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 chairmanship of Dr. Douding Lu (China) and Dr. Mark Wells (USA), on October 30, 2018, in Yokohama, Japan. Dr. Lu welcomed all participants, introduced and congratulated the new Co-Chair Dr. Mark Wells and expressed appreciation to Dr. Vera Trainer for her long-time outstanding leadership and great contribution to S-HAB. The meeting was attended by members from all PICES member countries (***S-HAB Endnote 1***). The proposed agenda for the meeting was reviewed and some items were rearranged or taken off the agenda before being approved by the Section (***S-HAB Endnote 2***).

Participants at the meeting of S-HAB at PICES-2018, Yokohama, Japan. Back row, from left: Douding Lu, Andrew Ross, Chuanxi Xing, Hao Guo, Misty Peacock, William P. Cochlan, Weol-Ae Lim, Tae Gyu Park, Louis Legendre (visiting participant), Mitsunori Iwataki, Pengbin Wang. Front row, from left: Vera L. Trainer, Ryuji Kuwahara, Natsuko Nakayama, Mark L. Wells, Yuji Tomaru, Seung Ho Baek, Ichiro Imai, Setsuko Sakamoto, Takafumi Yoshida.

AGENDA ITEM 2
Country reports

Canada

Prof. Mark Wells reported on behalf of Ms Nicola Haigh and Prof. Charles Trick regarding HABs and toxicity monitoring in Canada. Based on Canadian Food Inspection Agency (CFIA) data, only very low levels of domoic acid (DA) were detected in shellfish samples (2.1 µg/g in NW Vancouver Island in late August, 1.2 µg/g on the BC Central Coast in early August) in western Canada in 2017; almost no DA was seen in 2018. There were no reports of human illness due to diarrhetic shellfish poisoning (DSP) in 2017, but there were quite a few samples with low levels of DSP toxins (0.01–0.06 µg/g pectenotoxins, 0.06–0.13 µg/g okadaic acid + DTX). There appear to have been even more DSP toxins detected in 2018, but those data are not finalized yet, and there still have been no reports of effects on human health. There were widespread paralytic shellfish poisoning (PSP) closures in the Salish Sea and west coast of Vancouver Island (Pat Bay, 2100 µg/g, June 27), and BC Central Coast, from late June through September, 2017. In 2018 there were fewer PSP closures (data up to September). In 2015–2017 *Heterosigma akashiwo* blooms in BC were less frequent than in previous years, but in 2018 a large *Heterosigma* bloom in early June killed 50% of harvest-sized farmed Atlantic salmon at two aquaculture sites in the Salish Sea. There was also a *Heterosigma* bloom in SE Vancouver Island in late August. In other fish-killing HAB species, much fewer *Dictyocha*, *Chrysochromulina*, and *Alexandrium* species were seen in 2018 than in 2016–2017, and there were no other reports of farmed salmon mortality after June 2018.

USA

Dr. Vera Trainer reported on NOAA's Ecological Forecasting Program that emphasizes the importance of providing early warning of HABs in the U.S. This forecasting effort takes the form of HAB Bulletins that are released in key regions of the U.S. to provide managers with the tools to make important decisions about seafood safety and public health. The priority regions include Florida (brevetoxins), Gulf of Maine (paralytic shellfish toxins), Lake Erie (freshwater toxins) and the Pacific Northwest and California (domoic acid poisoning). Priority regions are selected based on the problem and identified user community, existing technical maturity, leverage for transition to operations, return on investment and budget. The Pacific Northwest HAB Bulletin benefited from the deployment of an ocean drone (the Submaran) in September 2018 which allows for automated sample collection, especially during times when weather does not allow for water to be collected by boats. Dr. Trainer reported on the Florida brevetoxin event that has resulted in the mortality of marine mammals, turtles and tons of fish. An Unusual Mortality Event has been declared for bottlenose dolphin deaths on the west coast of Florida. Information on the speculated causes for this extensive brevetoxin event is sparse although some theorize that recent hurricanes have caused the mixing and spread of *Karenia brevis* cells and nutrients to support the blooms.

