2.0 WORKING GROUPS

2.1 Disbanded Working Groups

2.2 Current Working Groups

The Executive Committee Reporter for each working group will present an update on working group activities and progress, and will make recommendations on actions to be taken. Working groups expire at each General Meeting, but can be renewed at the meeting and can be disbanded whenever appropriate.

2.3 Working Group Proposals

2.1 Disbanded Working Groups

2.1.1 SCOR/LOICZ WG 132 on Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems

Members of this working group continue to publish papers related to the group's work. Recent papers include the following:

Bouwman, L., A. Beusen, P.M. Glibert, C. Overbeck, M. Pawlowski, J. Herrera, S. Mulsow, R. Yu, and M.J. Zhou. 2013. Mariculture: Significant and expanding cause of coastal nutrient enrichment. *Env. Res. Lett.* 8: 044026 (5 pp)

Glibert, P.M., J.I. Allen, Y. Artioli, A. Beusen, L. Bouwman, J. Harle, R. Holmes, and J. Holt. 2014. Vulnerability of coastal ecosystems to changes in harmful algal bloom distribution in response to climate change: projections based on model analysis. *Global Change Biology*. doi: 10.1111/gcb.12662

Glibert, P.M., R. Manager, D.J. Sobota, and L. Bouwman. In review. The Haber-Bosch- Harmful algal bloom (HB-HAB) link. **Envir. Res. Lett.**

2.1.2 SCOR/WCRP/IAPSO WG 136 on Climatic Importance of the Greater Agulhas System (with WCRP and IAPSO)

WG 136 Final Report 2012/2013

SCOR Working Group 136:
On the Climatic Importance of the Greater Agulhas Current System.

Lisa Beal and Arne Biastoch, co-Chairs

Our Working Group terms of reference (TORs) are complete. We would like to take this opportunity to thank all our sponsors including SCOR, WCRP, IAPSO, IUGG, NOAA, NSF, Dutch institutes IMAU and NIOZ, ONR Global, IRD, and IOC Perth. Below is a list of our four TORs with a brief description of what we achieved.

1. To facilitate collaborations between existing and planned studies of the region

Our membership (Lisa Beal, Arne Biastoch, Meghan Cronin, Will de Ruijter, Juliet Hermes, Francis Marsac, Graham Quartly, Mike Roberts, Tomoki Tozuka, and Rainer Zahn) and associate membership was inclusive of all oceanographic disciplines and representative of many different countries. The result has been many new scientific collaborations. In addition, through our second meeting in Mauritius joint with a DBCP workshop (Data Buoy Cooperation Panel), and our Chapman Conference in South Africa, we have developed a strong Agulhas community and improved links with regional partners in developing countries.

2. **Write a review paper on the climatic importance of the greater Agulhas**

Our review paper was accepted and published by Nature and currently has 86 citations.

Beal, L. M., W. P. M. de Ruijter, A. Biastoch, R. Zahn, and SCOR/IAPSO/WCRP Working Group 136. 2011. On the role of the Agulhas System in Ocean Circulation and Climate. *Nature* 472:429-436, doi:10.1038/nature09983.

3. **Science Plan for Sustained Observations in the Greater Agulhas System**

We developed a science plan which has subsequently been ratified by the CLIVAR Indian Ocean Panel to become part of the Global Ocean Observing System (GOOS/GCOS). The main elements of the plan are:

(1) **A surface flux reference station**. The Agulhas is a region of strong net heat loss from the ocean, which influences storm track development and rainfall over Africa. A reference station will provide in situ, high-resolution time series of episodic and long-term changes in regional climate and a means for improving and assessing errors in synthesis surface flux products. This would be the first such mooring in the Southern Hemisphere.

(2) **A reference mooring in the Mozambique Channel.** Flow through the Mozambique Channel is part of the global thermohaline circulation, linking inflow from the Pacific with the Agulhas Current. A decade of observations in the Channel (LOCO, INATEX) represent the only oceanic time series to exceed even one year in the region and have shown important changes linked to Indian Ocean Dipole events. A reference mooring (or two), in combination with satellite sea surface height data, can continue to provide information on decadal variability in the region.

(3) **Monitoring array across the Agulhas Current**. The volume, heat, and freshwater transports of the Agulhas provide a measure of the Indian Ocean gyre and overturning strengths, and are related to leakage fluxes into the Atlantic. Changes in Agulhas leakage have been implicated in past climate transitions, through influence on the Atlantic meridional overturning circulation. Sustained observations of the most significant Western Boundary Current in the Indian Ocean are a priority.

WG members Hermes, Beal, Roberts, and Ridderinkhof are collaborating to implement (3) through international resource-sharing and regional capacity building. A Memorandum of Agreement has been drafted.

(4) **Organize a Chapman Conference with participation of the African science community**

Our Chapman Conference was held October 8-12th, 2012 in Stellenbosch, South Africa. The first of its kind on the African continent. Details of the conference program can be found at the AGU website: http://www.agu.org/meetings/chapman/2012/ecall/index.php. WG members raised $95,000 towards conference costs and travel support for students and scientists from developing countries. The conference attracted 16 invited speakers, from Europe, the US, Japan, and Africa, and a total of 103 abstracts. The conference was opened by Dr. Gansen Pillay, Vice- President of the National Research Foundation in South Africa (NRF) and closed by AGU President Mike McPhaden. For a full report, see:

de Ruijter, W., L. M. Beal, A. Biastoch, and R. Zahn, (2013) The Role of the Agulhas System in Regional and Global Climate, AGU Chapman Conference Report, Eos, Transactions American Geophysical Union, Volume 94, Issue 10, DOI: 10.1002/2013EO100005.

2.2 Current Working Groups

2.2.1 SCOR WG 134: The Microbial Carbon Pump in the Ocean *Urban* (2008)

Terms of Reference:

- Summarize representative microbial data on biomass, production and diversity of functional groups (AAPB, CFB, Roseobacter, Archaea) and overall microbial communities, as well as DOC data focusing on the context of RDOC dynamics along environmental gradients (productivity/temperature/salinity gradient such as estuarine to oceanic waters); Establish the current state of knowledge about microbial processes that produce RDOC at the expense of DOC, and identify essential scientific questions regarding microbial carbon pump to be addressed in the future;
- Assess the available techniques for quantifying microbial functional groups and demonstrating the bioreactivity of marine DOC, document state-of-the-art techniques and parameters addressing microbial processing of organic carbon, and establish/standardize key protocols for the essential observation/measurements;
- Convene International Workshop(s) and publish a special volume in an internationally recognized peer-reviewed journal, or a protocol book (practical handbook) by a major publisher on measurements of the key parameters related to microbial processing of carbon in the ocean.
- Make recommendations for future research related to the microbial carbon pump in the ocean, toward development of a large-scale interdisciplinary research project.

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Other Full Members	**Associate Members**	
Xosé Antón Álvarez-Salgado (Spain) Arthur Chen (China-Taipei) Dennis Hansell (USA) Gerhard Herndl (Netherlands) Gerhard Kattner (Germany) Michal Koblížek (Czech Republic) Nagappa Ramaiah (India) Colin Stedmon (Denmark)	Ronald Benner (USA) Craig Carlson (USA) Feng Chen (USA) Sang-jin Kim (Korea) David Kirchman (USA) Ingrid Obernosterer (France)	Carol Robinson (UK) Richard Sempere (France) Christian Tamburini (France) Steven Wilhem (USA) Susan Ziegler (Canada)

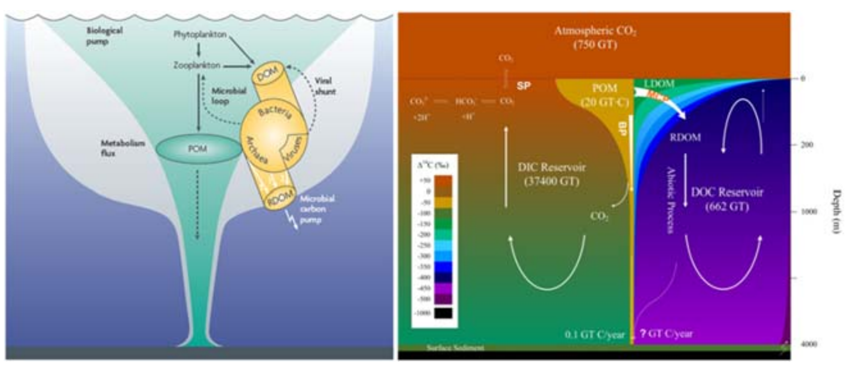
Executive Committee Reporter: Bjørn Sundby

Part I. Summary of SCOR WG134 (2009-2012)

1. Scientific progress and outcome

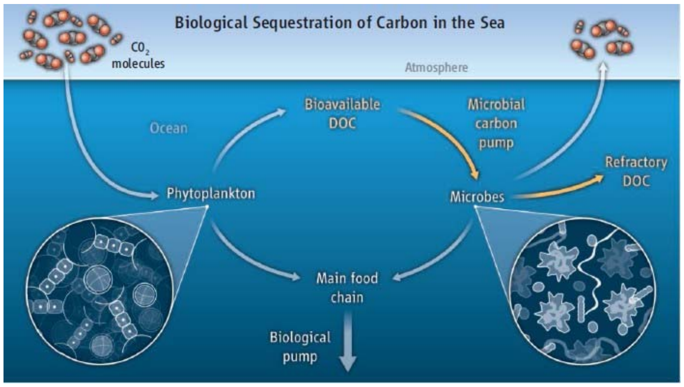
The SCOR WG134 on the MCP was founded in 2009, led by Dr. Nianzhi Jiao (China) and Dr. Farooq Azam (USA) and joined by 26 scientists from 12 countries. It had been successfully carried on for four years by 2012, with a series of scientific progress achieved and terms of reference completed. The MCP theory is not only a conceptual framework which covers a broad range of disciplines, but also aims to seek a synthesis for future research on and an in depth understanding of the kinetics and mechanistic processes of dissolved organic matter (DOM) dynamics in the oceans. Thus the core aim of WG 134 is to obtain a better understanding of microbial and biogeochemical processes causing labile DOM (LDOM) degradation and alteration, along with the microbial and chemical formation and modification of refractory DOM (RDOM) in the ocean.

The MCP concept was established with the publication of a featured article in *Nature Review Microbiology* (NRM) 2010, volume 8. In the paper, the background, rationale and application of the MCP concept were discussed, including representative microbial data on biomass, production and diversity of marine microbial communities in the context of DOM dynamics along environmental gradients, the current state of knowledge about microbial processes that utilize, generate and transform DOM, and essential scientific questions and hypotheses regarding DOC accumulation through the MCP. Moreover, the gaps in our understanding of marine DOC and the microbial community structure in different marine regions regarding bioreactivity and future research directions were also addressed. It is noteworthy that this paper was highlighted on the cover and the contents of the issue as well as on the website of *Nature Reviews Microbiology*.



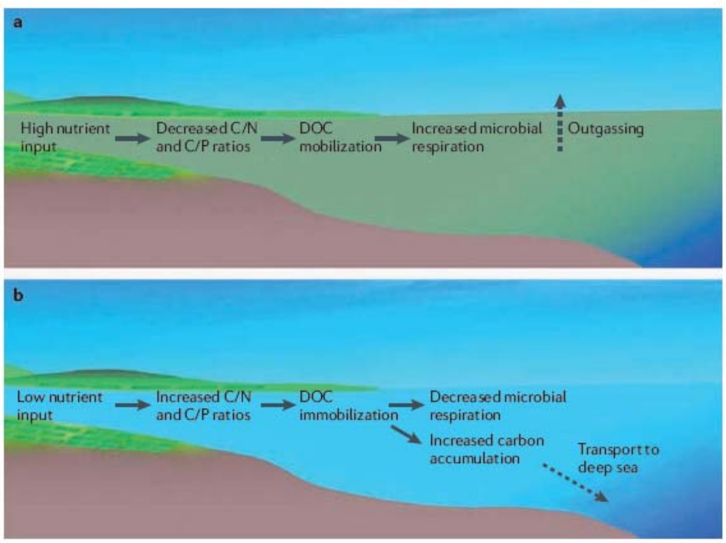
Diagrams showing the concept of the MCP and its relationship with the biological pump (left) and the major carbon reservoirs and carbon storage in the ocean (right) (Jiao et al. *Nature Review Microbiology* 2010 (8):593-599)

Not long after the publication of the MCP theory, a Science News Focus article (SCIENCE 328:1476-1477, 2010) addressed another story about the MCP: its origin, rationale, implications, applications, impacts, and prospects. In this article, the MCP is considered as “An invisible hand behind the vast carbon reservoir”



The so called “double-barrel pump” pointed that each year, the biological pump deposits some 300 million tons of carbon in the deep ocean sink. However, even more massive amounts are suspended in the water column as dissolved organic carbon, much of which is converted into refractory forms by the microbial carbon pump.
(R. Stone. *Science* 18 June 2010: Vol. 328. no. 5985, pp. 1476 -1477)

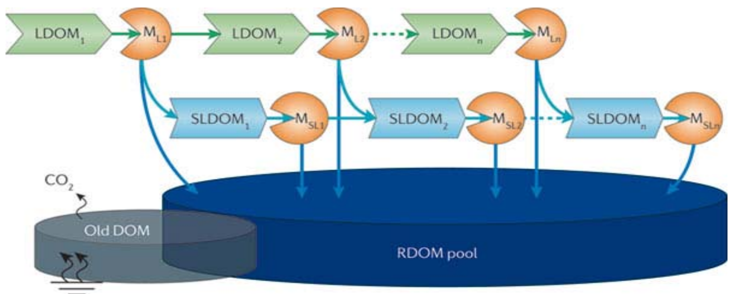
In addition, the principle of MCP has been adapted to land carbon sequestration by other colleagues in soil science and Dr. Nianzhi Jiao proposed the idea of “Increasing the microbial carbon sink in the sea by reducing chemical fertilization on the land”.



The key information delivered by the aforesaid paper: Microbial carbon processing scenarios under different environmental conditions. Figure a shows that microbial respiration of DOC is mobilized by enhanced terrestrial nutrient input, and b shows microbial carbon sequestration is enhanced by reducing terrestrial nutrient input.
(Jiao, et al. *Nature Reviews Microbiology*. 2011. 9(1):75.)

Currently, most coastal waters suffer from excessive nutrients (nitrogen and phosphorus) discharge, which result in eutrophication and harmful algal blooms. More importantly, when nutrients are replete, dissolved organic carbon can be mobilized for microbial degradation and respiration. That is why the estuarine waters, being productive, but are often sources rather than "sinks" of atmospheric CO_2. Reducing nutrient input from the land would be a realistic way to increase microbial carbon sink in such coastal waters.

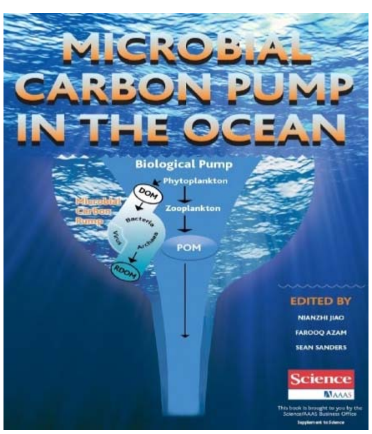
In correspondence, an article entitled "The microbial carbon pump and the oceanic recalcitrant dissolved organic matter pool" was published in *Nature Reviews Microbiology* 9, 555 (July 2011).



A representative figure from the paper indicates the successive microbial carbon pump processes for RDOM formation and subsequent contribution to the oceanic RDOM pool. ML and MSL represent those microorganisms that can use labile dissolved organic matter (LDOM) or semi-labile DOM (SLDOM), respectively. The subscript numbers indicate the numerous compounds or microbes.

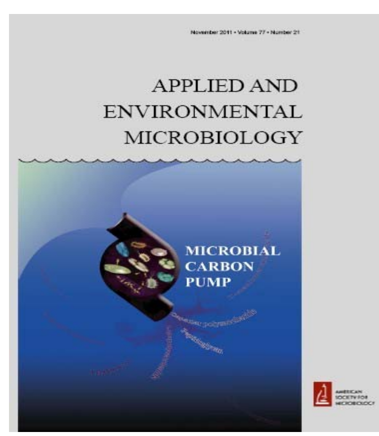
(Jiao et al, *Nature Reviews Microbiology* 9, 555, July 2011))

A *Science* booklet on MCP including 10 papers previously published in Science and 10 new articles written by the WG134 members, appeared as a "Supplement to *Science*", was distributed worldwide with the 13th of May 2011 issue of Science. Its electronic version is available on the *Science* website at the following link (http://science.imirus.com/Mpowered/book/vscim11/i2/p1). A special section on MCP in *Applied and Environmental Microbiology* was published in 2011. The MCP image was published on the cover of AEM, Nov. 2011, Vol 77, No. 21.



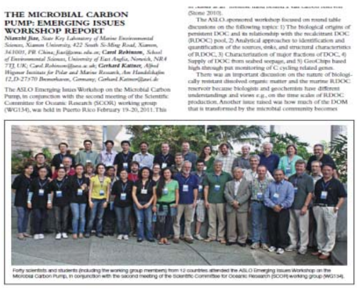
The MCP booklet supplemental to *Science* (left)

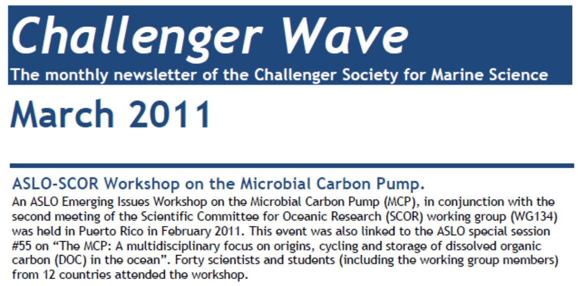
The *AEM* cover with MCP image (right)



Other representative publications and interesting research findings related to MCP by WG134 members are summarized here:

- Marine snow are active sites of microbial remineralization
  Bochdansky, A.B., H.M. van Aken, G.J. Herndl, 2010: Role of macroscopic particles in deep-sea oxygen consumption. Proc. Natl. Acad. Sci. USA, 107: 8287-8291.
- ASLO Emerging issues workshop report, *Limnology and Oceanography Bulletin* 20(2) June 2011, 37-38 (see below)





Challenger Wave

The monthly newsletter of the Challenger Society for Marine Science

March 2011

ASLO-SCOR Workshop on the Microbial Carbon Pump.

An ASLO Emerging Issues Workshop on the Microbial Carbon Pump (MCP), in conjunction with the second meeting of the Scientific Committee for Oceanic Research (SCOR) working group (WG134) was held in Puerto Rico in February 2011. This event was also linked to the ASLO special session #55 on "The MCP: A multidisciplinary focus on origins, cycling and storage of dissolved organic carbon (DOC) in the ocean". Forty scientists and students (including the working group members) from 12 countries attended the workshop.

- ASLO–SCOR Workshop on the Microbial Carbon Pump (the picture above)
  Challenger Society for Marine Science, Challenger Wave – March 2011: 8-9
- Molecular biogeochemical provinces in the eastern Atlantic Ocean. Editors: Boris Koch, Gerhard Kattner, Gerhard Herndl. Special Issue in Biogeosciences, 2011.
- Kawasaki, N., R. Sohrin, H. Ogawa, T. Nagata and R. Benner. 2011. Bacterial carbon content and the living and detrital bacterial contributions to suspended particulate organic carbon in the North Pacific Ocean. Aquat. Microb. Ecol. 62: 165-176.
- Kaiser, K., and R, Benner. 2012. Organic matter transformations in the upper mesopelagic zone of the North Pacific: chemical composition and linkages to microbial community structure. J. Geophys. Res., 117, C01023, doi: 10.1029/2011JC007141.

2. Academic Meetings and Research Activities

(A) SCOR WG134 workshops

The first WG 134 meeting was held in Xiamen, China, from October 27 to 30 in 2009, under the theme of "Bridging Biology and Chemistry in Ocean Carbon Sequestration".

Open Science Meeting (left) and Closed Workshop (right) of WG134 1st meeting

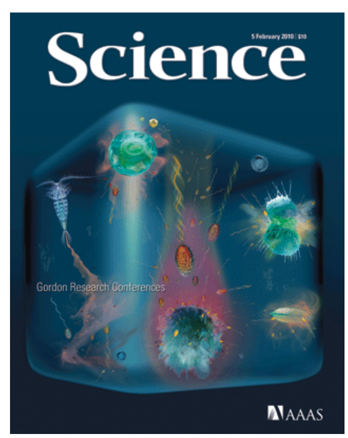
The second meeting was held in Puerto Rico, USA during February 19-20 in 2011, along with the ASLO Emerging Issue Workshop on MCP (it was selected by ASLO as an emerging issue for the 2011 Aquatic Science Meeting).

WG134 2nd meeting in conjunction with the ASLO Emerging Issues Workshop on the MCP

Our third meeting of SCOR WG134 was held in Hanse Institute for Advanced Study (HWK) of Delmenhorst in Germany, during August 26 to 29 in 2012.

WG134 3rd meeting at HWK on 27 Aug. 2012

This meeting aimed at summarizing the microbial and geochemical research progressin recent years in the context of MCP and its impact on microbial oceanography research with specialization in DOM cycling and diagenetic alterations. In addition, future research activities within the conceptual framework of the MCP were discussed and put forward.



(B) Meeting sessions hosted/chaired by WG134 members beyond the SCOR workshops

- The cross-disciplinary Workshop (Beijing, China, 24-26 July, 2009)
- The "International Training Workshop on Organic Matter Characterization Using Spectroscopic Techniques" (Granada, Spain, 19-21 May, 2010)
- A special titled microbes and carbon cycling in the ocean at the First International Conference on Marine Science and Earth System (Shanghai, China, 27-30 June, 2010)

- Gordon Research Conference on Marine Microbes from Genes to Global Cycles (Tilton School, NH, USA, 4-9, July, 2010). The image (Glynn Gorick; Roman Stocker; Justin Seymour) interpreting the microbes-DOC interaction (see right) selected for use as the cover of Science journal (Feb. 2010)
- A session on Microbial Roles in Marine Carbon Cycling and Ocean Acidification Impacts during the AOGS 2010 Meeting (Hyderabad, India, 5-9 July, 2010)
- A session on Marine Microbiology at ISME 13 (Seattle, USA, 22-27 August, 2010)
- AAPB workshop (Trebon, Czech Republic, 22-24 September, 2010)
- The 9th International Marine Biotechnology Conference (IMBC) with session of Biotic Carbon Sequestration (Qingdao, China, 8-12 October, 2010.)
- The ASLO Aquatic Science Meeting Special Session 55 on the Microbial Carbon Pump in the Ocean (San Juan, Puerto Rico, 17-18 February, 2011)
- A Chinese Science & Technology Association Forum on Marine Carbon Sink (Sanya, China, 15-16 Dec. 2011)
- The 2012 Ocean Science meeting sessions of “Shedding Light on the Dark Ocean: Advances in Linking Physical and Microbial Oceanography to Biogeochemistry” and “Dissolved Organic Matter and the ‘Hidden’ Carbon Cycle” (Salt Lake City, Utah, USA, 20-24 February 2012)
- A special session titled “Microbes and Carbon Cycling in the Ocean” at the Second International Conference on Marine Science and Earth System (Shanghai, China, 2-4 July 2012),
- A session titled “The Global Ocean Ecosystem: Patterns, Drivers and Change” at the ASLO Aquatic Science Meeting (Lake Biwa, Japan, 9–13 July 2012)

(C) Meetings participated by WG134 members, mainly listed below:

- The AGU Chapman Conference on the Biological Carbon Pump of the Oceans (Brockenhurst, Hampshire, England, 14 September, 2009) and AGU Fall Meeting (San Francisco, USA, 13-17 December, 2010).
- The 11th International Estuarine Biogeochemistry Symposium (Atlantic Beach, NC, USA, 15-19 May, 2011)
- The Symposium on Aquatic Microbial Ecology SAME-12 (Rostock, Germany, 28 Aug - 2 Sept. 2011)
- The ISME 14 (Copenhagen, Denmark, 19-24 August 2012)

3. Research activities

A variety of experiments were carried out through oceanographic cruises participated by our work group members, namely the 2010 Svalbard pelagic mesocosm experiment of European Project on Ocean Acidification (May 18- July 16, 2010), two cruises to the Western Pacific Warm Pool during 2010 and 2011 designed as pilot studies of the nutrient enrichment effects on MCP efficiency, and another two cruises (funded by the US National Science Foundation) to the Ross Sea in January-March 2013 and the Gulf of Alaska in June-July 2013 with the aim to evaluate organic carbon dynamics in the meso- and bathypelagic ocean. As for research projects and proposals, a European Science Foundation project on the role of deep water autotrophic prokaryotes in the organic matter synthesis of the deep North Atlantic was launched in 2010, a

MCP based proposal under the grand project was sponsored by the Ministry of Science and Technology of China, and also the project of "Qualitative and Quantitative Evaluation of Processes Governing Microbial Carbon Pump in the Indian Ocean Regions" was provided by the Ministry of Earth Sciences of Government of India.

4. Academic Honors

- WG134 member Ronald Benner was awarded the Einstein Professorship of the Chinese Academy of Sciences (CAS) in 2010 and was elected a Fellow of the American Geophysical Union (AGU) in 2011.
- WG134 member Gerhard Herndl received the Wittgenstein-Prize, the highest Austrian science honor and prize (1.5M €), 2010.
- WG134 chair Nianzhi Jiao was elected a member of the Chinese Academy of Sciences (CAS) in 2011.
- WG134 member Chen-Tung Arthur Chen was reappointed a vice chair of the International Geosphere Biosphere Programme in 2011.
- WG134 member Virginia Edgcomb was awarded the 2012 Seymour H. Hutner Prize in Protistology by International Society for Protistologist.
- WG134 member Michal Koblizek has continued his service to the Czech National Committee of the Intergovernmental Oceanographic Commission, UNESCO.
- WG 134 co-chair Farooq Azam is selected by the ASM to receive the 2013 D. C. White Award for interdisciplinary research and mentoring.

Part II. Follow-up activities of SCOR WG 134

1. Workshop at IMBER IMBIZO III conference and outputs

The MCP theory based, entitled "Impacts of anthropogenic perturbations on ocean carbon sequestration via BP and MCP" workshop (2), was convened by Dr. Nianzhi Jiao, Dr. Farooq Azam, and Dr. Carol Robinson et al., during the 2013 IMBER IMBIZO III conference held in Goa of India. We gladly point out that this workshop attracted scientists from multiple disciplines including microbial ecology, biogeochemistry, organic chemistry, climate science, fisheries and marine economy. All together we shared exciting ideas and discussed methods to integrate MCP into the oceans and global carbon cycle through innovative carbon sequestration models. Three scientific sessions in total covered topics of the nature of DOC, microbial processing of DOC and genetic diversity, the interaction between MCP and BP and their responses to anthropogenic perturbation, and large temporal and spatial scale dynamics and links to humanity.

MCP video was playing at the IMBIZOIII.

Discussions at workshop 2

During the meeting, a keynote presentation from workshop 2 was given by Dr. Farooq Azam: Microbial carbon pump and ecosystem connectivity. The scientific highlights in this presentation focused mainly on the opportunity exploring the linkages and interaction between MCP and Biological Pump (BP). Dr. Jiao addressed the importance of reducing the use of chemical fertilization on the land which could lead to an enhancement of the MCP as a carbon sink in eutrophic coastal waters during the plenary session. Results of microbiological and photochemical transformation of organic carbon during an in situ iron and phosphate addition experiment conducted by Dr. Carol Robinson indicated that the important role of both microbial and biological carbon pump to organic carbon under changing nutrient conditions.

Very importantly, a key question concerning the MCP theory received lots of attention and well discussed by the conference attendees: how does carbon transform through both MCP and BP and how do these two pumps interact with each other. The following keywords accomplished during the discussion session of the meeting are noteworthy: anthropogenic perturbation, land and atmospheric nutrients uploading, higher trophic levels, and natural scenarios from estuary to deep ocean, and upwelling and eddy habitats. It was suggested the future work should focus on the quantity, rate and proportion of the role MCP plays, through a combination of multiple efforts from genes to ecosystems, and from observation to modeling.

Additionally, a summary report and a template for workshop synthesis paper were accomplished during the meeting synthesis session. A special issue on MCP in the journal of Biogeosciences will bring together articles arising from this workshop. Topics to be investigated include the organisms and microbial processes which produce and transform dissolved organic carbon in the ocean, organisms and processes influencing the interaction between the BP and the MCP, and the impact of anthropogenic perturbations such as nutrient addition and ocean acidification on oceanic carbon transformation, export and sequestration. Manuscripts under review for the Special Issue are listed below:

- Presence of Prochlorococcus in the aphotic waters of the western Pacific Ocean. N. Jiao, T. Luo, R. Zhang, W. Yan, Y. Lin, Z. I. Johnson, J. Tian, D. Yuan, Q. Yang, J. Sun, D. Hu, and P. Wang. Biogeosciences Discuss., 10, 9345-9371, 2013.
- Why productive upwelling areas are often sources rather than sinks of CO2? – a comparative study on eddy upwellings in the South China Sea.N. Jiao, Y. Zhang, K. Zhou, Q. Li, M. Dai, J. Liu, J. Guo, and B. Huang.Biogeosciences Discuss., 10, 13399-13426, 2013.

- Natural ocean carbon cycle sensitivity to parameterizations of the recycling in a climate model. A. Romanou, J. Romanski, and W. W. Gregg.Biogeosciences Discuss., 10, 11111-11153, 2013
- Temperature and phytoplankton cell size regulate carbon uptake and carbon overconsumption in the ocean. S. E. Craig, H. Thomas, C. T. Jones, W. K. W. Li, B. J. W. Greenan, E. H. Shadwick, and W. J. Burt. Biogeosciences Discuss., 10, 11255-11282, 2013.
- The role of mixotrophic protists in the biological carbon pump. A. Mitra, K. J. Flynn, J. M. Burkholder, T. Berge, A. Calbet, J. A. Raven, E. Granéli, P. M. Glibert, P. J. Hansen, D. K. Stoecker, F. Thingstad, U. Tillmann, S. Våge, S. Wilken, and M. V. Zubkov. Biogeosciences Discuss., 10, 13535-13562, 2013
- Mechanism for initiation of the offshore phytoplankton bloom in the Taiwan Strait during winter: a physical–biological coupled modeling study. J. Wang, H. Hong, Y. Jiang, and X.-H. Yan.Biogeosciences Discuss., 10, 14685-14714, 2013

2. Coming Meetings Planed

- In the coming December, WG134 members (Chuanlun Zhang and Nianzhi Jiao) together with Holly Simon will convene the AGU session OS005-- From mountains to the ocean: Physical, chemical and microbial impacts on carbon fluxes.
- The IMBER Open Science Conference will be held at Norway during 23-27 June 2014, a session titled “Microbial and geochemical perspectives of global carbon cycling and climate change: from genes to ecosystems, from ancient to current” will be convened by WG members Farooq Azam, Carol Robinson, Nianzhi Jiao.
- WG134 members Kang-Jin Kim, Nianzhi Jiao, Joe Zhou are involved as local organizers in the 15th International Symposium on Microbial Ecology (ISME-15) in Korea in August 2014.
- The 2014 WG134 meeting focusing on the mechanisms of MCP at the modern scales is in the planning stage.

3. Pan-China Ocean Carbon Alliance, COCA

A large increase in the amount of CO_2 released into the atmosphere has resulted in the intensification of global warming. The ocean has been discovered to be a large carbon reservoir, and oceanic carbon storage mechanisms are the vanguard of global warming research. The recognized mechanism that allows for this carbon storage relies on two separate processes: the POC-based “biological pump” and the dissolved inorganic carbon-based “solubility pump”. Although research into these two areas of study has proven to be a great success, there still exists many inexplicable and unknown scientific anomalies and mechanical processes that have yet to be explored. The MCP exposed a new mechanism of carbon storage that does not rely on the sinking of POC and offered up a potential research based strategic solution for China to reach its “low carbon” goals.

Based on the MCP and related background, a national organization, entitled “Pan-China Ocean Carbon Alliance, COCA” was launched. It was initiated by CAS Academician research group led by Dr. Nianzhi Jiao, and supported by the State Oceanic Administration, China Association for Science and Technology, Chinese Academy of Sciences, Ministry of Environmental Protection (Chinese Research Academy of Environmental Sciences), the National Climate Committee, etc. The COCA members consists of marine science and technology personnel from 21 domestic research institutes including Xiamen University, and enterprises including China National Offshore Oil Corporation (CNOOC).

COCA, therefore emerged in an attempt to partially alleviate the pressure on the organizations that are focused on decreasing CO_2 emissions. We believe that cultivation of prime MCP conditions could enhance the carbon absorption and storing capabilities within the ocean surrounding the Chinese coast, thus become a potentially complete solution. The final goal of COCA is to seek for ocean carbon storage mechanisms by uniting national strengths and make the best of both carbon emission reduction and sink increase through “policy-industry-research” cooperation strategy.

Main targets and tasks of COCA:

1) To build an international monitoring station of ocean carbon sink
   Using the world famous ocean time series station ALOHA in the Northern Pacific and BATS in the Northern Atlantic Ocean as our benchmark, a Coastal Ocean Time Series Station (COTS) under human activities influence will be constructed as a research and development base for ocean carbon sink through jointly cooperation with CNOOC.
2) To establish a standing international forum of ocean carbon sink
   Based on our academic advantages of MCP study and past experience of hosting/chairing various international scientific conferences, we plan to set up an International Forum for Ocean Carbon Utility and Sequestration (FOCUS) through collaboration with the world class Gordon Research Conference organization. This forum will appeal international colleagues, collect think tank in relevant fields of marine science and serve as incubator for the formation of “Ocean Carbon Sink International protocols and Standards”.
3) To draft the ocean carbon sink international technical protocols
   An international protocol draft for ocean carbon sink which has not been addressed so far, will be ultimately established with the combined data achievements from COTS and efficient international collaboration system built through FOCUS.

4. Chinese open program-2011 Collaborative Innovation Cluster on marine carbon sink

Initiated from the MCP, and added together with the typical biological pump (BP), the 2011 Collaborative Innovation Cluster on marine carbon sink focuses on research in the wide range of in depth understanding of biological processes and mechanisms of the MCP theory, systematically assessing the potentials of carbon storage in Chinese coastal waters, and its controlling factors through biological, chemical and physical pathways. The major goal is to develop ocean carbon sink detection and monitoring technology, to establish monitoring system of stereoscopic coastal ocean carbon sink, to promote in-depth studies on marine carbon sink theories and pathways, and to draft the ocean carbon sink international technical protocols.
The program will be supported by the National 2011 Program of China, a highly innovative program initiated by the Ministry of Education of P. R. China. It aims to become a world leading

research cluster on frontiers of ocean carbon sink and related fields. It will act as a platform for joint and interdisciplinary research involving research groups covering biologists, chemists and geologists, and comparative studies between ancient and modern marine environments. Facilities and platforms have been developed both within and outside of Xiamen University, including coastal marine station, BP-MCP research and monitoring station, off shore platform for BP-MCP time series study, and general-purpose university class RV. By putting the MCP theoretical framework into practical field and laboratory studies, we hope to ultimately provide a new, integrated view of microbial mediated carbon flow in the marine environment to fill knowledge gaps in oceanic carbon sequestration.

2.2.2 SCOR/InterRidge WG 135: Hydrothermal Energy Transfer and its Impact on the Ocean Carbon Cycles (2008) ***Coustenis***

Terms of Reference:

- Synthesize current knowledge of chemical substrates, mechanisms and rates of chemosynthetic carbon fixation at hydrothermal systems as well as the transfer of phytoplankton-limiting micronutrients from these systems to the open ocean.
- Integrate these findings into conceptual models of energy transfer and carbon cycling through hydrothermal systems which would lead to quantification of primary production in view of a future assessment of the contribution of these systems to the global-ocean carbon cycle.
- Identify critical gaps in current knowledge and proposing a strategy for future field, laboratory, experimental and/or theoretical studies to bridge these gaps and better constrain the impact of deep-sea hydrothermal systems on ocean carbon cycles.

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Executive Committee Reporter: Missy Feeley

2.2.3 WG 137: Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Comparative Analysis of Time Series Observation *Volkman*

(2009)

Terms of Reference:

- Identify existing long time series of phytoplankton data in coastal oceans around the world.
- Facilitate migration of individual data sets to a permanent and secure electronic archive. (Requirements for development of a fully stocked phytoplankton database greatly exceed the resources of this WG. However, we expect to produce a small working proto-type, based on the existing archive (to be identified) to demonstrate the value of sharing data through an international database.)
- Develop the methodology for global comparisons for within-region and within-time period data summarization (e.g., spatial, seasonal, and annual averaging, summation within taxonomic and functional group categories). The goal is to clarify what level of detail provides the optimal tradeoff (i.e., information gain vs. processing effort).
- Based on the above, develop priorities and recommendations for future monitoring efforts and more developed re-analysis of existing data sets.
- We will carry out a global comparison of phytoplankton time series using (in parallel) a diverse suite of numerical methods. We will examine:
    - Synchronies in timing of major fluctuations, of whatever form.
    - Correlation structure (scale and spatial pattern) for particular modes of phytoplankton variability (e.g. changes in total biomass, species composition shifts, among different geographic distribution).
    - Amplitude of variability, both for total biomass and for individual dominant species, and a comparison to the amplitude of population fluctuations.
    - Likely causal mechanisms and consequences for the phytoplankton variability, based on spatial and temporal coherence with water quality time series
- Through comparative analysis, we will address the 3 guiding questions.

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SCOR WG 137:
Global Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Comparative Analysis of Time Series Observations

Annual Report 2013

Kedong Yin and Hans W. Paerl

June 17, 2014

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I. Summary of activities since 3rd meeting during October 12-14 in Japan

The SCOR WG 137 had its 4th meeting, which is a joint SCOR/CERF Workshop in San Diego, USA, during November 4-7, 2013. WG 137 also held a CERF special session SCI-062: Global Patterns of Phytoplankton Dynamics in Estuarine and Coastal Ecosystems. The session was a large one, taking a full day and attracting a large crowd.

WG137 has made an arrangement with *Estuarine, Coastal and Shelf Science* (ECSS: Impact Factor 2.324) to publish a special issue contributed by WG137 members, associated members and meeting participants.

II. List of special issue manuscripts

Tentative titles and authors of SCOR WG 137 manuscripts for the *Coastal, Estuarine and Shelf Science* special issue are shown below. Some of the proposed manuscripts may not meet the submission deadline for the special issue, but could appear later in other issues.

1. Phytoplankton in a changing world: Responses to hydrological variation as predictors of impacts associated with climate change. Peter Thompson*, Todd O'Brien, Sirpa Lehtinen, Alex Kraberg, Jacob Carstensen, Hans Paerl, Jim Cloern, Abigail McQuatters-Gollop, Paul Harrison, Kedong Yin, Yves Collos, Richard Gowen, Clarisse Odebrecht, Katja Philippart, N.N. Ramaiah, Nathan Hall, Adriana Zingone.
2. Vertical migration patterns of estuarine phytoflagellates: A sporadic occurrence or a "day in day out" process with ecosystem level consequences. Nathan Hall*, Anthony Whipple and Hans Paerl
3. The need of QC/QA for phytoplankton dataset. Adriana Zingone*, Sirpa Lehtinen, Paul Harrison, Abigail McQuatters-Gollop.

4. Phytoplankton biovolumes for ecologically important species from time series. Paul Harrison*, Hans Henrik Jakobsen, Adriana Zingone, Sirpa Lehtinen, Karen Wiltshire, Alexandra Kraberg, Ramaiah Nagappa
5. Phytoplankton responses to global change: recent highlights from the Continuous Plankton Recorder survey. Abigail McQuatters-Gollop* et al.
6. Phytoplankton blooms in coastal ecosystems: Cosmopolitan or local species? Jacob Carstensen* and others.
7. A comparative study on recurrent blooms of *Alexandrium catenella* in two Mediterreanean coastal environments over eleven year period. Sampedro, N., Vila, M., Garcés, E., Collos, Y*
8. How much of local scale variation in phytoplankton biomass can be explained by progressively larger scale variation? Katja Philippart*, James Cloern, Sirpa Lehtinen, Abigail McQuatters-Gollop, Todd O'Brien, Monika Winder.
9. Changes in Thou Lagoon phytoplankton in response to phosphorus management. Richard Gowen*, Yves Collos, Cordula Scherer, and others.
10. Skeletonema: a review. Paul Harrison, Adriana Zingone, Theodore Smayda, Yves Collos, Ramaiah Nagappa*, Tett et al.
11. Zooplankton phytoplankton shifts Seen as interactions in the North Sea with an emphasis on and Helgoland Roads. Maarten Boersma* and Karen Wiltshire.
12. Coastal Phytoplankton Production, Species Diversity and Sustainable Development. Thomas Malone* and others.
13. Contrasts and similarities of Guanabara Bay and Patos Lagoon estuary: short-term, seasonal and long-term phytoplankton trends in subtropical coastal environments in Brazil. by C. Odebrecht*, C.; Abreu, P.; Fragoso, G.; Gomes, D.F.; Haraguchi, L.; Villac, M.C.; Tenenbaum, D.
14. Ecological cues governing the preponderance and persistence of Skeletonema in coasts across the globe. Ramaiah Nagappa, Richard Gowen, Alexandra Kraberg , Adriana Zingone, Kedong Yin, Paul Harrison, Hans Paerl.
15. Long-term phytoplankton dynamics in the Baltic Sea: spring and summer bloom dynamics. Monika Winder* and others
16. Temperature and Phytoplankton Phenology in Narragansett Bay: Relevance to Climate Change. Ted Smayda* and others.
17. Long-term Rythmic Phytoplankton Behavior in Narragansett Bay. Ted Smayda* and others
18. Multidecadal Bloom Behavior of Skeletonema costatum s.l. in Narragansett Bay. Ted Smayda* and others
19. The regime shift in phytoplankton biomass in 1990 in the East Sea: its causes and impacts on the upper trophic levels. S. Yoo & J. Yoon.
20. Long-term variations in primary production in an eutrophic sub-estuary: Significance of short-term events. Chuck Gallegos, Patrick Neale
21. Seasonal distribution of phytoplankton and HABs in coastal waters. Yin et al.
22. Climate effects on phytoplankton floral composition in Chesapeake Bay. L.W. Harding, Jr., J.E. Adolf, M.E. Mallonee, W.D. Miller, C.L. Gallegos, J.M. Johnson, K.R. Sellner, and H.W. Paerl
23. About hydrological forcing of Patos Lagoon Estuary, bloom forming. Clarise Odebrecht, Jacob Carstensen, Paulo Abriu
24. Estimating time series phytoplankton biomass: Comparing volume to carbon scaling ratios.

