which included 32 commercial and 24 recreational shellfish closures in the inland waters of Puget Sound. There were no shellfish closures on the outer Pacific coast due to paralytic shellfish poisoning (PSP) toxins in 2013. Over 1300 shellfish samples were analyzed for domoic acid which resulted in no samples above the regulatory limit of 20 ppm. No commercial or recreational closures were necessary. Shellfish samples (1920) analyzed for diarrhetic shellfish toxins resulted in 21 samples above the regulatory limit of 16 micrograms per 100 g tissue. There were no commercial closures but 11 recreational closures. More dual PSP and diarrhetic shellfish poisoning (DSP) closures were observed. In November 2013, a shipment of geoduck to China contained high levels of PSP toxins and inorganic arsenic. China suspended all shellfish imports from Alaska to northern California until May 2014 when the ban was lifted. This ban revealed vulnerabilities in the export certification process as well as a potential seafood safety problem.

AGENDA ITEM 3
Collaboration with NOWPAP

Dr. Takafumi Yoshida reported on the joint PICES/NOWPAP Study Group on *Scientific Cooperation in the North Pacific Ocean* (SG-SC-NP). NOWPAP is interested in providing regular information updates through regional reports every 5 years. NOWPAP plans to actively participate in S-HAB meetings, develop

mechanisms for sharing information on HABs from the regions of overlap, and to continue the organization of joint sessions, workshops and reports. PICES interests are in regular information updates through regional reports and understanding dynamic mechanisms for future forecasting potential. S G-SC-NP was established to explore new areas of collaboration between PICES and NOWPAP. PICES and NOWPAP gave prioritized scores to a suite of activities. Information on the expansion or movement of HAB species is a subject of interest. HAB research was determined to be high priority based on several factors, including the fact that PICES collaboration with NOWPAP has occurred in the past. NOWPAP is now focusing on eutrophication. Therefore, this subject is of high interest to the agency. The relationship between red tide occurrence and eutrophication is useful. NOWPAP can provide member states with advice on how to manage river inputs and how to manage their coastal resources. NOWPAP is an environmental program whereas PICES is a fisheries-based program.

MEQ Chairman, Mr. Chuanlin Huo, spoke about NOWPAP and PICES collaborations, and how both organizations regard HAB work as a high priority.

AGENDA ITEM 4
Marine Ecosystem Health and Human Well-Being (MarWeB) project

Dr. Charles Trick reported that PICES has been funded by Japan's Ministry of Agriculture, Forestry and Fisheries (MAFF), through the Fisheries Agency of Japan, for S-HAB to provide training and support to developing nations. A current 5-year PICES project on "*Marine ecosystem health and human well-being*" deals with the relationship between marine resources and the wellness of communities. He provided an introduction to the Guatemala case study, showing the strong relationship that the coastal people have with the sea. The Guatemalan study looks to explore an alternative to wild fishing by helping to establish an aquaculture possibility with the mangrove oyster. The other part of the study deals with performing a community needs assessment and social science survey. The questionnaire would be devoted to understanding the needs of the community: 1. What do they want, what are they missing? 2. How could we measure success if change were to occur? The intention is for the S-HAB members of the MarWeB Project Science Team to build a local team that is community driven, not science driven.

AGENDA ITEM 5
Report on publication on "*HABs and climate*" from PICES/ICES/IOC workshop

Dr. Mark Wells presented the results of a PICES/ICES/IOC workshop on "*Harmful algal blooms in a changing world*" held March 18–22, 2013, in Friday Harbor, USA. The findings are now summarized in a publication that will be submitted as a "Commentary" by December 2014 for the journal *Harmful Algae*. The structure of the paper discusses the parameters: temperature, stratification, light, ocean acidification, nutrients, and grazing. Each parameter will be given an analysis of what is known, what is unknown, and the pathway forward into the future. Recommended observer site locations and parameters that should be measured to address questions about HABs and climate as well as linkages to other programs, summary and next steps are discussed. A short discussion, put it into context of FUTURE, will also be submitted to PICES Press.

