6.0 RELATIONS WITH INTERGOVERNMENTAL ORGANIZATIONS

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6.1 Intergovernmental Oceanographic Commission (IOC) *Arico, Sicre*

6.2 Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) *Urban*

GESAMP WORKING GROUP 38
THE ATMOSPHERIC INPUT OF CHEMICALS TO THE OCEANS

Annual Report to SCOR by the Co-Chairmen of GESAMP Working Group 38
Robert Duce and Timothy Jickells
July 2018

History, early meetings and their results

1 GESAMP Working Group 38 was formed in 2008 because of growing concern about the impact of atmospheric deposition of both natural and anthropogenic substances on ocean chemistry, biology, and biogeochemistry, as well as climate. WG 38 has held meetings at the University of Arizona, Tucson, Arizona, United States, in 2008; at IMO in London in 2010, in Malta in 2011; and at the University of East Anglia, Norwich, UK in 2013 and 2017. Sponsors of those WG 38 efforts have included WMO, SCOR, IMO, the U.S. National Science Foundation, SIDA, the European Commission Joint Research Centre, the University of Arizona, the International Environment Institute at the University of Malta, and the University of East Anglia. Following the initial terms of reference and the meetings through 2011, five scientific papers were published in the peer-reviewed scientific literature. These were as follows:

[1] Okin, G., A. R. Baker, I. Tegen, N. M. Mahowald, F. J. Dentener, R A. Duce, et al., "Impacts of atmospheric nutrient deposition on marine productivity: roles of nitrogen, phosphorus, and iron, Global Biogeochemical Cycles, 25, GB2022, doi:10.1029/2010GB003858, (2011).

[2] Hunter, K.A., P. S. Liss, V. Surapipith, F. Dentener, R. A. Duce, M. Kanakidou, et al., "Impacts of anthropogenic SO_x, NO_x and NH_3 on acidification of coastal waters and shipping lanes", Geophysical Research Letters, 38, L13602, doi:10.1029/2011GL047720 (2011).

[3] Kanakidou, M., Kanakidou, M., R. Duce, J. Prospero, A. Baker, et al., "Atmospheric fluxes of organic N and P to the ocean", Global Biogeochemical Cycles, GB3026, doi:10.1029/2011GB004277 (2012).

[4] Schulz, M., J. M. Prospero, A. R. Baker, F. Dentener, L. Ickes, P. S. Liss et al., "The atmospheric transport and deposition of mineral dust to the ocean - Implications for research needs", Environmental Science and Technology, 46, doi:10.1021/es30073ul, 10,390-10,404 (2012).

[5] Hagens, M., K. A. Hunter, Peter S. Liss, and Jack J. Middelburg, "Biogeochemical context impacts seawater pH changes resulting from atmospheric sulfur and nitrogen deposition", Geophysical Research Letters, 41, doi:10.1002/2013GL058796 (2014).

Nitrogen workshop in Norwich, United Kingdom, 2013

2 New Terms of Reference for continued work of GESAMP WG 38 were approved in 2011 to address issues related to the impact of the atmospheric deposition of anthropogenic nitrogen to the ocean. A highly successful workshop on "The Atmospheric Deposition of Nitrogen and its Impact on Marine Biogeochemistry" was held by WG 38 at the University of East Anglia in February 2013 to address the new terms of reference. Twenty-three scientists participated in the workshop. As a result of the Norwich nitrogen workshop several papers have been published in the peer-reviewed scientific literature on this nitrogen issue. These include

[6] Kim, T.-W., K. Lee, R.A. Duce and P.S. Liss, "Impact of atmospheric nitrogen deposition on phytoplankton productivity in the South China Sea", Geophysical Research Letters, 41, 3156-3162, doi: 10.1002/2014GL059665 (2014).

[7] Somes, C., A. Landolfi1, W. Koeve1, and A. Oschlies, "Limited impact of atmospheric nitrogen deposition on marine productivity due to biogeochemical feedbacks in a global ocean model, Geophysical Research Letters, 43, 4500–4509, doi:10.1002/2016GL068335 (2016).

[8] Kanakidou, M., S. Myriokefalitakis, N. Daskalakas, G. Fanourgakis, A. Nenes, A.R. Baker, K.Tsigaridis, and N. Mihalopoulos, "Past, Present, and Future Atmospheric Nitrogen Deposition", Journal of the Atmospheric Sciences, 73, 2039-2047, doi:10.1175/JAS-D-15-0278.1. (2016).

[9] Sharples, J., J. J. Middelburg, K. Fennel, and T. D. Jickells, "What proportion of riverine nutrients reaches the open ocean", Global Biogeochemical Cycles, 31, 39–58, doi:10.1002/2016GB005483. (2017).

[10] Jickells, T.D., E. Buitenhuis, K. Altieri, A.R. Baker, et al., "A re-evaluation of the magnitude and impacts of anthropogenic atmospheric nitrogen inputs on the ocean", Biogeochemical Cycles, 31, 289–305, doi:10.1002/2016GB005586. (2017).

[11] Baker, A.R., M. Kanakidou, K. E. Altieri, et al., "Observation- and model-based estimates of particulate dry nitrogen deposition to the oceans", Atmospheric Chemistry and Physics, 17, 8189-8210, (2017).

One final nitrogen paper will be submitted this fall:

[12] Suntharalingam, P., L. M. Zamora, H.W. Bange, S. Bikkina, E. Buitenhuis, A. Landolfi, L. Resplandy, M. M. Sarin, S. Seitzinger and A. Singh, "Increasing inputs of anthropogenic nitrogen to the Northern Indian Ocean and impacts on oceanic N_2O fluxes: the need for a nitrogen observation and modelling network", To be submitted to Deep Sea Research II, special issue on the Second International Indian Ocean Expedition

3 Following the completion of the publication of the papers resulting from the 2013 workshop on the impacts of atmospheric nitrogen deposition to the ocean, WG 38 prepared a synthesis of the results from the scientific papers derived from that workshop. That report was reviewed by GESAMP and published by WMO in early 2018 as GESAMP Reports and Studies No. 97, The Magnitude and Impacts of Anthropogenic Atmospheric Nitrogen Inputs to the Ocean.