Hans Henrik Jacobsen*.

25. Potential additional submission by Katja Philippart et al (coupling of spatiotemporal variation in nutrient and phytoplankton species composition)

*Lead Author

III. 4th Meeting Summary

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1. Meeting Summary

During the first meeting in October 2010, participants presented their systems and proposed research questions and other relevant subjects. In the second meeting, the focus was on presenting new products: comparisons and synthesis of different data sets from different regions, and new approaches to examine multiple data sets. In the third meeting, participants discussed how to address and approach the 'research questions' raised in the previous meetings and had take-home assignments for preparing papers. The participants in this 4th meeting presented their synthesized work and decided to publish a special issue for WG137 research in *Estuarine, Coastal and Shelf Science*. WG 137 also decided to continue the WG activity and discussed places for having the future plan for the meetings and research.

CERF Special Session: SCI-062 Global Patterns of Phytoplankton Dynamics in Estuarine and Coastal Ecosystems

Phytoplankton biomass and community structure have undergone dramatic changes in estuarine and coastal ecosystems over the past several decades in response to climate variability and human disturbance. These changes have short- and longer-term impacts on global carbon and nutrient cycling, food web structure and productivity, and coastal ecosystem services. There is a need to identify the underlying processes and measure rates at which they alter coastal ecosystems on a global scale. SCOR Working Group 137 (WG 137) has been gathering long time-series data sets from estuarine and coastal systems worldwide in order to examine patterns of anthropogenic and climate-driven change. We encourage participation from investigators with decadal observational data from geographically diverse regions. The wealth of information in these data sets provides an unprecedented opportunity to develop a global analysis and investigation of the dynamics and status of ecosystems where land and sea meet.

2-22

2. Meeting objectives:

- Presentations on progress made by previous WG137 participants.
- Reviewing and revising research questions
- Participants will formulate tasks for writing papers for the special issue in *Estuarine, Coastal and Shelf Science.*

3. Meeting program and presentations

November 1	Arrival	
Nov 2 (Sat)	Day 1 （9:00-18:00）	Closed meeting
9.00 – 9.05	Welcome by local host	
	Progress reports	James Cloern: Review: Phytoplankton Primary Production in the World's Estuaries Peter Thompson: Variations in the hydrologic cycle: impacts on phytoplankton
	Progress reports	Richard Gowen: 1) Phosphorus management: has it altered phytoplankton functional diversity in the Thau Lagoon (France), 2) Hydrodynamics and HABs Adriana Zingone 1) species/assemblage comparisons (Q6); 2) the molecular perspective in monitoring 3) Transition of scientific time series to a marine observatory addressing issues relevant to societal needs
12:00-13:30	Lunch	
13:30-	Progress reports	Jacob Carstensen The phytoplankton composition across the world’s coastal ecosystems
		Paul Harrison Phytoplankton cell biovolumes from field samples Hans Jakobsen Fixed cell sizes versus variable cell sizes Annual dynamics of carbon to chlorophyll ratio in temperate coastal waters and implications for modelling of marine coastal systems

Nov 3 (Sun)	Day 2	Meeting is open to all CERF colleagues
09:00	Presentations by WG 137 and CERF participants	Hans Paerl Human-and climate-driven changes in phytoplankton dynamics of 2 North Carolina lagoonal estuaries: teasing apart episodic from chronic water quality impacts using long-term data sets
	Presentations by WG 137 and CERF colleagues	Riina Klais Phytoplankton of the Baltic Sea
12:30-13-30	Lunch	
	Discussion among WG 137 and CERF participants (can be entire group or smaller focus groups---TBA)	Karen Wiltshire LONG-TERM PHYTOPLANTON DYNAMICS IN THE NORTH SEA: DYNAMICS OF KEY SPECIES AND NEW ARRIVALS Hans Jakobsen How does C relate to Chl? Adriana Zingore, Question 6 Common seasonal patterns for single species and communities Molecular methods can help break down species complexes LTER MC Phytoplankton t-s presentation
	Discussion among all CERF participants	Collos Yves A comparative analysis of Alexandrium catenella/Tamarense blooms in Annaba Bay and Thau Lagoon (France) over 18 years Peggy Lehman Cyanos of San Francisco Bay Delta Special issue discussion
Nov 4(Mon)	Day 3	**CERF Special Session SCI-062** (from 09:00 – 18:00

4. List of registered participants for SCOR WG137 meeting

	Name	Affiliation	email
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2	Cloern, James	US Geological Survey	jecloern@usgs.gov
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6	Alexandra Kraberg	AWI, Germany,	Alexandra.Kraberg@awi.de
7	Lehtinen, Sirpa	Marine Research Centre Finnish Environment Institute (SYKE) Erik Palmenin aukio 1, 00251 Helsinki Finland	sirpa.lehtinen@ymparisto.fi
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12	Richard Gowen	Fisheries and Aquatic Ecosystems Branch, Agriculture Food and Environmental Science Division, Agri-Food and Biosciences Institute, Newforge Lane, Belfast, BT9 5PX, UK	Richard.gowen@afbini.gov.uk
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14	Wiltshire, Karen Helen	AWI, Germany,	Karen.Wiltshire@awi.de

15	Yin, Kedong (co-chair)	School of Marine Sciences Sun Yat-Sen (Zhongshan) University Guangzhou, China	yinkd@mail.sysu.edu.cn
16	Zingone, Adriana	Stazione Zoologica A. Dohrn, Villa Comunale, Italy	<zingone@szn.it>

5. Special CERF Session SCI-062 Presentations for WG137
*Presenters

SCI-062A (November 4 am) Global Patterns of Phytoplankton Dynamics in Estuarine and Coastal Ecosystems. Hans Paerl, Kedong Yin, James Cloern, and Paul Harrison

- The phytoplankton composition across the world's coastal ecosystems. Jacob Carstensen*, Hans Paerl, James Cloern.
- Phytoplankton trait based functional diversity as an indicator for stability. Sirpa Lehtinen*, Riina Klais, Kalle, Olli, Timo Tamminen.
- Long-term phytoplankton dynamics in the North Sea: Dynamics of key species and new arrivals. Alexandra Kraberg*, Martin Edwards, Mirco Scharfe, Karen Wiltshire.
- The Baltic Sea phytoplankton dataset. Riina Klais*, Kalle Olli, Timo Tamminen.
- Phytoplankton associations at the LTER-MC station in the Gulf of Naples (Mediterranean Sea). Adriana Zingone, Cristina Tortora, Laurent Dubroca, Francesca Margiotta, Diana Sarno.
- Diatom and dinoflagellate blooms in Thau lagoon (Southern France) over the last 20 years : dichotomy in controlling factors. Yves Collos*, Cecile Jauzein, Widya Ratmaya, Philippe Souchu, Eric Abadie, Andre Vaquer.
- Analyses of long-term changes in phytoplankton diversity and biogeography in tropical estuarine and coastal regions. Ramaiah Nagappa*, Abdul Alkawri, Naseera Kh, Cindrella Das, Sandip Savant, Elaine Sabu.
- Phytoplankton in the Pearl River estuarine coastal waters: Anthropogenic and climate influences. Kedong Yin*, Jianzhang He, Paul Harrison.

SCI-062B (November 4 pm) Global Patterns of Phytoplankton Dynamics in Estuarine and Coastal Ecosystems. Hans Paerl, Kedong Yin*, James Cloern, and Paul Harrison

- Phytoplankton responses to global change. Abigail McQuatters-Gollop*.
- How much of local scale variation in phytoplankton biomass can be explained by progressively larger scale variation? Catharina Philippart*, James Cloern, Sirpa Lehtinen, Abigail McQuatters-Gollop, Todd O'Brien, Monika Winder.
- Biovolume of ecologically important phytoplankton species from time series datasets. Paul Harrison, Adriana Zingone*, Hans Jakobsen.

- COPEPODITE: An online toolkit for plankton time series data analysis and visualization. Todd O'Brien. Carbon to chlorophyll ratio in temperate coastal waters: seasonal patterns and relationship to nutrients. Hans Jakobsen*, Stiig Markager.
- Little Lake Worth Florida, a 'borrow-pit' style coastal lagoon: Use of pigments and water quality to detect anthropogenic perturbations. J.William Louda*, Keren Bolter.

SCI-062C (Nov 4 pm) Global Patterns of Phytoplankton Dynamics in Estuarine and Coastal Ecosystems. Hans Paerl, Kedong Yin*, James Cloern, and Paul Harrison

- Thompson*, Todd O'Brien, Jacob Carstensen, Richard Gowen, Paul Harrison, Clarisse Odebrecht, Katja Philippart, N. Ramaiah, Yin Kedong, Hans Pearl, Adriana Zingone.
- Hydrologic variability associated with climatic change: Its effect on phytoplankton biomass and composition in 2 lagoonal North Carolina estuaries. Hans Paerl*, Nathan Hall, Benjamin Peierls, Karen Rossignol.
- Comparison of phytoplankton dynamics in mid-Atlantic estuaries using long-term data. Lawrence Harding*, Jason Adolf, W. David Miller, Hans Paerl, Nathan Hall, Benjamin Peierls, Karen Rossignol.
- Long term variability in annual primary production in the Rhode River subestuary of Chesapeake Bay. Charles Gallegos*.
- Seasonal and interannual variability of winterspring phytoplankton in Chesapeake Bay: 1988-2010. Younjoo Lee*, Walter Boynton, Dong Yoon Lee.
- Phytoplankton productivity and dynamics in a shallow, microtidal, extensively modified subtropical estuary on the southwest coast of Florida, USA. Loren Mathews*, Edward Phlips.

6. Post-Meeting Assignments: Special Issue

List of Proposed Papers for the Special Issue of ECSS (updated 22 Nov 2013)

To be edited by Riina Klais (riina.klais@ut.ee), Paul Harrison (paul.harrison@eos.ubc.ca), and Jim Cloern (jecloern@usgs.gov)

2.2.4 SCOR/IGBP WG 138 on Modern Planktic Foraminifera and Ocean Changes
(2010) ***Feeley***

Terms of Reference:

1. Synthesize the state of the science of modern planktic foraminifera, from pioneering to ongoing research including their spatial and temporal distribution in the world ocean their calcification mechanisms and shell chemistry and their eco-phenotypical and genotypical variability as a peer-reviewed publication in an open-access journal (**deliverable 1**).
2. Provide guidelines (cookbooks) in terms of species identification, experimental setup for culture studies, laboratory treatment prior to geochemical analysis (**deliverable 2**) by identifying existing gaps in the available knowledge in order to direct future research.
3. Establish an active Web-based network in cooperation with ongoing (inter)national research programmes and projects to guarantee an open-access world-wide dissemination of results, data and research plans (**deliverable 3**).
4. Document the work of the group in a special issue of an open-access journal (**deliverable 5**) in connection with a specialized symposium with special emphasis on modern ocean change i.e. thermohaline circulation and ocean acidification, during one of the AGU or EGU conferences, ideally held at the joint EGU/AGU meeting (envisaged for 2013 or 2014) and/or at the FORAMS 2014 meeting in Chile (**deliverable 4**).

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Executive Committee Reporter: Missy Feeley

2.2.5 SCOR WG 139 on Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean (2011) *Urban*

Terms of Reference:

1. To inform the Ocean Sciences community of this WG and related objectives via a widely distributed publication in *EOS* or analogous journal.
2. To summarize published results on all aspects of metal-binding ligands in the oceans (e.g., distributions, chemical structure, sources, sinks, stability constants), and to contribute to the organic ligand database for use in biogeochemical models and for those working in the field (including results from ongoing GEOTRACES, SOLAS and CLIVAR efforts). The summary will be included in a review paper published after year 2, as well as in the database on the proposed website.
3. To expand upon the ligand intercalibration programme, initiated by GEOTRACES, to evaluate key analytical issues with currently employed methodologies and determine how to best link ongoing efforts in trace metal and organic geochemistry to assess natural metal-binding ligand.In a recent intercalibration the preservation of samples for Fe and Cu-organic speciation by freezing at -20°C as been found suitable and will enable to make samples taken during GEOTRACES cruises available to interested scientists. A large intercalibration will thus be possible in the future without additional joint cruises or sampling exercises, but could be performed with samples from several 'normal stations' of a GEOTRACES leg. Results from intercalibration efforts will be presented in a manual available via download from the proposed WG website.
4. To identify how best to incorporate published and future data into biogeochemical models.
5. To debate the nature of sampling strategies and experimental approaches employed in laboratory and field efforts in workshops and meeting discussions that are needed to enhance our understanding of the links between the provenance, fate, distribution, and chemistry and biological functions of these organic metal-binding ligands in the oceans.
6. To recommend future approaches to ligand biogeochemistry in a designated symposium, including ongoing GEOTRACES field efforts (i.e., regional surveys and process studies), integration of CLE-ACSV and organic geochemistry techniques, and the need for rapid incorporation of this research in biogeochemical models. Such future recommendations will also be included in the aforementioned downloadable manual on the WG website.
7. To establish a webpage for this SCOR working group, to promote a forum for discussion of ideas and results in form of a blog, soliciting input from the trace metal biogeochemistry, organic geochemistry and modeling communities and provide a platform to propose special sessions on trace metal-binding ligands at international meetings such as Ocean Sciences, AGU and/or EGU.
8. To produce conclusions resulting from the outcome of the above objectives in the form of a Website, a journal special issue or book, and a report to SCOR.

2-30

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SCOR Working Group 139: Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean

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Stan van den Berg, UK

Recent Meetings

The third meeting of the members of SCOR WG 139 "Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Oceans" was held at the University of Hawaii, Manoa on February 23, 2014. Fourteen members and four guests were in attendance, and new associate member Parthasarathi Chakraborty (India) was welcomed to the group. Members discussed the Terms of Reference at this meeting, including constructions of a ligand database, incorporation of speciation data into models, a special issue of the journal *Marine Chemistry* and ongoing intercalibration efforts. The results of the intercalibration effort for interpretation techniques of speciation data were presented, and recommended software programs from this work are now available free of charge from the WG website. A field intercalibration effort is currently being planned, and a database for speciation data is being assembled for Fe, Cu, Co and Zn. A series of invited presentations covered recent advances in ligand research, and the meeting finished with discussions of upcoming WG events: the special issue in *Marine Chemistry* for WG-related research and a final research symposium with an early-career training workshop planned for spring 2015 in Croatia.

In addition to the meeting of WG members, the co-chairs of WG 139 also chaired a special session at the joint AGU/ASLO Ocean Sciences meeting held in Hawaii in February 2014. This special session was awarded a morning of oral presentations, 8 in total, as well as a supplementary poster session. Presentations in the session covered a wide range of topics related to metal-binding ligands, including distributions in marine and estuarine environments, sources and sinks, relationship between organic ligands and primary production, and progress in modelling efforts.

A Town Hall Meeting was held on February 27, 2014 during the Ocean Sciences Meeting at the Hawaii Convention Centre in Honolulu, Hawaii. A total of 47 people attended the Town Hall. WG co-chairs Maeve Lohan, Sylvia Sander, and Kristen Buck provided an overview of the WG's motivation and terms of reference, major achievements so far, and plans for the final year of the WG funding period. Results from the recently completed intercomparison of interpretation techniques were presented by co-chair Sylvia Sander. Sylvia also demonstrated how to use the two recommended interpretation software programs for multiple analytical windows from the intercomparison: MCC, created by Dario Omanovic, and KMS, created by Robert Hudson. Both of these programs are available via the SCOR WG 139 webpage (http://neon.otago.ac.nz/research/scor/index.html) free of charge.

Highlighting opportunities for community participation in WG activities was an important component of this Town Hall. Opportunities for involvement included:

1) Join the WG email list to keep up to date on activities and progress. We now have 184 subscribers on the mailing list.
2) Contribute published and/or unpublished data to WG databases.
3) Participate in upcoming field intercalibration activities for seawater analyses.
4) Publish a manuscript on ligand-related studies in an upcoming special issue in *Marine Chemistry*, submission due May 2014.
5) Join us in Croatia for the final WG research symposium and hands-on training workshop in Spring 2015.
6) Serve as a reviewer of WG special issue submissions, and best practices manual.

Plans for work between meetings

The working group has identified action items resulting from each meeting that are assigned to specific members for completion, facilitating continued progress in accomplishing the terms of reference between meetings. The co-chairs are tasked with following up on assigned action items and coordinate activities with each other via regular phone conferences and email contact.

Plans for next meeting

The next meeting of SCOR WG 139 members is planned for early April 2015 and will be final research symposium with early-career training workshop planned in Primosten, Croatia and will be open to the community. We have secured funding from SCOR (US$5000) for early-career scientists from developing nations to participate in the early-career training workshop. These participants will also be invited to the final research symposium.

Overall progress toward Terms of Reference

The working group is making steady progress toward accomplishing the terms of reference laid out in the original proposal and amended in the first group meeting. Three members-only meetings have taken place. In addition, the WG has chaired three special sessions at international conferences. Two publications (*Eos*, IUPAC *Chemistry International*), email distribution lists (contact a chair to join), and a website http://neon.otago.ac.nz/research/scor/index.html were completed in the first two years.

The special issue planned for *Marine Chemistry* on metal-binding organic ligands has16 papers submitted to date and with additional submissions expected. The deadline for submission has been extended to June 14 and we hope to have first papers published on-line by the end of the calendar year 2014.

Intercalibration: results from the completed intercomparison of interpretation techniques initiated by the WG 139 in which members of the WG and other scientists participated will be published in the special issue of *Marine Chemistry*. In addition the two recommended interpretation software programs for multiple analytical windows from the intercomparison: MCC, created by Dario Omanovic, and KMS, created by Robert Hudson, are available via the SCOR WG 139 webpage (http://neon.otago.ac.nz/research/scor/index.html) free of charge. The field intercalibration will take place in 2015 due to postponement of the research cruise to the Celtic Sea where samples were due to be collected.

The best practices manual to guide future approaches in determining organic ligands is in progress and will be published on the WG 139 website.

Updates on SCOR WG 139 activities, links to published articles and minutes from WG meetings may be found on the website, as well as several other useful links and documents for information relating to ligands in the marine environment.

2.2.6 WG 140 on Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII) (2011) *Volkman*

Terms of Reference:
1. Standardisation of methods for data intercomparison.
2. Summarizing existing knowledge in order to prioritise processes and model parameterizations.
3. Upscaling of processes from 1D to earth system models.
4. Analysing the role of sea ice biogeochemistry in climate simulations.

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SCOR WG 140
Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII)
- Annual Report 2014 -

In the second full year of WG140, BEPSII's activities were coordinated through three Skype meetings, which were held on 20 June 20 and 18 October 2014, and 3 February 3 2014. An in-person meeting took place after the IGS "International Symposium on Sea Ice in a Changing Environment" in Hobart, Australia, on 16 March 2014. 22 members of the BEPSII network, representing 11 countries, attended the meeting. The group consisted of 50:50 established versus early-career scientists and 50:50 female and male participants. During the meeting, the Belgian Full Member Jean-Louis Tison asked to be replaced by Associate Member Bruno Delille; Tison will stay as an Associate Member. Full Member Sang Heon Lee was replaced by the Finnish Associate Member Letizia Tedesco; Lee will remain an Associate Member. A full report of the meeting is presented in **Annex I**.

Participants of the BEPSII meeting in Hobart, 16 March 2014

Overview of activities

Task Group 1 on Methodologies and Intercomparisons (Leads: Lisa Miller and Lynn Russell) has three primary goals:

1. Methodological review;
2. Intercomparisons and intercalibration projects; and
3. Guide of Best Practices.

The activities of TG1 to meet these goals were:

1.1 A review on sea-ice methodologies has been compiled: In a combined effort by 20 authors from BEPSII's network, the paper "Methods for biogeochemical studies of sea ice: Where are we and where are we going?" was submitted to *Elementa: Science of the Anthropocene* and is currently under revision.

1.2 During the past year an inventory of potential field campaign sites for intercomparison projects has been performed. While it is not the aim of BEPSII to organize such a campaign within the current project period, it is the aim to stimulate discussion and seek options to organize such a project on a reasonable time scale. A poster on the subject was presented at the IGS symposium in Hobart (**Annex II**). Options for two different campaigns are currently under investigation: one in Japan (Saroma-Ko lagoon) concerning intercomparison of ice-melt procedures and potentially gas-exchange measurements; and one in Finland (Baltic, Tvarminne) on various primary production measurement methods.

1.3 Given the fact that Eicken's *Sea Ice Methods* book is not going into a second edition, and hence there is no opportunity to add chapters on biogeochemical parameters, it was agreed that a complete Guide of Best Practices is currently not an option. However, a website on Best Practices, as part of a BEPSII website (now under construction), is currently under investigation.

Task Group 2 on Data (Leads: Klaus Meiners and Martin Vancoppenolle) has two primary goals:

1. Produce new data inventories by collation of existing data;
2. Provide recommendations for standardized protocols and databases.

The activities of TG2 to meet these goals were:

2.1 The collection of chlorophyll-*a* data from the Arctic is taking shape under Canadian/German lead. There is potentially access to a Russian database, through the efforts of people from the Alfred Wegener Institute, Germany.

2.2 Other parameters have been much less frequently monitored in the past decades than chlorophyll-a. Nevertheless, there is information available on macro-nutrients, dissolved organic carbon and also micro-nutrients (Antarctic iron data). These are currently collated and will inform preparations of mechanistic reviews and data inventories in collaboration with task 2 of TG3 (see below).

2.3 The ASPeCt log-sheet – an Excel file with a standardized protocol for ice-core metadata – will be adapted and published on the BEPSII website. A recommendation has been added to the methods review (1.1), encouraging scientists to use the template consistently, which will greatly help future data access and interpretation.

Task Group 3 on Modeling (Leads: Nadja Steiner and Clara Deal) has four components:

1. Recommendations from modellers to observationalists,
2. Review papers on major biogeochemical processes
3. Intercomparison of 1D models and publication of a review,
4. Application in regional models with links to global and regional climate modelling.

The activities of TG3 to meet these goals were:

3.1 A paper on "What sea-ice biogeochemical modellers need from observationalists" is in its final stages and planned for submission in fall as part of a BEPSII special issue (see below).

3.2 A list of 9 reviews on specific sea-ice parameters was drafted, of which 8 have confirmed (co-) authors. Some reviews are well underway, while others are just starting. The reviews will describe sea-ice related processes and will include – whenever possible – an overview of available data (overlap with TG2). Topics include DIC/ALk, Fe, nutrients, DMS(P), light transfer through ice, ice-algal release, halogens, DOC/POC, and community structure. These reviews are planned to be published within a BEPSII special issue. Negotiations are currently underway with the journals *Frontiers in Marine Science* and *Elementa*. Both journals have the option for a special feature or research topic and are very interested in having BEPSII publish in their journal. In addition, a publication on improved light transfer through snow-covered sea ice is being prepared as part of BEPSII. The paper will likely be submitted before the special issue is active.

3.3 A 1-D model intercomparison exercise is now underway with 8 groups contributing. The goal is to evaluate outcomes on biomass and primary production over a seasonal cycle, both in the Arctic and the Antarctic. A model plan and intercomparison strategy has been prepared and common forcing data sets will go out to all groups by the end of summer. More specific 1-D model intercomparisons on under-ice primary production and DMS are currently being discussed.

3.4 Several regional model intercomparisons are being planned (e.g., upper-ocean circulation in the Arctic and impact of sea ice; formation of a deep chlorophyll maximum in the Arctic) as part of our collaboration within FAMOS.

A comparison of the outcome of Earth System models on acidification was published as a contribution to BEPSII[1].

Status of fulfilling terms of reference

The Terms of Reference of BEPSII are as follows:

1. Standardisation of methods for data intercomparison.
2. Summarizing existing knowledge in order to prioritise processes and model parameterizations.
3. Upscaling of processes from 1D to Earth system models.
4. Analysing the role of sea ice biogeochemistry in climate simulations.

ToR1 is covered by the activities of TG 1 and part of TG2. It has largely been fulfilled with the submission of the review paper to *Elementa* (activity 1.1). Also activities 1.3 and 2.2 contribute to this ToR. Given the large heterogeneity of sea ice (in space and time), the limited accessibility for field work, the limited number of research groups working on ice and the new methodological developments, a continued effort for testing and intercalibrating sea-ice methods is needed. Therefore, TG1 will continue its work through the stimulation of a joined field campaign (activity 1.2).

ToR2 is well underway with activities 2.1 and 3.2. The planned special issue will be a major end product of BEPSII.

ToR3 is currently being implemented in the 1-D exercise described under activity 3.3 and expansion to regional models in 3.4. Currently, none of the global climate models which had been submitted to the 5th coupled model intercomparison project (CMIP5) contain sea ice biogeochemistry and a fully integrated sea-ice biogeochemistry module is not expected to be implemented and analyzed within BEPSII. However, based on results from activity 3.3 and 3.4, we hope to make recommendations indicating which processes and variables might need to be considered in global climate models. Also, simulations of inorganic carbon cycle are under way (S. Moreau et al.) using a 1D sea ice model, with suggestions for model up-scaling.

ToR4 has so far been limited due to the lack of sea-ice biogeochemistry within global climate models. Initial analyses of CMIP5 models on CO_2 exchange, acidification and pelagic primary production in the Arctic have been performed and published under the lead of BEPSII full members.[1] Further analysis on the role of sea ice biogeochemistry in climate simulations is expected to be performed as a regional downscaling effort (regional models with sea-ice biogeochemistry will be forced with output from global CMIP5 models). This is one of the last

[1] Steiner, N.S., J.R. Christian, K.D. Six, A. Yamamoto, and M. Yamamoto-Kawai. 2014. Future ocean acidification in the Canada Basin and surrounding Arctic Ocean from CMIP5 earth system models. *Journal of Geophysical Research: Oceans* 119:1–16, doi:10.1002/2013JC009069, 2014

activities to be undertaken and will likely extend past the life of BEPSII as a SCOR working group.

Plans for the coming year in relation to the terms of reference and capacity building

1. A major activity in the coming year will be the organization of more of less simultaneous drafting of review papers for the special issue (i.e., continuation of activity 2.1/3.2). The submission of papers to either *Elementa* or *Frontiers in Marine Science* will be opened in autumn 2014 and is planned to stay open for 9 months. Both journals have the option of publishing on-line the moment a paper is accepted. Hence, contributors do not need to wait for the last paper to be accepted.
2. Also the first 1-D model intercomparison is planned for the coming year. Currently, the instructions for model runs are being finalized and together with forcing data will be sent out to the participants in early autumn 2014 (L. Tedesco, M Vancoppenolle et al.). First results are planned to be ready before the next BEPSII meeting in 2015. Regional model comparison will be coordinated with FAMOS (annual meeting in October).
3. Large-scale data collections on Arctic ice biomass (Ilka Peeken, C. Michel et al.), inorganic carbon (B. Delille et al.), inorganic macro-nutrients (F. Fripiat et al.) and iron (D. Lannuzel and V. Schoemann) are under way.
4. Activities to implement a methods-intercalibration campaign on a longer time scale (possibly 2016/17) will continue. The Japanese and Finnish options will be further explored. Goals, parameters and sampling schemes for each of the campaigns will be developed, so as to function as a "white paper" for organizers and participants to raise funds.
5. To improve coordination of the different activities, a more interactive BEPSII website will be built. Through the website, we will make papers, references to datasets, data-log sheets, and other information available to the community.
6. The BEPSII Facebook page will be further developed for outreach purposes (https://www.facebook.com/SCOR.BEPSII?fref=ts).
7. The next life BEPSII meeting is planned after the Gordon Research Conference on Polar Marine Science, which is held from 15-20 March 2015 in Lucca, Italy. (https://www.grc.org/programs.aspx?id=12641).

Special requests for extra funding for outreach and/or capacity building activities
The costs for publication of a Special Issue in either *Elementa* or *Frontiers*, is expected to be around €1000 per article. A minimum of 8-10 papers is envisioned. A contribution by SCOR would be more than welcome.

Challenges or opportunities the group will experience in the coming year
Except for the plans in the coming years, one other challenge will be to explore pathways for continued support of the activities and collaborations started by the BEPSII initiative. For both the planning and organization of intercalibration field campaigns and the upscaling of model intercomparisons a BEPSII 2.0 is needed. The question to SCOR is whether or not an extension of the current project period is possible.

Besides this option, other avenues also must be explored. In this respect, BEPSII is involved in the submission of a Polar Science Network Cluster to Future Earth, which is led by Faye McNeill (IGAC/OASIS). This initiative has recently been granted US$40,000 with the goal of "co-ordinating and developing a new proposal which addresses how polar (or Arctic) issues should be addressed through one process in Future Earth" This proposal will then be submitted to a new call for Future Earth proposals in 2015.

ANNEX I

Minutes SCOR-WG 140 (BEPSII) Meeting
Hobart, Australia, Sunday March 16th 2014

Present: Delphine Lannuzel (AUS), Veronique Schoemann (B), Jean Louis Tison (B), Clara Deal (USA), Nadja Steiner (Can), Jacqueline Stefels (NL), Francois Fripiat (B), Lisa Miller (Can), Anne-Julie Cavagana (B), Yubin Hu (Ger), Daiki Nomura (J), Bruno Delille (B), Lynn Russell (USA), Agneta Fransson (Nor), Paul Shepson (USA), Elena Golubeva (Rus), Gauthier Carnat (B), Celia Sapart (B), Klaus Meiners (AUS), Martin Vancoppenolle (F), Steve Ackley (USA), Janne Rintala (Fin).

9:00 Welcome

In the preceding week – in the fringe of the IGS International Symposium on Sea Ice in a Changing Environment – several task-group meetings were held in preparation of this plenary meeting. This allowed a few new people to become involved in BEPSII's activities.
Goals of the meeting were to establish where we are, what we still miss, how we get there and what the next steps are. The official life span of BEPSII is until 2016.

9:15 Crosslinks with other organisations

- Update on OASIS (Paul Shepson):

OASIS' goal to connect ocean, ice and atmosphere didn't really work out until now. It has mainly been an atmospheric chemistry group that has been very successful in obtaining grants for field campaigns during and beyond IPY. The group has hence been successful in gathering lots of data, but less so in understanding the underlying processes. More integrated science is needed to address what are the main processes and fluxes associated with boundary layer turbulence. Currently, a new NSF proposal is pending (PHAME) to use BrO satellite data and airplane measurements. The OASIS community has taken the initiative to submit a Future Earth Cluster Activity (lead: Faye McNeill) for an International, Interdisciplinary Polar Science Network. BEPSII is invited to become partner on the proposal.

- Update on SIP (slides from Eric Wolff):

There are several sea-ice proxies that are relevant for BEPSII. Currently, the final SIP workshop is being organised in Bremerhaven, June 23-25, 2014, by Rainer Gersonde. The aim of the meeting is to complete multi-proxy comparisons. The involvement (in the 3rd meeting or more generally) of biogeochemists who are interested in the way the proxies behave from an observational or modelling viewpoint is greatly appreciated. Those interested can contact Eric Wolff (ew428@cam.ac.uk) or Rainer Gersonde (rainer.gersonde@awi.de)

- MOSAIC ("Multidisciplinary drifting Observatory for the Study of Arctic Climate"; website:

http://www.mosaicobservatory.org/index.html) The project is in an early stage. Coordinator is Matthew Shupe. Currently, a white paper is being produced. The contribution of biogeochemistry seems limited. We will write an email on the aims of BEPSII and will direct possible inputs to individual BEPSII participants.

- PICES (Lisa Miller):

PICES is still very supportive. Would probably be especially supportive of a field campaign in Japan.

- ASPeCt (Steve Ackley):

ASPeCt is working on the science questions within SCAR's horizon project, which currently contain hardly any sea-ice biogeochemistry questions. Klaus M. will collate all questions, send around and ask the community to formulate the 3 most important questions. He will communicate the outcome with Rob Massom for input to the April meeting of SCAR. Later in the meeting, a web questionnaire was organised amongst the meeting participants to rank the questions. The outcome is used as basis for the SCAR input.

9:45 TG2 (Klaus Meiners/Martin Vancoppenolle)

Task 1. Produce new data inventories and datasets by collation of existing data
This task is highly relevant given the limited number of polar data sets, the high logistical costs to collect new data and the inability to observe sea-ice biogeochemical properties from space. Important science questions to be asked are: what do modelers need; what are the key parameters to focus on; which properties and processes are relevant; do we need to collect data from both pack and fast ice? To put the biogeochemical data in perspective, it is important to also provide the correlated physical data.

So far, the group has produced a pack-ice compilation of chlorophyll-a in Antarctic sea ice [*Meiners et al.*, 2012]. Over the last few months, a master student of Klaus Meiners, Natalie Radojcic (Institute for Marine and Antarctic Studies), continued the analysis of this dataset, trying to understand the role of snow on Antarctic sea-ice chlorophyll. To some extent, the role of snow on nutrient supply and light limitation could be identified.

In addition, five other projects are ongoing or were initiated during the meeting:

1. Efforts from Christine Michel (Fisheries and Ocean, Canada) and Ilka Peeken (AWI, Germany), towards the extension of the chlorophyll-a work in the Arctic regions. Christine and Ilka collected hundreds of cores from different groups and are about to start analyses.
2. Bruno Delille (ULg, Belgium) called for contributions towards the compilation of inorganic carbon parameters (DIC, alkalinity, …). Bruno listed several associate and full members as contributors. Planning: Summer to collect the data; fall putting data together.

3. Delphine Lannuzel (IMAS, Australia) and Véronique Schoemann (ULB, Belgium) have gathered practically all ice core data for iron in sea ice, totalizing about a hundred cores. They are about to start analyses and their group targets the submission of a paper by the end of the year.
4. Klaus Meiners has initiated a project to collate historical chlorophyll-a data from Antarctic fast ice over the next years.
5. A lack of action with respect to nutrients was identified. Francois Fripiat (VUB, Belgium) proposed to collate macro-nutrient data, starting from the Antarctic in the current year.

Task 2. Provide recommendations for standardized protocols and databases (datacentre)
It was agreed that all researchers should use the ASPeCt/ASPeCt-Bio ice core log sheet to store their ice core data. This saves a lot of time when compiling large amounts of data. It was mentioned that the ASPeCt log-sheet was not all-inclusive. An updated version will be prepared in the coming months (action Jean-Louis, Klaus, Martin?). This updated version will be made available through the new BEPSII website.

ASPECT bridge-based observation logging software will be updated in the next few months: One of the issues is that ice colour will be included: 4 classes and 3 communities: top, interior and bottom. Relationship with snow thickness has received particular attention. Representative pictures as examples are needed to be included in the database and can be send to Klaus.

How the collected data could be stored and how we could manage them is a much more difficult task. We reached the conclusion that our SCOR-WG cannot really handle that. Currently, data are stored in national data centres. Jenny Baeseman from CliC mentioned that similar discussions were running in the ASPeCt sea ice physics group. Discussions between CliC and the main data centers have started, and she will keep us informed.

11:00 TG1 (Lisa Miller/Lynne Russell)

Task 1. Methodological review
A 70-pages manuscript has been submitted to *Elementa-Oceans*. There is still room for small additions and corrections. A figure showing an example ASPeCt ice-core data sheet will be added.

Task 2. Intercomparisons and intercalibration projects
During the past months, several people were asked to provide information on facilities and associated costs of potential field locations for intercomparison experiments. A summary of this inventory is provided in the below table. Prices are in approximate 2013 US dollar equivalents:

	Transport (roundtrip)	Lodging/Food (d^{-1})	Capacity	Lab/Other Facilities (most charge fees)
Alert	3000 from Trenton	100	100	Wet lab and staging
Ny Alesund (Svalbard)	1700 from Tromso	190	50?	Various
Longyearbyen	800 from Tromso	250	50?	Various
Saroma-ko Lagoon	40 from Memanbetsu	30	200	Various
SERF @ Manitoba	100 from Winnipeg	100-200	Unlimited	Ice pool (artificial SW) for $100/PI/d
IOS @ Victoria	200 from Vancouver	100-200	Unlimited	Clean rooms, etc.
Tvarminne	100 from Helsinki	50-100	90	Various (labs, boats, saunas)
McMurdo	NSF-only/infrequent	NSF funded	?	Various
Barrow	800 from Seattle	100-200	100+town	Various (labs, transport, guards)
CRREL @ Hanover, NH	200 from Boston	200	Unlimited	Wave tank

Francois had prepared a potential ice-camp design for intercomparison experiments with the goal to compare different melting procedures (with and without seawater or brine) and sampling techniques (sack holes, and bulk melting) by using the same analytical methodology for a set of parameters. Concerning the design of the experiment, it was suggested that instead of repeating the experiment at the same location, the experiment should be repeated in contrasting locations (snow cover, ...).

Several other potential intercomparison experiments were discussed. Given the different needs for experiments to be successful, an all-inclusive campaign does not seem feasible. A discussion followed on the characteristics of the available sites and what is needed for the different intercomparison experiments. Here follows a summary of parameters, needs and questions (leaders in parentheses):

- Biomass & primary/secondary production: (Fripiat, Rintala, Stefels)
  - sea ice with algae
  - representative community?
  - more saline than Baltic for biomass (Janne Rintala has done it in the Baltic)
  - Salinity not so important for primary production test, because it hasn't been done, yet
  - uniform, flat ice
  - Temperature range doesn't matter

  - incubation issues? How are samples taken? Need statistical sampling (Latin square?) (Rintala)
  - sampling over 10 days not vigorously needed for intercomparison, but useful for adding robustness to project
  - could artificially control more/less light?
  - bacterial production in winter then primary production later
- Genomics & community structure: (Bowman? Rintala, van Leeuwe?)
  - different needs from biomass?
  - pigments, genomics, microscopy
  - large, diverse community: spring
  - vertical resolution within the cores
- Oxygen in ice: (Tison)
- Gas fluxes: (Nomura & Zappa)
  - natural ice – we need fluxes
  - more variable environment desired
- Carbonate system parameters: (Delille, Miller, Nomura)
  - lab would be ok
  - natural ice would need to be uniform, flat, fast ice
  - range of temperatures desired
- Trace elements (Lannuzel & Schoemann)
- Aerosols: (Russell & Shepson)
  - Southern Ocean better because of less anthropogenic pollution
- Hyperspectral surveys from the air (Zappa)
  - autotrophic community structure
  - gas and heat fluxes

In summary:

	Salinity	Uniform / fast ice	Variable / pack ice	Community	Season
Sites:					
Alert	High	X		Arctic	
Ny Alesund (Svalbard)	High	X		Arctic	
Longyearbyen	High	X		Arctic	
Saroma-ko Lagoon	Medium	X	X	Low-Lat	
SERF @ Manitoba	High	X		None	
IOS @ Victoria	High	X		None	
Tvarminne	Low	X		Low-Lat	
McMurdo	High	X		Antarctic	
Barrow	High/Low	X	X	Arctic	
CRREL @ Hanover, NH	High	X		None	

MOSAIC	High		X	Arctic	
Experiments:					
Primary/secondary production	High/Low	X		High	Spring
Biomass	High	X		High	Spring
Genomics/Community structure	High	X		High	
Gas and radiative fluxes			X		Fall/Spring
Carbonate system parameters	High	X			All
EPS		X		High	Fall/Spring

Conclusion:

- Saroma-Ko looks most promising for biogeochemical parameters.
  - Problems: Ice is relatively warm and isothermal. C-14 is not allowed.
  - Nomura and Nishioka will pursue organization and inquire regarding Japanese funds for international collaborations.
- Other alternatives:
  - Tvarminne (Finland) looks most promising for primary/secondary production experiments: Janne will explore and organize.
    (After-meeting information from Janne: the station management is more than happy to support an intercomparison campaign. Details can be found at: http://luoto.tvarminne.helsinki.fi/english/visitors.html. So far, no funding is available. So funding needs to be found through participating partners.)
  - Shipboard: Dedicated ship time is likely difficult for the purpose of intercomparison, whereas an existing science project is not likely to accept duplicate measurements on board. However, a few options can be explored:
  -
    Eurofleets? Bruno to investigate
    MOSAIC (Polarstern): Multi-year, multi-ship freeze-in. What are possibilities? Jacqueline & Agneta to investigate.

Funding:

- US: NSF could support a workshop to plan a project
  - ONR a good source for large, collaborative projects – Contacts: Scott Harper, Martin Jeffries
  - Keep it under $1 million, then the long-term project planning isn't needed
  - Bowman (currently finishing his Ph.D.) has offered to help write a US proposal
- EU: Horizon 2020 Framework – need to advocate through national representatives
  - Long and complicated process, and national programs may be more effective
  - Jacq/Jean-Louis looking into it

- Finland (Janne): new program a possibility for work in the Baltic, can fund non-Finnish scientist, including travel (not salary); may include local cost, travel, resources
- Belgium: Small proposals easy (Bruno)
  - Big proposals more likely to be successful (Jean-Louis)
- Japan: Fund for international collaborations
  - Belgium-Japanese Intercollaboration fund
- People should look for national funding: fieldwork support or bilateral cooperation funds.

Next steps:
1. Move forward with plans for Saroma-ko and Tvärminne for whatever would work there in 2016-17
2. Francois will adapt the ice-camp design proposal to take into account all the discussed comments (due June 2014).
3. Continue developing plans for each intercomparison (names associated with each parameter).
4. Develop proposals to national funding sources.
5. Continue exploring other locations/platforms.
6. A summary of locations and parameters will be posted on the new BEPSII web page.

Task 3. Guide of Best Practices.
Hajo Eicken's Sea Ice book is not going into a second edition. Alternative: individual papers can go on the BEPSII website. Possibly pulled together in a 'book'/Special Issue at the end?