China

Dr. Hao Guo gave a report on the status of red tides in China during 2017. About 68 events of marine red tides with an affected area of 3,680 km^2 were witnessed along the Chinese coastline. The number of red tide events were similar to the previous year but the cumulative occurrence area decreased by 51% compared to that in 2016. The highest frequency was 40 times, with the largest cumulative area of 2,189 km^2 occurring in the East China Sea. High incidences of red tide mainly occurred in June. Red tides were caused by a total of 34 species. Among them, *Karenia mikimotoi* was the most dominant species which caused the outbreak of as many as 12 red tides. In June, a red tide caused by *Gymnodinium catenatum* occurred in the coastal waters of southern Fujian Province, and PSP was detected in mussels and oysters. The area where green tides, *Enteromorpha prolifera*, have occurred has been the smallest in the past five years.

Japan

Dr. Natsuko Nakayama reported some of the issues related to HABs which occurred in Japan from 2016 to 2018. The report includes the following three main points; 1) HAB events, 2) Major HABs, and 3) DSP and PSP in Japan. In 1), there has been inter-annual variation in the blooms and fisheries damages for HAB events over the past few decades in western Japan, such as the Seto Inland Sea and Kyushu area, and following that, from 2016 to 2018. In the Seto Inland Sea, the number of blooms decreased during the mid-1970s-1980s and subsequently has been flat at approximately 100 cases or less per year. On the other hand, in the Kyushu area, the number has been increasing in recent years. In 2), a lot of cultured fish were damaged during July and August in 2018. The causative species was *Karenia mikimotoi*, which has scored the highest both in the number and monetary damage of blooms recently. In 3), the causative species for PSP are *Alexandrium tamarense* and *Alexandrium catenella*, which are common throughout Japan, and *Alexandrium tamiyavanichii* and *Alexandrium ostenfeldii*, which are in western Japan. *Gymnodinium catenatum* is also common in western Japan. The causative species of DSP are *Dinophysis fortii* and *Dinophysis acuminata*. The distribution of species with PSP has expanded and the distribution of those with DSP has been flat recently. PSP occurred extensively in both northern and western Japan in the spring of this year. The causative species was *A. tamarense*. The number of shipping regulations due to PSP was 56 cases by April 26, 2018, and will become the largest number in the record to date.

Korea

Dr. Weo-Ae Lim gave a report on the *Cochlodinium polykrikoides* blooms that have occurred in Korean coastal waters for more than 20 years, since 1995, and continue to cause damage to fisheries. In order to reduce fisheries damage caused by *C. polykrikoides* blooms, periodical investigations have been carried out on marine environmental factors and phytoplankton composition, as well as the use of real-time PCR

to analyze free living cells and cyst of *C. polykrikoides.* In the last three years, *C. polykrikoides* blooms did not occur, or blooms were very small because the water temperature was 3 to 5°C higher than average; higher temperatures are not suitable for the growth of *C. polykrikoide*. As a result, diatoms have dominated with the absence of *Cochlodinium*, as well as blooms of *Karenia mikimotoi*, *Chattonella*, and *Alexandrium affine*. Although the exceptionally high water temperature for the last three years is not direct evidence of climate change, if the water temperatures remain often high, it is highly likely to result in succession of HABs species.

Russia

Dr. Tatiana Orlova was unable to attend the S-HAB Meeting but sent a Russian HAB report to the Section Co-Chairs. The Russian monitoring program detected an under-ice bloom of unidentified algae from the class *Pelagophyceae* in Amur Bay (Peter the Great Bay) in February–March 2018 at a water temperature of –0.3 to –1.47°C and a water salinity of 32.68–34.26‰. Their maximum concentration reached 8.4 million cells/L.

The studies of the harmful dinoflagellate *Prorocentrum foraminosum* are continuing. Recent data suggest that marine bacteria could be involved in dinoflagellate toxicity (DTX-1). Clones of *P. foraminosum* and its associated bacteria from the culture collection "Marine Biobank" (http://marbank.dvo.ru) were analyzed after twelve months of cultivation in batch cultures. An integrated study, using different microscopy and molecular techniques, Raman microspectroscopy and HR LC-MS, was undertaken to elucidate biological aspects, and to identify main metabolites including toxins. The first data on the use of specific and universal molecular genetic markers for 16S rDNA, 23S rDNA and some genes of polyketide synthases (PKS) for determining the symbiotic composition of microorganisms associated with cultures of *P. foraminosum* were presented. The data provides evidence for an association between this dinoflagellate and bacteria.