The primary conclusions of R&S 97 were as follows:

3.1 This synthesis by GESAMP WG 38 provides new current best estimates of nitrogen inputs to the ocean from the atmosphere (39 TgN y^{-1}), and for context synthesises comparable estimates of inputs from rivers (34 TgN y^{-1}) and natural biological nitrogen fixation (164 TgN y^{-1}). Most of the atmospheric nitrogen input reaches the open ocean beyond the shelf break, while a substantial part of the riverine input is trapped on the shelf. Both the riverine and atmospheric nitrogen inputs have been substantially increased by human activity, with the atmosphere now the main vehicle by which anthropogenic nitrogen reaches the open ocean. The atmospheric input of nitrogen is estimated to now be almost 4 times that in 1850, and even in 1850 conditions were not pristine.

3.2 Atmospheric deposition of nitrogen to the ocean involves several distinct chemical components, each of approximately the same magnitude; oxidised nitrogen, primarily nitrate aerosol and nitric acid; reduced nitrogen, primarily ammonium aerosol and ammonia; and a poorly characterised organic nitrogen component. Identification of sources is important for the effective management of nitrogen inputs to the ocean. The main anthropogenic source of oxidised nitrogen is fossil fuel combustion on land plus an increasingly important source from fuel combustion on ships, while for reduced nitrogen the primary anthropogenic emission source is from intensive agriculture. There is also an important, but poorly understood, natural recycling of ammonia and organic nitrogen between the atmosphere and the ocean. The quantification of the net magnitude of atmospheric nitrogen inputs to the ocean and their impact is sensitive to the uncertainties in the magnitude of this recycling.

3.3 Atmospheric nitrogen emissions come predominantly from areas of high fossil fuel combustion and high rates of intensive agriculture. The largest emission sources are in North America, Europe, India and Southeast Asia. Models based on future emission scenarios suggest that total nitrogen inputs to the ocean will change little between now and 2050, but that emissions are likely to increase over south Asia and decline over North America and Europe. The largest inputs of nitrogen to the ocean occur downwind of these large emission sources over the North Atlantic, Northern Indian and northwest Pacific oceans. Impacts of this atmospheric deposition on the marine environment have been previously suggested for the northwest Pacific, and impacts in this region and the northern Indian Ocean are likely to increase in the future, based on the emission scenarios considered. Such impacts may include increases in phytoplankton production; in the northwestern Indian Ocean this may lead to increases in the emissions of the greenhouse gas N_2O from the low-oxygen waters that occur naturally at depth in this region.

3.4 More generally, the impact of nitrogen deposition to the ocean will be an increase in primary production in regions that are currently nitrogen limited, which include the surface waters of tropical ocean gyres. The increase in ocean production at the present day compared to 1850 levels is estimated to be about 0.4%, with an associated increase in the ocean uptake of CO_2 of 0.15Pg C y^{-1}. This estimate is very sensitive to assumptions about feedbacks that involve atmospheric nitrogen deposition suppressing nitrogen fixation. There is also, on a longer time scale, a sensitivity to feedbacks in which increasing nitrogen inputs to the ocean increase primary production and organic matter inputs to the deep ocean, increasing denitrification and anammox and leading to increased emissions of N_2 and N_2O gas.

Current Activities of Working Group 38

4 For the fifth year in a row WG 38 organized a session on atmospheric input of chemicals to the ocean for the 2018 European Geosciences Union meeting, held in Vienna, Austria in April – "Air-sea Exchanges: Impacts on Biogeochemistry and Climate". Several oral and poster papers at this session were presented by a combination of WG 38 members and other scientists.

5 Tim Jickells attended the INMS International Nitrogen Management System annual meeting in Edinburgh UK on 16-19 April to represent WG38 and supported by INMS. At the meeting he informally presented the work of WG 38 to relevant leaders of INMS activity, particularly those leading initiatives in Southeast Asia, and he presented details of our synthesis report. He made clear the enthusiasm of WG38 to work with the INMS initiatives if they felt that would be useful and we await their responses.

One response has been that Tim Jickells has been invited to attend and participate in the 2nd East Asia Nitrogen Conference in Tsukuba, Japan from 19 to 22 November 2018. He will be giving a keynote talk on the atmosphere/ocean aspects of the nitrogen cycle on behalf of WG 38, and he will participate in a subsequent workshop. We hope that this effort will increase our interactions with the INMS activity.

6 WG38 proposed the following activity to be considered for the OceanObs'19 ocean observing community conference: "Ocean observations to estimate atmospheric nutrient and trace metal inputs to the oceans". This has been adopted and will be incorporated as part of a white paper that is currently being prepared for a special issue of Frontiers in Marine Science in advance of the conference. Alex Baker is taking the lead on this effort by WG 38.

7 At the meeting of GESAMP 42 at IOC in Paris in September 2015, GESAMP approved two new workshops for WG 38. These two simultaneous workshops were related to the changing acid/base character of the global atmosphere and ocean and the impact of these changes on certain air/sea chemical exchange processes. Funding was obtained for these workshops from the U.S. National Science Foundation (through SCOR), from WMO, and from IMO. SOLAS also sponsored these workshops. The workshops took place at the University of East Anglia (UEA) in Norwich, United Kingdom from February 27 through March 2, 2017.
The topics of the two workshops were as follows:

Impact of Ocean Acidification on Fluxes of Atmospheric non-CO_2 Climate-Active Species

Changing Atmospheric Nutrient Oceanic Solubility

8 The workshops took the form of rather informal presentations from experts followed by very lengthy discussion sessions exploring multiple issues and feedbacks evident in these complex air-sea interaction issues. The invited scientists were selected for their expertise and interest in these areas, and also to provide a wide spectrum of expertise from modellers to experimentalists. Thirty-four scientists from 16 countries and also from a wide range of career stages, from senior scientists through to graduate students, participated in the workshops. At the present time the following papers have been published, are in press, have been or shortly will be submitted, and are still in preparation from the workshop discussions:

Published:

[13] Kim, J.-M, K. Lee, Y.-S. Suh, and I.S. Han, "Phytoplankton do not produce carbon-rich organic matter in high CO2 oceans", Geophysical Research Letters, 45, 4189–4197. https://doi.org/10.1029/ 2017GL075865 (2018).