13:00 TG3 (Nadja Steiner/Clara Deal)

Task 1. Recommendations from modelers to observationalists
A journal paper draft started with Nadja Steiner, Clara Deal, Letizia Tedesco, Diane Lavoie, Delphine Lannuzel. It contains some good points, but tends to drift off into some kind of review. A brainstorming session during Saturday's side meeting provided some more ideas and we added Jacqueline and Lisa. Francois Massonet joined the meeting and gave some valuable comments based on his experience with physical sea-ice modelling. It was suggested to include Katya Popova's cartoon of the "5-star scientist". Katya has been contacted and is interested in contributing.

Nadja added suggestions, reread, and sent out a new draft. The paper is planned to be a contribution to the BEPSII special issue (see below).

Task 2. Review papers on major biogeochemical processes
Several processes have been identified, which warrant a review including both the status of observations as well as the status of model parameterisations. Depending on the availability of data, there will be overlap with the data collation under TG1. The plan is to publish all reviews in a special issue, using an online journal, which allows continuous publication until a specified end date is reached. This will avoid putting papers on hold. 2 journals were identified:

1. *Frontiers*: This is a collaborative forum with the Nature Publishing Group. Reviews as well as articles can be submitted. The procedure is efficient and at the end the collected publications will be published as an e-book. (http://www.frontiersin.org/ - looks promising, but is not cheap)
2. *Elementa*: Steve Ackley will contact Jody Deming (chief editor) to find out options.
Biogeosciences was also mentioned, but some negative experience with the open-review procedure was ventilated. Hence, for the time being, we will not go for this journal.

Planned review papers:

a) DIC/Alk separation during the freezing process: slow start due to field work, but now active (contact Bruno Delille)
b) Release and transfer of iron and other minerals: in progress (contact Delphine Lannuzel and Veronique Schoemann). The review will cover both Arctic and Antarctic. All data have been collected. An evaluation of the spatial (vertical and horizontal) versus seasonal control of the Fe cycle in sea ice will be done, following the set-up of the chlorophyll-paper by Klaus et al.. Data sets include snow and under-ice data, as well as ancillary parameters (ice texture, temp, salinity, macro-nuts, DOC, POC and Chl-a when available). Budget calculations will be done from sea ice and compared with other Fe sources (ice bergs, sediments). Impacts of changing sea-ice cover on primary production estimates in the marginal ice zone will be discussed.
c) Parameterization of light transfer in sea ice: A publication for improved light transfer through snow is currently in writing (lead C. Abraham/contact Nadja Steiner); during the IGS meeting Bonny Light was approached who agreed to lead a review, but will need some support due to other writing commitments. A potential model intercomparison is in discussion (Nadja Steiner and Clara Deal).
d) Processes of ice-algal release into the water: process is initiated (contact Letizia Tedesco). Several co-authors have agreed to contribute.
e) DMS(P) in sea ice: new topic (contact Jacqueline Stefels and Gauthier Carnat). It was discussed that sufficient data is now available. Also perspectives for modelling will be included. A potential model intercomparison is in discussion (Nadja Steiner and Clara Deal).
f) Major nutrients: new topic (contact Francois Fripiat). Francois will start with data collection from the Antarctic, in July.
g) DOC/POC: No lead yet. Jacqueline will contact David Thomas and see if a review is appropriate or if it will be included in his book.
h) Community structure, including microbial communities and plankton functional types: possibility but no lead yet, the BEPSII community will be asked to step-in.
i) Halogens: (contact Paul Shepson) new topic. Lots of data on halogens around Antarctica are available, which need to be integrated into one database. PS discussed this with Robyn Schofield as a potential product of BEPSII. ICECUBE: option to seek for funding for such a collation of data. PS also stresses the need to write a review paper on the major scientific questions that need to be addressed in order to bring this field forward.

Dirk Notz pointed out that a review of small-scale physical processes has just been written, lead by T. Vihma. The paper is currently in the discussion phase:
http://www.atmos-chem-phys-discuss.net/13/32703/2013/acpd-13-32703-2013-discussion.html

If processes relevant to BEPSII have recently been published elsewhere, we will not repeat, but refer to respective reviews in an introductory 2-pager to the special issue (e.g. the Vihma review and the new edition of David Thomas' Sea Ice book).

Task 3. Intercomparison of 1D models

a) The 1D-model intercomparison project led by Letizia Tedesco (FMI, Finland) and Martin Vancoppenolle (LOCEAN-CNRS, France) is gradually taking shape.
The goal of the intercomparison project is to evaluate one-dimensional biogeochemical sea ice-ocean models in terms of biomass and primary production over a seasonal cycle and in both hemispheres.

Such an intercomparison is based on voluntary efforts from the different modeling groups. 8 modeling groups from various countries (Belem et al, Jin & Deal, Elliott et al, Lavoie et al, Saenz et al., Steiner et al., Tedesco et al., Vancoppenolle et al.) have expressed their interest in the project over the last year.

The target is to use two sites for model evaluation, one in the Arctic, and the other in the Antarctic. Regarding the Arctic site, Christine Michel contributed with a 3-month long dataset in Resolute (Canadian Archipelago), which was used earlier in the paper by Lavoie et al., (2005). Jean-Louis Tison suggested that we might want to use the Barrow data set (Zhou et al., 2013). Regarding the Antarctic, several potential datasets have been identified including two full seasonal time series at Dumont D'Urville (Fripiat et al., D. Delille et al.) but those data sets are incomplete at this stage. A series of four simulations for each site has been suggested:

EXP1= prescribed ice physics + prescribed ocean biology
EXP2= prescribed ice physics + interactive ocean biology
EXP3= interactive ice physics + prescribed ocean biology
EXP4= interactive ice physics + interactive ocean biology.

EXP1 and 2 are meant to assess the uncertainties associated with the biogeochemical component in the absence of uncertainties associated with the physics. EXP3 and 4 will add the contribution of physics to the uncertainties. Prescribed versus interactive ocean will inform on the role of biogeochemical ice-ocean couplings. Most groups agreed to do EXP3-EXP4, a few of them will do EXP1-EXP2. A clear protocol for numerical simulations, including initial & boundary conditions, forcing files, validation data and output files requirements, will be provided to the modeling groups in the next few months. The Arctic data set is ready to go. We hope that the Antarctic data set will follow. First results should be available by the end of summer.

b) Physical 1-D intercomparison (Elena Golubeva)
Elena Golubeva evaluated the connection between under-ice physics and biogeochemistry, but it is not clear yet whether this will result in an intercomparison exercise.
Potential evaluation and discussion topics were:

- Effects of biologically influenced changes in solar radiation on sea-ice and upper-ocean mixing. (The parameterization of penetrating radiation - “Green” or “Blue” ocean - is very important in ocean models).
- Changes in algal growth within sea ice and effects on sea ice melting.
- One of the important elements of numerical ocean models is the parameterization of turbulent mixing and upper mixed layer. The upper ocean water state influences the intensity of biological processes in the ice and in under–ice water layers. Therefore, it is necessary to test models of the upper mixed layer used in regional and global ocean models and compare them with observational data. There is currently an effort within the international project FAMOS (Forum for Arctic Modeling and Observational Synthesis) for an upper-layer intercomparison of models. Within the frameworks of FAMOS and BEPSII task groups, testing of the upper mixed layer parameterizations are planned for 2014-2015.

c) An intercomparison of DMS models is on hold since Clara is still the only one maintaining a sea-ice DMS model. Nadja's group is working on another one within the Canadian NETCARE project. (contact Clara Deal)

d) Pelagic: Chl-a max /decoupling/causes & under ice PP (within FAMOS, contact Nadja Steiner)

e) Atmosphere: we will not include an atmospheric model intercompoarison at this time

Task 4. Application in regional models with links to global & regional climate modeling.
This task links to the Forum for Arctic Modelling and Observational Synthesis (FAMOS), where several topics are under development:

Regional:
a) Chl-a max (within FAMOS) (contact N. Steiner, K. Popova)
b) Other ideas are: Productivity in sea ice, DMS, Acidification. These ideas will be further discussed at the FAMOS meeting in October.
c) Assessment of the role of ice in the redistribution of the methane flux to the atmosphere (2014) is a project at the Russian Academy of Sciences, which models the subsea permafrost related methane emissions in the East Siberian Arctic Shelf (ESAS). The study aims at examining the stability of the ESAS submarine permafrost and the permafrost-related gas hydrate stability zone; simulating the dissolved methane transport from the bottom reservoirs in the shelf water, estimating the diffusive methane flux from ESAS to the atmosphere. This project can link to BEPSII (contact E. Golubeva).

Global ESM:
In order to assess what results from BEPSII can be used to improve global Earth system models (ESMs), some initial analysis of Arctic biogeochemistry within those ESMs have been compiled.

a) Arctic Primary Production - response to nutrient supply and light (published, Vancoppenolle et al. 2013)
b) Arctic Ocean Acidification (published, Steiner et al. 2014))
c) Pelagic deep Chlorophyll maximum (within FAMOS 1d/regional/ESM comparison contact N. Steiner)

So far none of the models includes sea-ice biogeochemistry, but will potentially be added in few ESMs for the next IPCC-AR6. Meanwhile, BEPSII can contribute to developing parameterisations of sea ice -bgc effects on the Arctic system, which might be suitable for ESMs.

15:30 Outreach (webpage/Facebook) (Francois & Jiayun)
The Facebook site is on: https://www.facebook.com/SCOR.BEPSII?fref=ts . Possibilities are limited, but subpages are possible. Francois will ask for education & outreach slides from the different task groups, as well as pictures and videos (due time = May 2014). We will think of schematics with links to scientists, who can be approached for specific subjects by the public. Nice examples of sea-ice schemes are given on the AWI- and CLIC-sites.

Everyone should send a link of his or her own blogs/sites of field campaign to Francois to be posted on Facebook.

In addition to this Facebook page, there is a need for a more versatile web site, which can be used for professional purposes. Issues to be posted are a.o.:

- Meeting minutes,
- Requests for the community (e.g. availability of data).
- Downloadable ASPeCt form for data collation during field campaigns.
- PDF's of publications that are inspired by BEPSII.
- Example texts referring to SCOR, in the acknowledgement of publications: "a product of…" or "a contribution to…": To distinguish between a planned product and a spin-off paper that was inspired by the discussions within BEPSII.
- Calls for student exchange
- Closed discussion site to work on joined publications

Bruno will set up a website in Google, starting with info from the SCOR site.

16:00 Overarching issues:

- Full Membership issues: exchange Sang Lee with Letizia. Bruno takes place of Jean-Louis, but J-L will remain associate member.
- Although the SCOR-life time of BEPSII may last until 2016 – with limited funding in the final year – there was a general feeling that we should already look for additional funding beyond this time frame. Everybody will look for options e.g.: EU-COST?, SCOR? CLIC/SOLAS working group? Future Earth?
- Next life BEPSII meeting: alongside the Gordon Research Conference on Polar Marine Science, March 15-20, 2015 in Lucca, Italy. Our meeting would be on 20 or 21. Jacq will ask the organisation for options.

- SOLAS: asked for young scientists to write 1 page for the upcoming 2014 Newsletter. Volunteers: Gauthier, Francois, Celia. Jacq will compile their information and research titles and send to SOLAS.
- A SCOR report is due June 1st; a summary report will be sent to the SOLAS Newsletter.
- The issue of a common datacentre was not well covered. Klaus will put the Antarctic data in the ASPeCt datacentre. PANGEA might be another platform to put data in. Currently Christine Michel is collating Arctic data; she might take the lead in this. Maybe link the ASPeCt datacentre with PANGEA? At this point we will use the BEPSII website to direct people to the PI of each parameter. CLIC (Jenny Baeseman, director) has similar issues -> Klaus will connect with CLIC and ask how they plan to solve this.

17:00 End of meeting

Methods and Madness in Sea Ice Biogeochemistry

Intercomparisons of Observational Techniques

SCOR working group 140 on Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII) task group on methodologies

The Problem

Sea-ice biogeochemists use a variety of methods, making it difficult to compare and synthesize results

- Community composition
- Photosynthesis
- Bacterial production
- Nutrients
- Organic matter
- Gases
- Sulfur cycle
- CO_2 system
- Trace metals
- Air-ice fluxes
- And…

Stay tuned for: Miller *et al.*, submitted to *Elementa: Science of the Anthropocene*. Methods for Biogeochemical Studies of Sea Ice: Where We Are and Where We Are Going.

The Tests

Intercomparison and intercalibration experiments

ON SHIPS:

Chl a intercomparison on Polarstern, 2013

IN CAMPS:

Saroma-Ko, Japan

Alert, Canada

Ny Ålesund, Svalbard

IN LABS:

The Solution

A manual of best practices

- A paper?
- A book?
- A website?
- A wiki?
- 8-Track tapes?
- Stone tablets?

Let us know what would work best for you

Want to get involved? Contact BEPSII task group II leaders
Lisa Miller (lisa.miller@dfo-mpo.gc.ca) and
Lynn Russell (lmrussell@ucsd.edu)

2.2.7 WG 141 on Sea-Surface Microlayers *Volkman*
(2012)

Terms of Reference:

1. Review sampling techniques and provide best practice sampling protocols. Such protocols will support new scientists entering the field of SML research to produce reliable and comparable data among different research groups/oceanic regions. The best practice sampling document will be made freely available online.
2. Create a consensus definition of the SML in terms of physical, chemical and biological perspectives for a better understanding within the ocean science community, and discuss the SML's role in a changing ocean. This will be delivered as an opinion/position paper in a peer-reviewed journal and will support future international projects concerning the SML and ocean change.
3. Initiate sessions on SML research during major meetings (e.g., Ocean Sciences Meetings), to increase the awareness of the importance of the SML within the general ocean science community.
4. Summarize and publish the latest advances in microlayer research in a special issue of a peer-reviewed journal, including consolidation of existing sea surface microlayer datasets among different disciplines (chemistry, biology, atmospheric, physics). The publication will promote new research ideas and projects at an interdisciplinary level.

Co-chairs:

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Other Full Members	**Associate Members**
Anja Engel (GERMANY)	David Carlson (UK)
Sanja Frka (CROATIA)	Alina Ebling (USA)
Sonia Giasenella (BRAZIL)	Werner Ekau (GERMANY)
Bill Landing (USA)	Blaženka Gašparović (CROATIA)
Mohd T. Latif (MALAYSIA)	Karstan Laß (GERMANY)
Caroline Leck (SWEDEN)	Miguel Leal (USA)
Gui-Peng Yang (CHINA-Beijing)	Anna Lindroos (FINLAND)
Christopher Zappa (USA)	Kenneth Mopper (USA)
	Alexander Soloviev (USA)
	Robert Upstill-Goddard (UK)
	Svein Vagle (CANADA)

Executive Committee Reporter: John Volkman

SCOR Sea Surface Microlayer Working Group Annual Report – 2014

Co-Chairs: Michael Cunliffe (UK) and Oliver Wurl (Germany)

Other Full Members: Anja Engel (Germany), Sanja Frka (Croatia), Sonia Giasenella (Brazil), Bill Landing (USA), Mohd T. Latif (Malaysia), Caroline Leck (Sweden) , Gui-Peng Yang (China-Beijing) and Christopher Zappa (USA).

Associate Members: David Carlson (UK), Alina Ebling (USA), Werner Ekau (Germany), Blaženka Gašparović (Croatia), Karstan Laß (Germany), Miguel Leal (USA), Anna Lindroos (Finland), Kenneth Mopper (USA), Alexander Soloviev (USA), Christian Stolle (Germany), Robert Upstill-Goddard (UK) and Svein Vagle (Canada)

Activities (including capacity building) and publications that resulted from the group's work since the previous year's report

- "Guide to best practices to study the ocean's surface"

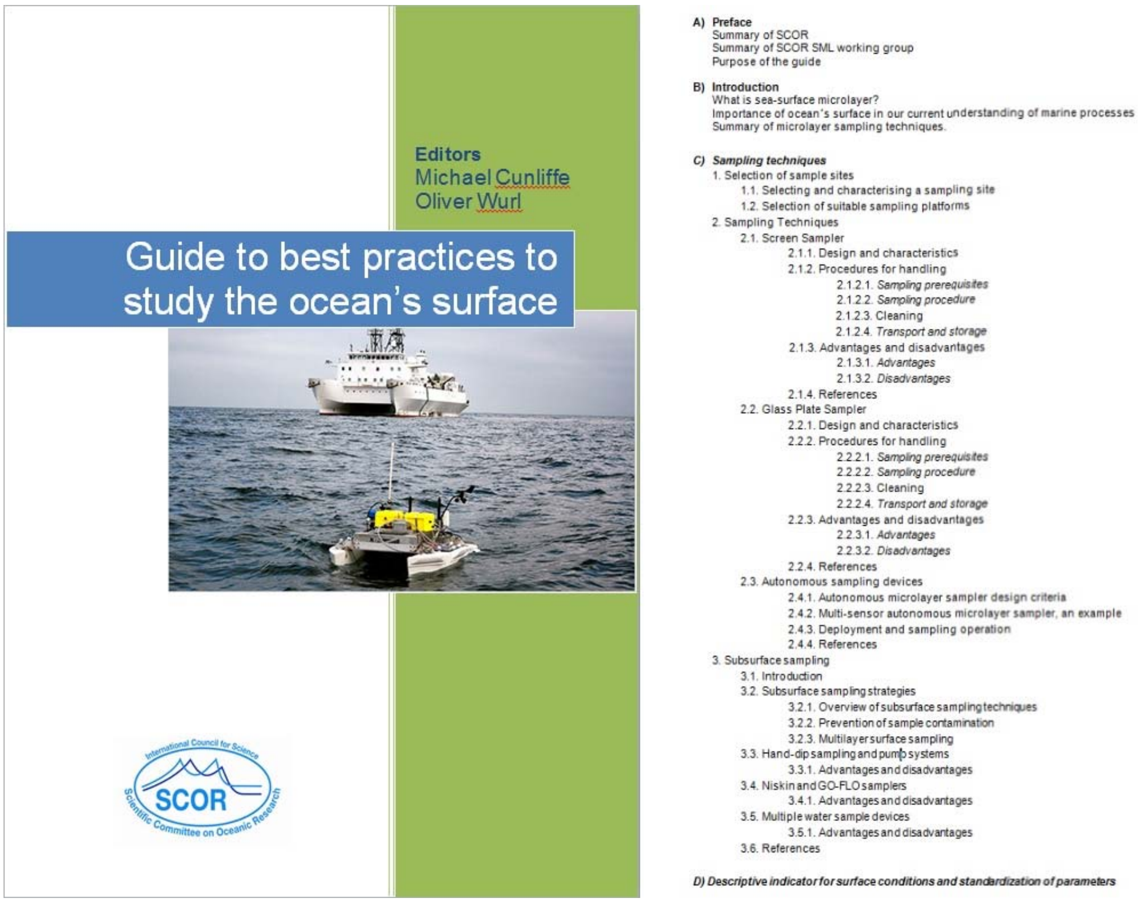
WG members (Full and Associate) are presently finalizing the SCOR report "Guide to best practices to study the ocean's surface". It reviews the most widely used SML sampling techniques and provides best practice sampling protocols for studying the ocean's surface. This guide is a source of practical knowledge in the sampling and analysis of the ocean's surface that is communicated in a logical manner. The front page and content is shown in Figure 1. The report (75-100 pages) is the first Term Of Reference (TOR 1) of the working group, and will be available for free download from the SCOR website and the National Marine Biological Library website (http://www.mba.ac.uk/NMBL/) by September 2014. The printed version will be introduced during the workshop in Qingdao in October 2014. The report includes 12 chapters; two are finalized, two are under review, five are under revision, and three remain to be submitted (expected mid-July).

- Schmidt Ocean Institute Application for a collaborative research SML cruise in 2016

Four WG members (Cunliffe, Landing, Wurl, Zappa) have been preparing a proposal to the Schmidt Ocean Institute (SOI) for a collaborative research cruise on SOI's RV *Falkor* in 2016. The initial expression of interest was accepted by SOI, and the members were subsequently invited to submit a full proposal, which is due for submission on 2 July 2014.

Briefly, the members have proposed the first dedicated multidisciplinary research cruise to increase our understanding of the significance and role of the air-sea interface (sea surface microlayer, SML) as the boundary layer controlling atmosphere-ocean interactions. Through a holistic approach that will be executed by the international multidisciplinary team, this study will have widespread and significant impact on the science of marine biogeochemistry and climate-related processes at a global scale. The proposed project interlinks (i) exchange of bio-limiting trace elements and organic compounds between the atmosphere and the sea surface (Landing), (ii) technological advancement of in situ techniques to characterize sea surfaces (Zappa), (iii) new parameterization for air-sea exchange of climate-relevant gases and heat (Wurl), and (iv) the sea surface as a habitat for complex microbial communities (Cunliffe). The holistic and multidisciplinary approach of coordinated observations and analysis utilizes a number of state-of-the-art technologies, including remote-controlled skimmers and unmanned airborne vehicles (Figure 2). The proposal includes an outreach program, including a ship-board science teacher, blogs, documentary video and live interviews with scientists.

Overall, the preparation of the proposal has led to further interconnection among the involved members, and, if funded, to new research collaborations. The overall mission of the proposed cruise is two-fold: (i) increase the understanding of the microlayer in air-sea interaction using new technology, and (ii) increase the awareness of the importance of the SML within the general ocean science community, which is part of TOR 3 of the working group.


Editors
Michael Cunliffe
Oliver Wurl

Guide to best practices to study the ocean's surface

SCOR
International Council for Science
Scientific Committee on Oceanic Research

A) **Preface**
Summary of SCOR
Summary of SCOR SML working group
Purpose of the guide

B) **Introduction**
What is sea-surface microlayer?
Importance of ocean's surface in our current understanding of marine processes
Summary of microlayer sampling techniques.

C) ***Sampling techniques***
1. Selection of sample sites
1.1. Selecting and characterising a sampling site
1.2. Selection of suitable sampling platforms
2. Sampling Techniques
2.1. Screen Sampler
2.1.1. Design and characteristics
2.1.2. Procedures for handling
2.1.2.1. *Sampling prerequisites*
2.1.2.2. *Sampling procedure*
2.1.2.3. Cleaning
2.1.2.4. *Transport and storage*
2.1.3. Advantages and disadvantages
2.1.3.1. *Advantages*
2.1.3.2. *Disadvantages*
2.1.4. References
2.2. Glass Plate Sampler
2.2.1. Design and characteristics
2.2.2. Procedures for handling
2.2.2.1. *Sampling prerequisites*
2.2.2.2. *Sampling procedure*
2.2.2.3. Cleaning
2.2.2.4. *Transport and storage*
2.2.3. Advantages and disadvantages
2.2.3.1. *Advantages*
2.2.3.2. *Disadvantages*
2.2.4. References
2.3. Autonomous sampling devices
2.4.1. Autonomous microlayer sampler design criteria
2.4.2. Multi-sensor autonomous microlayer sampler, an example
2.4.3. Deployment and sampling operation
2.4.4. References
3. Subsurface sampling
3.1. Introduction
3.2. Subsurface sampling strategies
3.2.1. Overview of subsurface sampling techniques
3.2.2. Prevention of sample contamination
3.2.3. Multilayer surface sampling
3.3. Hand-dip sampling and pump systems
3.3.1. Advantages and disadvantages
3.4. Niskin and GO-FLO samplers
3.4.1. Advantages and disadvantages
3.5. Multiple water sample devices
3.5.1. Advantages and disadvantages
3.6. References

D) Descriptive indicator for surface conditions and standardization of parameters

Figure 1 Front page and content of the SCOR report “Guide to best practices to study the ocean’s surface”.

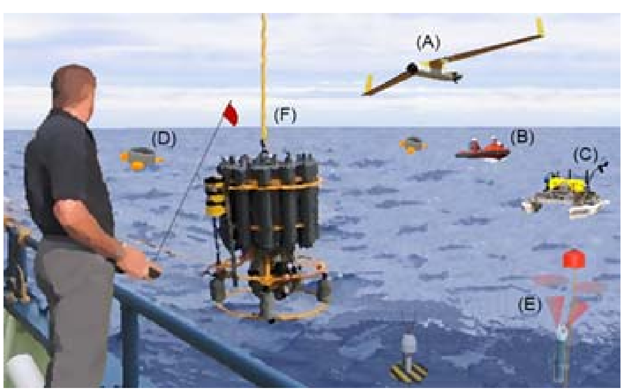


Figure 2 Illustration of the multidisciplinary sampling approaches in the SOI proposal: (A) unmanned airborne systems, (B) small boat operation for manual sampling and deployments, (C) a remote controlled catamaran for surface skimming, (D) free-floating chambers for measurements of gas exchange, (E) sensor packages for near- surface measurements and (F) CTD

- Preparation for SCOR SML workshop in Qingdao in October 2014

WG members have been preparing for the upcoming SCOR SML workshop in Qingdao in October 2014. The workshop will run from Monday 13 October to Friday 17 October. The timetable is attached. The workshop schedule is as follows;

- Monday, WG members arrive and prepare;
- Tuesday, series of lectures delivered by the WG members, followed by a poster session for researchers and students attending the workshop from Qingdao University;
- Wednesday, practical demonstrations, including SML sampling and sample analysis;
- Thursday/Friday, WG members will write the opinion/position paper that will be published in a peer-reviewed journal (TOR 2).

Recent Publications related to the group's work (WG members are highlighted)

Taylor JD & **Cunliffe, M** (2014) High-throughput sequencing reveals neustonic and planktonic protist diversity in coastal waters. Journal of Phycology in press.

Taylor JD, Cottingham SD, Billinge J **& Cunliffe M** (2014) Seasonal microbial community dynamics correlate with phytoplankton-derived polysaccharides in surface coastal waters. The ISME Journal 8: 245–248.

Cunliffe M, Engel A, Frka S, Gasparovic B, Guitart C, Murrell JC, Salter S, Stolle C, **Upstill-Goddard R**, **Wurl O**. (2013) Sea surface microlayers: A unified physicochemical and biological perspective of the air–ocean interface. Progress in Oceanography 109: 104-116.

Shoffian Amin Jaafar , **Mohd Talib Latif,** et al. (2014) Surfactants in the sea-surface microlayer and atmospheric aerosol around the southern region of Peninsular Malaysia. Marine Pollution Bulletin 84 35-43

Nur Ili Hamizah Mustaffa & **Mohd Talib Latif** et al. (2014) Source apportionment of surfactants in marine aerosols at different locations along the Malacca Straits. Environ Sci Pollut Res. 21: 6590–6602

Schneider-Zapp K, Salter ME, Mann PJ, **Upstill-Goddard RC**. (2013) Comparison of storage strategies for surface microlayer samples. Biogeosciences 10(7), 4927-4936.

S. Zhou, L. Gonzalez, A. Leithead, Z. Finewax, R. Thalman, A. Vlasenko, **S. Vagle**, et al. (2014) Formation of gas-phase carbonyls from heterogeneous oxidation of polyunsaturated fatty acids at the air–water interface and of the sea surface microlayer. Atmos. Chem. Phys. 14: 1371–1384.

Yan-Ping Zhang**, Gui-Peng Yang**, et al. (2013) Seasonal variations of dissolved monosaccharides and polysaccharides in the surface microlayer and surface water of the Jiaozhou Bay and its adjacent area. Continental Shelf Research 63: 85-93.

Yan Chen, **Gui-Peng Yang**, et al. (2013) Concentration and characterization of dissolved organic matter in the surface microlayer and subsurface water of the Bohai Sea, China. Continental Shelf Research 52: 97-107.

Jing Zhang, **Gui-Peng Yang** (2013) Chemical characterization of colored dissolved organic matter in the sea-surface microlayer and subsurface water of Jiaozhou Bay, China. Acta Oceanologica Sinica 32(6): 26-39.

Galgani, L. and **Engel, A.** (2013) Accumulation of gel particles in the sea-surface microlayer during an experimental study with the Diatom Thalassiosira weissflogii. International Journal of Geosciences 4 (1): 129-145.

Galgani, L., Roa, J. and **Engel, A**. (2013) Sea-surface microlayer In: Surface Ocean – Lower Atmosphere Study (SOLAS) in the upwelling region off Peru - Cruise No. M91 – December 01 – December 26, 2012 – Callao (Peru) – Callao (Peru). , ed. by Bange, H. W. Meteor- Berichte, M91. DFG Senatskommision für Ozeanographie, Bremen, Germany, pp. 36-37, 69 pp. DOI DOI:10.2312/cr_m91.

Examples of meetings, workshops and symposia (WG members are highlighted)

Engel, A. (2014). Dynamics of extracellular organic matter in a changing ocean. SOLAS Symposium Day on Biological, Chemical and Physical processes at the ocean-atmosphere interface. Weizmann Institute of Science, Rehovot, Israel.

Galgani, L., Piontek, J. and **Engel, A**. (2014) The Gel-like nature of the sea-surface microlayer during the 2012 arctic sea-ice minimum. Ocean Sciences Meeting 2014, 23.-28.02.2014, Honululu, Hawaii, USA .

Galgani, L., Piontek, J. and **Engel, A.** (2013) The marine surface microlayer, link between ocean surface biology and cloud properties: results from an expedition to the Central Arctic [Poster] In: 10. JaGFOS Symposium, 31.10. - 3.11.13, Tokyo, Japan.

Galgani, L., Roa, J., **Engel, A.,** Bange, H.W. and Gade, M. (2013) The sea-surface microlayer during the R/V Meteor Cruise M91: Measurements and satellite detection of surface films [Poster] In: SOPRAN Kick-off Meeting, 19.-20.03.2013, Leipzig, Germany .

Galgani, L., Stolle, C., Endres, S., Schulz, K. G., Jürgens, K. and **Engel, A.** (2013) Bacteria mediated alteration of the gelatinous surface microlayer [Poster] In: SOPRAN Kick-off Meeting, 19.-20.03.2013, Leipzig, Germany.

Stolle, C., Galgani, L., Endres, S., Schulz, K.G., **Engel, A.** and Jürgens, K. (2013) Interplay of bacteria and organic gel particles at the air-sea interface: effects on ocean carbon dynamics in a changing climate [Poster] In: First EMBO Conference on Aquatic Microbial Ecology – SAME13, 8.09.13-10.09.13, Stresa, Italy .

Ebling, A.M. and **W.M. Landing.** Residence Times of Trace Metals in the Sea Surface Microlayer. 2014. AGU/ASLO Ocean Sciences Meeting, Honolulu, HI (Poster).

Ebling, A.M. and **W.M. Landing.** The Distribution of Trace Metals in the Sea Surface Microlayer and Underlying Water Column in the Western Mediterranean Sea. 2013. Gordon Research Conference on Chemical Oceanography, Biddeford, ME (Poster).

Ebling, A.M. and **W.M. Landing**. Trace Metals in the Sea Surface Microlayer. 2013. ASLO Aquatic Sciences Meeting, New Orleans, LA.

Status of fulfilling terms of reference (TOR)

1) **Review sampling techniques and provide best practice sampling protocols. Such protocols will support new scientists entering the field of SML research to produce reliable and comparable data among different research groups/oceanic regions. The best practice sampling document will be made freely available online.**

- As discussed above, TOR 1 is going well and the sampling guide is expected to be completed by September 2014. We will use the guide during the workshop in October 2014.

2) **Create a consensus definition of the SML in terms of physical, chemical and biological perspectives for a better understanding within the ocean science community, and discuss the SML's role in a changing ocean. This will be delivered as an opinion/position paper in a peer-reviewed journal and will support future international projects concerning the SML and ocean change.**

- As discussed above, we have scheduled two days during the workshop in October to write the paper. We anticipate that TOR 2 will be completed and the paper submitted for peer review by December 2014.

3) **Initiate sessions on SML research during major meetings (e.g., Ocean Sciences Meetings), to increase the awareness of the importance of the SML within the general ocean science community.**

- During the workshop in October 2014 we will discuss potential major meetings at which to have the first SML session, and after consultation with all of the WG members, Cunliffe and Wurl will initiate the session.

4) **Summarize and publish the latest advances in microlayer research in a special issue of a peer-reviewed journal, including consolidation of existing sea surface microlayer datasets among different disciplines (chemistry, biology, atmospheric, physics). The publication will promote new research ideas and projects at an interdisciplinary level.**

- During the SCOR SML WG meeting held in Vienna in 2013, we proposed that the journal for the special issue would be *Biogeosciences*. We will confirm the journal selection during the October workshop in Qingdao. Calls for paper will not open until after the SML special session at a major meeting.

Any special requests for extra funding for outreach and/or capacity building activities

- At present, we do not have any special requests for extra funding.
- If the Schmidt Ocean Institute application for a collaborative research SML cruise in 2016 is accepted, we plan to request extra funds for the WG to develop an outreach

programme associated with the cruise and to maximise the potential of the cruise, for example, e.g. increase PhD student and Post-Doctoral Researcher involvement.

Any challenges or opportunities the group will experience in the coming year

- We are not anticipating any major challenges for the WG in the coming year.
- As discussed above, the Schmidt Ocean Institute application (if funded) could be an exciting opportunity for multidisciplinary and collaborative research between several WG members.

SCOR Sea Surface Microlayer Working Group Workshop hosted by Qingdao University October 2014.

Timetable

	OPEN WORKSHOP						CLOSED MEETING	
13/10/2014	14/10/2014			15/10/2014			16/10/2014	17/10/2014
Monday	**Tuesday**			**Wednesday**			**Thursday**	**Friday**
	8.30-8.50	Opening Ceremony	Gui-Peng					
	8.50-9.00	Introduction	Michael	9.00-09.10	Introduction	Michael		
	09.00-09.40	Physicochemical	Sanja	09.10-10.00	SML sampling discussion	Oliver		
	09.40-10.20	Chemical	Kristian	10.00-11.00	Franklin's teaspoon of oil experiment	Oliver, Alex		
preparation	10.20-10.40	coffee					paper writing	paper writing
	10.40-11.20	Metals	Bill					
	11.20-12.00	Surfactants	Talib	11.15-12.30	Microlayer sampling demonstration and collection	Gui-Peng, Oliver		
	12.00-12.40	Particles and aerosols	Anja					
	12.40-13.40	lunch		12.30-13.30	lunch			
	13.40-14.20	Gas exchange (fundamentals)	Chris					
	14.20-16.00	Gas exchange (biogeochemistry)	Oliver					paper writing
preparation	16.00-16.20	tea		13.30-16.30	Microlayer sample analysis in laboratory	All	paper writing	
	16.20-17.00	Biology	Michael					
	17.00-17.10	Summary	Oliver					planning next meeting
	17.20-19.20	Poster session (with drinks)		16.30-18.00	summary & close of workshop	Oliver, Michael		
	Workshop Dinner (hosted by Qingdao University)							

2.2.8 WG 142 on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders *Feeley*

(2012)

Terms of Reference:

1. Summarize and assess the current status of biogeochemical sensor technology with particular emphasis on float-/glider-readiness (pressure and temperature dependence, long-term stability, calibration accuracy, measurements time constant, etc.).
2. Develop pre- and post-deployment quality control metrics and procedures for oxygen and other biogeochemical sensors deployed on floats and gliders providing a research-quality synthesis data product.
3. Collaborate with Argo and other data centers to implement these procedures in their standard routines.
4. Disseminate procedures widely to ensure rapid adoption in the community. Develop ideas for capacity building in this context.

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Dong-Jin Kang (KOREA)
Satya Prakash (INDIA)
Osvaldo Ulloa (CHILE)

Executive Committee Reporter: Missy Feeley

SCOR WG 142
on
Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders

Co-Chairs: Arne Körtzinger (Germany) and Ken Johnson (USA)

Other Full Members
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Annual Report: April 2013/2014

1. Introduction and terms of reference

The deployment of biogeochemical sensors on profiling floats and gliders is a rapidly expanding activity that is occurring at the global scale (Fig. 1). For example, more than 400 profiling floats with oxygen sensors have now been deployed, with 205 that are currently active (Takeshita *et al*., 2013). These systems promise to revolutionize our understanding of ocean biogeochemistry, in much the same way that the Argo system has influenced our understanding of ocean physics. However, these sensors do have several recognized deficiencies that can impact their utility as a global sensor network. Given the large number of systems that are deployed, there is a rapidly accumulating body of experience that can be used to mitigate these problems and greatly improve data quality. Further, there is an expanding number of sensor manufacturers and each has adopted differing protocols for calibration and data reporting and each sensor has different performance characteristics. The function of WG 142 is to act as a conduit to accelerate the dissemination of this experience to users and manufacturers. Our specific terms of reference include the following:

- Summarize and assess the current status of biogeochemical sensor technology with particular emphasis on float glider readiness (pressure and temperature dependence, long-term stability, calibration accuracy, measurements time constant, etc.).
- Develop pre- and post-deployment quality control metrics and procedures for oxygen and other biogeochemical sensors deployed on floats and gliders providing a research-quality synthesis data product.

- Collaborate with Argo and other data centers to implement these procedures in their standard routines.
- Disseminate procedures widely to ensure rapid adoption in the community. Develop ideas for capacity building in this context.

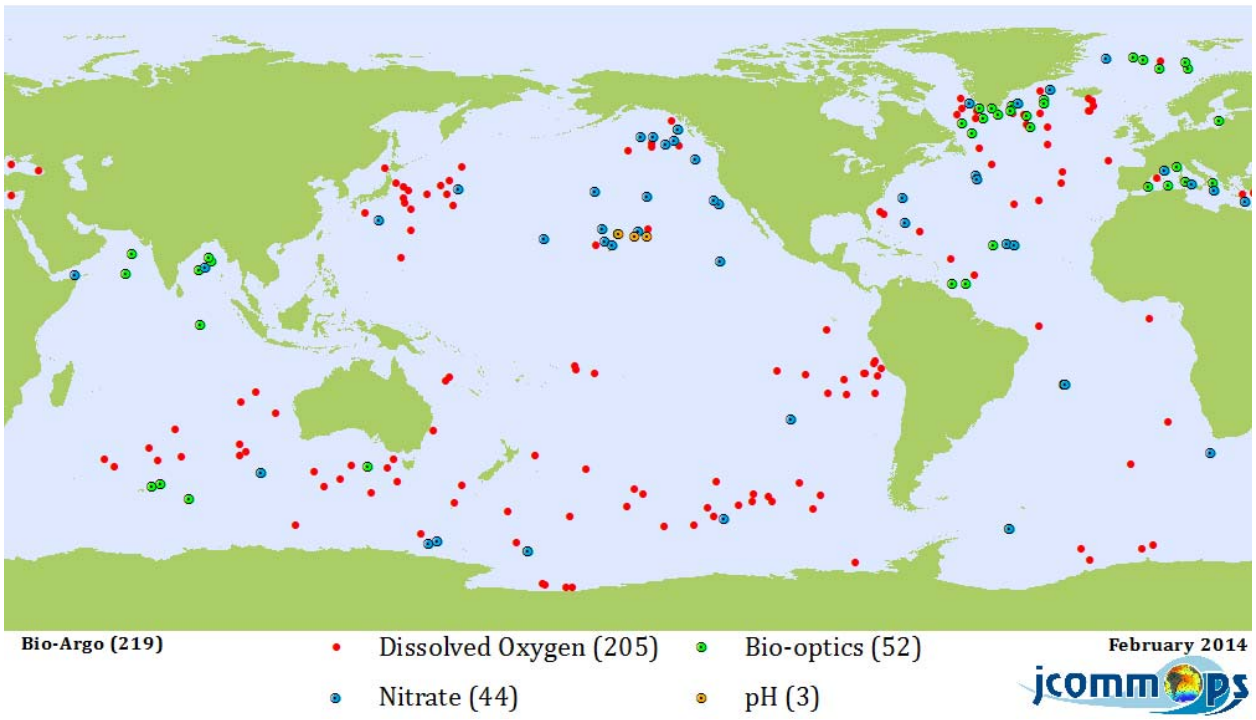

Figure 1. Distribution of biogeochemical sensors operating on profiling floats during February, 2014. The figure was downloaded from the Argo JCOMMOPS website: http://argo.jcommops.org/maps.html.

2. Activities during 2013 to April 2014

Our major focus during 2013 and 2014 was organizing the committee and planning for our first meeting in February 2014. In addition, several of the committee members have been acting as contacts with the Argo Data Management Team. BioArgo is now a recognized as an activity of the Argo program. This brings two obligations to the ocean science community that relate to WG 142. The first is to ensure that all of the data enter the Argo data system in a useable form with appropriate metadata. The second is to ensure that all data are quality controlled by procedures acceptable to the broader community and to ensure its maximum utility. Oxygen is now the most common biogeochemical sensor in use (Fig. 1) and the WG efforts will be an important component of ensuring the Argo data quality.

2.1 2014 WG Meeting

2.1.1 Organization, participation, and agenda

SCOR WG 142 completed its first meeting on March 1, 2014 at the East-West Center in Honolulu, Hawaii following the 2014 ASLO Ocean Sciences Meeting. The meeting was attended by 8 of 10 working group Full Members (1 via a representative) and 4 Associate Members, in addition to 4 guest experts. Two members also participated in the meeting via teleconference using the SCOR GoToMeeting software.

The meeting started at 9:00 with a short welcome address by A. Körtzinger. Afterward, all attendants briefly introduced themselves. The meeting agenda was reviewed and approved. Also the “terms of reference” of SCOR WG 142 were presented and discussed. No revision of the TOR was felt necessary.