Long-term (2007–2013) studies of morphology, genetics and toxicity of *Pseudo-nitzschia* spp. in the Russian waters of the Sea of Japan have been completed. Phylogenetic analysis of LSU and ITS1-5.8S rDNA-ITS2 sequences revealed five species: *P. calliantha*, *P. hasleana*, *P. multistriata*, *P. pungens* var. *pungens*, and *P. delicatissima*. *P. hasleana* is a new record for the Sea of Japan. The ITS1-5,8SrDNA-ITS2 topologies showed that the *P. delicatissima* clade A is formed from three subclades, including Pacific strains, as well as isolates from Scotland and Spain. The high values of genetic distances between subclades (3.7−5%) and the morphological similarity between strains are indicative of cryptic genetic diversity within the *P. delicatissima* clade A. Different ITS types, including a possibly recombinant type, occur in the same monoclonal culture of *P. multistriata*, suggesting the hybridization of the local populations in the studied area. *P. pungens* var. *pungens*, *P. delicatissima*, *P. calliantha*, and *P. multistriata* are bloom-forming species that can reach a high percentage of occurrence (6–21%) and a high density ($>10^4$ cells $\cdot$ L^{-1}) in the phytoplankton. The DA toxicity of *P. multistriata*, *P. calliantha*, *P. delicatissima*, and *P. pungens* var. *pungens* has been confirmed for the first time based on laboratory cultures isolated from the northwestern Pacific. The highest cellular DA concentration was found in cultures of *P. multistriata* and *P. calliantha* (up to 0.57 and 0.44 pg $\cdot$ $cell^{-1}$, respectively) isolated during their bloom events. Despite the DA, concentration in bivalves tissues was low and ranged from 0.01 to 0.3 mg $\cdot$ kg^{-1}; the increase of DA concentration in the mussel digestive gland samples during fall and early winter coincided with blooms caused by *P. multistriata* and *P. calliantha*. The results suggest a potential risk of seafood contamination in fall, which can be related with the recurrent blooms of toxic *P. calliantha* and *P. multistriata* in the study area.

AGENDA ITEM 3

Progress of Global HAB including Best Practices Manual

Dr. Vera Trainer reported on the GlobalHAB meeting in Villefranche sur mer, France, April 9–13, 2018, where she served as the *ex-officio* member representing PICES. The overall goal of GlobalHAB is to

improve understanding and prediction of HABs in aquatic ecosystems and to manage and mitigate their impacts. The mission of GlobalHAB is to foster international cooperative research to address the scientific and societal challenges of HABs, including the environmental, human health and economic impacts in a rapidly changing world. Researchers can request endorsement of their projects from GlobalHAB using the form on the website (www.globalhab.org).

One of the primary limitations in HAB science is that it currently is not possible to quantitatively compare findings among studies, even when working with the same organism, toxins, field programs or time series analyses, due to the wide range of methodologies used. The PICES S-HAB has taken the lead in working to overcome this problem by promoting the development of a "*Guidelines for Best Practices in the Study of HABs and Climate Change*". Dr. Mark Wells (S-HAB Co-Chair) is the lead editor of the manual, together with Michele Burford, Anke Kremp, Marina Montresor, Grant Pitcher and Gires Usup. The focus for the manual is to create a toolbox that enhances our ability to study the specific effects that climate change may have on the character, frequency and intensity of HABs. Draft chapters are due early in the new year.

A special issue on "Climate Change and HABs" is being prepared for the journal *Harmful Algae*, with 14 articles in progress. Dr. Mark Wells is a co-editor for this issue along with Dr. Chris Gobler (USA). GlobalHAB will support the open access of articles. Dr. Wells is leading a summary titled "*The future of HAB science: Directions and challenges*", Dr. Trainer is leading a chapter titled "*Pelagic HABs and climate change*", and Dr. Charles Trick is leading a chapter titled "*Fish-killing HABs and climate change*".