In Press:

[14] Kanakidou, M., S. Myriokefalitakis, and K. Tsigaridis, "Aerosols in atmospheric chemistry and biogeochemical cycles of nutrients, In press, Environmental Research Letters (2018).

Submitted:

[15] Ito, A., S. Myriokefalitakis, M. Kanakidou, N.M. Mahowald, R.S. Scanza, D.S. Hamilton, A.R. Baker, T.D. Jickells, M. Sarin, S. Bikkina, Y. Gao, R.U. Shelley, C.S. Buck, W.M. Landing, A.R. Bowie, M.M.G. Perron, C. Guieu, N. Meskhidze, M.S. Johnson, Y. Feng, J.F. Kok, A. Nenes, and R.A. Duce, "Constraints on attribution of labile iron in aerosols to combustion and mineral dust sources from observations and models", Submitted to Nature Communications, (2018).

[16] Myriokefalitakis, S., A. Ito, M. Kanakidou, A. Nenes, M. C. Krol, N. M. Mahowald, R. A. Scanza, D. S. Hamilton, M. S. Johnson, N. Meskhidze, J. F. Kok, C. Guieu, A. R. Baker, T. D. Jickells, M. Sarin, B. Srinivas, M. M. G. Perron, and R. A. Duce, "The GESAMP atmospheric iron deposition model intercomparison study", Submitted to Biogeosciences (2018)

To Be Submitted Shortly:

[17] Hopkins, F.E., P. Suntharalingam, M. Gehlen, O. Andrews, S.D. Archer, L. Bopp, E. Buitenhuis, I. Dadou, R.A. Duce, N. Goris, T.D. Jickells, M. Johnson, F. Keng, C.S. Law[j], K. Lee, P.S. Liss, M. Lizott, G. Malin, C. Murrell, H. Naik, A. Rees, J.

Schwinger, and P. Williamson, “Changing ocean acidity as a modulator of atmospheric biogeochemistry and climate”, To be submitted to Proceedings of the National Academy of Sciences (2018).

[18] Baker, A.R., M. Sarin, R.A. Duce, T.D. Jickells, M. Kanakidou, A. Nenes, S. Myriokefalitakis, A. Ito, D. Turner, N.M. Mahowald, R. Middag, C. Guieu, Y. Gao, P. Croot, R. Shelley, and M.M.G. Perron, "Changing Atmospheric Acidity and the Oceanic Solubility of Nutrients", To be submitted to Proceedings of the National Academy of Sciences (2018).

In Preparation:

[19] Peter Croot, lead author, “Controls and impacts of atmospheric nutrient solubility in the ocean”.

[20] Peter Croot, lead author, “Impacts of the episodic atmospheric deposition on ocean biogeochemistry”.

[21] Steve Archer, lead author, “A synthesis of the DMS response to ocean acidification observed in mesocosm experiments”.

Future Activities of Working Group 38

9 The goal of WG 38 for the next year is to complete the submission and publication of all papers resulting from the 2017 workshop at the University of East Anglia.

6.3 North Pacific Marine Science Organization (PICES) *Sun Song*

SCOR and PICES Collaborative Activities

Report from PICES for the 2018 SCOR Annual Meeting
September 4-7, 2018, Plymouth, UK

The North Pacific Marine Science Organization (PICES) is an intergovernmental scientific organization established by an international convention in 1992, in order to promote and coordinate marine scientific research in the North Pacific and adjacent seas. Our current member countries are Canada, Japan, People's Republic of China, Republic of Korea, Russian Federation and the United States of America. Our goals are to (1) advance scientific knowledge and capacity available for the member countries, including information on human activities affecting, and affected by marine ecosystems; and (2) provide a mechanism for collaboration among scientists in addressing timely and critical scientific questions about the North Pacific. In the 27 years since its establishment, PICES has become a major forum for the discussion and sharing of marine science in the North Pacific. Information on the Organization and its activities is available on the PICES website at http://www.pices.int.

SCOR and PICES have worked out ways of cooperation that have made it possible for an international non-governmental organization and a regional intergovernmental organization to share their strengths. Continuing and expanding collaboration between PICES and SCOR is based on the recognition that PICES can play an important role in bringing a North Pacific perspective to the global activities of SCOR, and that by participating in and implementing these activities in the region, PICES can advance its own scientific agenda. PICES contributes scientific expertise to SCOR-sponsored international large-scale ocean research projects (HABs [GlobalHAB], IMBeR, SOLAS, GACS [Global Alliance of Continuous Plankton Recorder Surveys]), to ocean carbon activities (IOCCP [International Ocean Carbon Coordination Project]) supported by SCOR, and to several SCOR Working Groups. In addition to the above, PICES and SCOR are both strong proponents of capacity building.

To discuss on-going and future collaborations, SCOR and PICES continue to regularly exchange observers to the other's annual/executive meetings. In recent years, SCOR was represented by Dr. Sinjae Yoo (Korea) at the PICES-2014 annual meeting in Yeosu, Korea, Dr. Sun Song, Vice-president of SCOR at the PICES-2015 annual meeting in Qingdao, China, and Edward Urban at the PICES-2016 meeting in San Diego, USA. Dr. Harold Batchelder (PICES, SCOR Capacity Building Committee Liaison) attended the 2013 SCOR Executive Committee Meeting (Wellington, New Zealand), the 2014 SCOR meeting (Bremen, Germany), the 2015 meeting in Goa, India, and the 2016 meeting in Sopot, Poland. A written report and PowerPoint file of PICES activities in 2017 was prepared by PICES and presented by Song Sun (China) on behalf of PICES at the 2017 SCOR meeting in Cape Town, South Africa.