The meeting was organized into the following four sessions with coffee breaks and a lunch break in between:

- Morning session I (9:00-10:30): Short presentations & discussion on current knowledge and status of oxygen sensor technology
- Morning session II (11:00-12:30): Short presentations & discussion on current knowledge and status of QC methods for float oxygen data
- Afternoon session I (13:30-15:00): Short presentations & discussion on bio-optical float data issues and scientific applications
- Afternoon session II (15:30-17:00): Discussion on WG product(s), tasks, responsibilities, schedule, next meeting, miscellaneous

During these four sessions the following presentations were shown:

- *Henry Bittig*: (Almost) everything you always wanted to know about oxygen optodes but were afraid to ask
- *Seth Bushinsky*: In-situ air calibration of oxygen optodes
- *Steve Emerson*: Mechanisms of bubble-produced oxygen supersaturation determined by inert gases
- *Hernan Garcia*: Recent release of the NODC World Ocean Database 2013 and World Ocean Atlas 2013
- *Ken Johnson*: pH status – SOCOM status – nitrate status – oxygen and nitrate delayed mode QC
- *Virginie Thierry*: Defining and testing real-time and delayed mode data processing techniques for Argo-oxygen data
- *Hiroshi Ushida*: Optode-based oxygen sensor calibration and some related topics

- *Xiaogang Xing*: Suggested real time and delayed mode QC procedures for chlorophyll-a fluorescence observed on floats/gliders

2.1.2 Results

The major outcomes of the presentations and discussions are briefly summarized below for the topics and issues addressed during the meeting:

- **Oxygen optode sensor calibration**: Various approaches for multi-point (in T and O_2) laboratory calibration of oxygen optodes are available that yield typical accuracies on the order of 1 µmol/kg over the entire oxygen range. The Uchida *et al.* (2008) model (mostly applied to pO_2) appears to be the most widely used model to describe the functional response of the oxygen optode. H. Ushida now proposes a non-zero exponent for the sensor output term $\{(V_o/V)^E\}$ which is specific per sensor type (e.g., 1.46 for Aanderaa optode).
- **Oxygen optode stability**: It is becoming more and more clear now that optodes exhibit a systematic drift pattern towards lower readings when they are not deployed in the field (e.g., D'Asaro and McNeill, 2013). This drift cannot be avoided by keeping the sensing foils dark and/or moist at all times. It appears, however, that warmer storage temperatures enhance the drift. Tests with cold-storage need to be carried out to prove a retarding effect of low temperature. An explanation for this well-documented drift pattern is not yet available. It is speculated that either diffusion of the luminophore in the membrane or aging of the membrane itself, that is, changes in the chemical environment of the luminophore, are responsible. In contrast, there is rather little evidence of any significant drift when deployed in the cold and dark deep ocean. Only near-surface deployments in warmer waters have shown some moderate drift.
- **Oxygen optode time response**: Lab and field experiments, further corroborated by 1-D diffusion models, show that the water-side laminar boundary layer in front of the sensing foil represents the major transfer resistance, that is, essentially determines the time response of optodes (Bittig *et al*., accepted). The response time of optodes can therefore be strongly reduced when they are pumped. This is the reason for the significantly shorter response time of the Sea-Bird SBE-63 optode (which is even slightly slower than the Aanderaa 4330 when used in unpumped mode). On the other hand, the Aanderaa 4330 achieves a somewhat faster response time than the SBE-63 when pumped. Pumping is therefore an effective way to significantly reduce the response time of optodes. At the same time pumped optodes don't lend themselves for measurement in air during the brief surfacing intervals of the float (see below), which is unfortunate. The unpumped JFE/ALEC Co. RINKO optode achieves very short response times but may be prone to larger drift. The new unpumped CONTROS optode also exhibits similarly short response times but has not yet shown to be long-term stable.
- **Air calibration of optodes**: Körtzinger *et al*. (2005) first introduced the idea to use the optodes' capability of in-air measurement during the float's surfacing intervals as drift control and means of calibration. Results of Bushinsky *et al*. (2013) indicated temperature-dependent offsets of the in-air measurements that would require careful characterization in

order to use the air calibration method. More recent results revealed, however, that this finding was most likely an artifact by enhanced drift of the fast-response foil (4330F) used during those experiments. Newer experiments with the standard foil (4330) no longer show such offsets and now support the idea of using in-air measurements for calibration. There remains, however, a slight discrepancy between freshwater and seawater calibrated air-measurements which needs some further attention. Given the problems with unstable calibrations, it would be very desirable to further develop the in-air calibration approach and implement it as a standard routine for optodes on floats. Where this is not possible (e.g., pumped optodes), a pre-deployment on-deck air calibration routine (using a standard calibration module that can be stuck on the float-mounted optode) should be developed.

- **Pressure sensitivity of optodes**: Currently, the revised pressure compensation of 3.2 %/1000 dbar (Uchida *et al*., 2008) is in use. Laboratory experiments in pressure tanks indicated a somewhat variable and perhaps slightly higher pressure sensitivity of up to 4 %/1000 dbar. A full evaluation of these experiments still has to be carried out. Additional in-situ experiments and more controlled (i.e., isochemical and isothermal) conditions are necessary. The hope is that the pressure sensitivity and any sensor-to-sensor variability can be better constrained from such experiments.
- **Float oxygen data NRT QC**: Oxygen data sets (and even more the other biogeochemical parameters) are difficult from an Argo data manager's perspective. There are several sensor types, several manufacturers, several versions per manufacturer, different functions, different corrections, continuously changing understanding, etc. The proposed NRT QC measures (Thierry *et al*., 2011) are implemented in some DACs. They consists of simple global range, spike, gradient and stuck value tests which remove unrealistic data, but still leave in a lot of problematic data. Regional criteria (e.g., for range and gradient) might improve the performance and avoid flagging of good data. No delayed mode data are yet available. A decision has been made to separate Argo data into two separate data products: a classical hydrographic data file and a "Bio-Argo" file which contains all other parameters including oxygen (plus the hydrographic data). An improved version of the Argo Data Management Manual for oxygen is under development. This needs input from SCOR WG 142.
- **Float oxygen data DM QC**: DM QC will require more elaborate approaches. (1) Air calibration during float surface time has shown potential to serve as DM QC measure for near-saturation oxygen concentrations. (2) Experience with climatological data (WOA08) for oxygen QC purposes has shown to principally work reasonably well globally (Takeshita *et al*., 2013). Regionally there can be significant problems with this approach because of the strongly smoothed (both vertically and horizontally) nature of the climatology as noted in the presentation by V. Thierry. The new WOA2013 version will soon be officially released which has more vertical layers and higher horizontal resolution, both of which should reduce the smoothing. The utility of this new edition needs to be explored for QC purposes of Argo O_2 (and nitrate) data. (3) In addition, tests need to be carried out to what extent the soon-to-be-available, internally consistent GLODAPv2 data set (GLODAPv1 +

CARINA + PACIFICA) can be used with available crossover analysis tools (see Tanhua *et al*., 2010; Stendardo *et al*., 2009) for DM QC purposes. Despite the lower spatial coverage, this data set lacks the smoothed character of the climatology. Especially in data-rich regions this could therefore be a useful approach.

- **QC aspects of other Bio-Argo data**: Approaches for NR QC and DM QC of chlorophyll a data were shown (presentation X. Xing). NR QC measures include offset and noise/spike corrections, as well as corrections for the effect of non-photochemical quenching. For DM QC measures both irradiance- and satellite-based methods have been proposed. All of this also needs further testing and work. Similarly, simple ideas exist for QC of nitrate and pH. Other parameters—such a particle backscatter, beam transmission, PAR, CDOM fluorescence etc.—are perhaps in less developed stages and need significant work.

2.1.3 Future activities

- **Homework & next meeting**: An E article on the kick-off meeting of SCOR WG 142 will be prepared (A. Körtzinger & K. Johnson to take lead and come up with first draft). The next WG meeting should be planned in conjunction with an international conference/workshop. A possible 5th Argo Science Meeting in 2015 would be a great such opportunity. Also there is an expressed interest from the GO-SHIP community to meet with SCOR WG 142. These opportunities will be further pursued. Finally, ideas for final WG products were discussed. These include a technical report, an updated whitepaper on Argo-O_2, as well as a special issue on scientific applications of O_2- and Bio-Argo data.
- **Argo Data Management Team:** WG 142 members Herve Claustre, Xiaogang Xing, Virginie Thierry and Kenneth Johnson continue to interact closely with the Argo Data Management Team. This will continue in the future.

3. Status of fulfilment of the terms of reference

SCOR WG 142 has made the following progress towards fulfilment of its terms of reference:

- TOR 1: As described in section 2.1.2 the working group made major progress with respect to TOR 1 during its first meeting. All important aspects were discussed and the latest available information was collected. Open questions and missing links were identified. The group will continue to work towards fulfilment of TOR 1 until the next meeting in 2005
- TOR 2: Ideas and concepts regarding TOR 2 were discussed. Some of these options require further testing and development, which the group is trying to foster to be available in time for the next meeting in 2005.
- TOR 3: Selected SCOR WG 142 members connect to the Argo Data Management Team and assure the flow of information between the two groups. More concrete work towards implementation of Argo routines (TOR 3) will be carried out at the planned joint meeting with Argo.
- TOR 4: The planned *Eos* article on the kick-off of SCOR WG 142 will be a first visible step of the group towards the fulfilment of TOR 4.

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2.2.9 WG 143 on Dissolved N_2O and CH_4 measurements: Working towards a global network of ocean time series measurements of N_2O and CH_4 ***Volkman***
(2013)

Terms of Reference:

1. Establish the analytical reporting procedures to be used for N_2O and CH_4
2. Adopt an appropriate standard to be used by the scientific community
3. Conduct an intercalibration exercise between the time series programs
4. Host at least two international meetings
5. Establish framework for an N_2O/CH_4 ocean time series network
6. Write a global oceanic N_2O/CH_4 summary paper for publication in *Annual Review of Marine Science* or an equivalent journal.

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2014 Annual Report for SCOR WG #143, 1st January 2014 – 31st December 2017

"Dissolved N_2O and CH_4 measurements: Working towards a global network of ocean time series measurements of N_2O and CH_4"

Sam T. Wilson (C-MORE/U Hawaii, USA) and Hermann W. Bange (GEOMAR, Kiel, Germany) Email: stwilson@hawaii.edu, hbange@geomar.de

Summary: WG#143 has a very specific remit in Years 1-2, which is to conduct an intercalibration exercise of dissolved N_2O and CH_4. Most of the reported activities documented below relate to this intercalibration exercise, which in June 2014 is 25% through its timetable (Table 1). Activity to date includes the first exchange of seawater samples, collection of the values from the respective laboratories, and identification of a timetable of activity which will take us into 2015. The next steps include the production and distribution of standards, coordinating a comparison of calibration procedures, and then this will be followed by a second exchange of seawater samples when the improvements will hopefully be evident. In 1 years' time (June 2015), we expect to begin writing a scientific report about the exercise.

Table 1. Timetable of WG activity relating to the intercalibration of dissolved N_2O and CH_4.

Activity	**Dates of activity**						
Analysis of seawater samples from Stn ALOHA	Nov 2013	May 2014					
Production of gas standards		May 2014	Sept 2014				
Comparison of calibration procedures				Oct 2014	Nov 2014		
2^{nd} analysis of ALOHA seawater					Nov 2014	May 2015	
Report writing							June 2015

The second half of the WG activity (Years 3-4) will include a rigorous assessment of existing measurements of N_2O and CH_4 in the marine environment. Marine provinces requiring higher resolution sampling will be identified, together with appropriate time-space sampling requirements and recommendations about complimentary measurements. Although this work is prioritized for Years 3-4, the groundwork is already being laid in a few key areas. The MEMENTO database is being established, which compiles existing N_2O and CH_4 measurements. WG members are also engaged in planning for SOLAS Phase II which includes Theme I "Greenhouse Gases and the Oceans".

Overall, it is evident the first 6 months has been busy. More work and coordination is required to see the first phase of WGH#143 successfully completed and the next 6 months will be critical, with the production of gas standards and the coordination of the calibration procedures. As we are not meeting as group until September 2015, communication will be via email and we discussed a web-based meeting during the interim period.

Specific Reporting Activity

1. Activities (including capacity building) and publications that resulted from the Working Group's work since the previous year's report

(i) Inaugural meeting

The first meeting of SCOR WG143 was held on 21 February 2014 at C-MORE Hale, University of Hawaii, Honolulu. The meeting was followed by the Ocean Sciences Conference in Honolulu with a Session on 'Biogenic Trace Gases'. Overall, the meeting went smoothly, with many comments and suggestion on how to achieve the group's objectives over the 4-year lifetime of WG#143. No insurmountable barriers to achieving the objectives were evident and two representatives from Picarro made an interesting contribution about the capabilities of their analytical instruments. Two of the major discussion items were the intercalibration exercise and gaseous standards. Both of these items are listed below as separate work activities. Additional relevant items discussed at the meeting included:

a. To maintain momentum of the WG, it was proposed to attempt Web-based meetings every 6 months (e.g., Skype or WebEx) with the whole group attending.
b. The MEMENTO database for N_2O and CH_4 concentrations is continuing to develop: https://memento.geomar.de/database. Please contact Annette Kock (akock@geomar.de) with questions.
c. Make videos of analytical procedures
d. Various sampling, storage, and analytical protocols, which were documented and will be included in the intercalibration report.

Participants of SCOR WG143 meeting on 21 February 2014:
Full WG Members: Hermann Bange (GEOMAR, Germany), Mercedes de la Paz Arandiga (ICMAN, Cadiz, Spain), Laura Farias (U Concepcion, Chile), Gregor Rehder (IOW, Germany), Philippe Tortell (UBC, Canada), Sam Wilson (UH, USA), Guiling Zhang (Ocean U China, China).
Associated WG Members: John Bullister (NOAA PMEL, USA), Annette Kock (GEOMAR, Germany), Alyson Santoro (U Maryland, USA).
Guests: Damian Arévalo-Martínez (GEOMAR, Germany), David Capelle (UBC, Canada), Bonnie Chang (UW, USA), Sara Ferron (UH, USA).

(ii) First intercalibration exercise
WG#143 is currently halfway through its first intercalibration exercise of dissolved N_2O and CH_4. Seawater samples from the Hawaii Ocean Time-series (HOT) program long-term monitoring Station ALOHA in the North Pacific were sent to participating laboratories for analysis. We are still receiving values from other participating laboratories, and once all results have been collected, a rigorous assessment of the calibration procedures and analytical methods employed, as well as sample collection and distribution, will be conducted.

(iii) Secured funding for production of gas standards
One item that is crucial to the success of the intercalibration exercise is the gaseous standards of N_2O and CH_4. While these are available from NOAA at concentrations close to current atmospheric values, standards at higher concentrations (e.g., 10x current atmospheric concentrations) are not available at high precision and the commercially available standards have a precision of +/- 2%, although +/-5% is not uncommon. This is particularly an issue for calibrating N_2O at the concentrations typically measured in seawater samples, due to the strong non-liner response of the ECD. To overcome this problem, we have secured $24,000 for the synthesis of N_2O and CH_4 gas standards for WG members. We are very grateful to SCOR and C-MORE for providing matching funding for these gas standards and to John Bullister at NOAA PMEL, who agreed to be the lead person for the production of these standards. It is intended that these will be primary standards that laboratories can check their existing standards against and therefore should last for decadal or longer periods. It is important to move quickly on this (within 2-3 months) as this will make a significant contribution to the intercalibration exercise.

(iv) Website created
A website has been set up to facilitate communication between WG members and to communicate WG activities to the wider scientific community: https://portal.geomar.de/web/scor-wg-143/home. The WG homepage is currently under construction and WG relevant content (e.g., documents) will be added as soon as possible.

(v) Non-scientific literature
A brief article about SCOR #143 and the ongoing intercalibration exercise will be published in the summer 2014 SOLAS Newsletter.

2. Status of fulfilling terms of reference

Terms of Reference #1: Conduct an intercalibration exercise
Seawater samples from the Hawaii Ocean Time-series (HOT) program long-term monitoring Station ALOHA in the North Pacific were sent to participating laboratories for analysis. To date, eight of the fourteen participating laboratories had analyzed the samples as part of the intercalibration exercise. We are still receiving values from other participating laboratories, and once all results have been collected, a rigorous assessment of the calibration procedures and

analytical methods employed, as well as sample collection and distribution, will be conducted. We hope to finish the first intercalibration exercise by the end of July 2014.

Terms of Reference #2: Initiate common protocols, including primary N_2O and CH_4 standards
This is being tackled at the moment and will be greatly enhanced by the production of the common gas standards mentioned above

Terms of Reference #3: Establish N_2O and CH_4 reporting procedures
This will be conducted in 2014/2015 alongside the intercalibration exercise.

Terms of Reference #4: Establish a framework for an N_2O/CH_4 ocean time series network
The MEMENTO database for N_2O and CH_4 concentrations is continuing to develop.

3. Plans for the coming year in relation to the terms of reference and capacity building
Between June 2014 and June 2015 we will (a) produce and distribute the gas standards, (b) conduct the second intercalibration exercise (target date is December 2014, 1 year after the first intercalibration exercise), (c) write a written report for dissemination and publication in the scientific literature which documents the exercise and provides a 'Best Guide' for analyzing dissolved N_2O and CH_4 in seawater.

The next all-hands meeting of WG#143 will be held in conjunction with the SOLAS Open Science Conference in Kiel, 7-11 September 2015: www.solas-int.org/osc2015.html.

The issue of capacity building has been discussed during the meeting in Honolulu. The group agreed that PhD students and postdocs working in the labs of the involved laboratories should be encouraged to participate in WG activities (e.g., annual meetings, intercalibration exercise etc.). Moreover, SCOR WG #143 will support applications for the POGO-SCOR fellowship program to involve PhD students, postdocs, and technicians from developing countries.

4. Any special requests for extra funding for outreach and/or capacity building activities
SCOR had contributed $12,000 to the production of gas standards which we are very grateful for. This has been match-funded by C-MORE (Dave Karl, University of Hawaii). There are no foreseeable requests for funding or outreach in the forthcoming year.

5. Any challenges or opportunities the group will experience in the coming year
No insurmountable challenges have been identified. We can foresee that it will be hard work to complete the intercalibration exercise due to the global distribution of the laboratories and the sample/data analysis that needs to occur in addition to WG members' other activities. Presentation of the WG activities at the SOLAS conference in September 2015 will be a key motivating factor, particularly given the relevance of SCOR WG#143 to the SOLAS objectives.

2.2.10 WG 144 on Microbial Community Responses to Ocean Deoxygenation Costello (2013)

Terms of Reference:

1. Convene a practical workshop in Saanich Inlet, a seasonally anoxic fjord off the coast of Vancouver Island, British Columbia, Canada, to ground truth common standards for process rate and molecular measurements and identify model ecosystems for future cross-scale comparative analyses.
2. Convene a meeting at the Leibniz Institute for Baltic Sea Research in Warnemünde, Germany to codify standards of best practice, and compose a white paper describing said standards and opportunities.
3. Sponsor a workshop at the marine lab of the University of Concepcion, Chile, to disseminate the best practices described in the white paper, and to provide hands-on experience to international participants, and local students and scientists, with those practices.
4. Convene a meeting at the National Institute of Oceanography in Goa, India, engaging local students and scientists in the project. The goal of this meeting is to compile a peer-reviewed monograph, which will be published as an electronic book in an open-access journal such as Frontiers or PLoS to ensure both visibility and long-term access.

Leadership Coordinator:

Bess Ward

Other Full Members

Sean Crowe (Canada)
Virginia Edgcomb (USA)
Veronique Garcon (France)
Steven Hallam (Canada)
Klaus Juergens (Germany)
Elsabe Julies (Namibia)
Phyllis Lam (UK)
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2.3 Working Group Proposals

2.3.1 Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC) **Fennel**

MARCHEMSPEC

Chemical Speciation Modelling in Seawater to Meet 21st Century Needs

1 Summary

Trace elements are important in the world's oceans and near-shore environments as nutrients, tracers, and contaminants. The dissolution of anthropogenic CO_2, a component in the oceanic carbon cycle, is a cause of ocean acidification. Despite the importance of chemical speciation in these marine biogeochemical processes and their consequences for global change, the available models and other calculation tools – often based upon the Pitzer equations – are relatively fragmented and are usually restricted to particular chemical compositions and ranges of temperature and pressure. The models are often neither user-friendly nor freely available, and the community lacks a comprehensive evaluation that relates the capabilities of speciation models to current needs in chemical oceanography (e.g., programmes such as GEOTRACES). To address these problems we will review and document the current status, uncertainties, and basis in laboratory measurements of Pitzer models of seawater and complexation of trace metals (including micronutrients such as Fe, Cu, and Zn). We will define their current capabilities and limitations for oceanographic and biogeochemical calculations, and establish requirements for the future. We will consult widely and develop a specification for a set of speciation models and associated documentation that will be interactive and web-based. Making use of our previous very successful work in this area (and with external funding) we will create the website and associated tools. This requires a coordinated international effort, particularly to ensure that the modelling tools meet the needs of a wide range of potential users in both research and capacity building. A SCOR Working Group is the ideal mechanism for this development.

2 Background and Rationale

2.1 Speciation models and data

Chemical speciation is defined as the distribution of a chemical element between different molecular and ionic forms in seawater. It determines the reactivity and bioavailability of the elements in seawater, and is key to our understanding of biogeochemical and acidification processes in the ocean. It is necessary to model speciation in order to predict how the rate and extent of chemical reactions in the global ocean will be affected by increasing temperature and decreasing pH.

The form in which a trace element or other component of seawater is present, and its tendency to react, depends on its *activity* (Clegg and Whitfield, 1991). This is the product of its concentration (usually molality) and an activity coefficient (γ) which is a complex function of temperature, pressure, and salinity (or, more generally, solution composition). Many of the important reactions in seawater involve acid-base equilibria, which introduces pH as a further variable. Changing pH is also at the heart of the process and effects of CO_2 uptake by the oceans, and of the speciation of dissolved inorganic carbonate. The definitions of pH and the use of buffers to calibrate pH instruments, and the relationship of measured pH to that calculated using thermodynamic models of seawater, are complex and not always appreciated.

It is desirable to be able to calculate pH, and the activities and speciation of all seawater components, within a unified framework that, (i) includes the major and trace elements in seawater and its mixtures with freshwaters, (ii) encompasses the buffers that are used to calibrate pH and other instruments, and (iii) can be extended to include other saline environments such as brines and pore waters. Progress has been made towards this goal, mainly in the 1980s and 1990s, and today the principal chemical speciation model of seawater is that of Millero and co-workers at the University of Miami (Waters and Millero, 2013, and references therein; see also Clegg and Whitfield, 1995). The model uses the equations of Pitzer (1991) to calculate activity coefficients, and is applicable primarily to major ion seawater (from 0 to 50°C, and 0 to >40 salinity) containing the species H^+, Na^+, K^+, Mg^{2+}, Ca^{2+}, Sr^{2+}, Cl^-, Br^-, OH^-, HCO_3^-, $B(OH)_4^-$, HSO_4^-, SO_4^{2-}, CO_3^{2-}, CO_2, $B(OH)_3$, and H_2O.

The measurements that are used to build models of mixtures such as seawater include: solvent and solute activities, apparent molar enthalpies and heat capacities (yielding the variation of the model parameters with temperature), apparent molar volumes (yielding the variation of the parameters with pressure), and other data. Complexation of trace metals by a number of ligands, both inorganic and organic, has been measured in artificial seawaters or simplified analogues (e.g., $NaCl_{(aq)}$), but usually over restricted ranges of concentration, at a single temperature (often 20 or 25°C), and only at atmospheric pressure. The results often depend on the methods used to make the measurements.

The numbers of new studies yielding the activity, thermal, and volumetric data and stability constants needed to develop our quantitative understanding of speciation in the oceans have been in decline for many years, even as the need to model the biogeochemistry and especially the carbonate chemistry of the oceans has become greater. The numbers of skilled experimenters and modellers have also fallen. Furthermore, there is no comprehensive evaluation that relates the capabilities of speciation models, and the measurements upon which they are based, to current and future needs in chemical oceanography as exemplified in current programmes such as GEOTRACES. **Objective 1** of this working group is therefore to document the current status, and basis in laboratory measurements, of Pitzer models of seawater and estuarine water and the complexation of key trace metals including Fe, Cu, Mn, Cd, Mn, and Zn. We will define current capabilities and limitations for oceanographic and biogeochemical calculations, and establish what is needed (in both laboratory measurements and modelling) to meet future requirements. The associated **Objective 2** is to provide a database of Pitzer model parameters and equilibrium constants for seawater (and their variation with temperature and pressure), including trace metal complexation, which can be used by skilled practitioners. The uncertainties, and the effects on calculated properties such as pH, will be evaluated.

2.2 Applications in research and capacity building

The use of computer programs to carry out chemical speciation and other complex calculations for aqueous solutions and natural waters has traditionally involved obtaining the program from the authors, understanding input and output facilities intended only for the authors' use, and learning to use the program with few instructions. These obstacles have hampered the use of state-of-the-art models and the spread of best practice in modelling.

The world-wide-web is the ideal means of making modelling tools universally available for interactive use – with a variety of user interfaces suitable for the problems being solved and the skills of the user – and for providing the supporting information and tutorials needed by both researchers and students. For example the ecological modelling package ERSEM (European Regional Seas Ecosystem Model) has just been released as a freely available download to the marine science community (see http://www.shelfseasmodelling.org/) One of us (SLC) has over 15 years' experience providing chemical speciation and gas/liquid/solid equilibrium models that can be used *interactively* on the web (the Extended Aerosol Inorganics Model (*E-AIM*: http://www.aim.env.uea.ac.uk/aim/aim.php, see Wexler and Clegg, 2002). Usage statistics for *E-AIM* demonstrate the benefits for research and capacity building that universal availability and ease of use can bring: in 2013 more than 32,000 individually entered calculations were carried out by users around the world (38% from the Americas, 35% from Europe, and 24% from Asia).

We believe that a similar website, for chemical oceanography applications related to the carbonate system and to trace metal speciation, could bring even greater benefits. **Objective 3** is to develop a written specification for such a website, based upon consultation within the group and with other programmes. This will, for example, define the range of chemical systems and types of problems to which the speciation models will be applied (hence the design of the user interfaces and supporting "help" information), and requirements for capacity building (tutorials and demonstrations). Other modes of use will also be considered (e.g., calls from users' own program code; generation of lookup tables for use in large scale models). **Objective 4** is to create the fully- functioning website.

2.3 Why a SCOR working group?

The work that we propose cannot be driven solely by the modellers who are experts in their field. An in-depth understanding of the requirements of different potential user groups is essential. This will enable us to define the key equilibria and chemical species to be included, and give direction to the review of currently available data (on which current models are based). It will also enable us to specify the requirements for web-based modelling tools and associated training and teaching elements. SCOR, with its broad coverage and links to other international programmes, provides the ideal basis for developing a consensus across the global chemical oceanography community. The outputs of this Working Group will both stimulate new measurements of physico-chemical properties to better understand chemical speciation, and advance our ability to model speciation and its role in oceanographic and biogeochemical processes. The work that we propose, including its strongly international element, is rarely fundable by standard research grants from national research agencies. That is why we are approaching SCOR.

3 Terms of Reference

1) To document the current status, and basis in laboratory measurements, of Pitzer models of seawater and estuarine water focusing on the chemistry of ocean acidification and micronutrient trace metals (including, but not limited to, Fe, Cu, Mn, Cd, Mn, and Zn). Current capabilities and limitations for oceanographic and biogeochemical calculations will be defined, and future needs established.
2) Important gaps in knowledge, which should have high priority for new measurements, will be identified. The components to be covered will include the seawater electrolytes, the selected trace metals, and buffer solutions and key organic ligands such as those used in CLE-CSV titrations.
3) To publish the results of the first term of reference in the refereed scientific literature, and to introduce the conclusions and recommendations to the oceanographic community at a "town hall" event or special session at an international ocean sciences meeting.
4) To specify the functions and capability for a web-based modelling tool that will make chemical speciation calculations easily accessible for a wide range of applications in oceanography research and teaching, and thus improve understanding and spread best practice in modelling.
5) To implement the web-based tool for chemical speciation calculations, based upon the specification developed in the third term of reference which will also be used to obtain external funding to develop the programs, documentation, and site.

4 Work Plan

There are several parallel strands to the activities of the WG. The timetable is given below, after further details of the objectives.

In the review and database constituting **Objectives 1 and 2**, the range of physicochemical conditions to be covered will be those relevant to estuarine and oceanic waters: temperature -2°C to 40°C; salinity 0 to concentrated brines (but with a strong focus on salinity 35); pressure 1 to 1000 atmospheres. The matrix of Pitzer model parameters for a major ion seawater of the composition noted in section 2.1, even excluding Sr^{2+} and boric acid, is considerable: 40 sets of cation-anion interactions, and potentially 250 ternary or "mixture" parameters. Although some can be neglected where all the interacting species are at very low concentration, the large numbers of interactions and the fact that they can vary with both temperature and pressure in the oceans emphasises the need to: (1) assess the completeness of any model and its basis in measured thermodynamic properties, (2) carry out an uncertainty analysis for the calculated quantities, and (3) establish what further measurements are required to completely characterise the behaviour of the seawater/estuarine water for its major and minor components, and trace metals, for the ranges of conditions encountered at sites around the world.

Our survey will relate the modelling and data needs to current developments in marine biogeochemistry, including the consequences of climate change and other anthropogenic forcing functions. This assessment will result in a state-of-the-art, self-consistent, database. It will also identify knowledge gaps that limit our ability to complement current research programmes such as GEOTRACES, IMBER and SOLAS with relevant calculations of chemical speciation.

To attain **Objective 3** we will first review current calculation tools and programs, including their availability and use by oceanographers. These programs include Pitzer seawater and brine models, and those for specific problems such as *CO2SYS* for the inorganic carbonate system. We will define the scope of solution chemistry and speciation modelling to be implemented, the types of problems to which the speciation models will be applied (hence the design of the user interfaces and supporting "help" information), and requirements for capacity building (tutorials and demonstrations). We will develop the specification for the website and speciation tools, matched to the capabilities, needs, and levels of expertise of users. Consultation between members of the WG, and with other programmes, will feed into this.

In the final phase, for **Objective 4**, we will create a fully-functioning chemical speciation site for oceanographers. Experience with the *E-AIM* aerosol chemistry website, developed partly with external funding, shows that this will require specialist expertise in web implementation that is not available within the WG. We will therefore seek the additional resources necessary for this work, and work on the speciation models, during second year of the WG. In this phase the WG members will act as a test and advisory panel, and help ensure that the supporting information (help texts and training material) is sufficient and correct. Success (or otherwise) in the funding effort constitutes a decision point in the timetable, which is shown below.

Month 1: 1st full WG Meeting.

- This will focus on planning. Issues include: the seawater components and trace elements, and ranges of physicochemical conditions, to be covered (based upon user needs); the allocation of tasks; compilation of a list of external contacts for consultation (in other programmes); and plans for securing additional funding for the web development.

Months 2 - 11

- Objectives 1 & 2: Collection and review of relevant physico-chemical information for the seawater electrolyte; analyses of current Pitzer parameter databases for data sources and coverage of agreed systems and environmental conditions; uncertainty analysis.
- Objective 3: User representatives defining requirements for the web-based speciation tools in research and capacity building (including external consultations); drafting of a proposal for funding to develop the web-based speciation tools and site.

Month 12: WG Sub-group Meetings

- There will be two sub-group meetings: the first will discuss progress on the Pitzer parameter database, and the second will agree the basic specification of the web-based modelling tools sufficient for a draft proposal.

Months 13 - 23

- Objectives 1 and 2: Collect and review all relevant information for trace components, and for pressure effects. Individuals will work on their sections of the draft paper and database. Assembly and completion of the draft paper, delivery to internal reviewers.
- Objective 3: Further consultations with working group members and participants in other programmes to define requirements for the user interface(s) of the web-based calculation tools and for associated teaching (capacity building) materials.
- Objective 4: Submission of proposal(s) to support the development of the web-based tools.

Month 24: 2nd full WG Meeting

- We will review the draft manuscripts of the chemical speciation review paper, and the Pitzer model database, in preparation for submission to a journal. This is also a **decision**

point for the development of the web-based modelling tools: we will report on the results of efforts to secure funding, and future prospects. If we have been successful, the project will continue as indicated below. Otherwise, we will either request a postponement (to allow further time to obtain support), or end the WG with the publication of the review paper, Pitzer parameter database, and report defining the needs for web-based tools for speciation calculations. Thus, even if additional funds are not obtained, the WG will (i) produce products valuable for scientists in this field; (ii) establish needs and give direction to future research; (iii) document the tasks needed to complete a Web-based tool.

Months
25 - 47

- Objective 4: Development of the web-based modelling tools and supporting programs and website information, with internal testing and review by WG members and other individuals towards the end of this period.

Month 48: 3rd and final full WG Meeting.

- Members will report on their experiences testing the web-based modelling tools, from both research and capacity-building perspectives. We will agree any necessary revisions, and changes will be made within 2 months of this meeting. The website will then be made public.

We will, where possible, organise WG meetings to coincide with relevant conferences so that the normal SCOR funding for three meetings can be stretched to four, and will explore the possibility of co-sponsorship by IAPSO and IUPAC.

5 Deliverables

1) A review paper, to be published in an international chemistry journal. This will include a statement of current speciation modelling capabilities, a survey of the available physico-chemical data for the major and minor chemical components (particularly related to chemical speciation and equilibria), and the identification of gaps and needs for future models and measurements. (Objective 1)
2) Accompanying the paper, a database listing the currently available Pitzer model parameters and equilibrium constants for seawater and trace components, their variations with temperature and pressure, and their origins in laboratory measurements (how they were obtained, uncertainties, and the references). (Objective 2)
3) Presentation of the results and conclusions of the review paper, for discussion and to stimulate new work, at a talk or special session on chemical speciation at an international ocean sciences meeting. (Objectives 1 and 2)
4) A report defining (a) the scope and specification of speciation modelling tools needed by chemical oceanographers for research and teaching (capacity building);

(b) how these tools should be implemented on a website to meet the needs of different potential user groups. (Objective 3)

5) A public website, with associated programs and documentation, meeting the specification set out in (4). (Objective 4)
6) Presentation of the website and its capabilities at a "town hall" meeting at an international ocean sciences conference. (Objective 4)

6 Capacity Building

There is an urgent need for capacity building in chemical speciation modelling. For example, many national and international research programmes are focused on Ocean Acidification (OA). Chemical speciation modelling is essential to an understanding of the development and consequences of OA, yet access to state of the art chemical speciation modelling tools is effectively restricted to a small (and ageing) group of marine scientists who are active researchers in the area. This WG will address the need for capacity building – training, and providing practical tools – at several levels.

Our vision is that state of the art chemical speciation modelling should be easily available to all marine researchers and students, not just the select few who have active research projects in the area. This will be achieved by the development of a web-based modelling tool that builds on a published, consistent and quality- controlled Pitzer database. The active involvement of representatives of key user communities in the WG will ensure that the structure and function of the web tool is appropriate for both research and teaching. In the case of teaching, we already have experience in providing tutorials and instructional videos on the subject of solution thermodynamics. The web-based modelling tools, augmented by the teaching and training materials, will provide the route to the capacity building so urgently needed in this field.

The work and products of the WG will also help to stimulate future capacity building and research in chemical speciation modelling. Publication of the reviewed database and release of the web tool will focus attention its importance. This will encourage new research efforts in this area, and develop a younger generation of scientists who can maintain and develop the database and modelling tools.

Finally, it is anticipated that the identification of important knowledge gaps in the database will stimulate new research to fill those gaps. History suggests that this is more than an idle hope. A 1981 paper co-authored by two of us (Turner et al., 1981) that identified the dearth of data on the carbonate complexation of trace metals, did indeed stimulate new measurements that now provide the basis for our understanding of this phenomenon in the oceans.

7 Working Group Composition

The WG will have 10 Full Members with the range of expertise needed to address the terms of reference, including speciation modelling, large scale biogeochemical modelling, metal-ligand titration techniques, chemical-biological interactions and teaching. Importance is attached to ensuring that the modelling tools to be developed are readily accessible to the whole community, thus "users" are in a majority in the WG membership. They represent a broad geographical spread, from Europe, North America, South America, China and New Zealand. Although the applications are not restricted to **GEOTRACES**, we see this project as an important complement to **GEOTRACES** that lies outside that programme's field focus. The Full Members include four members of the **GEOTRACES** SSC (Turner, Hatje, Maldonado, Tagliabue), which will ensure effective coordination. The Associate Members provide additional complementary user expertise, together with experienced modellers (including 2 members of the related SCOR WG 127, see section 9.4) who can contribute to reviewing the database and model development.

7.1 Full members

Name	Gender	Place of Work	Expertise
David Turner (chair)	M	University of Gothenburg, Sweden	Physical chemist, oceanographer and modeller: chemical speciation in seawater
Simon Clegg (vice-chair)	M	University of East Anglia, UK	Modeller: chemical thermodynamic modelling (inc. Pitzer equations), development of web-based tools for research and teaching
Sylvia Sander (vice-chair)	F	University of Otago, New Zealand	User: experimental studies of trace metal speciation, focus on data analysis
Heather Benway	F	Woods Hole Oceanographic Institution, USA	Executive Officer, Ocean Carbon and Biogeochemistry Project Office; expert in communication and outreach.
Arthur Chen	M	National Sun Yat-sen University, Taiwan	User: CO_2 system, estuarine, and marine and hydrothermal biogeochemistry
Andrew Dickson	M	Scripps Institute of Oceanography, USA	Physical chemist and modeller: CO_2 system in seawater, reference materials for measurements
Vanessa Hatje	F	INCT Energy and Environment, Bahia, Brazil	User: trace metal accumulation in marine organisms
Maite Maldonado	F	University of British Columbia, Canada	User: biological oceanographer

Alessandro Tagliabue	M	University of Liverpool, UK	User: development of global biogeochemical models
Rodrigo Torres	M	Centre for the Investigation of the Patagonian Ecosystem (CIEP) , Chile	User: ocean acidification and iron

7.2 Associate members

Name	**Gender**	**Place of Work**	**Expertise**
Eric Achterberg	M	GEOMAR, Kiel, Germany	User: chemical oceanographer, CO_2 system and trace metals
Yuri Artioli	M	Plymouth Marine Laboratory, UK	User: ecosystem modeller, member of the ERSEM group
Giles Marion	M	Desert Research Institute, USA	Modeller: developed the FREZCHEM chemical speciation model for cold water systems (http://frezchem.dri.edu/main.html)
Peter May	M	Murdoch University, Australia	Physical chemist and modeller, author of Joint Expert Speciation System (JESS).
Frank Millero	M	University of Miami, USA	Physical chemist and modeller: many measurements of the thermodynamic properties of seawater, and long experience of applying Pitzer models to marine systems
Stan van den Berg	M	University of Liverpool, UK	User: competitive ligand titrations in seawater
Wolfgang Voigt	M	TU Bergakademie Freiberg, Germany	Physical chemist and modeller: properties of concentrated salt solutions and brines (THEREDA database). May also involve close colleague Helge Moog.
Christophe Völker	M	Alfred Wegener Institute, Germany	User: development of global biogeochemical models
Dewen Zeng	M	Institute of Salt Lakes, China	Physical chemist and modeller: expert in chemical speciation with a background in hydrometallurgy.

8 Working Group Contributions

David Turner contributes a broad-based understanding of the field, with experience in chemical speciation modelling, and also in field-based biogeochemistry as Chief Scientist on 3 JGOFS cruises. He also contributes experience as a former WG co-chair (WG109, co-sponsored with IUPAC).

Simon Clegg (modeller) has long experience in applying Pitzer equations both to seawater and atmospheric aerosols, and has an extensive knowledge of the data upon which they are based. His experience in developing the *E-AIM* modelling website (section 2.2) will also make an important contribution to the WG.

Sylvia Sander (user) is expert in competitive ligand titrations, which are used to characterize metal-organic binding in seawater: there is a clear need for improved speciation modelling in this area. As one of the leaders of WG139, she will be able to ensure that the two WGs complement each other effectively.

Heather Benway (capacity building) is an essential link to the Ocean Carbon and Biogeochemistry Programme, for which she is Executive Officer. She also brings a strong record of outreach and community involvement and will contribute greatly to the teaching and training elements of the web-based speciation tools.

Arthur Chen (user) contributes a wide expertise in marine, estuarine and hydrothermal biogeochemistry and the application of speciation modelling to these systems.

Andrew Dickson (modeller) is an expert in laboratory measurement and modelling of chemical speciation; and also in the development of standard materials, calculation methods and documentation for the marine CO_2 system.

Vanessa Hatje (user) contributes expertise in the study of the trace metal content of marine organisms, an area where improved chemical speciation modelling is needed.

Maite Maldonado (user) contributes expertise in the study of chemical-biological interactions, most particularly the uptake of trace metals by microorganisms. Understanding uptake processes is dependent on good chemical speciation models.

Alessandro Tagliabue (user) contributes expertise in global biogeochemical modelling where there is a clear need for improved descriptions of (particularly) iron speciation.

Rodrigo Torres (user) contributes expertise in studies of ocean acidification and its consequences for iron biogeochemistry

9 Relationships to Other Programmes and SCOR Working Groups

9.1 GEOTRACES

The data generated by the **GEOTRACES** programme, as exemplified by the recently released Intermediate Data Product, is a game-changer in marine biogeochemistry. **GEOTRACES** involves simultaneous sampling for key trace elements and supporting parameters with an accuracy, coverage and resolution far beyond that previously available for trace elements. However, the marine biogeochemistry community currently lacks readily available tools for complementing the **GEOTRACES** data with state of the art calculations of chemical speciation. This proposal aims to fill that gap.

9.2 Global change programmes

The need to understand the effects of climate change and other anthropogenic forcings on marine biogeochemistry is inherent in a number of international programmes such as **IMBER** and **SOLAS**, large scale models such as the **European Regional Seas Ecosystem Model**, and national programs such as the Ocean Acidification Programme in the UK (**UKOARP**, see below). This will continue as a priority within the Future Earth programme now under development. Within these programmes there is an increasing focus on multi-stressors, i.e. the way in which different forcings combine synergistically or antagonistically to produce a net effect. An understanding of chemical speciation is of key importance here. Iron, which is now known to be a limiting nutrient in large areas of the ocean, is one example. The proposed WG is highly relevant to these ongoing and future studies.

9.3 UK national programmes

Both the **UKOARP** and the Shelf Sea Biogeochemistry Programme (**SSB**) have been contacted, and common interests identified. A UK-hosted workshop in 2015 is likely to be attractive to **SSB**, and co-funding is possible. This will be requested later in 2014 when the announcement of opportunity for such 'added value activities' is made.

9.4 SCOR WG 127

The thermodynamic equation of state for seawater, 2010, was produced by this WG. It is a Gibbs function (an equation) from which the thermodynamic properties of seawater are calculated. Most relevant to this WG is the fact that the osmotic coefficient, and also the density, of seawater can be calculated from TEOS 2010. These are important constraints for the speciation models, and should be adhered to.