AGENDA ITEM 6
Joint ICES/PICES/GEOHAB symposium on "*HABs and climate change*"

Dr. Mark Wells reported on a joint ICES/PICES/IOC/SCOR (including the replacement of GEOHAB possibly called "Global HAB") symposium on "*Harmful algal blooms and climate change*" scheduled for May 19–22, 2015, at the Conference Centre Wallenberg at the University of Göteborg, in Göteborg, Sweden. The scientific steering committee is composed of Drs. Bengt Karlson (Sweden), Mark Wells (USA), Raphael Kudela (USA), and Angela Wulff (Sweden). The local organizing committee consists of Drs. Bengt Karlson,

Angela Wulff, and Åke Hagström. The specific aims of this symposium are to bring together algal physiologists, ecologists, oceanographers, modelers and climate change specialists to present the most recent scientific results and to ascertain the most pressing future research needs. The aims are to:

1. Provide examples of locations and events where climate change may be affecting HABs and their impacts;
2. Identify and promote research on critical topics/aspects of the broader field of HAB research to advance our knowledge of the impacts of climate change on the global scale;
3. Attract and retain new expertise from other scientific disciplines;
4. Evaluate the use of new technologies for the collection and analysis of long-term data on appropriate parameters;
5. Develop the HAB component of global climate observing systems;
6. Foster framework activities to facilitate identifying and responding to climate change-driven effects on HABs, including risk assessment with associated probabilities and uncertainties;
7. Develop best practice recommendations for research and monitoring to fill critical knowledge gaps;

The organizing committee would like to plan for 11 invited speakers plus ancillary costs. They have submitted a proposal to the Swedish Research Council Forma for 30k USD and will have a decision in November 2014. Another request for funding has been made to the Swedish Science Council Vetenkapsradet for 30k USD and a decision will be made regarding this funding by 1 December 2014. ICES is unable to provide funds for the symposium because it has already committed to a number of other symposia. However, it is likely to endorse or help in some other way. S-HAB will make a request for PICES support, especially for western Pacific representatives to attend. There is a concern that the location may prevent a number of PICES scientists from attending the meeting. Dr. Wells will request funding from NOAA (Dr. Rob Magnien).

AGENDA ITEM 7

Joint Harmful Algal Bloom Programme and International Oceanographic Data and Information Exchange Harmful Algae Information System: An update and country maps

Dr. Trainer reviewed the Harmful Algal Information System (HAIS) with S-HAB members and demonstrated how global HAB data could be accessed.

AGENDA ITEM 8

IOC/IPHAB global HAB report

Dr. Vera Trainer presented a power point presentation on behalf of Dr. Henrik Enevoldsen who could not attend. Included in the Global HAB Status Report is Decision IPHAB-XI.2 on the "Development of the Harmful Algal Information System" that describes the resolution to invite PICES' S-HAB to participate in a project Task Team on the development of a periodic Global Harmful Algal Bloom Status Report that shall:

1. Provide a global status and overview of HAB events and their societal impacts;
2. Provide a global overview of the occurrence of toxin producing microalgae;
3. Assess the status and probability of change in HAB frequencies, intensities, and range expansions resulting from global change.

The goal is to provide access to high quality data on current taxonomic names of harmful algae, the biogeography of harmful species and occurrence of harmful algal events, and provide details of monitoring and management systems worldwide to scientists, managers of regulatory monitoring programs, and policy administrators. Data will be shared with WoRMS (taxonomy reference list), HAE-DAT (harmful algal events), OBIS (biogeography data).

The PICES HAEDAT focal points are:
Canada – Dr. Jennifer Martin (Dr. Nicky Haigh to be added)
China – Dr. Chunjiang Guan

Japan – Dr. Shigeru Itakura
Korea – Drs. Changkyu Lee, Taegyu Park
Russia – Drs. Tatiana Morozova, Tatiana Orlova
USA – Dr. Don Anderson (Vera Trainer to replace Rita Horner)

The PICES OBIS and WoRMS focal points are:
Canada – Drs. Nicky Haigh, Charles Trick
China – Dr. Chungjiang Guan
Japan – Dr. Shigeru Itakura
Korea – Drs. Chang Hoon Kim, Tae-Gyu Park
Russia – Drs. Tatiana Orlova, Tatiana Morozova
USA – Dr. Vera Trainer