Dr. Sinjae Yoo (Korea) represented SCOR at the PICES-2014 annual meeting in Yeosu, Korea; Dr. Sun Song, Vice-president of SCOR, represented SCOR at the PICES-2015 annual meeting in Qingdao. Ed Urban represented PICES in 2016 in San Diego. According to our records, SCOR was not represented at PICES-2017 in Vladivostok. No one has been confirmed as a SCOR

representative to PICES-2018 for the Yokohama, Japan meeting (25 Oct – 4 Nov 2018).

This report provides an update on PICES-SCOR collaborations since the 2017 SCOR Meeting in South Africa. This period includes the PICES 26th Annual Meeting, which was in Vladivostok, Russia in September 2017.

During this reporting interval, SCOR generously provided financial support for travel/local costs of early career scientists of "countries with economies in transition" for a symposium held in La Paz, Mexico titled "*Understanding Changes in Transitional Areas of the North Pacific*" from 24-26 April 2008 (see Appendix 1, Table 1), and we hope and anticipate support for PICES-2018 (Yokohama, Japan) in October 2018 (a completed request for SCOR financial support was emailed to Dr. Urban on 9 June 2018). PICES is greatly appreciative of SCOR's support, since it is difficult for PICES to fund participants from non-PICES countries.

(1) SCOR provided $2500 USD for the PICES-2017 Annual Meeting that was held from 22 September – 1 October 2017 in Vladivostok, Russia. Plus, Ed Urban approved transfer of $283 USD residual from the PICES/ICES ECS3 to PICES-2017. Awarded support from SCOR to PICES-2017 participants is shown in **Appendix 1 Table 2.**

(2) SCOR provided $3000 USD to PICES to support international travel of early career scientists to attend the International Symposium on *Understanding Changes in Transitional Areas of the Pacific*, which was held in La Paz, Mexico, from 24-26 April 2018. See **Appendix 1 Table 1a**.

(3) SCOR provided $3000 USD to PICES to support international travel of scientists from developing countries to attend the 4th Effects of Climate Change on the World's Oceans Symposium in Washington, DC, 2-9 June 2018. See **Appendix 1 Table 1b**.

(4) SCOR provided $5,200 USD to PICES on behalf of SOLAS to support international travel of scientists from developing countries to attend the 4th Effects of Climate Change on the World's Oceans Symposium in Washington, DC, 2-9 June 2018. See **Appendix 1 Table 1c**.

LARGE-SCALE OCEAN RESEARCH PROJECTS CO-SPONSORED BY SCOR

PICES contributes to SCOR-sponsored international large-scale ocean research projects, particularly IMBeR and SOLAS, by: (1) convening joint sessions/workshops with the projects at PICES Annual Meetings, (2) co-sponsoring symposia/workshops/summer schools, (3) assisting projects having North Pacific activities with meeting logistics, and (4) contributing to participation of early-career scientists from the North Pacific region in project activities.

Integrated Marine Biosphere Research (IMBeR)

- Joint sessions/workshops at PICES Annual Meetings
  Co-sponsorship by IMBeR has been reduced during the past few years, as IMBeR focused on redefining its strategic and implementation plan for the transition from IGBP to Future Earth (FE). In May 2016, PICES Science Board Chairman Thomas Therriault and Hal Batchelder of the PICES Secretariat met with Eileen Hofmann (former chair of IMBeR SSC), Einar Svendsen (Executive Officer, IMBeR), and Lisa Maddison (Deputy Executive Officer,

IMBeR) in Bergen, Norway to discuss how to enhance collaborations between PICES and IMBeR.

- The PICES-2016 Annual Meeting held November 2-13, 2016, in San Diego, CA, USA had a theme of "*25 Years of PICES: Celebrating the Past, Imagining the Future*". IMBeR was invited to submit a theme and cosponsor a topic session or workshop for PICES-2016 (San Diego), but chose not to. The 2016 meeting was the 25th anniversary meeting of PICES, and had a different structure with more workshops (10), fewer concurrent sessions and more plenary sessions than are typical of the PICES annual meeting. Because there were many more posters than usual, posters were displayed for four days rather than the usual three days, and there were two evening poster receptions rather than one. Gro van der Meeren (IMBeR Executive Officer) and Cisco Werner (IMBeR SSC Vice-Chair) represented the IMBeR International Project Office at PICES-2016, and both made presentations to the PICES Science Board. They highlighted some of the areas of overlap and common interest including the ESSAS Regional Program, the Carbon Working Group, and the connections between the IMBeR Human Dimensions Working Group and the PICES FUTURE integrative science program. At PICES-2017, PICES transitioned the Section-Human Dimensions expert group to full committee status (Human Dimensions Committee), which provides greater responsibility and visibility to socioeconomic issues and HD a voice on the PICES Science Board.

Co-sponsorship of symposia/conferences/workshops

IMBeR co-sponsored (providing $3,000 USD) the *4th Effects of Climate Change on the World's Oceans Symposium*, held from 2-9 June 2018 in Washington, DC. About 550 scientists participated and benefited from the information provided within 18 topic sessions spread across five days, and 11 workshops on the first weekend.

Capacity building activities

PICES approved financial support of $7,000 CAD to IMBeR for cosponsorship of the IMBeR IMBIZO 5 that was held in Woods Hole, MA, USA on 2-6 October 2017. Support for IMBIZO 5 was provided to two scientists from Canada and one from China. **See Appendix 2, Table 1**

IMBeR Regional Programs == ESSAS

- IMBeR Regional Program on *Ecosystem Studies of Sub-Arctic Seas* (ESSAS)
  - PICES and ESSAS share the goal of using a comparative approach in developing predictions of how climate variability and change affect, and will affect, the sustainability of goods and services obtained from Sub-Arctic seas.
  - A PICES/ESSAS special issue of *Progress in Oceanography* on "*Modeling and observational approaches to understanding marine ecosystem dynamics*" (Guest Editors: E. Curchitser, S.I. Ito, M. Kishi, M. Peck and K. Rose) was published electronically in late 2015 and in hard copy in early 2016.
  - ESSAS requested financial support from PICES to cosponsor the ESSAS Open Science Meeting (OSM) in Tromso, Norway in June 2017. PICES Science Board agreed to

provide $14,000 CAD for early career scientist travel to the OSM. The ten supported ECS were reported to SCOR in the report last year.