9.5 SCOR WG 139

The current SCOR WG, entitled "Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean", addresses the experimental characterisation of interactions between trace metals and natural organic matter in the ocean. There is a strong focus on the use of competitive ligand titrations, from which stability constants and concentrations are derived for a small number of "ligands". Our proposal complements WG 139 by providing (i) a chemical speciation model for all other interactions affecting the trace metal in question; (ii) a chemical speciation model for the titrations that are frequently used to characterise the trace metal – natural organic interactions; and (iii) a framework for including the experimentally derived "ligand" concentrations and stability constants in a chemical speciation model. The leadership of WG 139 has confirmed that this proposal does not overlap WG139.

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Appendix: Key Publications of Full Members

David Turner

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2.3.2 Towards comparability of global oceanic nutrient data (COMPONUT) Naqvi

Summary/Abstract

To better manage the global impacts of human activities on the world's oceans, it is necessary to have accurate observations of changes in carbon and dissolved nutrients in both upper and deep ocean waters. By establishing mechanisms for comparability of nutrient analyses, we will be able to detect changes in nutrient levels due to human impact and shifting physical processes. Such changes could, either alter the supply of nutrients to the upper ocean directly or be from changes to ocean circulation. A recent Framework of Ocean Observing statement introduced the concept of Essential Ocean Variables (EOVs), and the assessment and development of readiness for sustained observations, with the aim of promoting collaboration in developing requirements, observing networks, and data information streams. Nutrients are identified as one of these EOVs. In 2014, two certified reference materials (CRMs) will become available for measurements of nutrients in seawater; a CRM provided by the National Metrology Institute, Japan, and MOOS-3, provided by National Research Council, Canada. The whole situation now calls for further international collaboration through SCOR, with a Working Group to establish the mechanisms for comparable oceanic nutrient data, using globally accepted CRMs. The primary goal is that for nutrient data collected anywhere by one individual laboratory, and data collected over long time periods by one or more laboratories, will be consistent and traceable with certified comparability. For future generations it is unacceptable to produce historical data sets without the absolute consistency necessary to assess spatial and temporal trends.

Scientific Background and Rationale

Changes are occurring on a global scale in ocean biogeochemical cycles and much of the cause of these changes, directly or indirectly, is from human activities. Therefore, it is necessary to have accurate observations of trends in carbon and dissolved nutrients in both upper and deep ocean waters. For these observations, it is critical that we can reliably compare results from different laboratories, for geographically similar ocean waters with total confidence. To get a global consensus for nutrient data, it is necessary to both have accepted certified reference materials (CRMs) and to have the requirement to use the CRMs, and these can be established by the authority of a SCOR Working Group. The focus for this proposed Working Group is for oceanic waters, but because the ranges of nutrients expected are similar, the effort can be extended, at least partially, to coastal and estuarine waters. There are currently established certified standardizations for only a few marine parameters; such as; temperature measurements (ITS90, traceable to SI using Standard Platinum Resistance Thermometer, SPRT), salinity measurements (comparability ensured using IAPSO salinity standard seawater provided by OSI, UK), and the carbonate system parameter measurements (comparability and traceability ensured using CRMs provided by Dickson's laboratory, SIO, USA, Dickson, 2003; 2010).

The 2007 IPCC Report highlighted the problem inherent in comparing data sets stating that: "Uncertainties in deep ocean nutrient observations may be responsible for the lack of coherence in the nutrient changes. Sources of inaccuracy include the limited number of observations and the lack of compatibility between measurements from different laboratories at different times"

(Bindoff et al., 2007). Results of nutrient concentrations from global crossover station analysis have shown discrepancies of up to 10 % for deep nutrient data during the last three decades (Aoyama et al., 2013), and the results of inter-laboratory comparison studies since 2003 showed a similar magnitude of discrepancy among some participant laboratories (Aoyama et al., 2007; 2008; 2010). This indicates that analytical problems may cause larger discrepancies for deep water nutrients, and these reported comparisons were from a small number of specific studies, whereas there are many oceanic nutrient data sets reported, published, and stored on international databases, with no references to CRMs at all. Although this situation has been improved somewhat, it is still difficult to ascertain with any certainty temporal changes in ocean nutrients. We can now detect changes in deep ocean temperature (and hence heat content) (Levitus et al., 2009; 2012; Kouketsu et al. 2009; Rhein et al., 2013) from observations due to comparability of temperature measurements, on the order of mK. Changes to the carbonate system parameters in the deep ocean are also reported with comparability being ensured by the use of CRMs (e.g. Wanninkhof et al., 2010, Ríos et al., 2012, Khatiwala et al., 2012). Similarly, changes to oceanic oxygen can now also be accurately observed (Stendardo and Gruber, 2012).

It is important to now establish mechanisms for improving the quality of reported oceanic nutrient data, which will then allow us to be able to more accurately detect changes in nutrient levels due to human impact and shifting physical processes, which might alter the supply of nutrients to the upper ocean in the future. Improved comparability of reported nutrient concentrations in the water column will also help us to improve estimates of the anthropogenic portion of the observed increase of total carbon in the water column.

To properly guarantee comparability of data from different laboratories, the precise mechanisms of a global consensus for reporting nutrient levels needs to be established. This will foster a move toward the comparability of nutrient data using globally accepted RMs/CRMs, followed by the recommendation of protocols for their use throughout the world-wide marine chemistry community. This has already been achieved by the use of CRMs for measurements of the CO2 system, and the use of the IAPSO standard seawater for salinity measurements. A potential problem with using nutrient CRMs is similar to that with the use of references for dissolved organic carbon (DOC); that is, some form of enforcement for their use should be established. There was significant improvement in community DOC measurement during the international JGOFS program due to encouragement by the US National Science Foundation and NOAA to participate in DOC comparability exercises (Sharp et al, 2002). A nutrient CRM SCOR working group should be able to provide the authority for not only certification of nutrient CRMs, but also for their use.

Historically, a U.S. National Research Council report (Dickson et al., 2002) clearly stated that certain key oceanic parameters lacked reliable and readily available reference materials. That report identified the most urgently required chemical reference materials based on certain key themes for oceanographic research. At the top of the list of the new reference materials needed were standards for the measurement of nutrients, with the statement: “There is an urgent need for a certified reference material for nutrients. Completed global surveys already suffer from the lack of previously available standards, and the success of future surveys as well as the development of instruments capable of remote time-series measurements will rest on the availability and use of good nutrient reference materials”. Since that time, RMs/CRMs for oceanographic use have been developed. These include a Danish RM, NRC-Canada CRM (MOOS-3), and one developed by KANSO-Japan. In 2014 NMIJ will start to provide CRMs (NMIJ CRM 7601-a, NMIJ CRM 7602-a, and NMIJ CRM 7603-a) with nutrient concentrations appropriate for the nutrient concentration ranges of Nitrate, Nitrite, Silicate and Phosphate found in the Pacific and Atlantic Oceans. MOOS-3 covers nutrient concentrations specifically for the Atlantic Ocean. Therefore, we now have the opportunity for traceability and comparability of nutrient concentrations throughout the globe, and a mechanism to provide RMs which is traceable to SI through CRMs. Global availability of the RM to traceable to NMIJ CRM will be made through JAMSTEC (Japan Agency for Marine-Earth Science and Technology), in a similar manner to the carbonate system CRMs from Dickson's laboratory (SIO, Scripps).

A nutrient CRM calls for further international collaboration through SCOR, and a Working Group to establish the mechanisms required to provide comparability of oceanic nutrient data, using globally accepted RMs/CRMs. A major challenge with this SCOR WG is to develop a system by which the comparability of data within and between laboratories is better than 1% at full scale of nitrate, phosphate and silicate concentrations. The levels of comparability achieved for the measurement of oceanic salinity and total inorganic carbon are considerably better than 1%. However, both of those parameters are comparatively simple, chemically, and exist in the open ocean in much narrower concentration ranges than do the inorganic nutrients.

The primary goal for the SCOR Working Group is for nutrient data collected at any one place by an individual laboratory and data collected over long time periods by one or more laboratories to be consistent with certified comparability. The experience of this SCOR WG will also give positive feed-back to the scientific community of coastal ocean observatories, and for researchers developing nutrient sensors for buoys and floats, by providing and recommending globally accepted RMs/CRMs for the calibration of instruments and sensors. Such feedback will move toward the goal of achieving comparability of nutrient data throughout the oceans, which will have been obtained by different methods, instruments, and technologies. This initiative will be based on previously developed collaboration with the IOC-ICES SGONS that ended in 2012. For future generations it is unacceptable to produce historical data sets without the absolute consistency necessary to assess spatial and temporal trends.

Terms of Reference (max. 250 words/177)

1. To establish mechanisms to ensure comparability of oceanic nutrient data
2. To assess the homogeneity and stability of currently available RMs/CRMs. It remains to determine whether the current producers are achieving a level of precision within and between laboratories which is comparable to or better than 1 %.
3. To develop standardized data-handling procedures with common data vocabularies and formats, across producers and users, and will include the future linking of national and international data archives. The group will seek to involve international data center representatives to contribute to and lead this task.
4. To promote the wider global use of RM's by arranging workshops to actively encourage their use and to provide training in analytical protocols and best practice, particularly targeted towards developing countries.

5. To continue regular global inter-comparison studies, following on from the previous exercises in 2003, 2006, 2008 and 2012, with collaboration of IOCCP-SSG and RCGC-JAMSTEC.
6. To update the GO-SHIP nutrient measurement manual, which was originally a product of the IOC-ICES SGONS, (Study Group on Nutrient Standards).
7. To publish reports on this WG's activities and workshops.

Working plan (logical sequence of steps to fulfil terms of reference, with timeline. Max. 1000 words/446)

This Working Group will work 3 years after acceptance by the SCOR General assembly in 2014. The time-line shown below highlights only the main meetings/activities. We will have regular e- mail exchanges, Skype meetings, and a variety of workshops/meetings among the full and associated members that will occur on a regular basis.

Year 1: 2015

Kick-off Meeting: Upon funding, the WG will have a kick-off meeting in early to mid 2015. In order to provide good international visibility, the 2015 EGU General Assembly (April 12-17
2015, Vienna, Austria) is a good potential venue where a WG meeting #1 on changes of nutrients in the world's oceans and use of RMs/CRMs could be held.

Conduct an inter-laboratory comparison experiment of currently available RMs/CRMs by several selected key laboratories to assess the homogeneity and stability of currently available RMs/CRMs. This will be organized by a few of full/associate members of the WG. The results of this will be published as soon as possible after the experiment.

Year 2: 2016

A potential venue for the half-way meeting, WG meeting #2 will be the 2016 Ocean Sciences Meeting (21 February 2016 — 26 February 2016, New Orleans, Louisiana, USA). During the OSM 2016, we will propose a presentation session at the meeting, and we will also hold a workshop to promote the wider global use of RM's, to actively encourage their use. We will also review synthesis papers and previously published inter laboratory comparison study reports, and prepare a revised version of the GO-SHIP nutrients measurement manual during this workshop. One of key issues is to update/confirm basic analytical methodologies for nitrate, nitrite, phosphate and silicate.

We will conduct a global inter-comparison study of RMs/CRMs following on from the previous exercises in 2003, 2006, 2008, 2012 and 2014, with the collaboration of IOCCP-SSG and RCGC-JAMSTEC.

In 2016 we will provide a training course in analytical methodologies and best practice of nutrient measurement, particularly for developing countries. Potential venues for this training course are NIOZ/The Netherlands, SIO/USA, or JAMSTEC/Japan. In this training course, participants will be given training by experienced analysts and the workshop will discuss the results of the global inter-comparison studies of RMs/CRMs so as to learn more about how to ensure comparability of oceanic nutrient data.

These opportunities, the training course and global inter-comparison study, will also contribute to building capacities in developing countries to measure nutrient concentrations in seawater.

Year 3: 2017

We will plan an international symposium "Towards comparability of global oceanic nutrient data". This symposium is also WG meeting #3. Potential venues for this symposium are JAMSTEC/Japan, NIOZ/The Netherlands and SIO/USA. We will particularly focus on inviting scientists from developing countries, and encourage their involvement in this symposium.

Deliverables (state clearly what products the WG will generate. Should relate to the terms of reference. Max 250/163). A workshop is not a deliverable. Please note that SCOR prefers that publications be in open-access journals.

1. Assessment reports of currently available RMs/CRMs based on inter-laboratory comparison experiments which will be submitted to 'Biogeochemistry' or similar open access journal.
2. A "best practice" manual which will provide the community with a recommended consistent approach to the sampling, analysis, use of RM's, quality control of nutrients, and subsequent data handling which will be an update of the GO-SHIP nutrients manual (Hydes et al 2010).

3. This manual will be available freely at the GO-SHIP website and will be able to be downloaded free of charge. A printed version of this manual may be published depending on additional funding availability.
4. A report on global inter-comparison studies of RMs/CRMs will be submitted to the journal "Earth System Science Data" published by EGU.
5. Synthesis papers on current nutrient measurements techniques/methodologies which will be submitted to the journal "Earth System Science Data" published by EGU.
6. A book will be published from the final International symposium "Towards comparability of global oceanic nutrient data".

Capacity Building (How will this WG build long-lasting capacity for practicing and understanding this area of marine science globally.Max500/277

This important aspect is reflected in two ways. The first is to promote participation of developing countries in inter-laboratory comparison studies of RM's through the involvement and help of POGO. The second is to invite participating laboratories to a 3-day training course in 2016 planned to be held at JAMSTEC/Japan, NIOZ/The Netherlands or SIO/USA (depending on additional funding) to learn more about analytical methodologies, best practice, and to discuss and interpret results of the global inter-laboratory comparison studies of RM's.

Building capacities in developing countries can be accelerated by providing a good simple manual based on "best practices" and we will encourage even greater participation in the future inter-laboratory comparison study of RM's proposed for 2016 from these developing countries. The aspect of capacity building could be further augmented by hosting a session (in conjunction with a WG meeting/AGU meeting/OSM meeting), at approximately mid-term, to discuss the needs and capabilities of developing countries with respect to using other suitable programs. We will initially instigate a targeted questionnaire to laboratories in developing countries to highlight their most important analytical requirements, this will all be accomplished with the help and advice of POGO.

The laboratories that took part in the 2012 inter-comparison exercise of nutrients in seawater are already from the following countries: Argentina, Australia, Belgium, Bermuda, Brazil, Canada, Cape Verde, Chile, China, Denmark, France, Germany, Iceland, India, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Russia, Saudi Arabia, South Africa, South Korea, Spain, UK, USA, Venezuela. This proposed SCOR WG will endeavor to expand the global participation of developing countries from the current number of 2012/2014 representatives into the 2016 inter-calibration exercise with more participants from developing countries.

Working Group composition (as table). Divide by Full Members (10 people) and Associate Members, taking note of scientific discipline spread, geographical spread, and gender balance. (max. 500 words)

Full Members (no more than 10, please identify chair(s))

Name	Gender	Place of work	Expertise relevant to proposal
1 Michio Aoyama*	Male	RCGC-JAMSTEC/IER-Fukushima Univ., Japan	Geochemistry, global nutrients distribution
2 E. Malcolm S. Woodward*	Male	PML, UK	Nanomolar level precision measurements
3 Toste Tanhua	Male	GEOMAR, Germany,	Chairman of the International Ocean Carbon Coordination Project (IOCCP)

4 Karin Bjorkman	Female	Laboratory for Microbial Oceanography, Hawaii, USA	HOT time series
5 Bernadette Sloyan	Female	CSIRO, Australia	Co-chair of The Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP)
6 Anne Daniel	Female	IFREMER, France	French nutrient reference laboratory (DYNECO/PELAGOS, IFREMER
7 Susan Becker	Female	SIO, USA	Repeat Hydrography
8 M. Dileep Kumar	Male	NIO, India	Chemical Oceanography
9 Claire Mahaffey	Female	University of Liverpool, UK	Nutrient Biogeochemist
10 Howard Waldron	Male	University of Cape Town, South Africa	Nitrogen dynamics in Ocean systems

* : Co-Chairs

Associate Member (no more than 10)

Name	Gender	Place of work	Expertise relevant to proposal
1 Alex Kozyr	Male	CIDIAC, USA	Multiple user database access
2 Karel Bakker	Male	NIOZ, The Netherlands	The Netherlands sea-going analytical facility
3 Takeshi Yoshimura	Male	CRIEPI, Japan	Organic Nutrients
4 Jonathan Sharp	Male	University of Delaware, USA	DOC RM experience
5 Andrew Dickson	Male	SIO, USA	Carbonate system RM experiences
6 Minhan Dai	Male	Xiamen University, China	Large global (LOICZ and Chinese programs)
7 Akihiko Murata	Male	JAMSTEC, Japan	Chemical oceanography, Global carbon/nutrient
8 Trevor Platt	Male	PKL, UK	Executive Director, POGO
9 Ralph Sturgeon	Male	NRC, Canada	CRM producer
10 Akiharu Hioki	Male	NMIJ, Japan	CRM producer

Working Group contributions

Michio AOYAMA organized the previous 4 Inter-laboratory comparison experiments for Reference Materials of Nutrients in Seawater, RMNS, in 2003, 2006, 2008 and 2012. He is working to develop RMNS, and has been PI of nutrients of 6 CLIVAR cruises in the Pacific Ocean. He is one of PIs of dissolve oxygen and nutrients part of Pacific Ocean Interior Carbon Data Synthesis project, PACIFICA. He has 104 publications in peer-reviewed journals and numerous reports.

Malcolm WOODWARD has worked as a Chemical Oceanographer for 35 years, and Head of the Plymouth Marine Laboratory Nutrients Facility for the past 20 years, has 100 publications in peer-reviewed journals and numerous reports. Has specialized and developed nanomolar nutrient analysis techniques and their applications in global oligotrophic oceans.

Toste TANHUA works on research fields of transient tracers in the ocean, ocean ventilation and mixing, tracer release experiments to quantify mixing. He also conducts CARINA Data Synthesis Project in the Atlantic Ocean. Now he works as a chair of The International Ocean Carbon Coordination Project (IOCCP). He has numerous publications in peer-reviewed journals reports and books.

Karin BJORKMAN works the field of microbial oceanography and nutrient dynamics with a special focus on phosphorus cycling in the oligotrophic North Pacific subtropical gyre. This work includes high sensitivity measurements low nano-molar concentrations of inorganic phosphate as well as the use of radioisotopes as tracers.

Bernadette SLOYAN works on International repeat hydrography and carbon program. She analyzes repeat hydrographic sections in the southern hemisphere oceans and simulation of deep ocean changes in climate models. She has numerous publications in peer-reviewed journals reports and books.

Anne DANIEL is in charge of the French reference laboratory (DYNECO/PELAGOS, IFREMER) for chemical measurement in marine and fresh waters. It supports laboratories by developing new methodologies, organizing performance tests and implementing quality system for accreditation according to the ISO/IEC 17025 norm. She also works in the implementation of the EU Water Framework Directive (WFD) and EU Marine Water Framework Directive (MSFD).

Susan BECKER is a manager and supervisor for the Oceanographic Data Facility within Shipboard Technical Support at Scripps Institution of Oceanography. She is responsible for overseeing the analytical analysis and data quality of inorganic nutrients, dissolved oxygen, and salinity. ODF provides the highest quality hydrographic data from CTD casts and discreet analysis of salinity, nutrients and dissolved oxygen for global repeat hydrography programs.

M. Dileep KUMAR is a Chemical Oceanographer focusing on nutrient and carbon biogeochemistry with particular reference to Climate Change. He has about 35 years of research experience at NIO (Goa) and has about 65 publications in peer-reviewed journals.

Claire Mahaffey is a nutrient biogeochemist and Senior Lecturer with over 10 years experience studying the source, cycling and fate of nitrogen, phosphorus and carbon in the subtropical open ocean and coastal and shelf seas. Has been responsible for nutrient analysis both at the Hawaii Ocean Time Series (USA) and Liverpool Bay Coastal Observatory (UK).

Howard WALDRON works on nitrogen dynamics of ocean systems including Benguela Upwelling, Southern Ocean and Atlantic Meridional Transect.

Relationship to other International programs and SCOR Working groups

Toste Tanhua is a Chair of The International Ocean Carbon Coordination Project (IOCCP). Bernadette Sloyan is a Co-chair of The Global Ocean Ship-based Hydrographi Investigations Program (GO-SHIP).

Trevor Platt is an Executive Director of the Partnership for Observation of the Global Oceans (POGO).

Michio Aoyama is a candidate of full member of SCOR WG proposal of marine radioactivity which will be submitted in 2014. Minhan Dai is also a candidate of co-chair of SCOR WG proposal of marine radioactivity.

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Appendix

For each Full Member, indicate 5 key publications related to the proposal.

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2.3.3 International Network for the Study of How Organisms Respond to Environmental change (INSHORE) Feeley

Abstract

Climate change and ocean acidification currently lead the international research agenda for marine ecosystems. Increased awareness of the effects of additional pressures arising from human activities has also led to the emergent research priority of 'multiple stressors', a theme recognized within international policy requirements for assessments of impacts on marine biodiversity. Despite increased understanding that global scale drivers will interact in complex ways with regional to local scale stressors to affect marine ecosystems, most research programmes currently study stressors in isolation. The effects of climate change are likely to be more complex than suggested by the simple trends and averages presently recognised. Similarly, most ocean acidification research has focused on single species mesocosms or small-scale observational studies across unrealistically short timeframes. A more realistic understanding of long term ecological responses to environmental change and multiple stressors requires a multidisciplinary organisms-to-ecosystems approach.

The overarching objective of the INSHORE Working Group is to develop a standard, integrative framework and modelling tool that can be applied internationally for research into multiple stressor impacts on coastal marine ecosystems. This will be achieved by 1) creating a global database of relevant ecological, biological and environmental datasets 2) developing a multiple stressor dynamic biostressor envelope model framework capable of operating over a range of spatial and temporal scales, 3) publishing a methodological best practice guide 4) hosting targeted workshops and a themed session at an international conference to engage the coastal benthic research community in an integrated scientific approach.

Scientific Background and Rationale

Scientific Background

Global climate change is now the milieu within which all biological, ecological and socio-ecological interactions must be positioned. The importance of a quantitative understanding of biological and physiological impacts of global change, and resultant changes to distributions and abundances of species within the marine environment is clear,[1,2] with an emphasis on predicting "winners" and "losers" among commercially, ecologically and culturally important species.[3,4] Understanding how multiple stressors will alter resilience and sustainability of ecosystems is thus a priority for marine scientists working across molecular to ecosystem scales.

Species and ecosystems respond to multiple stressors via multivariate changes in abiotic conditions and biotic interactions across a range of spatial and temporal scales, yet this is under- represented within current research programmes. Analyses of ecological responses to climate change are frequently communicated in generalized terms such as 'poleward range shifts', with drivers represented as trends in long-term averages across large spatial scales.[5,6] It is increasingly clear, however, that decadal-scale increases in mean climate are not the proximate drivers of organismal survival. Instead, vulnerability through mortality or sub-lethal performance and consequently species distributions respond more directly to shorter-term variation in environmental conditions including extreme 'climatic' events and anomalies.[7,8] Consequently, predictions may have little relevance for individual species, nor be appropriate for ecosystem status assessments at local to regional scales. Eutrophication studies suffer from similar problems of scale, being predominantly focused on localized coastal areas and results scaled up to produce 'regional' generalized trends.[9] Such extrapolation can produce misleading or incorrect biological impacts forecasts due to a poor understanding of the biotic response mechanisms to changes in water chemistry in different locations. In stark contrast, due to inherent difficulties in studying impacts within natural systems, research into ocean acidification has focused on detailed physiological and organismal scale experiments conducted in small, controlled mesocosms or natural experimental areas, although there is a recognized need for larger scale approaches.

Small scale physiological studies provide yardsticks to gauge the sensitivity of organisms to changes in their environment, but their applicability to observable patterns in nature is difficult to assess due to the often single-species approach taken, and discipline-specific narrow focus adopted. Importantly, the stressors of greatest concern resulting from changing climatic conditions, temperature and ocean acidification frequently interact with one another and with other non-climatic stressors such as eutrophication, which subsequently alter sublethal responses within the same species.[10,11] To avoid potential misinterpretations we propose that expectations of how climate, OA and eutrophication are likely to affect ecologically important species should be based on ecologically-functional trait based metrics over appropriate spatial and temporal scales.[12-14] Such predictions should emphasize how multiple stressors interact to drive local-scale processes, and acknowledge the often overriding importance of biological responses and interactions in determining patterns of vulnerability over multiple spatio-temporal scales.

Rationale

The proposed INSHORE (International Network for the Study of How Organisms Respond to Environmental change) Working Group will employ a multi-disciplinary approach, integrating analyses of functional mechanisms and ecological processes with climatic and ocean chemistry data to provide realistic insights into the effects of global change on marine biological systems. Using an organism-to-ecosystem perspective we will develop a multiple stressor version of a dynamic bioclimate envelope model (DBEM) and methodological best practice guide for data collection and analysis to enhance our understanding of the most important and appropriate aspects of the responses of coastal marine species and ecosystems to global change.

We recognize that scientists cannot account for every possible combination of environmental conditions when forecasting ecological responses to global change. Rather, our central tenet is to determine what comprises an appropriate test of model skill and stationarity, meaning that models constructed from contemporary observations can effectively predict responses under future, often novel, environments.[15] To be effective, forecasts need to capture bio/eco-logically relevant stressor metrics,[1,2,8,14,16,17] over appropriate spatio-temporal scales (10-

100kms) applicable to the scientific research agenda and national and international policy drivers[12] (e.g. EU Marine Strategy Framework Directive, Water Framework Directive).

The Working and Associate Group members will review existing climate and ocean acidification models alongside published experimental research and methodologies for climate, ocean acidification and eutrophication experiments and studies for rocky intertidal systems. From this review and expert knowledge within the group a best practice guide to designing and carrying out experimental and observational studies to deliver fit-for-purpose data for use in multiple stressor modeling will be prepared and submitted for publication in PLOS One.

We will integrate detailed information on the mechanistic biology of species from experimental studies with molecular, physiological and ecological data,[14,16,17,18] biogeographical time-series[8,19-21] and environmental datasets[22,23] within a macro-scale DEBM, sensu.[24,25] The DEBM will use these data to simultaneously estimate impacts of temperature, pH and nutrient levels on physiological performance, population dynamics, and dispersal to generate predictions of the impacts of multiple stressors on the biogeographic distributions of intertidal species. Model outputs will be created at a regional scale (100s km) within areas of the Atlantic and Pacific forwhich physiological, ecological, biogeographical and environmental data exist (e.g.[19,26]).

Rocky intertidal systems provide a highly tractable, data-rich system in which to develop and test such models. An important component of coastal habitats globally, they underpin both benthic and pelagic food webs, represent an important carbon pathway and support many species of both commercial and conservation value. The rocky intertidal also represents some of the most extreme and dynamic habitats in the marine realm. Organisms inhabiting this highly variable system are subject to high selection pressure arising from diurnal, seasonal and interannual fluctuations in environmental drivers and biological interactions[27] and are at high risk from multiple human-induced pressures, exhibiting some of the fastest responses to global change in any natural system.[8,19]

The INSHORE Working and Associate Groups comprise researchers with international track records and ongoing research projects determining the impacts of climate change, OA and other human stressors on intertidal ecosystems. Expertise spans marine biodiversity time-series data collection and analysis (Mieszkowska, Russell, Lima), biogeography, macroecology and population ecology (Mieszkowska, Helmuth, Harley, Williams, McQuaid, Broitman, Fawzi, Chan, Christopholetti), physiological and behavioral experimentation (Russell, Sarà, Williams, Dong, McQuaid, Kroeker, Rilov) and modelling (Sarà, Helmuth, Williams, Mieszkowska), molecular transcriptomics (Dong, Williams), dynamic energy budget modeling (Sará, Helmuth, Williams), ecological climate impacts modeling (Broitman, Helmuth, Lima, Fawzi, Harley), climate and OA modelling (Broitman, Lima). Several members have previously collaborated and published together as evidenced by the cited research in this proposal.

A SCOR Working Group grant will provide a unique mechanism by which world-leading researchers with complementary cross-cutting, multi-disciplinary expertise can develop a novel, standardized multidisciplinary approach to research on multiple stressor impacts. This scope does not fall within the remit of national research council funding, given the variety of biological, spatial and temporal scales at which such questions need to be addressed. The wide geographical spread of expertise and datasets, and the global distribution of rocky intertidal systems far exceeds geographical boundaries defining existing regional or bi-national funding schemes (e.g. NSF, EU Horizons 2020).

The proposed topic of advancing multiple stressor impacts research via an integrated, international approach is timely given the major findings of the 2014 IPCC Report on Impacts, Adaptation and Vulnerability[28] that CO_2 emissions are driving unprecedented changes in global marine climate and ocean pH, multiple stressors 'impinge on resilience from many directions' and may be 'irreversible in terms of possible futures'. This knowledge gap with respect to marine ecosystems is also identified within the EU Marine Strategy Framework Directive.[29] Given these needs, this Working Group could be instrumental in leading a global, standardized approach to detecting, quantifying and predicting the impacts of multiple stressors on marine systems.

Terms of Reference

INSHORE will pursue the following terms of reference:

1. Disseminate the Working Group activities and outputs via: development of a website with associated blog and Twitter account; hosting targeted sessions on multiple-stressor impacts research at major international meetings to increase awareness and engage scientists from multiple countries with the need for a standardized, multi-disciplinary approach to address this complex problem.
2. Create a database of relevant biogeographical, ecological, biological and environmental datasets held by, and accessible to the group.
3. Review existing climate models and ecological, biological and physiological experimental research into climate change, ocean acidification and eutrophication to develop a best practice for integrated multiple stressor research protocols. These best-practice approaches will consolidate the international research effort into marine climate change and provide standard protocols by which scientists new to this research field can produce comparable, robust data across research groups and nations.
4. Produce a best practice methodology and a case study output for the region of each Working Group member using the multiple stressor model.
5. Develop and test a next generation multiple stressor impacts model using existing time- series, experimental and environmental datasets collated in ToR 2.

Working plan

To achieve its goal INSHORE will:

1. integrate an international Working Group with expertise in physical, ecological, physiological and molecular sciences which will have the goal of developing a novel multiple stressor profiling model. This model will assess recent change and forecast future impacts of short-term weather and decadal-scale climate on biodiversity, functioning and resilience of rocky intertidal ecosystems.
2. to initiate this model, the group will utilize their unique wealth of scientific and monitoring datasets as well as those collected by the wider global marine climate research community including existing data repositories (e.g. ICES, PICES, OBIS, EMODnet, Redmap) and time- series such as the UK MarClim dataset (led by CoChair Mieszkowska) and Pacific USA dataset (Broitman) to create a dataset of biogeographic distributions, species traits (e.g. thermotolerance), lifecycle dynamics and population abundances for rocky intertidal ecological- engineer species. These data will be entered into a purpose-built database and used to derive best practice methodologies and to develop and test the DBEM.
3. Based on the outcomes from (2) the experts in climate impacts modeling from the Working Group and Associate Members will lead a review of their own and other existing global change impacts models with input on novel methodologies and parameters necessary to develop next generation multiple stressor models provided by the Working Group and Associate experts.
4. Assessment of species-specific physiological performances and tolerances, changes to trophic interactions, and macroecological data on distributional range shifts and abundances will be integrated with the climate models in a context of IPCC AR-5 scenarios (2014) to develop a Dynamic Biostressor Envelope Model that will provide quantitative assessments of the future vulnerability of organisms and ecosystems to climate change.
5. Finally, the model outputs will be designed at spatio-temporal scales relevant to policy and management drivers including OSPAR Regions, EU Regional Seas and Marine Protected Areas (e.g. the Australian Representative Network of MPAs, UK Marine Conservation Zone and Special Areas of Conservation Networks, EU MPA Network) and disseminated via the INSHORE website and direct communication from Working Group members to policymakers via existing science- policy groups such as the UK Healthy and Biologically Diverse Seas Evidence Group, Marine Climate Change Impacts Partnership, Australian National Climate Change Research Facility).

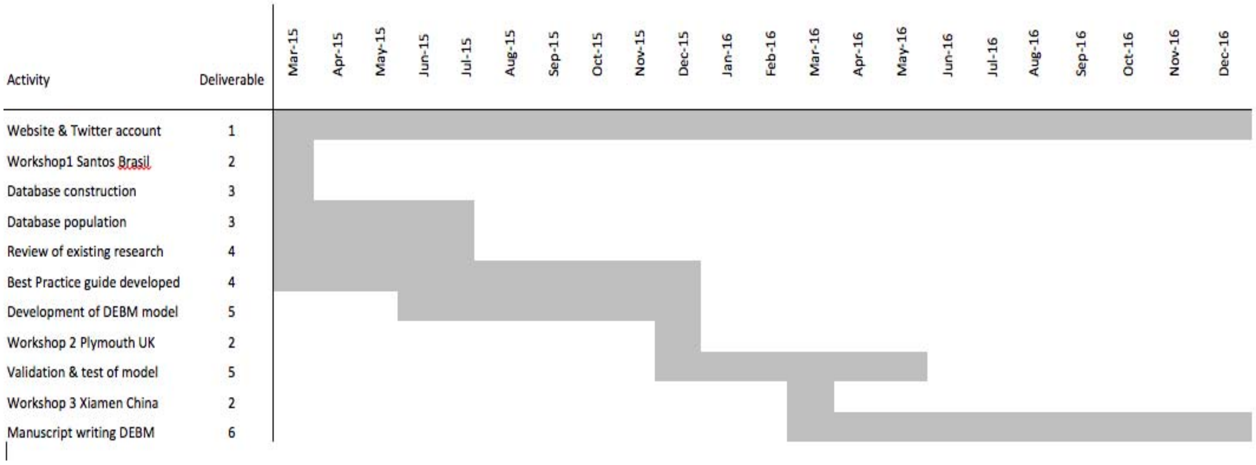
Timeline

The first INSHORE working group meeting will be a three day workshop and themed session held at the 'Third International Symposium on Effects of Climate Change on the World's Oceans', 23-27 March 2015 in Santos, Brazil. This meeting is coordinated by ICES and sister affiliations the North Pacific Marine Science Organization (PICES) and the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO). The driver is a recognized symbiosis between the oceans and society, underpinned by the role of science, and a need for the assessment of the consequences of climate change on the world's waters, ecosystems and living resources. The associated SCOR workshop will be organized by Co-Chair Mieszkowska and INSHORE Associate Member Christofoletti, from the conference host institute Universidade Federal de São Paulo, who will cover venue costs as an 'in kind' contribution. The workshop and themed session will be open to participation by students from Instituto do Mar and other registered participants of the conference. Working Group members will present relevant research at the symposium and participate in the workshop.

This meeting will involve presentations of working group members' research activities and launch of a website (Term of Reference 1, Deliverables 1,2), the construction and population of a meta-database of relevant biogeographical, ecological, biological and environmental datasets held by, or accessible to the group (ToR 2, Deliverable 3), a review of existing climate models will be carried out (ToR 3, Deliverable 4) and a best practice guide for multiple stressor impacts research in coastal marine systems drafted (ToR 4, Deliverable 4). Presentations on the state of climate impacts modeling and availability of datasets for climate, OA and eutrophication at ocean basin, national and regional scales will be given by Broitman, Helmuth, Lima, Kroeker, Harley, Fawzi and Mieszkowska who are world-leaders in this field. Ecological responses to multiple stressors will be presented by Williams, Harley, McQuaid, Helmuth, Chan and Christofolettii. Williams, McQuaid, Dong, Sarà, Rilov and Mieszkowska will present work on molecular and physiological single and multiple stressor research. Discussions between the group members will include datasets to be incorporated into the new multiple stressor model and an agreed time-line for remote participation and delivery of data to the modelers.

A second workshop will be held at the end of 2015 at the Marine Biological Association, Plymouth, UK. Co-Chair Mieszkowska will host the four day workshop, with venue costs covered as an 'in-kind' contribution. The developing DEBM model will be showcased at this workshop and the working group will test and validate the model using the metadatabase collated at the first workshop in Brasil (ToR 5, Deliverable 5). Between workshops two and three the review manuscript of the status of the marine multiple stressor research field will be written by the Working Group using cloud file sharing and virtual group working methods successfully employed by members for previous publications.

A final workshop will be held in early 2016 at Xiamen University, China, hosted by Working Group member Dong. Here the working group will test the final version of the model with datasets held by the Working Group and perform model runs targeted at regional scales relevant to management of adaptation strategies, harvest of commercially important species, and zonation and planning of Marine Protected Area networks. The working group will write a manuscript on the DEBM model using this case study for submission by the end of 2016 (Deliverable 6).



Deliverables

The WG will provide a mechanistic approach to understanding how coastal marine species and ecosystems will respond to climate change, ocean acidification and eutrophication to challenge the paradigm of predictions based on existing time-series and physiological data from the ICES community and new, high resolution (10-100 kilometers) environmental data.

Specific outputs are to:

1. Launch a website and Twitter account providing information on the project activities, model outputs and links to related ICES activities.
2. Present Working Group expertise in multiple stressor research and promote the ongoing activities of the Working Group at international scientific meetings.
3. Create a database of biological and environmental datasets for use in developing and the best practice guide (4) and testing the multiple stressor model (5).
4. Publish a review of existing climate models alongside a best practice guide of the multidisciplinary, integrated methodological approach to next generation multiple stressor profiling modeling in the open access international journal PLOS One.
5. Develop a novel DEBM multiple stressor profiling model and make the code available to the international marine research community.
6. Publish model codes and outputs in international journals (e.g. Ecological Modelling, Global Change Biology) highlighting the roles of climate, ocean acidification and eutrophication in shaping and changing intertidal ecosystems.

Capacity Building

The INSHORE Working Group membership encompasses researchers from developing nations (Chile, South Africa, China, Iraq) and associate members from Brasil, Israel and Taiwan. INSHORE comprises ten Working Group members and five Associate members spanning early to mid career international researchers (Mieszkowska, Broitman, Harley, Russell, Sarà, Dong, Kroeker, Lima), and international experts in global change biology running research institutes and university departments (Helmuth, Williams, McQuaid, Fawzi).

The membership of leading scientists in global change impacts spans all major continents to ensure an international scope for the exchange of knowledge, data and expertise. The range of expertise from molecular genetics through physiology, biology, ecology to climate modeling will ensure exchange of knowledge and skills between participants and nations. SCOR Working Group funding would allow the individual members to foster long-term collaborative working relationships and facilitate continued exchange of skills and expertise across developed and developing nations that would not be possible under other existing funding opportunities (e.g. research council or regional networking grants).

The group will present their contributions to an integrated multiple stressor research perspective at the Third International Symposium on Effects of Climate Change on the World's Oceans in Brasil, and host workshops to develop the integrated methodology and associated multiple stressor profiling model in Brasil, China and the UK. The Brasil conference will be attended by PICES and ICES member nations researchers ensuring an international scientific audience, as well as the international science-policy community via the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO). This global science-policy meeting is a high profile venue for the dissemination of the Working Group's activities and best practice integrated research programme.

Students from host and local institutes will be invited to interact with the global Working Group at these events, and Working Group members will give presentations on this project at host universities and associated research laboratories. These dissemination activities will promote the INSHORE project to the benthic research communities and early career scientists and students associated with the Working Group members and workshop host institutes in South and North America, Europe, Africa, Asia and Australasia.

An INSHORE project website will be set up with an associated blog and Twitter account to provide continuous dissemination of project activities and outputs, including the DEBM model methodology and code and the best practice guide that will be promoted as an integrated standard approach within the global change research community. The website will be linked to the SCOR website and all Working Group and Associate Member laboratory websites. This will provide a lasting, open access record of achievements and activities, and facilitate exchange and sharing of experimental approaches developed across member countries.

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Working Group composition
Full Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Nova Mieszkowska	Female	Research Fellow, Marine Biological Association of the UK	CoChair. PI, MarClim; most spatio-temporally extensive intertidal species time-series globally. Macroecological responses to multiple stressors. Mesocosm and field experimental physiology; responses to climate, OA, nutrients. PI
2 Gray Williams	Male	Director, The SWIRE Institute of Marine Science, University of Hong Kong	CoChair. 20+year experience in tropical intertidal ecology: field and laboratory approaches to physiological responses and impacts on local and regional community dynamics. Large-scale latitudinal projects
3 Brian Helmuth	Male	Director, Sustainability Science and Policy Initiative. Professor, College of Science, Northeastern	Ecological forecasting, physiological mechanistic responses to climate, thermal engineering technology, mathematical modeling.
4 Bernardo Broitman	Male	Director, Centro de Estudios Avanzados en Zonas Aridas, Santiago, Chile Associate Professor, Facultad de Ciencias del Mar, Universidad	Community ecology, responses of coastal organisms to climate. Environmental modelling, coastal oceanography. PI most extensive coastal observation network on the Southeast Pacific. Deputy Director, MUSELS multiple stressor research centre.
5 Christopher McQuaid	Male	Chair of Zoology and SARCHI Research Chair in Marine Biology, Rhodes University, South Africa	Substantial track record in ecology of benthic ecosystems, species interactions, invasive species, climate change. Importance of multiple stressors through multiple spatial scale experiments.
6 Chris Harley	Male	Associate Professor, Department of Zoology, University of British Columbia, Canada	Impacts of climate and OA on coastal ecology. Physiological responses of intertidal invertebrates and macroalgae.

7Yunwei Dong	Male	Professor, State Key Laboratory of Environmental Science, Xiamen University, China	Physiological and molecular (transcriptomics, proteomics) responses of intertidal invertebrates to multiple stressors.
8 Nadia Al-Mudaffar Fawzi	Female	Head of Department, Biological and at Marine Science Centre, University of Basra, Iraq	Impacts of anthropogenic stressors on coastal ecosystems. Eutrophication & water quality research programme.
9 Bayden Russell	Male	Southern Seas Laboratory, University of Adelaide, Australia	Experimental assessment of physiological changes and resultant ecosystem functioning due to eutrophication, CO_2,
10 Gianluca Sará	Male	Associate Professor, Department of Earth and Marine Science, University of Palermo, Italy	Experimental estimation of functional traits under multiple stressors to feed Dynamic Energy Budget models assessing life-history traits of bentho- demersal organisms.

Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Fernando Lima	Male	Centro de Investigação em Biodiversidade e Recursos Genéticos, Portugal	Biogeography of intertidal organisms, climatic reconstruction and analysis, modelling.
2 Kristy Kroeker	Female		OA impacts on marine invertebrates.
3 Ronaldo Christofolettii	Male	Instituto do Mar, Universidade Federal de São Paulo, Brasil	Trophic interactions within intertidal ecosystems.
4 Benny Chan	Male	Principal Scientist & Associate Professor, Coastal Research Laboratory, Academia Sinica, Taiwan	Intertidal, supply-side and larval ecology, biogeography of tropical intertidal invertebrates.
5 Gil Rilov	Male	Senior Scientist, National Institute of Oceanography, Israel	Community biodiversity, biogeography, benthic-pelagic coupling. Multiple stressor mesocosm and long-term field programme.

Working Group Contributions

Mieszkowska. International track record spanning biogeographical to molecular impacts of global change on intertidal species and ecosystems. PI and primary data collector of world-leading UK MarClim Project and New Zealand, Australian and Icelandic sister projects with associated extensive experimental mesocosm and field datasets for physiological impacts of multiple stressors.

Williams. Established the first trans-Chinese field time-series of biophysical and environmental sensor network within rocky intertidal habitats, leads internationally renowned SWIRE Institute research programme into multiple stressor impacts on intertidal systems.

Helmuth. World leader in thermal engineering, energetics and bioclimate research using intertidal ecosystems as a testbed for NASA and NSF funded climate modeling projects. Leads biophysical experimetnal latitudinal research projects along Atlantic coastline of USA.

Broitman. Internationally acclaimed bioclimate modeler, PI of most extensive Pacific intertidal time-series dataset, PI of Chilean research programme into multiple stressor impacts on marine systems.

McQuaid. South African National Research Foundation 'A rated' researcher with a global profile in environmental impacts on intertidal systems, McQuaid has held posts including Director of the Southern Ocean Group (SOG) at Rhodes University for 20 years, South African Research Chair (SARChI) in Marine Ecosystem Research at Rhodes University. Holds extensive datasets for South African intertidal.

Harley. Leading expert in field experimental research into impacts of climate change and ocean acidification on species physiology and ecology, community structure and functioning.

Dong. Driving cutting-edge physiological and molecular techniques for application to mechanistic research into responses of marine intertidal species to environmental stress. Leading the Chinese research drive into climate change impacts.

Fawzi. Leading authority in Iraq for water quality and impacts on coastal ecosystems. Heads research efforts into eutrophication and pollution research in the Persian Gulf system.

Russell. Expert in experimental testing of multiple stressor impacts on macroalgae and trophic interactions via development of state-of-the-art mesocosm systems. High impact publication record for climate change and ocean acidification impacts on macroalgae, with associated field and experimental datasets for Australia.

Sará. Developed dynamic energy budget models that have been adopted as the international standard for coastal marine invertebrate species. IPCC AR5 national reviewer and research co-ordinator for Italian-Asian binational research networks.

Relationship to other international programmes and SCOR Working Groups

INSHORE will link to existing international working groups and research networks via the proposed Working Group and Associate members. This will ensure wider knowledge exchange, continued dialogue and ensure complementarity without overlap between the various networks. These include:

- GRIEN Global Rocky Intertidal Ecology Network that involves field monitoring of intertidal biodiversity and environmental parameters, led by Dr Gil Rilov and involving Working Group members Mieszkowska, Williams, Helmuth, Sará, Harley and McQuaid.

• Ocean Acidification Network led by Dr Kristy Kroeker and involving Working Group members Russell and Harley.
• Millennium Nucleus Center for the study of multiple-drivers on marine socio-ecological systems - MUSELS, investigating the effects of environmental and socioeconomic drivers on the shellfish farming industry both in northern and southern Chile, PI Working Group member Broitman.

No current SCOR Working Groups are investigating global change multiple stressor impacts, but INSHORE will continue to monitor the activities of all Working Groups including WG137 that is collating large datasets on plankton distributions via an international database similar to the one planned for benthic species through INSHORE.

Key References

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Appendix
Five key publications per Working Group Member (author and co-authors who are also WG members highlighted in bold):

Mieszkowska

1. **Mieszkowska N.**, Burrows M., Pannacciulli, F. & Hawkins, S.J. 2014. Multidecadal signals within co-occuring intertidal barnacles *Semibalanus balanoides* and *Chthamalus* spp. linked to the Atlantic Multidecadal Oscillation. 10.1016/j.jmarsys.201211008.
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Williams

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Helmuth

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McQuaid

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Harley

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2.3.4 Patterns in global plankton biogeography (MARBIOG) Taguchi

Proposal for a SCOR working group on Patterns in global plankton biogeography

Abstract

Marine planktic ecosystems respond to changes in environmental conditions such as global warming and ocean acidification, but they also drive global biogeochemical cycles themselves. Thus, a major reorganization in plankton biogeography due to climate change will feed back onto climate and global biogeochemical cycling by modulating ocean CO2 storage and emissions of climatically important trace gases. Recently, the MARine Ecosystem DATa (MAREDAT) initiative brought together over 500'000 abundance and biomass measurements. For the first time, it is now possible to investigate plankton biogeography at the global scale, and within the context of a diverse set of applications from marine ecosystem model validation to applications in theoretical ecology. However, the MAREDAT data set is inhomogeneous, and has strong biases due to inconsistent sampling and data recording strategies. In order to fully understand plankton biogeography, a pairing with physiological trait data is essential. Here, we propose a SCOR working group on the analysis of plankton biogeography. The SCOR group would develop new protocols for the reporting and collection of global-scale planktic ecosystem data relevant for ocean biogeochemical cycles and macroecology, and would extend the current MAREDAT collection. We propose to include geo-referenced abundance/biomass and plankton physiological traits as well as biological rates in the next version of MAREDAT, and to analyse global patterns of plankton and trait biogeography across multiple trophic levels. We will synthesize data on both zooplankton and phytoplankton, develop tools to extrapolate scarce biological data to global scales, and compare global patterns of trait and plankton biogeography and diversity.

1. Scientific Background and Rationale

Anthropogenic climate change has been shown to impact marine planktic ecosystems in several crucial ways: On a global scale, the ocean is simultaneously undergoing warming, deoxygenation and acidification (Doney, 2010); that is, the ocean is "warming up, losing breath, and turning sour" (Gruber, 2011). Increased stratification in subtropical and temperate latitudes may limit nutrient availability and decrease primary productivity over this century (Steinacher et al. 2010). These changes may already be underway: the oligotrophic regions of the oceans appear to be expanding (Polovina et al. 2008), Pacific species have been shown to migrate into the Atlantic (Reid et al. 2001), zooplankton species shifts have been recorded in the North Atlantic (Beaugrand et al. 2004, 2008), and regime shifts have occurred in the Black and Caspian seas (Oguz & Gilbert, 2007). These and many more studies show that anthropogenic impacts affect ecosystems across multiple trophic levels and in many different ways (Doney et al. 2012).

Marine planktic ecosystems play an important role in the global biogeochemical cycling of key elements such as carbon, nitrogen and sulfur. Marine plankton form the base of the food web, and are of crucial importance for everything from the marine biological pump and ocean CO_2 storage to global fisheries and food security. Specific plankton groups produce nitrogen, sulfur and organohalide trace gases that can affect climate and atmospheric chemistry. Marine biodiversity forms a resource that is exploited in many industrial ways from the use of genes that code for low-temperature enzymes in detergents, to food supplies and animal food stocks. However, many marine ecosystem services related to global biogeochemical cycling, food provision and genetic diversity are still poorly quantified (Worm et al. 2006), since few aspects of marine ecosystem structure and composition are routinely monitored on the global scale. Thus, changes in marine ecosystem structure and functioning may crucially impact global climate and the livelihood of millions of people relying on marine resources. The FAO estimates that about one billion people worldwide rely on fish as their primary source of animal protein (FAO, 2000).

Recent advances in remote sensing now allow the estimation of different plankton functional types (PFTs) and size structure from space using water-leaving reflectance (Alvain et al. 2005, Hirata et al. 2008, 2011) or backscattering (Kostadinov et al. 2009, 2010), with prospects for long-term monitoring. However, most remote sensing algorithms have been validated using only a few hundred data points in limited ocean regions (e.g. Hirata et al. 2011, Alvain et al. 2012). Extensive sets of validation data are essential in order to use the high-resolution products to monitor patterns of change on the synoptic global scale. In order to quantify potential future change, ecosystem model simulations are required (Bopp et al. 2001, Hashioka et al. 2009, Steinacher et al. 2010). Marine ecosystem models are becoming increasingly complex (Follows et al. 2007), and the availability of trait data for their parameterization, and biomass data for their evaluation, is an important determinant in the rate of progress (Le Quéré et al. 2005, Litchman et al. 2006).

Recent years have seen an exponential increase in the availability of plankton trait data. Published phytoplankton trait data comprise maximum growth rates and nutrient, light and temperature responses (Klausmeier et al. 2004; Litchman et al. 2007, Litchman and Klausmeier 2008; Edwards et al. 2012; Thomas et al. 2012). Zooplankton trait data on size distribution, feeding strategies and behavioral patterns are also abundantly available (Forster et al. 2011, Kiørboe, 2008, Kiørboe 2011). Yet, an understanding of marine ecosystem structure and functioning based on first principles of ecology remains elusive, as high observational coverage remains limited to a few regions. In their recent review, Barton et al. (2013) suggest that an initiative to collect trait data in a concerted manner similar to MAREDAT is essential for further progress on the understanding of marine planktic ecosystem structure and functioning.

The MAREDAT2012 atlas of PFT abundance and biomass, compiled by members of this group, published publically available databases and peer-reviewed documentation. The analysis of the datasets is under way (Brun et al. in prep.; Vogt et al. in prep.; O'Brien et al., in prep.), and initial results reveal exciting insights into plankton biodiversity and biogeography. Yet, methodological and sampling biases are present, which need to be addressed in order to understand plankton community structure and its vulnerability to global change: (1) inconsistency in the reporting of species information, (2) bias due to inconsistent sampling methods, (3) seasonal and regional bias, and (4) does not include all existing data. While these issues were unavoidable in a first round of data collection, some can be addressed in a second round, and global standards can be set in a joint international effort.

In terrestrial ecosystems, trait and abundance measures have been combined into multiple indices of, for example, functional diversity, which is shown to relate to the magnitude of ecosystem services (e.g. Randerson et al. 2009; Clark et al. 2012). In order to quantify marine ecosystem services, a similar effort is necessary to understand, model and predict present and future changes in marine planktic ecosystems, and their consequences for ecosystem service provision. The systematic data collection we propose opens the door for a variety of different applications:

1. predict spatio-temporal patterns in species characteristics (Edwards et al. 2012, Thomas et al. 2012),
2. elucidate biodiversity patterns (O'Brien et al., in prep., Worm et al. 2006, Irigoien et al. 2004, Rutherford et al. 1999),
3. study the flow of matter across different trophic levels (Buitenhuis et al. 2013b),
4. study ecological niches of plankton species (Brun et al., in prep., Irwin et al. 2012),
5. investigate species and biome shifts in marine planktic ecosystems (e.g. Beaugrand, 2004, Beaugrand et al. 2008, Alvain et al. 2013),
6. assess global patterns of elemental ratios that are crucial for global biogeochemical cycling (Martiny et al. 2013),
7. determine the drivers of plankton biogeography (Dutkiewicz et al. 2012, Luo et al. 2014),
8. quantify ecosystem services related to global biogeochemical cycling, such as primary production (Buitenhuis et al. 2013b) nitrogen fixation (Luo et al. 2014), DMS production (Schoemann et al. 2005), and opal production and export (Sarmiento and Gruber, 2006),
9. calibrate remote sensing algorithms of phytoplankton groups (Alvain et al. 2012, 2013, Hirata et al. 2011).

1.3 Timeliness and relevance of the activity

The proposed activity is timely, as global data sets have only recently become available, and standards for their formats, archiving and quality control have not yet been set. Defining standards and joint interpretation will provide added value and will speed up research on the impact of climate change on marine ecosystems.

1.4 Relevance for SCOR sponsorship

This proposal addresses a topic at the forefront of current marine ecosystem research, focusing on global patterns of marine biogeography and potential changes in marine ecosystem structure and functioning, and will solve essential methodological and ecological questions that would otherwise remain unanswered were it not for the synergy between MAREDAT, international data archives such as ICSU's World Data System, GBIF, EMODnet and others, and the physiological/ecological trait communities that a SCOR working group provides on an international level. It would allow the participants to address ecological questions across multiple trophic levels by specifically tailoring the new plankton atlas to the scientific questions it aims to address. The working group would allow the combination of global scale information on ecosystem function and trait biogeography with information on community structure and plankton distribution, for example to address the role of biodiversity and functional diversity for ecosystem functioning and ecosystem service provision.

2. Terms of Reference

The proposed working group would

(1) summarize and assess the current availability of experimental and field measurements of plankton abundance, biomass, pigments and traits,
(2) collaborate with data archives such as PANGAEA, BCO-DMO, and COPEPOD, and with SeaDataNet, the ICSU World Data System, the IMBER data management group, EMODnet, GBIF and others in order to develop and publish a comprehensive *Guide of standard protocols and best practices for the compilation of plankton data*, including specifications about data citation, geolocation, collection methods, standard parameter vocabularies & units, and quality control
(3) publish a new open access atlas of marine plankton abundance and biomass data (MAREDAT2017) and a collection of geo-referenced and in situ life history and physiological trait data across multiple trophic levels in marine ecosystems.
(4) develop and disseminate new methods to interpolate scarce biological data to scales relevant to address important concepts of theoretical ecology and to quantify important ecosystem services provided by marine ecosystems, using statistical tools from terrestrial ecosystem research and important concepts of theoretical ecology, and the quantification of important ecosystem services.
(5) generate a knowledge base of taxon-specific and phylogenetic-specific traits for the full size spectrum of plankton, i.e. from viruses to large planktonic metazoans and inform the observational community of our data needs and current gaps in our understanding of marine ecosystem structure and functioning.
(6) joint analyses of global patterns in trait and plankton biogeography and diversity and their role for marine ecosystem functioning across multiple trophic levels.

3. Working Plan

The workflow is broken down into 3 work packages.

Work package 1. Synthesis of plankton biomass data and plankton biogeography: WP1 will produce an update of the MAREDAT2012 first global atlas of marine plankton functional type abundance and biomass data in 2017. MAREDAT2017 will contain at least 14 contributions: updates of the 12 databases in MAREDAT2012 for diatoms (Leblanc et al. 2012), coccolithophores (O'Brien et al. 2013), nitrogen fixers (Luo et al. 2012), *Phaeocystis* (Vogt et al. 2012), picophytoplankton (Buitenhuis et al. 2012a), bacteria (Buitenhuis et al. 2012b), micro- (Buitenhuis et al. 2010, 2013a), meso- (Moriarty and O'Brien, 2012) macrozooplankton (Moriarty et al. 2013), pteropods (Bednarsek et al. 2012) and planktic foraminifers (Schiebel and Movellan 2012), as well as HPLC pigments (Peloquin et al. 2013). In addition, an update of the World Ocean Atlas Chlorophyll *a* database (Conkright et al. 2002) will be included, as well as a new database on autotrophic/mixotrophic dinoflagellates. We will also solicit contributions on gelatinous plankton, virioplankton and planktic species in palaeoceanographic sediment records.

Work package 2. Synthesis of plankton life history traits: WP2 will generate a knowledge base of taxon-specific traits for the full size spectrum of plankton (MARETRAIT), which will be included in the taxonomic register WoRMS. WP2 will produce comparisons of phytoplankton and zooplankton traits across size classes, and of trait biogeography across multiple trophic levels. The zooplankton traits will include grazing rate and respiration rate as a function of temperature, assimilation and gross growth efficiency, and DOM exudation (Buitenhuis et al. 2006, 2010, Kiørboe and Hirst 2014). The phytoplankton traits will include intra- and inter-PFT changes in growth rate with cell size (Le Quere et al. in prep.), temperature dependence of growth rate (Buitenhuis et al. 2013b; Thomas et al. 2012) and nutrient uptake traits (Klausmeier et al. 2004; Litchman et al. 2007, Edwards et al. 2012). This WP will also address the issue of compatibility between geo-referenced and laboratory trait data, and develop recommendations for the collection, reporting and use of these different data types.

Work package 3 Understanding marine ecosystem structure and functioning: WP3 will combine trait and biomass data to further our understanding of marine ecosystem function. It will develop and test statistical techniques for the extrapolation of scarce biological data to larger scales, using methods common in species distribution modeling. It will build on the MAREDAT2017 and MARETRAIT datasets, and the EURO-BASIN special issue which includes key links between planktic systems and ecosystem services. WP3 will quantify fluxes between the different trophic levels, and assess links between different forms of diversity and the magnitude of ecosystem services related to biogeochemical cycling and food-web dynamics. WP3 will also identify gaps in our understanding of marine ecosystems and associated data needs, and publish a joint paper on this issue.

Pre-meeting: The members of the proposed SCOR working group will attend the IMBER Open Science Conference in Bergen in June 2014, but it will not rely on SCOR funding. A pre-meeting will take place after a common session between the trait and biomass community on: “Data synthesis and modeling of marine planktic ecosystems with plankton functional types and trait-based models”. This session invites discussion between members of trait ecology and plankton biogeography on how to combine abundance and biomass data with trait and pigment data, and how to link them for a better quantification of ecosystem services.

Kick-Off Meeting: In order to provide international visibility and assure high attendance, the kick-off meeting would coincide with a relevant international conference, probably the ASLO Aquatic Sciences meeting in 2015 in Granada, Spain. We will organize a 2-day workshop after the meeting where data collection strategies will be coordinated.

Further meeting: A second business meeting would be organized in 2016 during the Ocean Sciences conference in New Orleans. During this meeting, the progress of data collection and publication would be reviewed, and the guidelines for data standards re- evaluated.

Workshop: In the beginning of 2017, the proposed SCOR working group would host a workshop at the University of East Anglia. WP1 will discuss ongoing and new scientific collaborations to exploit the MAREDAT2017 databases (e.g. ecological niche determination, gap filling algorithms, bottom-up / top-down interactions). WP2 will finalise the zooplankton trait intercomparison and discuss the phytoplankton trait intercomparison. Both groups together will discuss mathematical tools to constrain PFT traits using biogeochemical models evaluated against the MAREDAT2017 databases. Furthermore, the group will coordinate the analysis of the collected data, i.e. identify lead authors for the planned set of synthesis papers. During the workshop, the group would generate an outline for the community white paper on our current understanding of marine ecosystem structure and functioning.

Final meeting: In 2018, members of this SCOR working group would meet either at the Ocean Sciences 2018 or at the ASLO meeting, and coordinate further joint analysis of the data collected.

Timeline of Milestones

Year 1 (2015):

A) Synthesis of protocols specific for each data type, method and plankton group (WP1&2).
B) Identification of ecological, physiological and morphological traits with sufficient data coverage, in space and time, to be included in MARETRAIT2017 (WP2).
C) Development and dissemination of guidelines for quality control (WP1&2). D) Data call for MAREDAT2017 (WP1).

Year 2 (2016):

A) Data collection for the different plankton groups to be included in MAREDAT2017 (WP1).
B) Submission of individual MAREDAT2017 datasets and papers. (WP1).
C) Inclusion of taxon-specific traits in the taxonomic register WoRMS (WP2).

Year 3 (2017):

A) Publication of a standard protocols and software (WP1&2) B) Workshop at UEA (WP1&2&3)
B) Papers analyzing phyto- and zooplankton trait biogeography across different PFTs (WP2)
C) Open access publication of final MAREDAT2017 papers and databases (WP1).

Year 4 (2018):

A) Submission of methods paper to interpolate scarce and highly variable biological data sets to larger scales (WP3).
B) Submission of a paper analyzing and comparing MAREDAT2017 biomass data across different taxonomic groups and trophic levels (WP1&3).
C) Submission of a paper analyzing links between phyto- and zooplankton biogeography and their respective patterns in trait distribution across different PFTs (WP3)

4. Deliverables

The main final products of the SCOR working group are the updated MAREDAT2017 atlas of global plankton biogeography by the end of 2016, consisting of a set of at least 14 papers on plankton abundance, biomass and pigment data; and a new MARETRAIT2017 atlas, with at least two papers on geo-referenced/laboratory trait data for zooplankton and phytoplankton and three synthesis papers that analyse the MAREDAT and MARETRAIT databases across all groups and links between plankton biogeography and global patterns in trait distribution. A guide will be published with data format and quality control recommendations, including taxonomic specification, and standard units for abundance, biomass, pigment and trait data to make them suitable for a wide set of applications in biological oceanography and marine ecosystem modeling. Common software will be created and published on the MAREDAT website (www.maredat.info) that handles (1) the quality control procedure, (2) the generation of gridded products, and (3) routines for the interpolation of data to larger scales using novel techniques (e.g., Lana et al. 2011; Landschützer et al., 2013). A white paper will be written by the end of year 3 that identifies gaps in our current understanding of marine ecosystem structure and functioning, and details the data needed to address these. A joint interpretation of the data and recommendations will also be highlighted in a high-profile publication written by the group in year 4.

5. Capacity building

From a socioeconomic perspective, many issues in current marine ecosystem research, such as the quantification of potential impacts of global change on marine ecosystem service provision is highly important for developing countries and economies in transition. The results of the proposed activity will inform policy makers and the public on potential hotspots of ecological change, and on locations with a high degree of diversity. The proposed SCOR working group would bring together the MAREDAT community with other marine ecologists, data archives, marine ecosystem modelers (e.g. MAREMIP initiative), and members of the remote sensing community. These communities have a common goal – the understanding of present and future marine ecosystem structure and functioning – but are currently not linked through an international working group. The SCOR working group would thus facilitate the important exchange of ecosystem data between different ecosystem researchers working toward a common goal. For example, the remote sensing community may require data for the evaluation of their algorithms, while marine ecosystem modelers will need physiological rates/trait data to implement further complexity into their models. A SCOR working group would also lead to the identification of data requirements and needs by these different communities, and how MAREDAT could accommodate a maximal set of such needs through sensible and simple data standards. Bringing these diverse communities together around a table would also increase the international visibility of marine ecosystem research, and will lead to future collaboration, ideas and findings. The SCOR working group would also increase efficiency in the expansion and establishment of global plankton data sets. The MAREDAT community already has experience with the generation of a global plankton atlas, and this know-how can be exploited by the trait community to collect and archive data more effectively. In addition, close contacts will be established with members of the terrestrial ecosystem community through the use of statistical tools and concepts that are common in terrestrial ecosystem research. Building necessary capacities in developing countries can be fostered by providing access to open- source data, best practice manuals and standard protocols that will augment access by members from countries with limited financial and infrastructural means to generate their own data. Additional funding would be requested from SCOR's travel grant program to finance the attendance of at least one additional young scientist from a developing country to attend international meetings, whenever the proposed SCOR group members meet. Thus, young scientists would be trained in essential networking and technical skills while being introduced to leading international members in the field.

6. Working Group Composition

Full members, chairs in bold

Name		Place of work	Expertise
Meike Vogt	F	ETH Zürich, Switzerland	Phytoplankton ecological niches and biogeochemistry, global plankton biogeography
Erik Buitenhuis	M	University of East Anglia, UK	Plankton ecology, global biogeochemical modelling, macroecology
Simon Claus	M	Flanders Marine Institute	Biodiversity patterns. Contact with EMODnet and WoRMS
Forough Fendereski	F	Gorgan University, Iran	Plankton biogeography and marine biomes
Takafumi Hirata	M	Hokkaido University, Japan	Detection of plankton functional groups from space
Xabier Irigoien	M	King Abdullah University of Science and Technology, Saudi-Arabia	Marine ecology, biodiversity
Thomas Kiørboe	M	DTU-Aqua, Denmark	Zooplankton ecology and traits
Elena Litchman	F	Michigan State University, USA	Phytoplankton ecology and traits
Yawei Luo	M	Xiamen University, China	Nitrogen cycling, traits of nitrogen fixers
Maria Deng Palomares	F	World Fish Centre, Philippines and University of British Columbia, Canada	Fish population dynamics

Associate members

Andrew Barton	M	Duke University, USA	Lower trophic level trait ecology, ecological modelling
Karine Leblanc	F	MIO CNRS, France	Diatom biology and silicon cycling
Stephane Pesant	M	Bremen University, Germany	Biological data collection, integration and publishing
Ralf Schiebel	M	University of Angers, France	foraminifera and palaeoceanography

7. Working Group Contributions

7.1 Full Members

1. **Meike Vogt**: Co-coordinator of MAREDAT2012 & 17. Collection of standardized plankton data for use in biological oceanography and ecosystem modeling. Standard protocols and data collection for use in model validation and marine ecology. Species distribution modelling and phytoplankton macroecology. Member of MAREMIP SSC.
2. **Erik Buitenhuis**: Co-coordinator of MAREDAT2012 & 17. Marine ecologist. Ecosystem model development and evaluation. Macroecology, interactions between biogeochemical cycles and both autotrophs and heterotrophs.
3. **Simon Claus**: Coordinates the biology project of EMODnet. Data management in the Belgian NODC, trait and abundance cross-referencing.
4. **Forough Fendereski**: Marine ecologist working on plankton biogeography and on neural networking methods for the definition of marine biomes. Intelligent clustering and interpolation of marine ecosystem data.
5. **Takafumi Hirata**: Detection of plankton functional groups from space / remote sensing. Member of the MAREMIP SSC.
6. **Xabier Irigoien**: Plankton ecology, trophic relations in plankton, climate effects and biodiversity patterns.
7. **Thomas Kiørboe**: Zooplankton traits, quantification of ecosystem services.
8. **Elena Litchman**: Phytoplankton community ecologist, plankton trait data. Interpretation of patterns from first principles and the combination of trait and abundance data.
9. **Yawei Luo**: Ocean nitrogen cycling. Traits and global biogeochemistry of nitrogen fixers. Member of MAREDAT
10. **Maria Deng Palomares**: Fish population dynamics and fish data. Coordinator of SeaLifeBase, which aims to provide a 'FishBase-like' database for all other marine organisms that are not included in fish databases.

7.2. Associate Members

1. **Andrew Barton**: Ecosystem modeler and trait ecologist. Global marine lower trophic level trait data, combination of abundance and trait data.
2. **Karine Leblanc**: Marine biology with a focus on diatoms and biogeochemical flux measurements.
3. **Stephane Pesant**: Plankton ecology, editor for biological data at PANGAEA, and advocate for citation, open access and reuse of scientific data. Stephane is a member of Tara Oceans, SeaDataNet, and EMODNet Biology, and was guest editor for MAREDAT 2012 Atlas.
4. **Ralf Schiebel**: Foraminifera and palaeoceanography. Long-term changes in marine ecosystem structure and functioning, with a focus on calcifying organisms.

8. Relationship to other international programs and SCOR Working groups

The proposed working group would allow knowledge transfer from SCOR working groups 125 (Global Comparisons of Zooplankton Time Series) and 137 (Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Comparative Analysis of Time Series Observation), but it would focus on open ocean and global scale patterns of both autotrophic and heterotrophic constituents of lower trophic level ecosystems, and the combination of different data types. We will work closely with the World Register of Marine Species (WoRMS), in particular for the review of ecological and biological trait information that is being coordinated in the European Marine Observation and Data Network (EMODnet). We will work closely with ICSU's World Data System, in particular with its thematic data center PANGAEA, where the MAREDAT atlases are published. Biogeographic data published at PANGAEA are cross-linked with registers for taxonomy (WoRMS) and are served/disseminated to SeaDataNet, GBIF, OBIS and EMODNet. The working group would facilitate data exchange on marine planktonic traits, presence/absence data, and methodologies to interrogate the databases to define biogeographies ecological niches and to quantify functional diversity.

9. References (Full member references in Appendix)

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2.3.5 Radioactivity in the Ocean, 5 decades later (RiO5) **Volkman**

Summary Abstract

Over the past 50 years, natural and anthropogenic radionuclides have been instrumental in addressing many important questions in oceanographic research. Yet knowledge gaps remain regarding their spatial and depth distributions and the temporal evolution of many radionuclides of importance to both oceanographic and human health issues. The Fukushima Dai-ichi disaster has also recently heightened public and policy concerns related to the human health effects of radioactivity attributable to external exposure from ocean contact and internal exposure from seafood consumption. The timing is thus right for a new SCOR Working group- "Radioactivity in the Ocean, 5 decades later". The goals of RiO5 are to synthesize in a series of papers, the latest scientific insights that have been gained from new global databases on natural and artificial radionuclide distributions, and to identify gaps in our current understanding and scientific knowledge of marine radionuclides. We also plan to create an online compilation of papers and lectures related to radioactivity in the marine environment that will assist in the education and training of the next generation of marine radiochemists and radioecologists. At the same time, we will develop tools to enhance public understanding of radioactivity. Finally, we will assist in the organization of an international symposium that would bring together academic, nuclear power industry and national laboratory experts working in this area.

Scientific Background and Rationale

The very first SCOR Working Group #1, entitled Radioactivity in the Ocean, was formed in 1958 and met in 1959. Chaired by the Japanese scientist, Dr. Yasuo Miyake, the primary objectives of WG1 were to standardize and improve analytical methods and coordinate world-wide measurements of artificial radioactivity. Indeed, when referring to radioactivity, most still focus on the immediate detrimental impacts of anthropogenic radiation and issues related to contamination. Yet since that time, there has been considerable advancement in the field of marine radioactivity, not only in the measurement and application of artificial radionuclides, but also of cosmogenic and U-Th series radionuclides to study ocean processes. Several SCOR WGs have taken advantage of these advances, such as in the use of thorium-234 as a particle export tracer (WG#116) and radium isotopes in the study of submarine groundwater discharge (WG#112). Many other radionuclides are instrumental in geochronology (^{210}Pb, ^{14}C, ^{137}Cs) or in studies on present and past ocean circulation (^{3}H, ^{129}I, ^{230}Th/^{231}Pa). Regardless of the application, it is necessary to understand: i) the evolution of radionuclide sources (both natural and anthropogenic) over a range of temporal and spatial scales, ii) how to use their inherent geochemistries and decay rates to answer a wide range of oceanographic questions and iii) the potential human health effects of radionuclides in the marine environment.

We propose a SCOR Working Group to look at Radioactivity in the Ocean, 5 decades later (RiO5). RiO5 would provide a comprehensive evaluation of our current knowledge of radioactivity in marine systems. RiO5 would be comprised of an international consortium of radiochemists and ecologists whose major focus will be on increasing scientific and public understanding of the sources, fate, and applications of natural and artificial radionuclides in marine systems. This will be accomplished through updating and improving access to radionuclide databases, providing a synthesis and review of radionuclide distributions, and developing a strategic plan for filling missing knowledge gaps.

The timing is right for RiO5 for many reasons. In the aftermath of the Fukushima Dai-ichi disaster – and after years of relative complacency – the public and policymakers have new, heightened concerns about radioactive contamination and potential human health concerns. We are also still limited by where radioactive wastes may be stored, due to perceived and real threats to environmental safety. Nuclear- fueled ships and submarines ply our oceans. The number of nuclear power plants worldwide (>430) is expanding in many countries and is likely to continue as we replace other forms of power that produce greenhouse gases. There are continued concerns regarding the spread of nuclear weapons and "dirty" bombs. Yet, at the same time, Cold War-era nuclear scientists and radiochemists have retired, creating a need for training the next generation of marine radiochemists and radioecologists. As this is happening, a new global view of natural and artificial radionuclides is emerging through programs such as the SCOR sponsored international GEOTRACES program. Although the isotopes measured by GEOTRACES are a limited set, this is the first such effort since the GEOSECS Program that mapped several radionuclide distributions in the oceans in the 1970's. Indeed, the time elapsed between both major efforts appear as a unique opportunity to examine not only how specific radionuclide inventories have changed, but what those inventory changes mean with regards to their marine geochemistry and implications for global biogeochemical cycles (e.g., Moore et al., 2014).

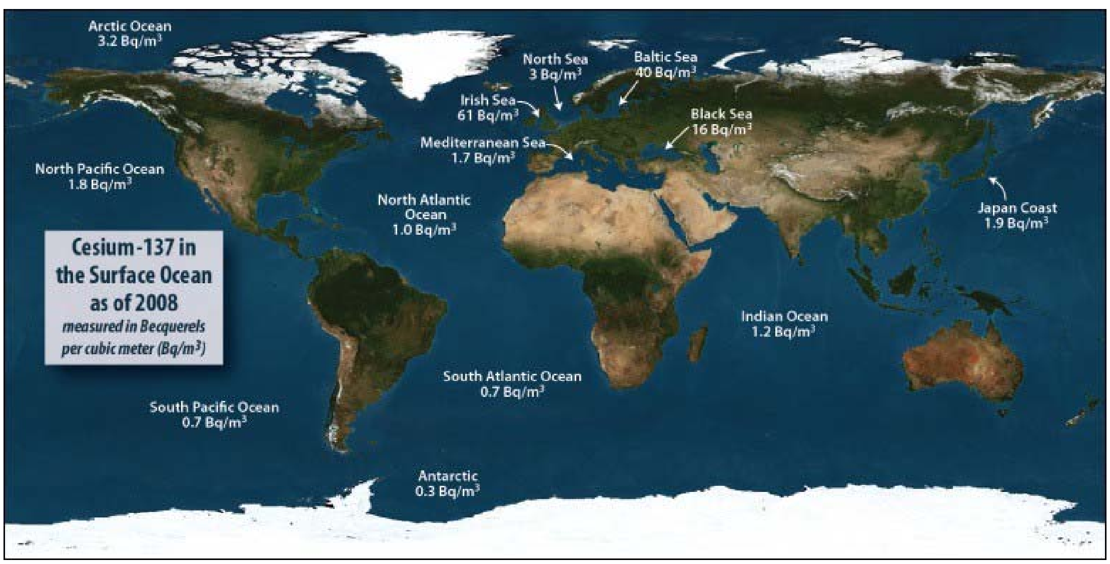

Figure 1. Example of recent compendium of ^{137}Cs activities in marine systems prior to the Fukushima accident. Data source: http://maris.iaea.org Available at: http://ourradioactiveocean.org

One example of the value of such a review of current knowledge is shown here by summarizing the global distribution of ^{137}Cs in the surface ocean (Figure 1). One can immediately observe the following: 1) 1960's fallout ^{137}Cs is rather uniform globally, with slightly higher values in the Northern Hemisphere (due to location of weapons testing) at background levels of 1-2 Bq m^{-3}; 2) higher levels from Chernobyl fallout in the Baltic and Black Seas (20-40 Bq m^{-3}); and 3) perhaps the most surprising, or at least less well known, is that the Irish Sea still maintains the highest ^{137}Cs levels in the ocean due to prior nuclear fuel reprocessing releases from Sellafield. This map further enables the establishment of a baseline for oceanic ^{137}Cs activities prior to Fukushima. In contrast to these levels, ^{137}Cs in the ocean peaked at over 50,000,000 Bq m^{-3} close to the reactors in April 2011 (Buesseler et al., 2012), which was of direct concern to human health and marine biota, and far higher than the concentrations observed after weapons testing or the Chernobyl accident. Three years later, the public remains concerned about the predicted ^{137}Cs activities of 10-30 Bq m^{-3} within the Fukushima plume approaching the west coast of North America (Rossi et al., 2013). However, these predicted activities are in fact lower than that found today in some of the world's oceans and should not cause any measureable impact on human health. Compilations of global baselines such as that shown in Figure 1 are clearly necessary and allow for such assessments to be made. This and other maps are part of the first steps of RiO5.

Figure 2 is an exciting example of a natural radionuclide data set only recently available online as part of the GEOTRACES Program. While variable and high dissolved ^{210}Pb activities in surface waters are expected due to atmospheric inputs, high activities of ^{210}Pb at depth not only suggest substantial remineralization of sinking particles, but an additional source of ^{210}Pb that has not been previously observed (using mass balance). Such profiles therefore demonstrate how ^{210}Pb may be used to examine sources and cycling of other stable trace elements of similar particle reactivity that are more difficult to assess from their concentrations in seawater.

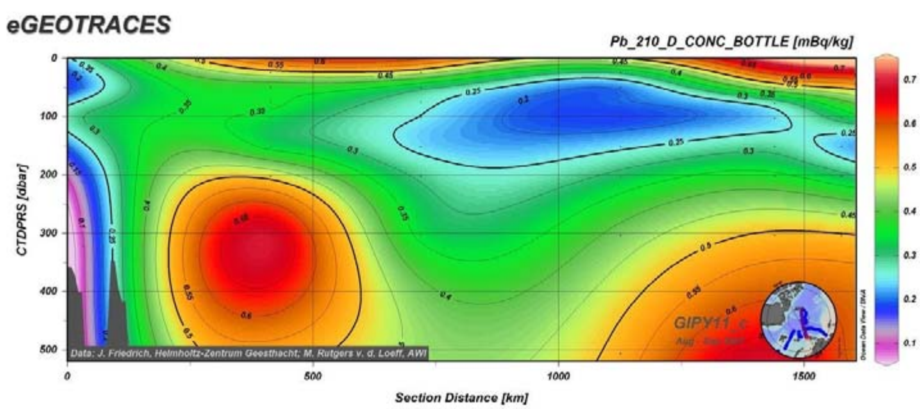

Figure 2. Example of radionuclide data available online as part of the GEOTRACES Program. Data source http://www.egeotraces.org/

A final example showing the strength of pairing natural and artificial radionuclides is from Charette et al. (2014), who used ^{224}Ra as an indicator of coastal water ages (time since contact with sediments and/or groundwater) and found that in samples collected in 2013, the activities of ^{137}Cs near the coast of Japan remained higher than those offshore, similar to ^{224}Ra. Using a mass balance approach they estimated that continued release of ^{137}Cs from the Fukushima NPP site must be occurring (9 GBq per day), a key unknown in the ongoing evaluation of Fukushima ocean impacts.

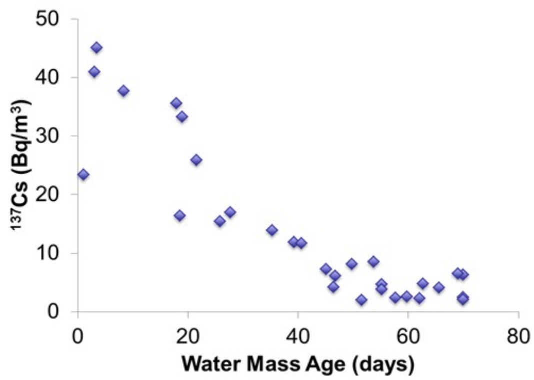

Figure 3. Plot of water mass age derived using ^{224}Ra versus ^{137}Cs activity off the coast of Japan. Source: Charette et al., 2014

These examples illustrate the breadth of new insights obtainable by synthesizing current radionuclide data sets (Figure 1); exploring new features in global transects (Figure 2); and combining studies that include both natural and artificial radionuclides (Figure 3). In addition, tremendous technological developments over the past decade have enabled the measurement of natural and artificial radionuclides at previously unattainable levels. This has revolutionized the radiochemistry field and has been instrumental in discovering new applications of radionuclides to address many important questions in oceanographic research.

RiO5 will bring experts together to review the current knowledge of radioactivity in marine systems and explore and identify research areas where new uses of radionuclides as tracers will be instrumental. These processes include: 1) understanding the global ocean carbon cycle with regards to sources of carbon to marine systems (gas exchange, riverine and ground water, hydrothermal vents, etc.) , *in situ* cycling (nutrient turnover), the transport of material from the surface ocean to depth (biological pump- mediated particle export and remineralization), and burial in marine sediments (months to millennia); 2) understanding ocean circulation in current and paleo climates from coastal ocean currents to large-scale tele-connections between various ocean basins; and 3) understanding contaminant sources, transport and removal of not only the radionuclides themselves, but other elements of similar chemistries, such as bioactive and particle reactive trace elements measured in the GEOTRACES program, some of which have their own pollution concerns (Pb, Hg, Cu, etc.).

Terms of Reference

We propose that SCOR establish a working group called “Radioactivity in the Ocean, 5 decades later (RiO5)” with the following terms of reference:

1. Combine and build upon existing global and individual databases of natural and artificial radionuclide distributions to make an user friendly and easily accessible on line product;

2. Summarize and publish review papers on these global radionuclide datasets and provide examples of how these can help improve our understanding of ocean processes and contaminant fate and transport;
3. Identify gaps in scientific knowledge in relation to radioactivity in the marine environment;
4. Bring together academic, nuclear industry and national laboratory expertise for an international symposium on radionuclides in the ocean;
5. Provide a warehouse of education materials to assist in the education and training of the next generation of marine radiochemists and radioecologists;
6. Develop tools to enhance public understanding of radioactivity, in particular in the ocean.

These activities would be achieved by convening WG meetings (1 per year for 3 years), exchanges among WG Members, building web-based informational resources, writing scientific manuscripts, and finding resources and partners for hosting a large international symposium.

Working plan

This Working Group is envisioned as a three-year activity that we hope will have a legacy beyond the funded study, to create a trusted resource for the ocean sciences and environmental community on matters related to radioactive substances, sources, and wastes in the oceans. The time-line delineated below outlines the major steps and their order to reach the deliverables (see below) according to the defined terms of reference. The timeline does not include much of the between-meeting activities and communications that are important to keep the WG going, which will be the responsibility of the two co- chairs to maintain.

Year 1

WG meeting #1- hosted by M. Dai, Xiamen U. (partial financial support in place through Xiamen U.). In conjunction with WG meeting, a two-day training workshop will be considered as part of the WG capacity building efforts (see Capacity Building below).