AGENDA ITEM 9
Workshop/Topic Session proposals for PICES-2015

The Section felt it necessary to modify the proposal for a workshop that was submitted in the summer of 2014 for consideration by Science Board for PICES-2015. The previous version was determined to be too ambitious for a single workshop as it focused on a series of HAB species. It was decided that the workshop for PICES-2015 be focused on harmful raphidophytes, and a proposal would be made for 2016 to focus on *Pseudo-nitzschia*. The S-HAB workshop on "*Contrasting conditions for success of harmful raphidophyte species in the western and eastern Pacific –A comparative ecosystem approach*" [later renamed as "*Contrasting conditions for success of fish-kill flagellates*"] *in the western and eastern Pacific –A comparative ecosystem approach*" (*S-HAB Endnote 3a*) will be led by Drs. Doudling Lu (China) and Charles Trick (Canada) who will provide "homework" for each country to prepare prior to the workshop. This homework will include describing the biological, physical and chemical characteristics associated with harmful raphidophyte blooms in each of the member countries.

A joint proposal for a Topic Session on "*The human dimensions of harmful algal blooms*" by the Section on *Human Dimensions of Marine Systems* (S-HD) and S-HAB was submitted for consideration by Science Board for PICES-2015. Co-Convenors will be Drs. Mark Wells (USA) and Mitsutaku Makino (Japan) (*S-HAB Endnote 3b*).

AGENDA ITEM 10
Terms of Reference and linkages to FUTURE and international programs

In accordance with the Rule of Procedure (Rule 13) in which Sections shall be reviewed every 3 years by their parent Committee, S-HAB submitted its report to MEQ detailing its achievements (2011–2014) and future plans (see *S-HAB Endnote 4* for the S-HAB report and proposed new Terms of Reference).
Dr. Itakura summarized S-HAB contributions to the FUTURE Science Plan as follows:

- HABs are a coastal pressure that generate substantial environmental, human health and economic impacts;
- HABs are driven by environmental conditions, some of which are well understood, and can be strongly influenced by anthropogenic pressures;
- S-HAB is working towards developing outlooks, and ultimately forecasts, of HAB events to aid society;
- S-HAB contributes directly to all three FUTURE Advisory Panels (AICE, COVE and SOFE).

The Section requests that its contributions to the FUTURE roadmap and FUTURE:
<u>Scientific Knowledge</u>

- HABs and Climate Change "Commentary" in the journal *Harmful Algae*,
- A workshop proposal on East–West HAB comparisons (mechanisms of HABs).

Status
- Contribute to HAE-DAT,
- Contribute to the Global HAB Status Report,
- Contribute to the PICES North Pacific Ecosystem Status Report by providing information on mechanisms underlying HAB occurrence and environmental changes between the eastern and western Pacific.

Forecast/outlook
- Organize an ICES/PICES/GEOHAB symposium on "*HABs and climate change*" in Göteborg, Sweden (May 19–22, 2015).

Outreach
- PICES Scientific Report No. 47: Proceedings of the Workshop on Economic Impacts of Harmful Algal Blooms on Fisheries and Aquaculture (2014),
- An article on S-HAB contributions to FUTURE in PICES Press (2015),
- An article on the mitigation of HABs – the way forward in PICES Press (2015).

AGENDA ITEM 11
Prioritized requests to MEQ

1. Travel support for PICES members from the western Pacific (Russia, Republic of Korea, China, Japan) to attend the symposium on "*Harmful algal blooms and climate change*" to be held May 19–22, 2015, in Göteborg, Sweden. Travel support also is requested for Dr. Mark Wells, a co-organizer of this symposium. Estimated total: ~$15,000 USD.
2. 1½-day joint PICES/NOWPAP Workshop on "*Contrasting conditions for success of harmful raphidophyte species in the western and eastern Pacific –A comparative ecosystem approach*" [later renamed as "*Contrasting conditions for success of fish-kill flagellates in the western and eastern Pacific — A comparative ecosystem approach*"] at PICES-2015 and funding for 1–2 invited speakers (expert(s) to talk about the NPO and other larger scale oscillations), Co-Convenors: Douding Lu (China) and Charles Trick (Canada). NOWPAP may fund 1 speaker. Estimated total: ~$2,500 USD.
3. ½-day Topic Session on "*The human dimension of harmful algal blooms*" at PICES-2015. Co-Convenors: Mark Wells (USA) and Mitsutaku Makino (Japan). No funding requested.
4. Funds for publication on "*HABs and climate change*" from the 2013 PICES/ICES/GEOHAB workshop on "*Harmful algal blooms in a changing world*" in the journal *Harmful Algae*. Estimated total: ~$1000 USD.
5. Funding for 1 S-HAB member to attend IPHAB-XII meeting April 28–30, 2015 in Paris, France.