Representation

To maintain close relations, IMBeR/ESSAS and PICES regularly exchange observers at each other's annual/executive meetings.

- IMBeR is normally present as an observer at PICES Annual Meetings. Dr. Yi Xu (Shanghai Regional Project Office) represented IMBeR at PICES-2015 and provided a presentation about IMBeR activities to Science Board; Gro van der Meeren (IMBeR Executive Officer) and Cisco Werner (IMBeR SSC Vice-Chair) represented the IMBeR International Project Office at PICES-2016. We anticipate that Cisco will represent IMBeR at PICES-2017 in Vladivostok, since he is also a member of the Governing Council of PICES.
- Drs. Franz Mueter and Sei-ichi Saitoh represented ESSAS at PICES-2015. Both, along with the third co-chair of ESSAS, Ken Drinkwater were at PICES-2016. Saitoh and Mueter are expected to attend PICES-2017. Sei-ichi Saitoh will represent ESSAS at PICES-2018.

IMBeR Regional Programs == CLIOTOP

- IMBER Regional Program on CLimate Impacts on Oceanic TOp Predators (CLIOTOP)
- No specific financial requests from CLIOTOP were received during the reporting interval, and CLIOTOP did not sponsor/co-fund any PICES activities in late 2017 or 2018.

Surface Ocean-Lower Atmosphere Study (SOLAS)

Joint sessions/workshops at PICES Annual Meetings

- We had no significant joint PICES-SOLAS activities in 2016 or 2017. This may be because of similar reasons as the IMBeR hiatus, as SOLAS was also proposing new initiatives to be associated with Future Earth (FE).

Capacity building activities

- In 2018, SOLAS is organizing a Summer School spanning the 23 July to 4 August in Cargese, France. This is the 7th International SOLAS Summer School, and the first since 2013.
- Objective of the 7th SOLAS Summer school is to expose graduate students and young scientists to recent developments and methods in the study of biogeochemical and physical feedbacks between the ocean and atmosphere in a changing environment. PICES committed $7,000 CAD to support travel and/or local costs for 2-3 students. The SOLAS International Project Office in Kiel, Germany identified two young scientists from Canada to be supported with PICES funding. Typically, for summer schools PICES prefers to distribute funding more broadly among the 6 PICES member nations, but the PICES funding was the only extramural funding available that could support scientists from Canada. **Appendix 2, Table 3** shows the scientists being supported and the amount of support they are receiving to participate in the summer school.

HARMFUL ALGAL BLOOM ACTIVITIES SUPPORTED BY SCOR

Co-sponsored symposia/conferences/workshops

PICES partnered with GEOHAB (with ICES and NOAA as other sponsors) in organizing and funding the workshop on "*Harmful algal blooms in a changing world*" (March 18–22, 2013, Friday Harbor, WA, U.S.A.) to assess the state of knowledge on HABs and climate change, and to identify the most critical research needs that can realistically be addressed over the next 5–10 years. The findings were published in the peer-reviewed journal *Harmful Algae*: Wells, M.L., V. L. Trainer, T. J. Smayda, B.S.O. Karlson, C.G. Trick, R.M. Kudela, A. Ishikawa, S. Bernard, A. Wulff, D. M. Anderson, W.P. Cochlan. 2015, Harmful algal blooms and climate change: Learning from the past and present to forecast the future. Harmful Algae, 49 (2015), 68–9.

- The topic areas identified by the workshop participants served as the foundation for an Open Science Meeting on "*Harmful algal blooms and climate change*" that was convened May 19-22, 2015, in Göteborg, Sweden, with supporting sponsors PICES, FORMAS (Swedish Research Council), and GEOHAB. Local sponsors and host in Sweden were the Swedish Meteorological and Hydrological Institute (SMHI) and the University of Göteborg. The symposium was endorsed by SCOR, IOC and ICES.

Other Activities

GlobalHAB, a new initiative of SCOR and IOC UNESCO held a 1st meeting of their newly formed Scientific Steering Committee in Oban, Scotland in March 2016. PICES supported the travel and participation of Dr. Vera Trainer (USA, co-chair of PICES Section on Harmful Algal Blooms) to the Oban meeting. The SSC and guests agreed to produce a GlobalHAB Science and Implementation Plan by early summer 2016, which would be presented and discussed at an International Conference on Harmful Algae in Brazil in October 2016. PICES supported Dr. Trainer to attend a GlobalHAB meeting in Naples in March 2017, which produced a paper,

Berdalet, E., Kudela, R., Urban, E., Enevoldsen, H., Banas, N.S., Bresnan, E., Burford, M., Davidson, K., Gobler, C.J., Karson, B., Lim, P. T., Mackenzie, L., Montressor, M., Trainer, V.L., Usup, G. 2017. GlobalHAB: New Program to Promote International Research, Observations, and Modeling of Harmful Algal Blooms in Aquatic Systems. Oceanography 30(1):70–81, https://doi.org/10.5670/oceanog.2017.111.

PICES funded the travel of Mark Wells to attend an IPHAB meeting in Paris, France in summer 2017. Other GlobalHAB members attended and presented at the IPHAB also. Vera Trainer presented about PICES and GlobalHAB activities to an International Whaling Commission meeting in Bled, Slovenia in May 2017.

HABs are important concerns in all six PICES member countries, especially so in the Asian members that border the Western North Pacific Asian seas, where HABs have been increasing in prevalence and frequency of occurrence. For this reason, the activities of the Intergovernmental Panel on Harmful Algal Blooms (IPHAB) to consolidate and expand databases on harmful algal events (HAEDAT) and on occurrence of harmful algal species (data will be stored in OBIS), with the view to publish a Global Harmful Algal Bloom Status Report, are important to PICES. PICES is contributing expertise to this report for the Northeast Pacific and Northwest Pacific regions. Other organizations involved in this activity are IOC UNESCO, IAEA, and ICES.