AGENDA ITEM 4
HAE-DAT, HABMAP

Dr. Vera Trainer reported on the interest by HAB researchers to publish a GlobalHAB Status Report to include maps summarizing HAB occurrences in the Harmful Algal Event Database (HAEDAT). Dr. Gustaaf Hallegraeff has proposed that a series of papers from each country (including PICES member countries) be published in a special issue of the journal *Harmful Algae*. He suggests that for each region, these papers should include: 1. A historical overview of HAB problems, 2. Overview of known HAB species in that area, 3. An analysis of HAEDAT events, 4. Information on long-term species of biotoxin data in the region, and 5. Interpretation of these trend data. Dr. Trainer will send more information to S-HAB to determine whether there is sufficient interest by S-HAB members to contribute to this publication.

AGENDA ITEM 5
New MAFF project plan

Dr. Mark Wells is Co-Chair with Dr. Mitsutaku Makino (HD) of the Ministry of Agriculture, Forestry and Fisheries-funded (MAFF) project on "Building capacity for coastal monitoring by local small-scale fishers". The Project Science Team includes members from each PICES member country with expertise in fisheries, HABs, and data management. The project collaborates with Dr. Suhendar Sachoemar of the Indonesian Agency for the Assessment and Application of Technology (BPPT). The overall goal of the project is to use smartphone-based citizen science to enable local small-scale fishers to monitor coastal ecosystems and coastal fisheries in Pacific Rim developing countries. The project is designed to enable the collection of environmental, and fisheries and harmful algal bloom data that can be used to address two key questions: (a) how do global changes in climate and economy affect coastal ecosystems? and (b) how may enhanced capacity for monitoring activities by local fishers help to improve fisheries management in coastal areas?

Indonesia was chosen as a developing Pacific Rim country to implement the project. The importance of having more effective fisheries management practices is widely recognized in Indonesia, and this leads to

support by the government and the willingness of local communities and stakeholders to consider new approaches such as development and implementation of a fisherman/citizen-based observation system, linked with fisheries scientists and managers.

The communities also harvest shellfish, but there is no seafood safety monitoring in the case study sites. The first MAFF project with PICES, the PICES Seafood Safety project, included HAB training with members of Indonesian Ministry of Fisheries, and the Indonesian Institute of Sciences (LIPI). The present MAFF project has linked with those experts at LIPI to develop citizen-assisted programs to help identify phytoplankton community composition changes and the appearance of Harmful Algal Species in the case study sites.

The project is midway through Year 2. To date, two Project Science Team meetings have been held (January and November, 2018, Yokohama), an exploratory site visit (March 2018) to three Indonesian communities, and a training workshop for community fishers from two communities.

AGENDA ITEM 6
Workshop proposal for 2019

S-HAB proposes a 2.5-day workshop on the "*Economic effects of HABs: Recommended practices*" for 2019 (S-HAB Endnote 3). GlobalHAB is also highly interested in fostering this workshop, along with other international organizations. Possible financial support will also come from ISSHA, IOC, ICES, and NOWPAP.

AGENDA ITEM 7
Nomination of potential new members

S-HAB nominated Pengbin Wang (China) and Andrew Ross (Canada) to be new members.

AGENDA ITEM 8
S-HAB--past, current and planned activities related to FUTURE

No discussion.

AGENDA ITEM 9
Requests to MEQ and other issues

a. Participation in GlobalHAB SSC meeting (Vera Trainer) - $3000 USD;
b. Participation in the Best Practices Manual (Mark Wells) meeting - $3000 USD [This was discussed at the MEQ meeting and the MEQ Chair requested more information about what has been accomplished to date on the Best Practices Manual to justify this additional request for funds.]
c. Half-day S-HAB meeting at PICES-2019;
d. 2.5-day workshop on HABs and economical impacts (tentatively co-sponsored by ICES, GlobalHAB, ISSHA, IOC, NOAA) - $2000 USD to supplement travel of PICES-2019 participants (to allow them to stay in Victoria 2 extra days for the workshop), plus student funding;
e. Pengbin Wang (China) and Andrew Ross (Canada) to be added the S-HAB membership.