- Charge to WG participants- gather information on existing and ongoing radionuclide data bases, such as Marine Information System (MARiS) (IAEA- Morris lead), HAM (Japan-Aoyama lead) and GEOTRACES (Schlitzer Associate Member lead). Use Ocean Data View tools for visualization and use these data to develop global distribution maps (see Figure 2 as example)
- Outline synthetic papers to present the current state of the global oceans for natural and artificial radionuclides, based on the combined datasets achieved above. Spatial distributions and evolution as well as a global overview of potential risk will be the focus of the artificial
- radionuclide datasets, while objectives for naturally occurring radionuclides include their relevancy with regards to applications and newly available tools
- Discuss challenges and frontiers in marine radiochemistry and radioecology
- Discuss plans for WG web site and how to expand and build and disseminate education materials for public and students. Use WHOI's Center for Marine and Environmental

Radioactivity site as host and model of similar activities (http://www.whoi.edu/cmer ; web site costs supported by CMER)

- Introduce plans for an international symposium on marine radioactivity. Decades ago, similar efforts were hosted by UK (MAFF) and French (IRSN) ministries in Cherbourg in 1996 (Radionuclides: a tool in Oceanography 1987; Radionuclides in the Ocean- RADOC 96). IAEA has been approached to help support and host the symposium and welcomes additional discussion upon SCOR funding of this WG.

Year 2

WG meeting #2- hosted by K. Buesseler (WHOI meeting facilities support in place); possible alternative is to hold in conjunction with international meeting such as Ocean Sciences to increase participation by Associate Members.

- Review progress done on the database efforts
- Review synthesis papers and prepare for publication
- Develop list of future challenge and areas of need
- Planning for international symposium on Radionuclides in the Ocean, including promotion and organizing co-sponsorship
- Review education and public outreach materials and discuss submission of e-lectures, fact brochures, hands on activities for primary and secondary education and coordinating ongoing hands-on training by various international groups of the next generation of radiochemists

Year 3

WG meeting #3- in conjunction with international symposium.

- International Symposium- collect extended abstracts & manuscripts
- Post conference publication/book and organize associated papers in open access format such as a **Frontiers Research Topic** (http://www.frontiersin.org/blog/What_is_a_Frontiers_Research_Topic_/620)
- Final preparation of wide release of educational materials- for both student and public audiences

Deliverables

1. Connect all available data bases via the IAEA's MARiS portal, including data collected via the GEOTRACES and HAM data bases and individual studies. MARiS is a publicly accessible database in the same spirit embraced by GEOTRACES (http://www.egeotraces.org/) and various time-series programs (HOT (http://hahana.soest.hawaii.edu/hot/hot- dogs/interface.html), PAPA (http://oceanobservatories.org/infrastructure/ooi-station- map/station-papa/), etc.) (WG Members lead: Morris, Aoyama, Masque; Associate Member: Schlitzer)

2. Review papers on ocean radionuclide distributions and future challenges in their measurement and application. (All WG Members)
3. Production of education tools at the primary school, undergraduate, and graduate level. This includes eLectures (http://www.aslo.org/lectures/), online course materials based on courses already being taught by SCOR WG Members (e.g. Johnson, 2014)
4. Public communication and dissemination (web tools and fact sheets) that include basic information on radiation literacy and marine radioactivity using lessons learned from Fukushima to motivate and attract attention (see example at http://www.ourradioactiveocean.org/) (WG Members lead: Benitez-Nelson, Masqué, Buesseler; Associate Member: Johnson)
5. International symposium in year 3 - Radionuclides and Marine Processes – attended by academia, industry, national laboratories, with published scientific abstracts, following the model of the MARC Applications of Radioanalytical Chemistry Conferences. Seek partnership with IAEA (WG Member- Morris) and other EU sponsors (WG Members lead: Oughton, Charmasson, Delfanti) and US private foundations (WG Members lead: Buesseler, Benitez- Nelson)

Capacity Building

Members will participate individually and collectively in efforts to increase public and scientific understanding of marine radioactivity and radioecology. This SCOR WG will seek financial support as needed from the national agencies of WG Members, international organizations like the IAEA and IOC/UNESCO and groups such as, IUR, etc. and private funding sources. By developing tools for web based training, the next generation of graduate students will be exposed more readily to the concepts needed to understand radioactivity and radioecology in the marine environment. By increasing interactions among WG Members and knowledge of national programs, student exchanges and mentoring and sampling opportunities will be enhanced. With web-based sources to promote public understanding about radioactivity and open-access publication of synthesis papers and symposium volumes, there will be new resources to help expand the field and provide information to the public and policy makers.

Activities will include the web-based education materials and documents as well as online courses explained above. But more specifically, RiO5 will also work to

- Coordinate short term training of both junior and senior researchers at WG Member laboratories
- Facilitate participation of young researchers in oceanographic cruises to be trained in sampling and analyses
- Seek and facilitate appropriate ways of funding for young researchers, for attending research conferences, short-term stays at research centers or PhD or postdoc fellowships
- Approach the IAEA for Technical Cooperation for developing countries. Some of RiO5 Members already collaborate with the IAEA on this and the WG can work with the IAEA to identify future requirements for capacity building
- Pursue capacity building for developing country scientists through participation of developing country scientists in WG, holding first meeting in China in conjunction with a

two-day training workshop, and seeking assistance from SCOR to involve participation of developing country scientists in WG activities

- Routine activities of outreach activities are also anticipated through national and regional user groups, such as COSEE China (China Ocean Science Education Excellence Partnership) which is officed at Xiamen U.

Working Group Members

Full Members of this Working Group were selected based upon their scientific contributions, participation in educational activities, leadership as evidenced by participation and chairing national and international committees and symposium, editorships, career awards and recognition, experience in launching new initiatives and a willingness to participate in public and policy discussions on important issues related to marine radioactivity and radioecology. Proposed WG Members were also chosen to be widely representative of international expertise in the field and to span a range of skills and knowledge in marine radiochemistry and radioecology. Associate Members were considered important to expanding that scientific and regional expertise, and will be invited when possible to join us at WG meetings and will be called upon between meetings to assist with specific WG deliverables, as needed.

Full Members

Name	Gender	Place of Work	Expertise
Ken Buesseler*	M	WHOI, USA	Marine radiochemistry, C cycle, public education, GEOTRACES
Minhan Dai*	M	Xiamen U., China	Coastal biogeochemistry, radionuclide applications, GEOTRACES
Michio Aoyama	M	Fukushima U., Japan	Marine radiochemistry, global nutrient cycling
Claudia Benitez-Nelson	F	U. So. Carolina, USA	Marine radiochemistry, methods and teaching
Sabine Charmasson	F	IRSN, France	Radioecology of natural and artificial radionuclides
Roberta Delfanti	F	ENEA, Italy	Radionuclides as ocean tracers of physical processes
Pere Masqué	M	UAB, Spain	Environmental radioactivity and nuclear physics, GEOTRACES
Paul Morris	M	IAEA, Monaco	Radium and thorium isotopes and radionuclide databases
Deborah Oughton	F	NMBU, Norway	Radioecology and radioecological risk assessments
John Smith	M	BIO, Canada	Radionuclides in Arctic and other basins

* = co-chairs

Associate Members

Name	Gender	Place of Work	Expertise
Andy Johnson	M	Black Hills State Univ., USA	Teaching radiation literacy
Reiner Schlitzer	M	AWI, Germany	Data management and visualization, GEOTRACES database lead
Gary Hancock	M	CSIRO Australia	Soil erosion and sediment transport
José Godoy	M	PUC, Rio de Janeiro, Brazil	Ra, Po, Pb isotopes and groundwater discharge
Nuria Casacuberta	F	ETH, Switzerland	Sr, U and other radionuclide tracers
Jordi Vives i Batlle	M	SKC-CEN, Belgium	Radioecology and radiological protection
Vladimer Maderich	M	Inst. of MMSP, Ukraine	Radioactivity dispersion and fate models
Sandor Muslow	M	ICML, U. Austral de Chile	Radiotracers, stable isotopes and benthic ecology

Working Group contributions

While all Members will participate in all activities of the group, a short description of each full WG Member's unique professional activities and interests, as well as contribution to the WG is provided below.

Ken Buesseler specializes in the study of natural and artificial radionuclides in the ocean and their application to better understanding ocean processes. He will serve as co-Chair of the WG. He leads the Center for Marine and Environmental Radioactivity, the goals of which include increasing scientific and public understanding of radioactive substances in the environment, and training the next generation of marine nuclear radiation experts - all are key components of the RiO5 mission. Buesseler chaired SCOR WG 116 on Sediment Trap and ^{234}Th Methods for Carbon Export Flux Determination.

Minhan Dai uses a suite of radionuclides to examine carbon and trace metal biogeochemistry in marginal seas and estuarine systems, and investigates the geochemistry of radioactive elements in surface and ground water. He will serve as WG co-Chair and contribute by promoting links to research and radioecology in China and in Southeast Asia and will host a WG meeting at Xiamen University.

Michio Aoyama works on the geochemistry of ^{137}Cs in the world ocean from global fallout, and nuclear power plant accidents and has developed a marine radioactivity database, HAM, for artificial radioactivity in the world ocean. He will contribute by further developing and linking current databases of artificial radionuclides in marine systems.

Claudia Benitez-Nelson is an expert in the development of new radiochemical techniques and in the application of short-lived naturally and artificially occurring radionuclides in Marine Systems. A gifted teacher and mentor who has received numerous accolades for her ability to communicate her science to the broader community, she will contribute by coordinating the writing of the overview manuscripts and in the development of classroom and broader public education and outreach materials.

Sabine Charmasson's field of expertise is mainly radioecology with use of both natural and artificial radionuclides as tracers of transfer processes within ecosystems (primarily land-to-sea fluxes, sediment recording, food chain transfer). She will contribute by promoting links with EC research and radioecology, in the development of education and training tools, and with public dissemination.

Roberta Delfanti's research uses radionuclides as tracers of marine processes, including water dynamics in the Mediterranean Sea, and sedimentation and bioturbation in coastal and deep-sea environments. She will contribute by promoting links with eastern European research and radioecology, as well as education, training and public dissemination.

Pere Masqué's research focuses on using both natural and artificial radionuclides as tracers of processes in the ocean at various time scales, from present to paleooceanographic. A former member of the scientific steering committee of GEOTRACES, he will contribute by coordinating database efforts and in the development of education and outreach materials.

Paul Morris has worked with natural radionuclides to study ocean processes such as particle export and mixing rates. Currently, Morris works for the IAEA as the manager and coordinator of the Agency's Marine Information System (MARiS), and will contribute by further developing and linking current MARiS to other emerging data bases on artificial and natural radionuclides in marine systems.

Deborah Oughton's research includes the use of radioactive isotopes as environmental tracers as well as socio-ethical aspects of radiation risk assessment and stakeholder engagement. She will contribute by promoting links with EC research and radioecology, as well as education, training and public dissemination.

John N. Smith carries out targeted research focusing on applications of radioactive tracers to studies of sedimentation and particle transport, fish growth and other biological processes, biogeochemical cycling, ocean circulation and climate change. He will contribute by promoting links with North American research and radioecology, as well as education, training and public dissemination.

Relationship to other international programs and SCOR Working groups

We outline briefly below, some of the agencies and groups we have already spoken to, who will have a role to play in our WG activities. It is important to note that none of these organizations or groups have programs that would replace the need for RiO5, but they all can assist in those efforts in some way.

International Atomic Energy Agency (IAEA) and its Environment Laboratories in Monaco

One of the IAEA's mandates is to advise and assist Member States in building capacity for measurement and assessment of radionuclides in the marine environment and tracer applications to oceanographic, climate-related and pollution studies. Through its Marine Laboratories in Monaco (http://www.iaea.org/monaco/page.php?page=10) the IAEA is the world's major producer of reference materials of marine origin, and organizer of interlaboratory comparisons and proficiency tests. The IAEA maintains the MARiS database, containing over 120,000 records on radionuclides in seawater, marine sediment, and biota. Also, the WG co-Chairs are in discussions regarding an International Symposium with the IAEA, which, pending funding and approval, may be in a position to collaborate through dedicated sessions at a larger conference on nuclear applications in the marine environment.

European Nuclear Safety Training and Tutoring Institute (ENSTTI)

ENSTTI (http://www.enstti.eu/) was founded in 2011 and offers applied training course and tutoring sessions in nuclear safety, nuclear security and human and environmental radiation protection. On this latter point links could be developed with RiO5 in order to provide ENSTTI with baseline studies worldwide, to underline various processes that may enhance radionuclide transfer in the marine environment, even to contribute to ENSTTI training course on marine radioactivity and radioecology.

Center for Marine and Environmental Radioactivity (CMER)

CMER (http://www.whoi.edu/cmer) was established in early 2013 at the Woods Hole Oceanographic Institution with the goals of increasing scientific and public understanding of the sources, fate, and consequences of radioactive substances in the environment, and training the next generation of marine nuclear radiation experts. CMER will host this SCOR WG web site at WHOI, and assist in making links to public, student and academic audiences, building upon several efforts to pass on lessons learned from Fukushima, such as the *Oceanus* (http://www.whoi.edu/page.do?pid=83397&tid=3622&cid=175809) Japanese/English issue- *Fukushima and the ocean*- as well as a highly visited FAQ site (http://www.whoi.edu/page.do?pid=83397&tid=3622&cid=94989) on Fukushima ocean impacts. Also CMER can help organize and co-sponsor one of the WG meetings at WHOI.

Center for Environmental Radioactivity (CRAD)

CERAD (http://www.umb.no/cerad) is a Norwegian funded center of excellence hosted by the Norwegian University of Life Sciences and covering research and education on the sources, transfer, effects and risk assessment of radionuclides in the environment. In addition to fundamental research they are also engaged in stakeholder engagement and policy public issues. They are members of the Radioecology Alliance, and EC projects STAR, COMET, NERIS, DoReMi and OPERRA. They will contribute to training and education activities and links with EU radioecology and radiation protection

International Union of Radioecology (IUR)

The IUR (http://www.iur-uir.org/en) is an independent, non-political and non-profit scientific organization. Its first overarching role is to perpetuate a "think tank" capacity on radioecology issues through the maintenance of a network of scientists and professionals from around the world to foster communication between researchers from different fields and geographical regions through brain storming in task groups, the publication and circulation of technical papers, organization of conferences, training courses, and job alerts. At present there is no marine radioactivity task group, and this is something that RIO5 would be able to promote within IUR, and would be to the benefit of both organizations.

GEOTRACES

GEOTRACES (http://www.geotraces.org/) is an international and SCOR supported effort to map global distributions of selected trace elements and isotopes of key interest in ocean sciences. Two WG Members (Dai and Masque) are former members of the international GEOTRACES SSC, and Associate Member Schlitzer, is leading database efforts that we hope to incorporate into our WG to produce added-value to the efforts underway as part of this program.

Other collaborations

In addition to these groups, we will build relationships through our Full and Associate Members with a wider range of organizations, programs and working groups. Included among these are the Intergovernmental Oceanographic Commission (IOC-UNESCO) (http://ioc-unesco.org/) and the European ALLIANCE (http://www.er-alliance.org/) network and associated COMET and STAR consortiums. These groups will help to identify appropriate ways to ensure and facilitate the accomplishment of RiO5 objectives, including the training of new researchers in the field. European RiO5 WG Members will be proactive in raising funds for training thorough adequate platforms and instruments such as EU-funded Marie Curie Training Networks and/or COST-Actions (European Cooperation in Science and Technology), on which they already have experience.

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2.3.6 Designing a biological observing system in the Southern Ocean to inform global ocean observing of marine ecosystems (SO-eEOV) Feeley

Summary/Abstract
Sustained biological observing of marine ecosystems is necessary for developing realistic scenarios of change in species, foodwebs and ecosystems and the attribution of change to their causes. This capability is essential for ecosystem-based management and for developing mitigation and/or adaptation strategies in the long-term. Investment in sustained biological observations requires demonstration that those observations are likely to contribute to detection and/or attribution of change. Current work in the Global Ocean Observing System (GOOS) and the Southern Ocean Observing System (SOOS) has identified many candidate 'ecosystem Essential Ocean Variables' (eEOVs) for long term observations. The comparative simplicity of the Southern Ocean ecosystem and the small number of human pressures compared to elsewhere makes this a useful experimental system for informing the development of biological observing for other more impacted and complex regions. This Working Group will significantly contribute to science of marine ecosystems by designing field programs to acquire data necessary to make scenarios of their dynamics realistic. It will do this by developing tools, procedures and experience from the Southern Ocean; specifically it will (1) assess whether candidate eEOVs will correctly indicate dynamics and/or change in ecosystems of the Southern Ocean, taking into account the potential confounding effects of fishing and global change, (2) evaluate the spatial and temporal sampling requirements, and their concomitant costs, of field observations needed to robustly estimate the candidate eEOVs in the Southern Ocean, and (3) disseminate the tools, framework and outcomes for supporting the design of ecosystem observing systems.

Scientific Background and Rationale
Realistic scenarios of change are a major challenge for marine science (see IPCC Working Group II Assessment Review 5, 2014), making it difficult to place research on the ecology of marine ecosystems in a realistic regional and/or global context. Knowledge of the magnitude and rate at which marine ecosystems are changing is fundamentally important for managing human activities that may affect ecosystem services (e.g., Millennium Ecosystem Assessment, 2005), either through short-term tactical adjustments to keep them sustainable, such as in fishing, or in strategic long-term planning for mitigation or adaptation to long-term change, as for managing climate change.

Currently available indicators relate to the physical environment or, for biology, only particular aspects of the ecosystem, such as biogeochemistry or foodweb components affected by fishing (Shin and Shannon 2010).

Assessing biological change requires a sufficiently long time series that allows differentiation of change from natural variability. To date ecosystem indicators have been derived opportunistically from available datasets (e.g., Coll *et al.*, 2009; Cury & Christensen, 2005; Perry *et al.*, 2010). This work suggests that indicators need to be better designed for correctly detecting change and that the observation system needs to be capable of detecting change when it occurs (Constable, 2011; Perry *et al.*, 2010).

The development of sustained biological observing programs for marine ecosystems has received much attention since the Ocean Observing conference in 2009 that led to the Framework on

Ocean Observing (FOO; Lindstrom *et al.*, 2012), with activities in the Global Ocean Observing System (GOOS)(First Technical Expert Workshop for the GOOS Biology and Ecosystem, and GOOS Biogeochemistry Panels, November 2013, Townsville, Australia), GOOS Deep Ocean Observing System, and Group on Earth Observations Biodiversity Observation Network (GEOBON). These activities and the recent workshop sponsored by the ICSU, SCOR and SCAR and the Southern Ocean Observing System (SOOS) held at Rutgers University in March 2014 (Constable *et al.*, 2014; hereafter termed 'the Rutgers worskhop') have identified biological variables that could be candidates for being 'ecosystem Essential Ocean Variables' as intended under FOO (Constable *et al.*, 2014). A key challenge that has not been resolved by any biological observing system is to demonstrate which candidate eEOVs need to be given priority for investment in the long-term, i.e. that their state of readiness is mature (sensu Lindstrom *et al.*, 2012). It is widely recognised that the state of readiness of many, if not most, biological variables is currently at the conceptual or pilot stage rather than mature.

An important task is to establish observing systems that can detect change. A second task is to establish and identify those observations that will enable attribution of change to specific causes, probably with the assistance of models. In this case, long-term measurements will be needed to make the dynamics of these models realistic, so that the relative importance of different drivers can be correctly interpreted. A third task is to take measurements that help combine historical datasets, thereby facilitating historical reconstructions to better understand current status and trends of key species and the ecosystem overall.

The set of field measurements to be taken in a biological observing system need to contribute to estimating eEOVs that will further these three tasks; eEOVs have been further defined at the Rutgers Workshop as essential biological or ecological quantities that reflect ecosystem properties – primary productivity, food web productivity, abundance, diversity, energy transfer and global and regional human pressures (Constable *et al.*, 2014). How can the maturity of an eEOV be judged in advance of its long-term implementation?

For the first task on 'detecting change', candidate eEOVs need field measurements that enable signals of change to be detectable above the variability of the system and the noise of measurement error. In this case, datasets that indicate spatial and temporal variation in measurements can be used as a foundation for evaluating two attributes of the eEOVs. The first attribute is whether the eEOV is likely to give a clear signal related to the possible drivers of change, such as whether a change in krill predator reproductive performance can be clearly attributed to change in the abundance of krill (de la Mare & Constable, 2000). Current uncertainties in ecosystem structure and dynamics may mean that differences in the eEOV over time may be difficult to interpret. The second attribute is whether the field sampling design is feasible in space and time to unambiguously yield the expected signal above the background variability. The inclusion of a candidate eEOV in the observing system will be contingent on the quality (interpretation) of the signal and the cost of obtaining that signal.

The second task is to provide measurements that will facilitate tuning models to be realistic in order to investigate change in unmeasurable parts of the system and the attribution of change to particular drivers. In this case, eEOVs do not necessarily need to detect change but provide the foundation for ensuring the dynamics of the model, in terms of the ecosystem properties identified above, are realistic. Sufficient representative (not all) eEOVs at critical times and locations will be needed to capture the dynamic properties of the ecosystem, including the covariance of different components of the system.

Historical datasets may include some eEOVs that will enable ecosystem reconstruction from these datasets. The third task, will be to capture the covariance between critical ecosystem properties and such historical datasets. This covariance will enable hindcasting of ecosystem models by estimating the historical ecosystem properties from these historical time series.

For many candidate eEOVs, field data that demonstrate their variability in space and time already exist. These eEOVs could be progressed to maturity if the requirements for the spatial and temporal design of the field measurements can be evaluated and tested. Data for the eEOVs, synoptic data, such as satellite and ocean model data, and ecosystem simulations can be used to determine how well the candidate eEOVs will generate unambiguous signals for ecosystem properties (change, ecosystem dynamics or covariance with historical datasets) and the cost to deliver those signals.

A SCOR Working Group in collaboration with other international groups, including the IMBER program's Integrating Climate and Ecosystem Dynamics (ICED) in the Southern Ocean, the Southern Ocean Observing System (SOOS), and the Global Ocean Observing System (GOOS), will provide an important vehicle to bring together the international scientific community to evaluate the readiness of candidate eEOVs in advance of their implementation, the latter of which will require long-term commitment and investment in sustained biological observations. The relative simplicity of the Southern Ocean ecosystem and the small number of current human pressures compared to elsewhere makes this a useful experimental system for informing the development of biological observing in other more complicated regions. Furthermore, compared to other global oceans, all regional human pressures in the Southern Ocean are reported, measured and managed through the regulatory bodies. Moreover, considerable progress has been achieved in developing individual methods for sampling Southern Ocean ecosystems (Agnew, 1997; Rintoul *et al.*, 2011) and for modelling these ecosystems (Murphy *et al.*, 2012). A large body of experience is available for assessing change in many marine ecosystems (Perry *et al.*, 2010; Shin & Shannon, 2010). Together, this experience can be harnessed to evaluate the readiness of candidate eEOVs (signal and the cost of field implementation) in the Southern Ocean Observing System. The procedures and results of this work can then inform the development of eEOVs in the GOOS and other observing systems, including organisations developing methods to assess the state of marine ecosystems.

Terms of Reference

The proposed Working Group will:

1. Assess whether candidate 'ecosystem Essential Ocean Variables' (eEOVs) will contribute to making ecosystem scenarios realistic by reliably indicating dynamics and/or change in ecosystems of the Southern Ocean, taking into account the potential confounding effects of fishing and global change.

2. Evaluate the sampling requirements in space and time, and their concomitant costs, of field observations needed to robustly estimate the candidate eEOVs in the Southern Ocean.
3. Disseminate the tools, framework and outcomes for supporting the design of ecosystem observing systems.

Working plan

The Terms of References will be achieved between 2015 and 2017, through coordinated modelling work and data analysis, workshops in South Africa (November 2015) and in the Republic of Korea (November 2016), and a larger symposium to be hosted in China to facilitate greater community involvement (September 2017).

Milestone 1: Assessment of the reliability of candidate eEOVs to indicate ecosystem dynamics and/or change in Southern Ocean ecosystems (November 2015).

Prognoses for change in Southern Ocean ecosystems have been summarised in Constable *et al*. (in press) and Nymand-Larsen *et al*. (2014). The IMBER Program ICED has developed models to represent these ecosystems (Murphy *et al.*, 2012) and determined future scenarios for investigating climate change impacts on the Southern Ocean (Cavanagh *et al*., in prep). The models and scenarios will be used to assess the degree to which uncertainty in ecosystem structure and dynamics may affect signals from candidate eEOVs in the future.

Candidate eEOVs will be those derived from the Rutgers Workshop on eEOVs in the Southern Ocean (Constable *et al.*, 2014); approximately 25 eEOVs have been identified, including those related to the CCAMLR Ecosystem Monitoring Program, to measure change in krill and krill predators, and for estimating the dynamics and trends in Southern Ocean food webs under climate change scenarios. eEOVs identified by GOOS will also be considered.

Work to assess the performance of candidate eEOVs will involve fine-tuning the models to achieve this task as well as developing appropriate metrics of ecosystem states and eEOVs, including methods to visualise and simplify potentially complex results, the latter of which are not currently available. The Working Group will monitor progress quarterly and provide feedback to expert teams established for different sectors of the Southern Ocean, in order to account for regional differences in the ecosystem.

Results will be integrated at the 2015 workshop with the aim of establishing which eEOVs could be classed as having *pilot* readiness, i.e. which candidate eEOVs could reliably indicate dynamics and/or change despite uncertainties and/or variability. The Working Group will then publish the tools and experience in the assessment of candidate eEOVs making them available to other researchers developing eEOVs for their marine ecosystems.

Milestone 2: Evaluation of the design and cost of field programs for measuring the pilot eEOVs (November 2017).

Realistic options for field designs will be determined by using existing data to characterise pilot eEOVs, including time series of *in situ* variables (west Antarctic Peninsula, Scotia Sea), satellite products and model re-analyses. These data and statistical analyses will be used to determine alternative spatial and temporal field sampling designs for measurements underpinning those eEOVs. These methods have not yet been developed for foodwebs and will be an important output of this Working Group. The approach will be discussed at the first workshop and will be undertaken over Year 2 of the Working Group.

A realistic design will need to take adequate account of the spatial and temporal variability that is likely to occur with field measurements. This work will identify the tradeoffs between the cost of the field design and the signal derived for the eEOV.

Prior to the next step, the ecosystem models will be refined so that they can report simulated field observations to support the eEOVs at realistic biological, spatial and temporal scales as well as incorporating possible measurement errors given the field conditions and methods. Methods to downscale ecosystem models to the level of field measurements will be developed in Year 2.

Next, ecosystem simulations of the future scenarios will be used to evaluate the performance and cost of the candidate field designs in the long-term. Performance of the eEOV in these simulations will be judged by how well the eEOV (estimated from the simulated measurements) compares to the actual quantity in the simulated ecosystem. This approach is similar to methods used to evaluate fisheries management strategies (Constable, 2011). These simulations will be used to optimise the quality of the signal relative to the cost of the field program for estimating the eEOVs into the future. The results will be used to determine which eEOVs are feasible and whether they could be regarded as mature and thus be included in the biological observing system. This work will be undertaken over Years 2 and 3.

The workshop in November 2016 will review progress and finalise papers from Milestone 1 and the first part of Milestone 2. This workshop will also be a major planning meeting for the symposium in September 2017, which will review all the outcomes of Milestone 2 and disseminate the experience and results.

Milestone 3: Develop an implementation plan for eEOVs determined to be at a mature stage of readiness and disseminate the experience, tools and products from the work of the Working Group (November 2017).

A Symposium on 'eEOVs and the design of biological observing systems' will be held in September 2017 to share the experience of this Working Group and to finalise an implementation plan for eEOVs for the Southern Ocean Observing System. The state of readiness of the other candidate eEOVs will be reviewed and advice provided on how they might be progressed to maturity. This symposium will have broad participation, which will include presentations on related works, along with a presentation of the candidate eEOVs and the associated design for field implementation of those eEOVs the working group regarded as mature. This symposium is designed to build capacity in biological ocean observing by bringing together experts involved in the work of this Working Group as well as from other national and international marine biological observing initiatives, particularly GOOS.

Deliverables

The third term of reference aims to provide outputs that are useful to other bodies who are also designing marine biological observing systems. These outputs will include:

i) ecosystem models used for evaluating whether signals (dynamics and/or change) arising from eEOVs will be robust to uncertainties in ecosystem structure and function;
ii) statistical methods developed for estimating eEOVs from field observations;
iii) tools and methods for utilising satellite and model data to evaluate the variability in estimates of eEOVs;
iv) methods and routines for downscaling large-scale ecosystem models to report on simulated measurements from the observing system;
v) a final report and consequent scientific publications in an open access journal on the evaluated performance of eEOVs for Southern Ocean ecosystems and their advantages (signal, sampling efficiencies) and disadvantages (cost of sampling, variability/noise); and
vi) an implementation plan for the biological theme of the SOOS.

These products will be made available to GOOS, IMBER, CCAMLR and other organisations interested in developing ecosystem observing systems, as well as to the general scientific community, through the SOOS website (www.soos.aq) and Southern Ocean Knowledge and Information wiki (www.soki.aq). Progress reports and product announcements will also be published regularly through the online SOOS newsletter, to ensure dissemination to the greater ocean observing community.

Capacity Building

An established need in marine ecosystem research is the capability for statistical and dynamic modelling of marine ecosystems. This Working Group will link key expert groups in both Southern Ocean and global ecosystem modelling to enhance existing capability to make ecosystem models realistic and useful for evaluating the design of field programs. The Working Group also has four full Members from developing nations that will provide important opportunities for building capacity in marine ecosystem modelling and approaches to the development of efficient sustained biological observing systems that could be applied to their local situations. In addition to this, the uptake by developing nations of consistent field sampling plans will help their observing efforts gain more leverage internationally, and have greater scientific and societal impact. Both workshops and the Symposium will be held in developing nations, which will further the sharing of skills and building partnerships between research groups in developed and developing nations. The Symposium is also intended to be an open event, and additional funds will be sought to support the attendance of developing country scientists where possible.

The expert groups for each milestone and Southern Ocean region will provide opportunities to build teams of researchers and post-graduate students around each combination of milestone and region. Support for these teams will be provided through ICED, CLIOTOP, SOOS and SCAR. This increased capability will further the objectives of IMBER and the Future Earth program. This Working Group will also contribute to an improved capability for evaluating climate change impacts on ecosystems and will be timely for the sixth assessment review by the IPCC.

SCOR will be approached for extra funding to involve additional developing country scientists in working group activities, beyond those who are Full members of the working group.

Working Group composition

This Working Group requires expertise in observing marine ecosystems, ecosystem modelling and statistics. The Working Group is designed to provide this expertise while achieving the desired discipline, geographical and gender balances. It has an emphasis on building capacity in developing nations in marine ecosystem research and observing.

Full Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Parli Bhaskar	Male	National Center for Antarctic and Ocean Research, India	Microbial ecology, biogeochemistry, Field and Laboratory studies. SOOS
2 Andrew Constable (co-chair)	Male	Australian Antarctic Division, Australia	Modelling, theoretical ecology, field observing. SOOS, ICED, CCAMLR
3 Dan Costa (co-chair)	Male	University of California Santa Cruz, USA	Marine mammal/bird ecology and bioenergetics, field observing measurements. SOOS, ICED, CLIOTOP
4 Katja Fennel	Female	Dalhousie University, Canada	Biogeochemistry, modelling. GOOS, OTN, IMBER
5 Beth Fulton	Female	CSIRO, Australia	End-to-end ecosystem modelling, theoretical ecology, field observing. PICES
6 Eileen Hofmann	Female	Old Dominion University, USA	Biophysical modelling. IMBER, ICED

7 Xianshi Jin	Male	Yellow Sea Fisheries Research Institute, China	Ecosystems/fisheries ecology, Field observing. PICES Fishery Science Committee
8 Olivier Maury	Male	University of Cape Town, South Africa	Ecosystem modelling. ICED, CLIOTOP
9 Monica Muelbert	Female	Universidade Federal do Rio Grande,	Habitat and population ecology, field observing. IWC, SORP, CLIOTOP
10 Yunne-Jai Shin	Female	Institut de Recherche pour le Développement , France	Ecosystem modelling, ecosystem indicators. IndiSeas Co-convenor

Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Sanae Chiba	Female	Japan Agency for Marine-Earth Science and Technology, Japan	SAHFOS, North Pacific ecosystems
2 Simon Jennings	Male	Centre for Environment, Fisheries and Aquaculture Science, UK	Ecosystem observing, fisheries, macroecology, survey design, indicators, food webs. ICES
3 Bettina Meyer	Female	Alfred Wegner Institute, Germany	Krill observations, systems ecology, Weddell Sea. CCAMLR
4 Eugene Murphy	Male	British Antarctic Survey, UK	Scotia Arc, Ecosystem observing, theoretical ecology, modelling. ICED.
5 Olav Rune Godoe	Male	Institute of Marine Research, Norway	Acoustic observations, ecosystem ecology, Scotia Arc, CCAMLR
6 Ian Salter	Male	University of Bremen, Germany	Microbial ecology, biogeochemical time-series. GOOS-DOOS, SOMLIT

7 Oscar Schofield	Male	Rutgers University, USA	Ecosystem observing, Palmer LTER. SOOS
8 Hung-Chul Shin	Male	KOPRI, Republic of Korea	Southern Ocean ecosystem ecology, CCAMLR
9 Sandy Thomalla	Female	CSIR, Republic of South Africa	Oceanography, Biogeochemistry, ocean observing. SOCCO
10 George Watters	Male	AMLR Program USA	Ecosystem observing, modelling. US AMLR, CCAMLR

Acronyms:

CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CLIOTOP	IMBER Climate Impacts on Oceanic Top Predators
GOOS-DOOS	GOOS Deep Ocean Observing System
ICED	IMBER - Integrating Climate and Ecosystem Dynamics in the Southern Ocean
ICES	International Council for the Exploration of the Sea
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research
IWC	International Whaling Commission
LTER	Long Term Ecological Research
OTN	Ocean Tracking Network
PICES	North Pacific Marine Science Organisation
SAHFOS CPR	Sir Alistair Hardy Foundation for Ocean Science)
SOCCO	Southern Ocean Carbon and Climate Observatory
SORP	Southern Ocean Research Partnership of the IWC
SSC	Science Steering Committee
US-AMLR	USA program on Antarctic Marine Living Resources

Working Group contributions

Parli Bhaskar has background in microbial processes and food-web dynamics (especially the microbial loop), in the Indian and Southern Oceans. He will contribute to field standardisation, evaluation and implementation of candidate eEOVs at lower trophic levels.

Andrew Constable (co-chair) is a theoretical ecologist using ecosystem models to assess the effects of climate change and fisheries on Southern Ocean ecosystems and is Vice-chair (Biology) of SOOS SSC. He will use his models and statistics to help standardise and evaluate eEOVs.

Dan Costa (co-chair) has extensive experience on the foraging ecology and movement of top predators in the Southern Ocean and the North Pacific and Bering Sea, is on the SCAR Expert Group on Birds and Marine Mammals, and SOOS, ICED and CLIOTOP SSCs. He has pioneered the use of animals to obtain oceanographic measurements and will provide expertise in obtaining data from animals about their movement and environment.

Katja Fennel has expertise in regional coupled physical-biological modelling and assimilation of biological and biogeochemical data. She will focus on modelling of ecosystem processes at lower trophic levels (i.e. phytoplankton and zooplankton dynamics), assimilation of observations and evaluation of observing system design.

Beth Fulton has extensive global experience in whole-system modelling (developer of Atlantis), leading teams to evaluate management and monitoring/observing strategies in marine ecosystems around the world. She and her team will use end-to-end ecosystem models to test the theoretical performance of different eEOVs and indicators and explore the information costs and benefits of alternative monitoring schemes.

Eileen Hofmann brings experience in modelling physical-biological interactions in marine ecosystems, with particular focus on the Southern Ocean and is Chair of the IMBER SSC and co- convenor of ICED SSC. She will contribute expertise on identifying eEOVs that are needed for development, calibration and evaluation using marine ecosystem models constructed for Southern Ocean systems.

Xianshi Jin is an expert in the ecology of ecosystems, including variability of ecosystem structure and high trophic level dynamics. He will contribute to the standardisation of eEOVs and their measurement, including field evaluations and implementation of eEOVs at high trophic levels.

Olivier Maury is on the CLIOTOP SSC and has worked to assess climate change impacts on top predators, particularly through development of size-based food web models (APECOSM). He will adapt APECOSM to the Southern Ocean to undertake simulation experiments to identify which variables would be critical to observe to characterise ecosystem variability, and to assess eEOVs on whether they properly characterise ecosystem states.

Monica Muelbert is on the SCAR Expert Group on Birds and Marine Mammals and is a key investigator in Brazil on tracking of marine mammals. She will provide the working group with expertise in population dynamics, genetics and tracking of higher predators in South America.

Yunne-Jai Shin is an IndiSeas co-convenor with end-to-end ecosystem modelling expertise (developer of OSMOSE) as well as expertise in the analysis of ecosystem indicators. She will use her ecosystem models to test the theoretical performance of different eEOVs, as well as the development of methods to analyse eEOVs from field data.

Relationship to other international programs and SCOR Working groups

This topic is of fundamental theoretical importance to marine science as well as management, which are key goals for SCOR. SCOR already has experience in providing leadership in the development of indicators through its Working Group 119 (Cury & Christensen, 2005), which provided foundations for further work on fisheries indicators, e.g. IndiSeas (Shin & Shannon, 2010) and PICES (Perry *et al.*, 2010), and Working Group 125, which considered trends in zooplankton. Also, SCOR has current working groups considering time series of phytoplankton (Working Group 137) and methods for developing time series of the chemical environment (Working Group 143), which together will provide important inputs to whole-ecosystem indicators and monitoring. The involvement of SCOR will provide the impetus for engaging with the wider community on this issue, including scientists from academic and government institutions as well as young researchers and those from developing countries.

Marine ecosystem management will require indicators of the underlying status of marine ecosystems and how they may be changing, such as is highlighted by the UN World Oceans Assessment whose first assessment is scheduled to be delivered in 2014 (the Regular Process for global reporting and assessment of the state of the marine environment, including socieconomic aspects, St. Aimee & Sauvé, 2011). Marine ecosystem indicators will also inform the science for assessment cycles of the emerging Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), as a parallel to the IPCC. However, development of such indicators is not far advanced, particularly whole-ecosystem indicators. Experts involved in these panels have become involved in discussions on eEOVs prior to the Rutgers workshop and will be engaged with the process of their evaluation.

Recent attention to the development of field programs to measure change on large ecosystem scales has recognised deficiencies in understanding what biological parameters may be routinely measured to provide effective indication of the trajectories of change of those ecosystems (Murphy *et al.*, 2008; Rintoul *et al.*, 2011). In particular, there is a growing recognition of the need to measure the background state of ecosystems to facilitate interpretation of indicators from fisheries, for example, the IndiSeas Working Group of the Eur-Oceans Network of Excellence (Shin & Shannon, 2010), the North Pacific Marine Science Organization (PICES) assessment of the North Pacific marine ecosystem status (Jamieson *et al.*, 2010), and in the Scientific Committee for the Conservation of Antarctic Marine Living Resources (SC-CAMLR) (SC-CAMLR, 2011). The delivery of biological observing systems and support modelling and statistical tools relevant to these organisations has been a focus of GOOS, GEOBON and SOOS, ICED, SCAR, and IMBER amongst others. Products arising from this Working Group will be provided to all these organisations through the Working Group Members that participate in these respective bodies.

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Appendix

Parli Bhaskar

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2.3.7 Optimized design of an ocean observing system for biogeochemistry in a changing climate

Volkman

1. Summary

While great strides have been made in ocean observing technology over the last decades, the ocean remains significantly under-sampled with respect to biogeochemistry. However, there is mounting evidence that the ocean is currently undergoing detectable changes and is not in steady state, with this having the potential to alter the ocean's future role in not only carbon uptake, but also the rates and locations of ocean acidification, the supply of oxygen to ocean ecosystems, and the availability of nutrients to fuel ecosystems and fisheries.

Concurrent advances in ocean biogeochemical models have facilitated the development of Observing System Simulation Experiments (OSSEs). OSSEs allow one to assess the skill of observing systems in identifying target signals. The goal of this Working Group is to make recommendations for optimal observing system design through combined consideration of observing platforms and state-of-the-art models.

2. Scientific Background and Rationale

In light of the public awareness and urgency of monitoring the oceans, the oceanographic biogeochemistry and ecosystem communities have articulated a number of key questions:

(A) How is the ocean uptake and storage of carbon distributed in time and space? Is it changing?
(B) What are the climatological structures of net community production (NCP), export production (EP), and primary production (PP) in the ocean?
(C) What are the climatological structures of ecosystem stressors in the ocean, including ocean de-oxygenation and the saturation state of aragonite (Ω_{arag})? And how are these changing in time?
(D) How do the principal biological provinces evolve in time? And how are they modulated by the subduction and obduction of nutrients within the ocean?

A variety of methods have been developed to characterize the evolving ocean uptake of carbon, making use of both interior inventory changes and global air-sea fluxes inferred from surface pCO_2 data, and the suite of methods applied in the RECCAP efforts of the Global Carbon Project. The results from the RECCAP efforts revealed that for much of the global ocean, large discrepancies remain at all but the largest spatial and temporal scales among the different techniques used to estimate carbon uptake.

For productivity, community efforts have led to the development of climatologies for Net Community Production (NCP), Export Production (EP), and Net Primary Productivity (NPP), and time- varying NPP products from satellite data. Ocean biological provinces have been characterized through a variety of methods that synthesize a broad range of constraints (*Sarmiento et al.*, 2004). Combined use of time-series data and repeat hydrographic measurements has facilitated the characterization of the ocean climatology, as well as trends in ocean de-oxygenation and acidification.