Recent HAB updates from Vera Trainer (Member and former co-chair of PICES Section on HABS)

Under GlobalHAB Theme 12. Climate Change

- **Economic Impacts of HABs workshop** – proposed for October 2019 in conjunction with the PICES Annual Meeting in Victoria, BC (see draft proposal below).
- **Special issue in *Harmful Algae*** (information from Chris Gobler). The submission deadline of 1 July 2018. 14 titles have been submitted. It is not clear which paper to make open access (paid by GlobalHAB), but maybe the first one would be the most appropriate (see draft chapters below).
- **Best-practices Manual** (information from Marina) – The first meeting was held in Napoli on 26 Feb.-1 March 2018. They discussed interactions with SCOR WG 149 (COBS). The idea is not to build a manual for all possible scenarios.
- **Symposium on Effects of Climate Change on World's Ocean** (information from Elisa) in June 2018. The session on HABs was merged with a session on human health issues.
- **IPCC 1.5C: SSPM on HABs and Climate Change**? –the two IPCC special reports are coming out this year and next year. It could link with the *Harmful Algae* special issue, best practices manual, and other GlobalHAB activities.

Draft Proposal for international workshop on Economic Impacts of HABs: Best Practices
Vera L. Trainer, Stephanie Moore, Henrik Enevoldsen, Marc Suddleson?, others

Over the last 2 decades, several reports have compiled what is known about the economic impacts of harmful algal blooms (e.g. Anderson et al., 2000. Estimated Annual Economic Impacts from HABs in the US, Hoagland and Scatasta 2006. Economic effects of harmful algal blooms, and Trainer and Yoshida, 2014. Proceedings of the workshop on economic impacts of harmful algal blooms on fisheries and aquaculture; and Sanseverino, et al., 2016. Algal bloom and its economic impact). Although these reports made the effort to gather economic impact data as comprehensively as possible, both the type and amount of available data were limited. Most coastal states have neither conducted economic analyses of HABs nor collected data that can be used to generate reliable quantitative economic impact estimates. In fact, few comprehensive economic studies exist, even though the need for such studies is discussed often at scientific meetings and has been documented in past reports. Economists often are invited to participate in HAB research as an afterthought, which is difficult and frustrating for social scientists. Proposals submitted to NOAA for economic impact studies demonstrate this lack of coordination in that they are strong either in the HAB science or economic assessments, but not both. Our community needs to attract and engage social scientists at the start of projects.

Here we propose an international workshop, prior to or in conjunction with the 2019 Annual PICES meeting in Victoria, Canada, with the goal of bringing 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 to guide priorities and methods for the future. Topics to be discussed include: (1) how scale matters for economic impact assessments (small coastal communities may experience big impacts that might not be seen at larger regional/county scales),

(2) the need to understand direct and indirect impacts and opportunities to recover losses, and (3) how to assign a value to forecasts and monitoring efforts. The output of this workshop will be a guide describing best practices for describing the economic impacts of HABs, focusing on establishing connections between researchers and economists. In addition, the workshop will (1) set priorities for the future; (2) develop partnerships between social scientist, economists and HAB researchers; and (3) attract resources to the field.

Timing: Fall 2019
Location: Victoria, B.C. Canada or Seattle, Washington
Strategy: Choose 3 example large-scale HAB events around the world and discuss how best to assess their impacts. Describe how monitoring and forecasting is evaluated.
Why now: Steph Moore has been involved with scientists from NOAA and University of Washington who together are assessing the impacts of the large-scale *Pseudo-nitzschia* bloom along the U.S. west coast in 2015. We could draw from the economists at the Northwest Fisheries Science Center (Seattle, WA) to help structure and find invitees from outside our field to participate in this workshop.

Climate Change and HABs: Special Issue of Harmful Algae (Draft – authors are in flux)

1) The Future of HAB Science: Directions and Challenges (Authorship: HAB-Climate Change Symposium Organizers and Breakout Discussion Leads) Mark Wells
2) Projected Latitudinal Changes in Environmental Conditions influencing HABs (Potential Authorship: (Fei Chai, Enrique Curchitser (Temperate latitude), Phil Boyd (High latitude), Low latitude
3) Modelling HABs in a changing climate (Potential Authorship: Kevin Flynn Lead).
4) Cyanobacterial HABs and Climate Change in Freshwater, Brackish and Marine Waters (Potential Authorship: Angela Wulff, Petra Visser, Michele Burford, Hans Pearl)
5) Fish-killing HAB and Climate change (Potential Authorship: Charles Trick, Gustaaf Hallegraeff, Allan Cembella)
6) Future observing systems (Potential Authorship: Raphe Kudela, Bengt Karlson, Stewart Bernard).
7) Macroalgae and Climate Change (Potential Authorship: Adriana Zingone, D. Liu).
8) Pelagic HABs and climate change (Vera Trainer, Stephanie Moore, Gustaaf Hallegraeff, William Cochlan
9) Dinoflagellate cysts and climate change (Don Anderson et al.)

OCEAN CARBON ACTIVITIES SUPPORTED BY SCOR

Communication/coordination

- PICES, through its Working Groups on *CO_2 in the North Pacific* (WG 13; 1998–2001) and *Biogeo-chemical Data Integration and Synthesis* (WG 17; 2002–2005), and now through the Section on *Carbon and Climate* (S-CC), has provided coordination for synthesis of ocean carbon research and the development of a network of ocean carbon observations in the North Pacific. The importance of ensuring effective two-way communication with other international scientific groups that have a responsibility for the coordination of ocean carbon research, such as the SCOR/IOC International Ocean Carbon Coordinated Project (IOCCP)

and to the SOLAS/IMBeR Carbon (SIC) Research Working Group, has been explicitly included in the terms of reference for S-CC. There are S-CC members on SIC's subgroups: Dr. Masao Ishii (Japan) is on the subgroup on *Interior Ocean Observations*, and Dr. Richard Feely is the lead of the subgroup on *Ocean Acidification-Global Context*.