AGENDA ITEM 10
Proposals for the future and review of assignments

Dr. Trainer reviewed member assignments before adjourning the meeting.

S-HAB Endnote 1

S-HAB participant list

Members

William P. Cochlan (USA)
Ichiro Imai (Japan)
Akira Ishikawa (Japan)
Shigeru Itakura (Japan, Co-Chairman)
Changkyu Lee (Korea)
Douding Lu (China)
Tatiana Yu. Orlova (Russia)
Vera L. Trainer (USA, Co-Chairman)
Charles Trick (Canada)
Mark L. Wells (USA)
Takufumi Yoshida (Japan)

Observers

Robin Brown (Canada)
Chuanlin Huo (China, MEQ Chairman)
Daisuke Hasegawa (Japan)
David Kidwell (USA)
Chang-Hoon Kim (Korea)
Jin Joo Kim (Korea)
Su Jin Song (Korea)
Yuji Tomaru (Japan)

S-HAB Endnote 2

S-HAB meeting agenda

1. Welcome, goals of HAB Section meeting (Itakura, Trainer)
2. Country reports and HAE-DAT usage (All)
3. Collaboration with NOWPAP
4. Update on Marine Ecosystem Health and Human Well-Being (MarWeB) project (Trick, Trainer)
5. Report on publication on "*HABs and climate*" (Wells)
6. Proposal for a joint ICES/PICES/GEOHAB symposium on "*HABs and climate change*" (Wells)
7. The joint Harmful Algal Bloom Programme and International Oceanographic Data and Information Exchange Harmful Algae Information System: An update and country maps (Enevoldsen, Trainer)
8. IOC/IPHAB Global HAB report (Enevoldsen, Trainer)
9. Workshop/Topic Session proposals for PICES-2015 (Wells)
10. Discussion of new S-HAB Terms of Reference and linkages to FUTURE and international programs
11. Prioritized requests to MEQ
12. Discussion of proposals for the future and review of assignments (Trainer)

S-HAB Endnote 3a

Proposal for a 1½-day Workshop on "*Contrasting conditions for success of harmful raphidophyte species in the western and eastern Pacific – A comparative ecosystem approach*"
[later renamed as "*Contrasting conditions for success of fish-kill flagellates in the western and eastern Pacific — A comparative ecosystem approach*"] at PICES-2015

Co-Convenors: Douding Lu (China) and Charles Trick (Canada)

There is clear evidence of contrasting occurrence and impacts of fish-killing fish-kill flagellates between the western and eastern Pacific in the comprehensive dataset (2000–2012) assembled during the PICES-2012 workshop on contrasting HABs in PICES member countries. These data provide a unique opportunity for east–west Pacific comparisons to identify and rank those environmental factors that promote HAB success at different times. This workshop will focus on the fish killing species- *Heterosigma akashiwo*, *Cochlodinium* and *Chattonella* and ribotypes—organisms that historically have had massive economic impacts in western PICES member countries, as well as increasingly prevalent impacts in eastern Pacific coastal waters. The

workshop foundation will be an extension of the current dataset to the 1990s and earlier where available, with PICES participants pre-submitting available data on: HAB species presence, maximum abundance, toxicity, optimal conditions for growth, time of year, temperature range, salinity range, water clarity, nutrients, wind, river flow (flooding), and upwelling indices. Workshop participants will evaluate the trends and patterns in these data to develop hypotheses for development into outlook products on day 1, and develop a detailed outline for manuscript preparation on day 2, including writing assignments and submission deadlines. The manuscript will be targeted for an appropriate peer-reviewed journal.