S-HAB Endnote 1

S-HAB participation list

Members

Seung Ho Baek (Korea)
William Cochlan (USA)
Hao Guo (China)
Ichiro Imai (Japan)
Mitsunori Iwataki (Japan)
Ryuji Kuwahara (Japan)
Weol-Ae Lim (Korea)
Douding Lu (China, Co-Chair)
Natsuko Nakayama (Japan)
Tae Gyu Park (Korea)
Misty Peacock (USA)
Setsuko Sakamoto (Japan)
Yuji Tomaru (Japan)
Vera L. Trainer (USA)
Charles Trick (Canada)
Mark L. Wells (USA, Co-Chair)
Takafumi Yoshida (*ex officio*, representing NOWPAP)

Observers

Louis Legendre (France)
Hongxia Ming (China)
Andrew Ross (Canada)
Pengbin Wang (China)
Chuanxi Xing (China)

Members unable to attend

Canada: Nicola Haigh
China: Chunlei Gao, Chuangjiang Guan, Qiufen Li, Mengmeng Tong
Korea: Hae Jin Jeong, Kwang Young Kim
Russia: Olga Lukyanova, Tatiana Morozova, Tatiana Orlova, Mikhail Simokon

S-HAB Endnote 2

S-HAB meeting agenda

1. Welcome address (Douding Lu and Mark Wells)
2. Country reports
3. Progress of Global HAB including Best Practices Manual
4. AE-DAT, HABMAP
5. New MAFF project plan
6. Workshop proposal for 2019 & Brief report on ICHA2018
7. Nomination of potential new members
8. S-HAB--past, current and planned activities related to FUTURE
9. Requests to MEQ and other issues

S-HAB Endnote 3

Proposal for a 2.5-day Workshop on "*Economic effects of HABs: Recommended practices*" at PICES-2019

Convenors: Vera L. Trainer, Vera.L.Trainer@noaa.gov (corresponding), Keith Davidson (ICES, WGHABD), and TBD

Co-sponsors: GlobalHAB, International Society for the Study of Harmful Algae (ISSHA), NOAA, NOWPAP, WESTPAC

Over the last 2 decades, several reports have compiled what is known about the economic effects of harmful algal blooms. However, both the type and amount of available data are limited, and these reports largely have been compiled by marine scientists rather than economic experts. Most coastal states have neither conducted economic analyses of HABs nor collected data that can be used to generate reliable quantitative estimates of net economic losses and economic impacts. Proposals submitted to NOAA for economic impact studies demonstrate this lack of coordination; they are strong either in the HAB science or economic assessments, but not both.

We propose a 2.5-day international workshop, prior to or in conjunction with the 2019 Annual PICES Meeting in Victoria, to bring together international experts on economics and the science of harmful algal blooms to develop a best practices manual for the study of economic impacts of HABs. The proposed workshop structure is:

Day 1: Recommended practices for 4 specific HAB examples – Consideration of 4 case studies of HABs globally, including losses to aquaculture, 2 wild fisheries and a recreational fishery. Breakout groups will discuss value of information from better or more refined forecasts and best practices for economic assessment, including economic impacts and net economic losses.

Day 2: Strategies for economic mitigation – Can contingency planning reduce losses, how do we open areas more quickly, how do we make closures shorter, and what is the value of information from better forecasts? In particular, we will discuss approaches for assessing the value of the forecasts *versus* the cost of monitoring.

Day 3 (half day): Social science – Discussion of social science impacts and how to assess impacts on health (including mental health), well-being, resilience of coastal communities (non-financial impacts). Wrap up and writing assignments.

The workshop will provide science-based progress towards achieving ocean Sustainable Development Goals. The output will be a guide on best practices for quantifying economic effects of HABs that focuses on establishing connections between researchers and economists. A shorter version of the guide may be prepared for submission to a journal. The workshop also will (1) set priorities for the future, (2) develop partnerships between social scientists, economists and HAB researchers, and (3) attract resources to the field.