- Ocean acidification has been proceeding for a century, at an accelerating rate, and its impacts are beginning to be felt in many corners of the North Pacific. A workshop on "*Acidification of the North Pacific Ocean: a basin-wide assessment*" was held on November 3, 2016 at the PICES Annual Meeting in San Diego, CA. It was well attended, and brought together scientists from all of the PICES countries to synthesize our observations and projections of acidification processes and impacts in our respective countries' waters and adjacent international waters. The workshop is the culmination of a two-year process of collation of relevant information, and synthesis of data collected in each of the countries of the North Pacific basin. The workshop proceedings will form the basis for subsequent assessments, with improved understanding of which ocean regions are most vulnerable to acidification impacts, and how additional resources might best be deployed to predict or detect changes likely to produce significant impacts. There were several topical presentations, as well as individual national updates and extensive discussion of the contents of the proposed Assessment and strategies for completing it. The discussions covered both the open ocean and coastal waters, and roles of observing systems on both sides of the Pacific. One key point that was noted was that locally secular trends in pH and other carbon system indicator variables often differ from the global mean trend, and it is often difficult to know whether this is simply a result of inadequate data or whether there are local influences that themselves have long-term secular trends. These deviations can be used to build a case for construction and maintenance of observing systems as necessary and interactive factors in decision-making. The driving factors will vary among regions, and we can use scientific understanding of these to guide design of observing systems, as well as mitigation and adaptation policies. Overall the workshop was highly productive and the assessment activity is on track to be completed in 2017.

SCOR WORKING GROUPS

PICES regularly provides comments on SCOR Working Group proposals and often recommends and funds an Associate Member for PICES-relevant groups. The support from PICES extends the expertise available within the group, increases the geographic coverage of the groups, and helps individual scientists from the North Pacific become more involved in SCOR activities, which benefits both organizations.

- PICES currently supports an Associate Members for three SCOR Working Groups:
  - WG 149 on *Changing Ocean Biological Systems: how will biota respond to a changing ocean? (COBS)* (Dr. Uta Passow, USA, Assoc. Member)
  - WG 154 on *Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)* (Dr. Sonia Batten, Canada, Assoc. Member)
  - WG 155 on *Eastern Boundary Upwelling Systems: Diversity, Coupled Dynamics and Sensitivity to Climate Change (EBUS)* (Dr. Ryan Rykaczewski (USA); Note also that Dr. Enrique Curchitser (USA) is a full member of EBUS and the Vice Chair of PICES.

- The SCOR Working Group proposals for 2018 are being reviewed by PICES' Standing Committees from the view point of their scientific interests and relevance to the PICES integrative science program, FUTURE. Results of the review by PICES and any recommendation regarding PICES sponsorship of an Associate Member will be provided at the SCOR Annual Meeting in Plymouth.
- PICES provided partial support to Sonia Batten to participate in the first P-OBS meeting immediately prior to the AGU Ocean Sciences meeting in Portland, OR in February 2018.
- PICES provided partial support to Ryan Rykaczewski to participate in a 2-day meeting of EBUS immediately prior to the 4th Symposium on the Effects of Climate Change on the World's Oceans, held in Washington, DC in early June 2018.

CAPACITY BUILDING

SCOR and PICES have a history of cooperating in capacity building.

- SCOR provides travel support for scientists from countries with "economies in transition" to participate in SCOR-relevant sessions/workshops at PICES Annual Meetings, international symposia and capacity building events led/co-organized by PICES. For this reporting period, funding from the SCOR/NSF fund was provided/committed for the following events (see Appendix 1 for details):
  - $2,500 USD for travel support from SCOR was targeted to support travel of two Russians and 6 Chinese participants to the PICES-2017 Annual Meeting in Vladivostok in the latter half of September. In addition to these specific funds from SCOR, Ed Urban approved the use of ca. $283 USD (~$386 CAD) that was not spent on the ECS3 due to a late withdrawal of a Bangladesh early career scientist. (Appendix 1, Table 2). Unfortunately, two Chinese participants (family emergency; failure to obtain visa) were unable to attend the Vladivostok meeting. This resulted in $1,193 CAD ($937 USD) of SCOR funds being unused. We hope that this can be redirected to support appropriate scientists to attend PICES-2018 in Yokohama, Japan.
  - $3,000 USD from SCOR was used to provide travel support for 2 scientists from Brazil and two from Peru to attend the Pacific Transitional Areas Symposium in La Paz, Mexico in April 2018. See **Appendix 1. Table 1a**.
- PICES provided travel support for students and early career scientists from PICES member countries to summer schools and meetings of SCOR-sponsored large-scale research projects. The following events were co-sponsored by PICES in late 2017 or 2018:
  - IMBeR IMBIZO-5, Total Funding: $5,230 CAD. "*Marine biosphere research for a sustainable ocean: linking ecosystems, future states and resource management*", in Woods Hole, MA, USA, October 2 -5, 2017. Support was provide to one from China and two from Canada. See **Appendix 2, Table 1**.
  - IMBeR ClimECO-6, Total Funding: $5,000 CAD. Summer School on "*Interdisciplinary approaches for sustainable oceans*" (August 1-8, 2018, Yogyakarta, Indonesia) by providing travel funds for three ECS (all from Canada). See **Appendix 2, Table 2.**
  - 7th SOLAS Summer School, Total Funding: $5,000 CAD. Summer school on "*Recent developments and methods in the study of biogeochemical and physical feedbacks between the ocean and the atmosphere.*" (23 July – 4 August 2018, Cargese, France) Travel support provided to two ECS from Canada. **See Appendix 2, Table 3.**

- SCOR and PICES share ideas on capacity building, and a PICES representative has participated on the SCOR Committee on Capacity Building. Dr. Harold Batchelder has served in this capacity since September 2012; beginning in 2017 he is one of several named liaisons to the SCOR Committee on Capacity Building.