S-HAB Endnote 3b

Proposal for a ½-day joint S-HD/S-HAB Topic Session on "*The human dimensions of harmful algal blooms*" at PICES-2015

Co-Convenors: Mark Wells (USA) and Mitsutaku Makino (Japan)

Harmful algal blooms (HABs) comprise a spectrum of ecological, economic, and human health impacts. High biomass phytoplankton blooms in coastal and shelf waters, most often stemming from anthropogenic inputs of macronutrients, can massively shift ecosystem structure away from the support of higher trophic levels, lead to hypoxia and associated ecological impacts in deep waters, and thereby dramatically affect the human dimension. Smaller biomass blooms of toxic cells can selectively impair ecosystem components, decimate aquaculture industry success, or substantially impact human health. In some instances there are clear effects from direct human activity on HAB development; in others the oceanographic conditions regulate the success of harmful species. Despite the obvious relationship between HABs and human wellness, there has been little formalized linkage between ecological and human wellness research. This topic session is aimed at initiating this linkage by stimulating the cross-thinking needed to better assess human-HAB interactions. Presentations are invited on the distributions and character of HAB events, particularly for PICES member countries and their national interests, and the potential social-economic consequences of these societally-defined (harmful) algal bloom events. This session will provide the foundation for more coordinated efforts between the HAB and Human Dimension Sections to generate inputs useful to Ecosystem Based Management activities, and to guide goals for the FUTURE program.

S-HAB Endnote 4

Report of the Section on *Ecology of Harmful Algal Blooms in the North Pacific* (2011–2014)

Introduction

During ISB-2014 (April 19–21, 2014, Kohala Coast, Hawaii, USA), Science Board discussed the status and progress of every Committee's expert group. It was unanimously agreed that harmful algal blooms (HABs) are very important in terms of human dimensions, especially in the Western Pacific. HAB scientists are generally very active, but PICES is not considered the main forum for their work. Despite the lack of incentives for HAB scientists to be more engaged with PICES, it was agreed that the Organization should find a way for PICES to be more attractive to them and for them to be more productive within PICES.

S-HAB was instructed by its parent committee, MEQ, to produce a report detailing progress and contributions to FUTURE, Terms of Reference (TOR) implementation, alignment with MEQ's Action Plan and with FUTURE as part of a regular review by the parent Committee (Rules of Procedure 13(iii)(d)) by PICES-2014. Below is a progress report in fulfillment with MEQ's request.

1. S-HAB activities and Terms of Reference implementation (2011–2014)

Motivation

To develop an essential understanding of the mechanisms of North Pacific harmful algal bloom occurrences including the underlying links to ecosystem dynamics and physical climate, in particular those factors that are influencing changing species/distributions of harmful algal blooms.

Terms of Reference

1. Continue PICES member country *data entry* into the joint ICES-PICES harmful algal event database to allow global comparison of changes in harmful algal bloom occurrences.

Result: In order to assess the impacts of HAB events globally, and to improve prediction capability, PICES member country data entry is ongoing although behind schedule.

2. Convene workshops and sessions including joint sessions with other international organizations to evaluate and compare results and maintain an awareness of state-of-the-art advances outside the PICES community.

Results:

- PICES-2011, Khabarovsk, Russia – MEQ Topic Session (S5) on "*Harmful algal blooms in changing world*", Co-convenors: Mark Wells (USA) and Tatiana Morozova (Russia);
- PICES-2011, Khabarovsk, Russia – FIS Workshop (W2) on "*Remote sensing techniques for HAB detection and monitoring*", Co-convenors: Tatiana Orlova (Russia), Vera Trainer (USA) and Takafumi Yoshida (CEARAC);
- PICES-2012, Hiroshima, Japan – MEQ Workshop (W6) on "*The contrasting cases of HABs in the eastern and western Pacific in 2007 and 2011*", Co-Convenors: Changkyu Lee (Korea) and Mark Wells (USA);
- PICES-2013, Nanaimo, Canada – MEQ Workshop (W6) on "*Economic impacts of harmful algal blooms on fisheries and aquaculture*", Co-Convenors: Chang-Hoon Kim (Korea) and Vera Trainer (USA);
- PICES-2014, Yeosu, Korea – MEQ Workshop (W3) on "*Mitigation of harmful algal blooms: Novel approaches to a decades long problem affecting the viability of natural and aquaculture fisheries*", Co-Convenors: Ichiro Imai (Japan), Changkyu Lee (Korea), Charles Trick (Canada) and Mark Wells (USA).