Each of the above goals still faces challenges associated with data/sampling sparsity issues of the current observing system. One such challenge is temporal bias given the tendency for most ship-board measurements to be made in summer. Another is spatial bias clearly encompassing the sparse coverage over many regions of the Southern Hemisphere. It is also important to consider that many of the successes in monitoring with the existing observing network have relied heavily on surface measurements, including those relying on pCO_2 and remote sensing products. An emerging conceptual framework of using ocean water masses to understand biogeochemical provinces and ecosystems has begun to emerge, but to date this approach has tended to focus on models due to lack of seasonal coverage. Additionally, the current CMIP5 generation of Earth System Models indicates that biogeochemical provinces aren't stationary and will be impacted by shifting gyre boundaries and water mass structures (*Bopp et al.*, 2001; *Sarmiento et al.*, 2004; *Bopp et al.*, 2013). Importantly, these questions are largely interrelated since ecosystem patterns are tightly connected to biogeochemical processes as well as to the 3-D structure of the ocean circulation. Given this inter-relatedness, and the potentially high cost of expanding the observing system, it is critical to consider ways to optimize the observing system.

Our goal in proposing a SCOR Working group is to develop an integrated view of observing system design that will optimally sample the ocean to address the needs of the community. Our interests as a Working Group span the four questions detailed above, although given the time constraints and scope of a SCOR Working Group our priorities will be on the first two. The observational challenges of answering these questions will clearly benefit from assessment of a shared multi-platform observing network, with a number of the essential ocean variables being common to our central priorities. A critically important goal in optimizing the observing network will be the specification of quantitative thresholds for detection of the fields described above, and to optimize the observing system to balance the needs of the community. It would of course be advantageous to define such thresholds for specific variables measured (T, S, DIC, nutrients, etc.) rather than for the more abstract concepts listed above. This will benefit from work that has already been conducted to define Essential Ocean Variables (EOVs) for physics, biogeochemistry, and ecosystems. Sampling strategies for these variables can then make use of Observing System Simulation Experiments (OSSEs) with state-of-the-art forced ocean model runs. For OSSEs, the full evolving state of the model can be assessed to round-off precision, and strategies for observing system design can be tested. Of course all of the caveats involved with using models will need to be considered as well.

This type of strategy has already been investigated with OSSEs for the case of carbon uptake by the ocean (item "A" above), where the Large Scale CO_2 Observing Plan (LSCOP) of *Bender et al.* (2002) prescribed 10% uncertainty in net carbon uptake as an upper bound for the target accuracy of the Repeat Hydrography network. This has been considered by *Plancherel et al.* (2013) for the case of uptake of anthropogenic carbon over the North Atlantic between the 1990s and 2000s (WOCE-to-CLIVAR), where it was argued that the Repeat Hydrography network should be capable of detecting decadal trends to within 10%. This strategy was also considered for the case of monitoring pCO_2 (and thereby air-sea fluxes of CO_2) over the Southern Ocean by *Majkut et al.* (2014). There an idealized representation of floats measuring pCO_2 was used to argue that 200 floats could be sufficient to monitor decadal trends in air-sea CO_2 fluxes. The non-eddying ocean model configurations used in these studies provide a useful first platform for iterative interactions with the observational community, and it is expected that models will benefit greatly from this interaction.

If an uncertainty threshold of 10% is considered appropriate for the other variables of interest, the current ocean observing system is insufficient. Although important work has been done in characterizing decadal trends in ocean interior O_2, we are not yet able to construct a global monthly climatology of O_2 in the upper ocean to within uncertainties of 10%. Clearly, even greater challenges lie in developing monthly climatologies for NCP, PP, and EP over the global ocean within a 10% threshold. The question naturally arises, if one begins by specifying an uncertainty threshold, what would be the optimal path for expanding the current observing system in order to achieve this goal? In addressing this question, it is important to consider water masses as a unifying framework for ocean biogeochemistry (Walin, 1981; Iudicone et al., 2011), and their value in the interpretation of data. The importance of water masses to classifications of biomes is already implicit in the study of *Sarmiento et al.* (2004), through the upwelling and subduction patterns over large scales.

2.1 Overview of target signals and tools

The central objective here is to recommend an optimally designed ocean observing system for addressing the science objectives listed at the head of this document. The system will need to be expanded to satisfy simultaneously the needs of physical, biogeochemical, and ecosystems communities, while at the same time integrating with and adding value to existing observing system elements such as Argo.

Through activities of the GOOS Framework for Ocean Observing (*Task Team for an Integrated Framework for Sustained Ocean Observing*, 2012), efforts are now underway to address a number of related objectives for ocean observing, including:

(1) To define a suite of Essential Ocean Variables (EOVs) for physics, biogeochemistry, and ecosystems for both scientific and resource management (monitoring) considerations
(2) To coordinate observing networks that contribute to the EOVs, including issues of standards, data sharing, and developing metrics etc.
(3) To coordinate with partner organizations to reach a consensus data model for EOVs
(4) To propose pilot projects for expansion of the observing network.

Although the larger objectives pertain to the science and resource management questions described above, the quantitative assessment of network design will hinge on measurements of a suite of Essential Ocean Variables (EOVs). We intend to build upon the recommendations provided by GOOS panels and advisory groups, themselves drawing on international expertise, in articulating the target variables and necessary sampling resolution for the expansion of the observing network.

The overarching goal of the Working Group will be to make a series of recommendations for pilot projects, as well more general recommendations for optimized design of the ocean observing system. Equally importantly, the group will also draw on the recommendations of GOOS panels in recommending a suite of unified EOVs for both the pilot projects and the global observing network. The recommendations will be focused on determining the optimal network design needed to address the set of community-shared scientific and monitoring priorities detailed at the head of this document. In other words, what is needed to achieve the high priority scientific goals listed above? What are the estimated costs?

Efforts to better quantify productivity (NCP, PP, and EP) will be important to both carbon cycle and ecosystems research, and improved estimates will be contingent on seasonally resolving, three- dimensional measurements. Important efforts have already been made to characterize these quantities through the use of remote sensing products. However, in the absence of seasonally varying subsurface fields, quantifying uncertainty associated with these fields has proven elusive. Thus, for the suite of biogeochemical and physical EOVs needed to characterize NCP, PP, and EP, the precision threshold should be ~10%. In addition to proposing optimal EOVs for monitoring the carbonate system in the ocean, *our goal will be to recommend strategies to detect global surface ocean trends, and to characterize thresholds for detection. It will be important to decide whether the 10% threshold is appropriate more generally, or whether a less stringent threshold of 20% or 25% would be appropriate.*

Even with a perfect observing system, there is also the ever-present question of whether measured decadal trends can be interpreted as the secular anthropogenic climate signal, or to what extent natural variability is included. For example, this question has been raised concerning the current decadal hiatus in global surface temperatures representing a pause in a trend towards global warming (*Meehl et al.*, 2011). In this context, it is useful to consider uncertainties associated with the observing system itself as “systematic uncertainty”, and uncertainties associated with natural variability as “random uncertainty”. Modeling efforts such as *Henson et al*. (2010) and *Henson et al*. (2013) have sought to address detection of secular trends in the presence of natural variability.

All of this needs to be considered within the context of the multi-platform observing system described above.

2.2 Modeling issues

Global ocean biogeochemical models have grown in sophistication over the last decade. Two commonly used classes of ocean-only models are used widely, (a) state estimates that assimilate observations such as the ECCO and SODA models, and (b) forward models such as MOM and NEMO. Although models are and will continue to be 'works in progress', they have demonstrated value in testing observing system design through Observing System Simulation Experiments (OSSEs).

Progress has been made in understanding the relationship between biogeochemical processes and water masses in the ocean (*Iudicone et al.*, 2011), and this has been complemented by important efforts with eddy-permitting models to better understand water mass transformation processes (*Nishikawa et al.,* 2013). The large-scale structures of biogeochemical properties are prescribed by the interplay between biological, chemical and thermodynamical processes and are thus best understood in terms of water masses. This three-dimensional dynamical view of the oceans needs to be coupled with ensembles of processes on seasonal and interannual time scales that further contribute to setting ocean properties in the photic zone. For example, the monitoring of nutrients in the interior has to be complemented by a characterization of the interplay between nutrient availability at the surface (as set by local physical and biological processes), and interior distributions via subduction-related processes and even non-local controls of surface processes (where obduction occurs). Important steps towards understanding the interplay between surface and interior processes have been taken (e.g., *Palter et al.*, 2005). Again, this is considered to set the context for the Working Group activities, which will be specifically focused on the observing network.

3. Terms of Reference

The main goals of the Working Group will be to make recommendations that fall into three general categories. The first will be to characterize the ocean biogeochemical state from the existing network. The second will be to articulate an appropriate suite of Essential Ocean Variables (EOVs) building on and extending the work of GOOS advisory groups and other experts, as well as to consider detection thresholds and OSSE design. The third and fourth will be focused on recommendations for pilot studies and on optimization of the global observing network. These questions will be considered within the context of the newly available technology, such as biogeochemical sensors for profiling floats and gliders, and complementing the existing global platforms such as Argo and remote sensing products.

4. Working Plan

4.1 Task Set #1: Characterize the ocean biogeochemical state from existing network

The first task set will involve a careful evaluation and review of what can be inferred from the existing observing network. Here we will identify 'state-of-the-art' estimates as those that have appeared in the peer-reviewed scientific literature.

(i) What is the optimal combination of Essential Ocean Variables (EOVs) for meeting the needs of communities monitoring physical oceanography, ocean biogeochemistry, and ocean ecosystems?
(ii) What estimates exist for the rate at which carbon is being absorbed by the global ocean?
(iii) What quantified estimates exist for biological productivity, and what are the associated uncertainties in current estimates of PP, NCP, and EP?
(iv) What is understood about the important ecosystem stressors, including ocean de-oxygenation and acidification parameters?
(v) What is the state-of-the-art for ocean biogeochemical modeling?

4.2 Task Set #2: Define detection thresholds and OSSE design

The second task set will focus on a synthesis of the candidate target variables and multiple- platform optimization:

(i) Refine and specify the target suite of Essential Ocean Variables (EOVs), incorporating the lists provided by the advisory panels to GOOS;
(ii) Refine and specify precision thresholds for these EOVs, both for climatological and secular trends;
(iii) Recommend a suite of models and conceptual tools that will be appropriate to the OSSE design;
(iv) Set a list of priorities as requirements for a unified OSSE design. It will be important to assess, for example, the degree to which winter under-sampling biases can be reduced with no cost through re-allocation of resources used for summer sampling.

4.3. Task Set #3: Design of pilot studies

The third suite of priorities concerns pilot studies for the observing goals described above. The goal will be to address temporal and spatial sampling issues in regions that are known to be important for the suite of questions listed at the beginning of this document. An important example would be that of subtropical mode waters, whose formation regions are at best severely under-sampled at the present time during winter. In this case one would choose a specific subtropical mode water formation region that can be considered broadly representative, and consider the pertinent spatial and temporal scales for monitoring. In addition to subtropical mode waters, it would be of interest to include regions representative of western and eastern boundary regimes, as well as subpolar and equatorial obduction or re-emergence regimes. Pilot studies will need to directly address the broader question of optimal system design. The important questions will include:

(i) Which dynamical regimes (mode water formations, boundary regions, obduction regions) and what seasons are most poorly constrained with the current observing system, for the suite of EOVs developed through Task Set #1?
(ii) What are representative regions well suited for Pilot Studies? And should a relatively stringent 10% uncertainty threshold be appropriate?
(iii) What pilot studies can help to identify the critical temporal and spatial scales for these regions?

4.4 Task Set #4: Recommendations for optimizing the global observing network

The fourth set of priorities concerns the more general question of the global observing network. This will draw on the recommendations made for OSSEs as well as the recommendations made for pilot studies. The questions to be addressed are:

(i) What is an appropriate uncertainty threshold for the EOVs as part of a global observing network? Would a less stringent threshold for uncertainty (e.g. 20% or 25%) be reasonable on global scales for 3-d fields, and a relatively stringent threshold (e.g. 10%) for surface fields?
(ii) What are the critical scales and processes needed for OSSEs on global scales?
(iii) What are the challenges for an integrated multi-platform OSSE?

5. Working Group Membership, Group Activities, and Capacity Building

5.1 Capacity Building

The members of the Working Group represent a broad international group of researchers with interdisciplinary research experience. In addition to scientific expertise in both observational- and modeling-based research, members of the Working Group have been actively involved in efforts to develop new observing strategies and/or the development and application of Observing System Simulation Experiments (OSSEs). In developing proposals for optimal observing system design, our interests are in building an international effort that builds capacity in developing countries as well as with younger scientists. Our final meeting will be held in a developing country. As two of our Full Members are representing South Africa and Brazil, it is our intention that the final meeting should occur in one of these two countries. It will be our intention with the final meeting to additionally organize a Workshop for two days on Observing System Design, with this meeting open to local participants. Special attention will be devoted to attracting early career scientists to the Workshop.

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Full Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Keith Rodgers (co-Chair)	M	US	Global ocean biogeochemical modeling
2 Daniele Iudicone (co-Chair)	M	Italy	Ocean biogeochemical modeling and water mass analysis
3 Toshio Suga (co-Chair)	M	Japan	Large-scale ocean circulation and ventilation processes
4 Moacyr Araújo	M	Brazil	Modeling of ocean circulation and turbulence, and modeling of ocean biogeochemistry
5 Hervé Claustre	M	France	Ocean color; optical oceanography
6 Katja Fennel	F	Canada	Regional biogeochemical modeling; data assimilation
7 Stephanie Henson	F	UK	Biological responses to climate variability and climate change
8 Masao Ishii	M	Japan	Ocean carbon and biogeochemical measurements
9 Eun Young Kwon	F	Korea	Global ocean biogeochemical modeling
10 Marcello Vichi	M	South Africa	Global ocean biogeochemical modeling

Associate Members

1 Claudie Beaulieu	F	UK	Statistical analysis and trend detection
2 Maria Cavanaugh	F	US	Ocean biological provinces
3 Fabrizio d'Ortenzio	M	France	Marine optics and remote sensing
4 Burke Hales	M	US	Ocean biogeochemical measurements
5 Andrew Lenton	M	Australia	Global ocean biogeochemical modeling
6 Sayaka Yasunaka	F	Japan	Variability in carbon and nutrient cycling in the ocean

Working Group Activities

Annual meetings will be organized by invitation, and will be limited to the members and invited experts to provide summaries of progress and to recommend future directions for the Working Group. We propose that one annual meeting be convened per year during 2015-2017. The first meeting will be in Japan, where Task Sets #1 and #2 will be considered. The second meeting will be conducted in New Orleans to coincide with the 2016 Ocean Sciences meeting, and this will be dedicated to Task Set #3. At the Ocean Sciences meeting, we will also organize a Town Hall meeting. The final meeting, which we intend to have in either South Africa or Brazil, will be dedicated to Task Set #4 as well as a synthesis of the first three Task Sets.

We also intend to develop and submit a paper on Observing System Design to Biogeosciences. Additionally, the suite of recommendations prepared by the group will be made available to the community in the form of reports of the annual meetings.

5.3 Deliverables

The principal deliverables of the Working Group will be consist of the set of recommendations for: a unified set of Essential Ocean Variables, thresholds for detection of these variables, and a suite of of Observing System Simulation Experiments. Additionally we will issue a set of recommendations for pilot studies and for the optimized global network. An additional deliverable will be the review article authored by the members on Observing System Design, to be submitted to Biogeosciences (open access).

6. Working Group Contributions

Here we present the contributions expected from the Full Members. Keith Rodgers' contributions will derive from his experience in using ocean models to interpret ocean biogeochemical measurements, as well as from experience in the design and interpretation of Observing System Simulation Experiments. Daniele Iudicone's contributions will reflect his research efforts to apply water mass transformation analysis to ocean carbon and biogeochemistry. Toshio Suga's contributions will derive from his extensive experience with Argo floats, as well as his extensive research experience involving ocean circulation and ventilation processes. Moacyr Araújo's contribution will stem from his broad interdisciplinary work with both observing system elements and models. Hervé Claustre's contribution to the Working Group will reflect his wide-ranging research into ocean ecosystems, through combined use of multiple elements of the ocean observing network, including Argo. Katja Fennel's contribution will derive from her broad experiences using models to interpret ocean biogeochemical measurements and ocean ecosystems. Stephanie Henson's contribution will result from her experience in trend detection for ocean biology and ecosystems, within the context of climate change, as well as her experience in questions of observing system requirements to detect trends in ocean biology and ecosystems. Masao Ishii's contribution will follow from his extensive work with measuring and interpreting ocean biogeochemistry and acidification trends, as well as through his leadership experience in producing the PACIFICA data product. Eun Young Kwon's contribution will reflect her expertise in modeling both ocean biogeochemistry and ocean ventilation processes. Marcello Vichi's contribution will follow from his extensive experience in modeling ocean biology and ecosystems.

7. Overview of existing SCOR elements

The proposed Working Group will build on the results of previous Working Groups supported through SCOR. In particular, we intend to build on the results of WG 142 focused on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders, as well as on WG 143, on Dissolved N_2O and CH_4 measurements. Interaction with WG 142 will be facilitated that both Hervé Claustre and Katja Fennel (Full Members in our proposal) are members of that WG. If our proposal is supported, we will also contact the co-chairs of WG143 so as to benefit from their work as well.

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Biographical Information

Below is a summary of the contact information, educational background, and pertinent publications for the Full Members of our SCOR Working Group Proposal “Optimized design of an ocean observing system for biogeochemistry in a changing climate”.

Full Members:

(1) Keith Rodgers (co-chair)
PhD, 1998 Columbia University, US
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5 pertinent publications:

Rodgers, K.B., J.L. Sarmiento, O. Aumont, C. Crevoisier, C. de Boyer Montégut, and N. Metzl (2008), A wintertime uptake window for anthropogenic CO_2 in the North Pacific, Global Biogeochem. Cycles, 22, GB2020, doi:10.1029/2006GB002920.
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5 pertinent publications:

Iudicone, D., K.B. Rodgers, I. Stendardo, O. Aumont, G. Madec, L. Bopp, O. Mangoni, and M. Ribera d'Alcala (2011), Water masses as a unifying framework for understanding the Southern Ocean Carbon Cycle, Biogeosciences, 8, 1031-1052.
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(3) Toshio Suga (co-chair)
PhD, 1991, Tohoku University, Japan
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5 pertinent publications:

Oka, E., B. Qiu, S. Kouketsu, K. Uehara, and T. Suga (2012), Decadal seesaw of the Central and Subtropical Mode Water formation associated with the Kuroshio Extension variability, J. Oceanogr., 68, 355-360.
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5 pertinent publications:

Brandt, P., M. Araújo, B. Bourles, P. Chang, M. Dengler, W.E. Johns, A. Lazar, C.F. Lumpkin, M.J. McPhaden, P. Nobre, and L. Terray (2013), Tropical Atlantic Climate Experiment (TACE), Exchanges (Hamburg), 18, 26-31.

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5 pertinent publications:

Claustre, H., M. Babin, D. Merien, J. Ras, L. Prieur, S. Dallot, O. Prasil, H. Dousova, and T. Moutin (2005), Toward a taxon-specific parameterization of bio-optical models of primary production: A case study in the North Atlantic, J. Geophys. Res., 110, C07S12, doi:10.1029/2004JC002634.

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5 pertinent publications:

Fennel, K., J. Hu, A. Laurent, M. Marta-Almeida, and R. Hetland (2013), Sensitivity of hypoxia predictions for the Northern Gulf of Mexico to sediment oxygen consumption and model nesting, Journal of Geophysical Research-Oceans, 118, 990-1002.

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5 pertinent publications:

Henson, S., H. Cole, C. Beaulieu, and A. Yool (2013), The impact of global warming on seasonality of ocean primary production, Biogeosciences, 10(6), 4357-4369.

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5 pertinent publications:

Ishii, M. R.A. Feely, K.B. Rodgers, et al. (2013), Air‐sea CO_2 flux in the Pacific Ocean for the period 1990‐2009, Biogeosciences, 11, 709‐734.

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PhD, 2008, University of California at Irvine
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5 pertinent publications:

Kwon, E.‐Y., S.M. Downes, J.L. Sarmiento, R. Farneti, and C. Deutsch (2013), Role of the seasonal cycle in the subduction rates of upper‐Southern Ocean Waters, 43, 1096‐1113.

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(10) Marcello Vichi

PhD, 2002, University of Oldenburg, Germany Associate Professor (as of Jun 1st 2014)
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5 pertinent publications:

Bopp, L. L. Resplandy, J.C. Orr, S.C. Doney, J.P. Dunne, M. Gehlen, P. Halloran, C. Heinze, T. Ilyina, R. Séférian, J. Tjiputra, and M. Vichi (2013), Multiple stressors of ocean ecosystems under global change: projections with CMIP5 models. Biogeosciences, 10, 6225--6245, doi:10.4195/bg--10--6225--2013.

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SCOR Working Group Proposal Template
(max. 5000 words, excluding Appendix)

Title:

Rheology, nano/micro-Fluidics and bioFouling in the Oceans.

Acronym:

RheFFO

Summary/Abstract (max. 250 words)

Scientific Background and Rationale (max 1250 words)

The sea is a non-Newtonian biofluid. Yet most oceanographers are still unaware of this, or if they are aware, they do not have the training to apply these findings to their own research and models.

Twentieth-century engineers successfully applied the Derjaguin-Landau-Verwey-Overbeek (DLVO) model of "no wall slip" to fluids in most industrial processes. This model was not designed for plankton. As recent developments in nano- and microfluidics, including "lab-on-a-chip", have shown, surfaces in fluids exert influence from nanometre to millimetre scale into the fluid. (Jenkinson, in press). This is extremely relevant to nano- and microplankton, particularly the micrometre-scale feeding appendages of copepods and other zooplankton.

Encounter and fouling of surfaces by plankton, including their larvae, take place largely in near-surface layers. Recent developments in "green" (i.e. non-toxic) methods of antifouling on ships and other marine structures, can be applied to investigate adhesion, recognition, and repulsion by plankton.

GEOHAB (2011) posed the question, "How can we quantify modifications in turbulence by phytoplankton through changes in the viscosity of its physical environment?" At that time, the state-of-the-art was that viscosity η of seawater and freshwaters was composed of an aquatic component η_W due to water (and salts) plus an excess organic component , η_E due mainly to EPS.

Total viscosity,

$$\eta = \eta_W + \eta_E \qquad \text{[Pa s]} \qquad (1)$$

Broadly, η_E shows a negative relationship power-law relationship with shear rate $\dot{\gamma}$, so that

$$\eta_E = k.\dot{\gamma}^P \qquad \text{[Pa s]} \qquad (2)$$

where k is a coefficient related to EPS concentration and type. P can vary from 0 to ~-1.4 (shear thinning), and has exceptionally been found positive (shear thickening). η_E also varies with phytoplankton concentration. Using chlorophyll *a* concentration *chl* as a proxy for phytoplankton,

$$\eta_E = chl^Q.\dot{\gamma}^P \qquad \text{[Pa s]} \qquad (3)$$

where Q is the phytoplankton concentration exponent, found to about 1.3 generally. Further research, however, has shown the Q can vary locally with the growth phase of the bloom, and even become negative (negative correlation between viscosity and *chl* locally in a *Phaeocystis* bloom) (Seuront et al., 2006). EPS also imparts elasticity to the water. Swimming trajectories of copepods over scales of mm to cm are also greatly changed by viscosity from *Phaeocystis* EPS (Seuront & Vincent, 2008).

EPS thickening, moreover, is generally lumpy; this produces length-scale dependent viscosity, which can be modelled using a lumpiness exponent.

Eq. 3 can now be "corrected" for length scale by a third exponent:

$$\eta_E = k.chl^Q.\dot{\gamma}^P.(L/M)^d \qquad \text{[Pa s]} \qquad (4)$$

where L is the length-scale of interest, M is the length scale of measurement, and d is the length-scale exponent. A model of whether lumpy EPS could thicken the water enough to stabilize a pycnocline found (Jenkinson & Sun, 2011a) found that the value of d in Eq. 4 was very critical. To investigate d, η of phytoplankton and bacteria (PB) cultures was measured in capillaries of different radii (Jenkinson & Sun, 2014). While η was increased in some combinations of shear rate, capillary radius, 0.35 to 1.5 mm, and PB) species, presumably by EPS, η was reduced in other combinations, including in low Reynolds-number flows, suggesting superhydrophobic drag reduction (SDR) at the surfaces of plankton and or aggregates of exopolymeric substance (EPS). SDR is well known on the surfaces of lotus leaves and many other natural and manufactured surfaces (Rothstein, 2010), where it can be associated with protection against dirt and fouling organisms (Durr & Thomason, 2010), while changing surface electrical fields (Qiu et al., 2011; Wang et al., 2014). These effects are active from nanometres to up to 25 µm (Ou et al., 2004) from surfaces.

Some effects of increased viscosity and elasticity, as well as nano- and microfluidics (NMF) (with suggested primary length scales) include:

	Effect(s)	**References**	**Associated scales**
1.	Damping of turbulence and of sub-Kolmogorov-scale water movement	Jenkinson (1986)	1 nm – 1 m
2	Due to elasticity and lumpiness, complex changes to patterns of water movement, and de-coupling of shear rate from dispersion:	Jenkinson (1986)	1 nm – 1 m
3	Partial and/or total clogging of the gills of fish, molluscs, tunicates, sponges, polychaetes, etc.	Jenkinson (1989), Jenkinson et al. (2007)	1 nm – 1 mm
4	Due to rising organic matter and adsorption to the air-sea surface, reduction of air-sea gas exchange, wave and ripple damping.	Carlson (1987), Calleja et al. (2009)	10 µm – 10 m
5	Complex situations, illustrated by *Phaeocystis*, which produces closely associated stiff mucus holding cells together in colonies, while also producing looser diffuse mucus that increases viscosity at larger scales, as studied in sludge organic aggregates.	Seuront et al. (2006), Liu et al. (2010).	50 µm- 1 m
6	Flocculation into mucous aggregates, thus increasing sinking or rising speed and hence vertical organic flux.	Mari et al. (2012)	a.~100 µm b. up to ~1000 m
7	Reinforcement of pycnoclines by PB EPS	Jenkinson & Sun (2011, 2014)	10 cm-10 m
8	Trapping of toxins close to metabolically active surfaces, such as cell membranes and gills	Jenkinson (1989)	10 nm-1 mm
9	Changes in electrical fields at surfaces of organisms, non-living organic structures and non-organic structures, relative to protection against corrosion, dirt and fouling	Qiu et al. (2011), Wang et al. (2011, 2014).	1 nm-1 mm
10	Changes in viscosity and elasticity by coordinated swimming in plankton	Thutupalli et al (2011)	1 µm- 1 mm

For references, please see both “Key References” and “Members’ Key Publications”.

Investigation techniques of seawater and lakewater to be considered by the *RheFFO* WG include:
Rheology

1. Rheometry: a) concentric cylinder; b) sliding piston; c) capillary flow; d) ichthyoviscometry;

2. Studies of fluid movement at small scale: a) 3D particle image velocimetry (PIV); b) 3D particle tracking velocimetry (PTV);
3. Studies of small forces at small scale: Atomic Force Microscopy (AFM)
4. Combination of electrochemical techniques with rheometry, microscopy and PIV/PTV, ***in situ* if and when possible**;
5. Taking advantage of high biomass in many harmful algae blooms (HABs) to use high-viscosity, marked surface effects and intense cell-cell ecological, physiological, biogeochemical and encounter interactions.

Nano- and microfluidics of biosurfaces (particularly sticking layers and slip layers at surfaces)

6. High-speed video with PIV and PTV of flow through capillaries coated with organic sculptured layers of hydrophobic (Rothstein, 2010), hydrophilic (Bauer & Federle, 2009) and omniphobic (Wong et al., 2011) surfaces. To be combined with transmission electron microscopy (TEM), scanning electron microscopy (SEM), pressure/flow curves, and possibly standard rheometry of the test materials.
7. Scanning electrochemistry of organic matter film dynamics: Hanging mercury drop.
8. Use of electrochemical techniques developed to study the effects of biological coatings on corrosion dynamics;
9. Studies of attraction-repulsion fields, electrical double layers (EDLs).
10. Immunological type radicle-radicle recognition and adhesion.
11. Impact of phytoplankton and EPS on clogging microfiltration apparatus particularly in relation to desalination plants and harmful algal blooms (HABs). (See also following section.)

Biofouling, with adhesion, recognition and repulsion

12. Fouling organisms need to encounter suitable surfaces, recognise them as suitable, then initiate a series of actions to adhere to the surface, and possibly to use means to penetrate it. Organisms subject to fouling are likely to have evolved antifouling mechanisms to avoid being fouled. Related to fouling and antifouling actions can be considered:
    a) Predation and avoidance of predation
    b) Sexual encounter and its defeat;
    c) Parasitism/symbiosis and its defeat;
    d) Pathogenic infection (by bacteria, viruses) and its defeat.

13. Techniques developed largely for "green" biomolecule-modulated industrial antifouling techniques (for ships, cooling intakes, fish-farm cages and nets, etc.) need to be used to investigate fouling of organisms by other organisms and of living and non-living substrates in the sea (plankton, fish and benthic organisms, organic aggregates, sediment, rocks, etc.).
14. Impacts of biofouling and antifouling techniques on clogging of microfilters and its mitigation, particularly in relation to desalination plants.

Rheology modification by co-ordinated swimming

15. Consideration of rheology modification by "swarmers" (Herminghaus, 2011)

Terms of Reference (max. 250 words)

Vision: The ocean science community lacks expertise in (1) Rheology; (2) Nano- and microfluidics; (3) Fouling and antifouling, adhesion, recognition and protection in relation to trophic, sexual, parasitic pathogenic and other types of encounter, that take place close to electrically controlled surfaces including glycocalyxes. Without this knowledge among ocean researchers, modellers and engineers, future models of how the oceans will react ecologically and biogeochemically to future changes will be unnecessarily flawed.

Objectives:

A To create a corps of ocean researchers, modellers and engineers literate in (1) Rheology, (2) Nano- and microfluidics; (3) Fouling and antifouling at surfaces, expertise that they will teach to their students, graduate students and postdocs.

B. During the lifetime of the WG, carry out expert-to-expert interdisciplinary CB and brainstorming sessions, to allow the WG members to carry this expertise to other oceanographic problems, to involve the members' students in theoretical and empirical research, published in scholarly papers, books, multimedia, and incorporated in outreach material across the globe.

Deliverables

See Working Plan below.

Working plan (logical sequence of steps to fulfil terms of reference, with timeline. Max. 1000 words)

Kick-off time, can be discussed with SCOR, perhaps September 2015, OSM in Qingdao in April 2016.

Year	**Actions**
1	To kick off the WG an advanced draft of the RheFFO WG Core Research Programme and Recommendations will be created, by the members before any meeting.. Back-to-back two-day Open Science Meeting and two-day restricted Brainstorming Workshop 1, both held in the Chinese Academy of Sciences, Institute of Oceanology, Qingdao, China. **Six to 12 months from beginning of WG in spring or autumn** **Two-day Open Science Meeting on RheFFO:** Invitations widely disseminated internationally. Anticipated attendance 50-70. Sponsorship sought in Chinese science organizations, city, province and national governments, cultural and scientific organizations, private and public companies. Publication of refereed proceedings in ***Chinese Journal of Oceanology and Limnology*** **(CJOL)** (Ian Jenkinson is Editor in Chief), including summary and conclusions and recommendations paper by the committee of experts. **RheFFO Workshop 1** Immediately following the Open Science Meeting; This is a **Two-day restricted workshop on RheFFO.** (1 day - science reports, discussion and expert-to-expert interdisciplinary CB; 0.5 day writing the summary, conclusions, recommendations; 0.5 day WG organization, and preparation for Year 2). Anticipated attendance 10 (all full members participate.) After the OSM and workshop, the experts will work together to write a paper on a designated aspect of RheFFO, for a high-impact, open-access, scholarly journal, led by designated chair. Decide on time and place of next workshop in about 12 months. Finalise the RheFFO Core Research Programme, with recommendations for future ocean research, CB. Progress report 1 for SCOR leadership.
2	**RheFFO Workshop 2:** time and place decided at previous workshop. All experts participate, with their PGs and PDs as deemed suitable. Anticipates attendance 10 to 20.

	Continued expert-to-expert interdisciplinary CB – One lecture per expert. Decide time and place of next workshop After the workshop, the experts will work together to write a paper on a designated aspect of RheFFO different from that in Year 1, for a high impact open access scholarly journal, led by designated chair. Progress report 2 for SCOR leadership
3	**RheFFO Concluding Workshop 3:** time and place decided at previous workshop. All experts participate, with their PGs and PDs as deemed suitable. Anticipates attendance 15 to 25. Continued expert-to-expert interdisciplinary CB –. One lecture per expert. Decide whether a future workshop is needed, and if so, its time and place. After the present workshop, the experts will work together on a paper on a designated aspect of RheFFO different from that in Years 1 and 2, with overall conclusions for a high impact open access scholarly journal, led by one or two designated chairs. Progress report 3.for SCOR leadership
4	**In Year 4, collaboration will be done by electronic contact, and physical encounters of opportunity, unless a designated meeting is deemed necessary.** All the publications and reports shall be completed or in press by the end of Year 4. Final report of the WG for SCOR leadership. In additional to this final WG report, a final paper for high-level publication will be prepared, that will be a scientific review of new conclusions derived from results obtained by members and others, made during the WG leading to conceptual advances in rheology, nano- and microfluidics, and biofouling, pointing out new questions and gaps in knowledge, and recommendations for future research.

Deliverables (state clearly what products the WG will generate. Should relate to the terms of reference. Max 250 words). A workshop is not a deliverable. Please note that SCOR prefers that publications be in open-access journals.

Proceedings of the Kick-off OSM in Year 1, with 10-20 refereed papers, to be published as a special edition of *Chinese Journal of Oceanology and Limnology.*

1 Kick-off Core research programme for the RheFFO WG

4 papers in top learned journals.

3 annual progress reports

1 Final Report for publication by SCOR.

Capacity Building (How will this WG build long-lasting capacity for practising and understanding this area of marine science globally. Max 500 words)

Capacity building (CB) will be intense in this WG, and partly atypical.

Because the WG will be highly interdisciplinary, initial CB will concentrate on the experts building capacity in each other to produce a world-wide corps of scientists with expertise in rheology, nano- and microfluidics, and biofouling and antifouling, along with the electrochemistry tools to do some of this research, all in relation to plankton ecology, biogeochemistry and other aspects of oceanography. This expert-to-expert CB will continue throughout the WG to progressively deepen interdisciplinary understanding.

In addition, from year 2 to year 4, more classical CB will kick in, with the different experts building interdisciplinary capacity in younger scientists. Interdisciplinary expertise will furthermore be built in these young scientists by teaching and co-mentoring of PDs and PGs by several experts, as well as other exceptional young scientists invited into the WG workshops.

Working Group composition (as table). Divide by Full Members (10 people) and Associate Members, taking note of scientific discipline spread, geographical spread, and gender balance. (max. 500 words)

Full Members (no more than 10, please identify chair(s))

Name	Gender	Place of work	Expertise relevant to proposal
1 Ian R. Jenkinson Initiator, possible chair	M	Chinese Academy of Science Institute of Oceanology, Key Laboratory for Ecology and Environmental Sciences, Shandong, Qingdao, China	Physical-Chemical-Biological coupling, particularly related to plankton. Pioneer on measuring the rheology (viscosity and elasticity) of seawater, particularly in relation to phytoplankton and harmful algal blooms. Rheology and ocean turbulence. Superhydrophobic surfaces. engineering; Early-career research on algal biofouling.
2 Elisa Berdalet Possible chair	F	Institut de Ciències del Mar (CSIC). Pg. Marítim de la Barceloneta, 37-49. Barcelona, Catalunya, Spain	Physical-biological interactions. - Harmful Algal Blooms. - Biochemical methods. - Microplankton physiology. Vice-chair of the Scientific Steering Committee of the SCOR/IOC-UNESCO program GEOHAB, Global Ecology and Oceanography of Harmful Algal Blooms (since 2009).
3 Stephen Herminghaus	M	Max Planck Institute of Dynamics and Self-Organization, Dept. Dynamics of Complex Fluids, Göttingen, Germany	Head of large research group at Max-Planck-Institut. Fields relevant to this WG are dynamics of complex systems, surface effects on deformation, effects of swarmers on liquid rheology.
4 James G. Mitchell Possible chair	M	School of Biological Sciences, University of Flinders, Adelaide, South Australia	His research group consists of 27 people, including postdoctoral fellows and scientific staff from all over the world. Research in his group focuses on the influences of nanometer to micrometer scale processes on marine ecosystems. The ocean is a complex environment on this scale. Lessons they have learned have been applied to nanotechnology, including microfluidics and nanofabrication.
5 Qiu Ri	M	State Key Laboratory for Marine Corrosion and Protection, Luoyang Ship Material Research Institute, Qingdao, Shandong, China	Assistant professor. Research interests are prevention of marine biofouling and corrosion, particularly using “green” organic techniques and surface properties. Superhydrophobic surfaces. Electrochemistry as a tool to measure ion migration and as for changing behaviour of fouling organisms.
6 Laurent Seuront Possible chair	M	Centre National de la Recherche Scientifique,	Phytoplankton, zooplankton, coastal oceanography, multiscaling and

		Laboratoire d'Océanologie et de Géosciences, Université de Sciences et de Technologies de Lille, Station Marine, Wimereux, France.	(multi)fractals in physical, biological and economic systems, and particularly in marine ecology, seawater viscosity in relation to phyto- and bacterioplankton.
7 Peng Wang	M	Chinese Academy of Science Institute of Oceanology, Key Laboratory for Marine Corrosion and Protection, Qingdao, Shandong, China	Assistant professor. Research interests are prevention of marine corrosion and biofouling, particularly using "green" organic techniques and surface properties. Electrochemistry. Superhydrophobic surfaces.

Possibility for adding member(s)

Associate Member (no more than 10)

Name	**Gender**	**Place of work**	**Expertise relevant to proposal**
1 Tim Wyatt	M	CSIC, Institut de Investigaciones marinas, Vigo, Galicia, Spain	HABs, fisheries, organic matter and ecological engineering; eclecticism and excellent writing style.
2 Li ZHUO	F	Tongji University, College of Environmental Science & Engineering, Shanghai, China	

Possibility for adding member(s).

Working Group contributions (max. 500 words)

Detail for each Full Member (max. 2 sentences per member) why she/he is being proposed as a Full Member of the Working Group, what is her/his unique contribution?

BERDALET, Elisa.

1. Elisa Berdalet is an expert on the modulation of the ecology and physiology of different microplankton groups by physico-chemical processes especially at small spatio-temporal scales.
2. She shall contribute to the WG through her experience in biochemistry (including dissolved organic compounds), physiology of phytoplankton and dynamics of harmful algal blooms, as well as using her recent experience of biofouling experiments related to desalination plants.

HERMINGHAUS, Stephen

1. Stephan Herminghaus heads the department 'Dynamics of Complex Fluids' at the Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, that performs research on collective behavior and pattern formation in soft matter systems, which are of central relevance in many geoscience problems, in particular for understanding the dynamics of self-propelled entities, such as some plankton.
2. SH shall provide expertise and guidance in microfluidics, rheology and structure formation in complex matter to the WG, will provide equipment and be instrumental outside the WG for the study of the interaction of active swimmers with the surrounding flow fields.

JENKINSON, Ian R.

1. Ian Jenkinson is a pioneer on measuring the viscoelasticity of seawater and algal cultures, in relation to turbulence and nano- and microfluidics in plankton, as well as to ecology, biogeochemistry and evolution, and he is now a researcher at the Chinese Academy of Science, Qingdao, China, and ACRO, France, as well as journal editor (Oxford University Press, Springer Publications).
2. IJ shall guide the WG particularly in respect to rheological aspects of seawater, and to the composition and subject composition of the WG deliberations.

MITCHELL, James G.

1. James Mitchell specialises in microscale structures and to biodynamic relations, particularly in plankton.
2. JG shall guide the WG in water flow and biodynamics at small scales, as well as in microfluidics and nutrient flux at rough and sculptured surfaces.

QIU, Ri

3. Ri Qiu has been using electrochemical tools to work on marine antifouling based on superhydrophobicity and slippery liquid-infused porous surfaces (SLIPS) for over 5 years, and he has 4 recent publication related to marine fouling and corrosion control.
4. Ri Qiu shall thus guide the WG particularly in relation to surface-based and electrochemically-based control by organisms, both of surface fouling and its defeat.

SEURONT, Laurent

1. L. Seuront is internationally recognized for his expertise in micro-scale patterns and processes in the ocean.
2. LS's 5 recent publications describing (i) the origin of biologically-driven viscosity and its temporal dynamics and (ii) inferring the potential impact of this excess viscosity on structure and function in pelagic ecosystems, shall allow him to guide the WG in relation to bioproduction of excess viscosity, as well as its effects on structure and function in pelagic ecosystems.

WANG, Peng

1. Peng Wang has worked for several years on the effects of superhydrophobic surface structure on modifying electrical fields and reducing corrosion. He is an expert in electrochemistry.
2. PW shall use his expertise for helping the WG to understand biomodification of surfaces and electrical fields at the surfaces of plankton organisms, and shall build capacity in the biologist members of the WG.

Relationship to other international programs and SCOR Working groups (max. 500 words)

- Air-sea exchange, ripple and wave dynamics, air-sea gas exchange, including GLOBEC, SOLAS, WOCE...
- Ocean turbulence programmes, including GOTM, GETM, FABM.
- Programmes related to ocean ecosystem ecology and biogeochemistry, related to global human population and lifestyle, such as IMBER.
- Programmes on dynamics of erosion-and deposition, dredging, etc. of cohesive sediment and fluid mud dynamics.
- Plankton encounter dynamics, trophic dynamics, mating and social dynamics in plankton.
- Programmes in Rheology
- Programmes in nano- and microfluidics.
- Programmes on protection against corrosion and biofouling of ships, aquaculture facilities, and other marine structures.

Key References (max. 500 words)

Please see also "Key Publications" by WG members.

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Yamasaki, Y., Shikata, T., Nukata, A., Ichiki, S., Nagasoe, S., Matsubara, T., Shimasaki, Y., Nakao, M., Yamaguchi, K., Oshima, Y., Oda, T., Ito, M., Jenkinson, I.R., Asakawa, M. & Honjo, T., 2009. Protein-polysaccharide complexes of a harmful alga mediate the allelopathic control within the phytoplankton community. ISME-J. 3: 808-817.

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<u>Appendix</u>

For each Full Member, indicate 5 key publications related to the proposal.

BERDALET, E.

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