REQUESTS PENDING FOR CONSIDERATION BY SCOR

- (**PENDING**): Travel support has been requested from SCOR for scientists from countries with "economies in transition" to attend sessions/workshops at the 2018 PICES Annual Meeting to be held in late October 2018 in Yokohama, Japan, under the theme "*Toward Integrated Understanding of Ecosystem Variability in the North Pacific*".

Appendices: Financial Summary to SCOR of Capacity Building Related expenditures

Appendix 1. Table 1. SCOR Funds for 2018 Events/Meetings:

(a) Pacific Transitional Areas Symposium, La Paz, Mexico,
(b) 4th Effects of Climate Change on the World's Oceans Symposium, (funds from SCOR)
(c) 4th Effects of Climate Change on the World's Oceans Symposium, (SCOR funds on behalf of SOLAS)
(d) PICES-2018 Annual Meeting, Yokohama, Japan, 25 Oct – 4 Nov, 2018

Event 1a.	**Pacific Transitional Areas (PTA), La Paz, Mexico, 24-26 April 2018**		
Funds provided by SCOR			**$3,000 USD (=$3,700 CAD)**
Country	**Name (Sex)**	**Grant (CAD)**	**E-mail**
Peru	Dante Espinoza-Morriberón (M)	$1,200	dantee15@gmail.com
Peru	Josymar Torrejón-Magallanes (M)	$1,100	ejosymart@gmail.com
Brazil	Carina Stefoni Bock (F)	$1,200	bock@lamce.coppe.ufrj.br
Brazil	Raquel Toste (F)	$200	rtoste@gmail.com
Event 1b.	**4th Effects of Climate Change on the World's Oceans, Wash, DC, USA 2-9 June 2018**		
Funds provided by SCOR			**$3,000 USD**
Country	**Name (Sex)**	**Grant (USD)**	**E-mail**
South Africa	Rodrigue Imbol Koungue (M)	$1,500	rodrigueanicet@gmail.com
China	Shigang Liu (M)	$1,500	lsgsounder@163.com
Event 1c.	**4th Effects of Climate Change on the World's Oceans, Wash, DC, USA 2-9 June 2018**		
Funds provided by SOLAS (SCOR)			**$5,200 USD**
Country	**Name (Sex)**	**Grant (USD)**	**E-mail**
Brazil	Carina Stefoni Bock (F)	$1,500	bock@lamce.coppe.ufrj.br
Bangladesh	Roksana Jahan (F)	$1,700	roksanazahan@yahoo.com
Russia	Amrtatjuti Sereda (F)	$2,000	amrtatjuti@poi.dvo.ru
Event 1d.	**PICES-2018, Yokohama Japan, 25 Oct–4 Nov 2018**		
Funds provided by SCOR	**Request Submitted to SCOR**		**$X,XXX USD**

			pending, to be determined

Appendix 1. Table 2. SCOR Funds supporting late 2017 Events/Meetings:

(a) PICES-2017 Annual Meeting, Vladivostok, Russia, 22 September – 1 October 2017

Event	**PICES-2017 Annual Meeting, Vladivostok, Russia, 22 September – 1 October 2017**		
PICES-2017 Annual Mtg (PICES-2017)	***SCOR Expenditures***		**$2,500 USD + ~$283 USD (residual from ECS3) SUM=$2,783 USD (~$3,543 CAD est.)**
Country	**Name (Sex)**	**E-mail**	**Grant**
China	Peng Lian (M)	V1352126@vip.qq.com	*$150 CAD*
China	Zhongxin Wu (M)	Wuzhongxin2007@126.com	*$500 CAD (cancelled family emergency)*
China	Wu Men (M)	menwu@tio.org.cn	*$500 CAD*
China	Xindong Pan (M)	550826950@qq.com	*$500 CAD*
China	Lisha Guan (F)	guanls@ysfri.ac.cn	*$500 CAD*
China	Benrong Peng (M)	brpeng@xmu.edu.cn	*$693 CAD (cancelled-visa issue)*
Russia	Natalia Shlyk (F)	shl@poi.dvo.ru	*$200 CAD*
Russia	Kristina Zhukova (F)	kzh@vniro.ru	*$500 CAD*
		SCOR CAD Expenses	***SUM=$2,350 CAD***
		CAD Residual	**$1,193 CAD**
		SCOR USD Expenses USD Residual	**SUM=$1,846 USD $937 USD**

Appendix 2, Table 1. PICES financial commitments to SCOR associated organizations for 2017.

Event	**IMBeR IMBIZO-5, Woods Hole, MA, USA, 2-5 October 2017**		
Funds provided by PICES			**$5,230 CAD**
Country	**Name (Sex)**	**Grant**	**E-mail**
China	Zeyn Zeng (M)	1710 CAD	N/A
Canada	Francisco Bravo (M)	1270 CAD	N/A
Canada	Tyler Eddy (M)	2250 CAD	N/A

Appendix 2, Table 2. PICES financial commitments to SCOR associated organizations for 2018.

Event	**IMBeR ClimEco6 Summer School, Yogyakarta Indonesia, 1-8 Aug 2018**		
Funds provided by PICES			**$5,000 CAD**
Country	**Name (Sex)**	**Grant**	**E-mail**
Canada	Juliano Palacios Abrantes (M)	1750 CAD	N/A
Canada	Ravi Maharaj (M)	1500 CAD	N/A
Canada	Virginie Bornarel (F)	1750 CAD	N/A

Appendix 2, Table 3. PICES financial commitments to SCOR associated organizations for 2018.

Event	**SOLAS Summer School, 23 July – 4 August 2018, Cargese, France**		
Funds provided by PICES			**$5,000 CAD**
Country	**Name (Sex)**	**Grant**	**E-mail**
Canada	Roghayeh Gharremaninezhad (F)	3500 CAD	N/A
Canada	Patrick Duke (M)	1500 CAD	N/A

Notes: (1) for all three of the above meetings/summer schools, the decisions on students/ECS to support were made by IMBER/SOLAS, and approved by PICES, considering the funding limitations imposed by PICES guidelines that priority should go to PICES member countries. (2) N/A-emails not known, but known to IMBER or SOLAS.