3. Convene a joint PICES/ICES workshop to assess the purported links between climate change and HAB character, frequency and severity, and publish a comprehensive review paper that identifies the near- and long-term research priorities and the monitoring structures needed to effectively hindcast and forecast future HAB events.

Results: Review paper based on the findings from the PICES/ICES/IOC Workshop on "*Harmful algal blooms in a changing world*" held March 18–22, 2013, in Friday Harbor, USA, and led by Drs. Mark Wells (PICES/USA) and Bengt Karlson (ICES/Sweden). A synthesis paper (led by Drs. Wells, Karlson, and Ted Smayda) will be submitted to the journal *Harmful Algae* by the end of 2014.

4. Produce and post on the PICES website papers that document the unanimous HAB Section opinion on timely subjects related to HABs, including topics related to FUTURE such as how human activities (increased cultural eutrophication and climate changes including temperature, changes in stratification and ocean acidification) might affect harmful algal bloom incidence and magnitude.

Results:

- "*Harmful algal blooms in a changing world*", PICES Press, Vol. 21, No. 2, Summer 2013;
- "*Completion of the PICES Seafood Safety Project – Indonesia*", PICES Press, Vol. 20, No. 2, Summer 2012;
- *PICES Seafood Safety Project: Guatemala Training Program*", PICES Press, Vol. 18, No. 2, Summer 2010;
- *Proceedings of the Workshop on Economic Impacts of Harmful Algal Blooms on Fisheries and Aquaculture*, PICES Sci. Rep. No. 47, 85 pp.;
- "*Climate change and HABs*" to be published as a Commentary in the journal *Harmful Algae* in 2015.

The Section is responsible to, and is reviewed regularly by, the parent Committee, MEQ. However, S-HAB felt the communication between it and MEQ was not sufficient to allow it to align properly with its parent's goals.

2. Summary of S-HAB's recent progress

2.1 *Reports and other publications*

Proceedings of the Workshop on Economic Impacts of Harmful Algal Blooms on Fisheries and Aquaculture, PICES Sci. Rep. No. 47

Harmful algal blooms (HABs) have adverse economic and social impacts on the aquaculture industry, human health, coastal economies, and wild fisheries. This 85-page report, edited by Vera Trainer (USA), and Yoshida Takafumi (NOWPAP), addresses two FUTURE Research Themes, namely, (1) what determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing, and (2) how do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?

Special Issue *Harmful Algae* on HAB species

S-HAB has held a series of workshops on HAB species at PICES Annual Meetings. Many of these species will be highlighted in a Special Issue of the journal *Harmful Algae* that include publications from several of the PICES invited speakers, and contributions by PICES member countries. These contributions are a direct result of workshops at past PICES Annual Meetings.

2.2 *Cooperation with other organizations*

IMBER

S-HAB has responded to a request from IMBER regarding potential future collaborations. The Section feels that an international comparative ecosystem approach will be valuable, and S-HAB's response to IMBER will be expanded upon in the "*Climate change and HABs*" paper that will be published in the journal *Harmful Algae* in 2015.

ICES, GEOHAB, SCOR, IOC

Together with international partners, ICES, GEOHAB, SCOR, IOC, S-HAB is writing a Commentary for the journal *Harmful Algae* on "*Climate change and HABs*". This includes subsections on 1. what is known, 2. what is unknown, and 3. the way forward for the following parameters that may influence HAB intensity and occurrence under future climate scenarios: stratification, light, grazing, nutrients, ocean acidification, temperature. A list of important ecosystem types that should be monitored internationally for the purpose of assessing climate change impacts on HABs will be suggested in the publication. An introduction and synthesis (way forward) for the entire manuscript will be included. This work will be in press by late 2014.

IPHAB

A number of S-HAB members will participate in a Symposium on "*Harmful algal blooms and climate change*", to be held May 19–22, 2015 in Göteborg, Sweden (IPHAB Decision IPHAB-XI.1). The "*Proceedings of the Workshop on Economic Impacts of Harmful Algal Blooms on Fisheries and Aquaculture*" was published in 2014 as PICES Scientific Report No. 47, helping to fulfill IPHAB Decision IPHAB-XI.4 on "Regional HAB Programme Development", fulfilling term of reference vi) "evaluate the socio-economic impacts of HABs". S-HAB will continue to enter data into HAEDAT, fulfilling the term of reference i) "collating data on a regional HAB events for inclusion into HAEDAT" (IPHAB Decision IPHAB-XI.4).

2.3 *Other activities*

PICES/MAFF projects

S-HAB members made significant contributions to a 5-year PICES project on "*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*" funded by the Ministry of Agriculture, Forestry

and Fisheries of Japan (MAFF) by conducting country-specific training courses most required to ensure seafood safety in Pacific countries outside the PICES region. S-HAB is contributing to another 5-year PICES/MAFF project on "*Marine ecosystem health and human well-being*" as one of the PICES expert groups on the Project Team. The Section led scientific "pond experiment" efforts in Indonesia and will lead both a social science and oyster culture study in Guatemala.

MEQ comments and recommendations

- S-HAB has made great strides in HAB science in contributing data to HAE-DAT;
- S-HAB has held a number of workshops and a Topic Session at PICES Annual meetings, PICES/ICES/IOC Workshop on "*Harmful algal blooms in a changing world*", training workshops in Pacific Rim countries outside the PICES region, and is contributing to social science efforts in these regions as well;
- S-HAB has contributed to publications in PICES Press, PICES Scientific report, and to a peer-reviewed journal;
- Although S-HAB is very active, more attention and effort is paid to collaboration with other international organizations than with PICES, and its TOR do not keep pace with FUTURE goals, or needs of MEQ.

Recommendations

- New Terms of Reference should be drafted to align with FUTURE goals and MEQ Action Plan;
- Communication should be strengthened with MEQ and with AP-AICE, with AP-AICE providing more guidance on development and operation;
- Cooperation with other international organizations should continue and help strengthen the relationship with PICES;
- More contributions should be provided within PICES, especially for FUTURE.

S-HAB TOR for 2011–2014 can be found in Annex 1, and the proposed new TOR for 2015–2017 can be found in Annex 2.

Annex 1

Terms of Reference (2011–2014)

1. Continue PICES member country data entry into the joint ICES-PICES harmful algal event database to allow global comparison of changes in harmful algal bloom occurrences;
2. Convene workshops and sessions including joint sessions with other international organizations to evaluate and compare results and maintain an awareness of state-of-the-art advances outside the PICES community;
3. Convene a joint PICES/ICES workshop to assess the purported links between climate change and HAB character, frequency and severity, and publish a comprehensive review paper that identifies the near- and long-term research priorities and the monitoring structures needed to effectively hindcast and forecast future HAB events;
4. Produce and post on the PICES website papers that document the unanimous HAB Section opinion on timely subjects related to HABs, including topics related to FUTURE such as how human activities (increased cultural eutrophication and climate changes including temperature, changes in stratification and ocean acidification) might affect harmful algal bloom incidence and magnitude.

Annex 2

Proposed new Terms of Reference (2015–2017)

1. Guide ongoing deliverables to address the goals of FUTURE, particularly AICE and SOFE, through reports, commentaries, and publications in the peer reviewed literature;
2. Contribute to the development of the PICES Ecosystem Status Report by providing information on the known mechanisms underlying HAB occurrence and the environmental changes between the eastern and western Pacific;
3. Contribute to the development and updating of the Global HAB Status Report (a joint ICES/PICES/IOC report) by providing taxonomy, species distribution, and other biogeography data from the PICES region;
4. Convene a joint PICES/ICES/IOC/SCOR Open Science Meeting in 2015 to assess the purported links between climate change and HAB character, frequency and severity, and recommend the most promising research priorities for the next decade;
5. Produce a summary report for PICES nations on the current status and effectiveness of HAB mitigation strategies, and the key research priorities;
6. Report on new findings in harmful algal bloom dynamics in PICES member countries, and ensure the recording of these data in the joint ICES-PICES harmful algal event database (HAE-DAT) to facilitate intercomparision of the environmental drivers of harmful algal blooms.