## 2.0 WORKING GROUPS

### 2.1 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.



### 2.2 Working Group Proposals

## 2.1 Current Working Groups

### 2.1.1 SCOR/InterRidge WG 135 on Hydrothermal energy transfer and its impact on the ocean carbon cycles *Smythe-Wright*

**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.

**Co-chairs:** Nadine Le Bris (France) and Chris German (USA)

**Other Full Members:** Wolfgang Bach (Germany), Loka Bharathi (India), Nicole Dubilier (Germany), Peter Girguis (USA), Xiqiu Han (China-Beijing), Louis Legendre (France), and Ken Takai (Japan)

**Associate Members:** Philip Boyd (New Zealand), Thorsten Dittmar (Germany), Françoise Gaill (France), Toshitaka Gamo (Japan), Julie Huber (USA), Bob Lowell (USA), George Luther (USA), Tom McCollom (USA), W.E. Seyfried, Jr. (USA), Stefan Sievert (USA), Margaret K. Tivey (USA), and Andreas Thurnherr (USA)

**Executive Committee Reporter:** Denise Smythe-Wright

### 2.1.2 SCOR/IGBP WG 138 on Modern Planktic Foraminifera and Ocean Changes (2010) *Brussaard*

**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**).

**Co-chairs:** Gerald Ganssen (Netherlands) and Michal Kucera (Germany)

**Other Full Members:** Jelle Bijma (Germany), Jonathan Erez (Israel), Elena Ivanova (Russia), Margarita Marchant (Chile), Divakar Naidu (India), Daniela Schmidt (UK), Howard Spero (USA), and Richard Zeebe (USA)

**Associate Members:** Caroline Cleroux (USA/France), Kate Darling ( UK), Lennart de Nooijer (Netherlands), Steve Eggins (Australia), Baerbel Hoenisch (USA), Sangmin Hyun (Korea), Zhimin Jian (China-Beijing), Thorsten Kiefer (Switzerland), Dirk Kroon (UK), Stefan Mulitza (Germany), Frank Peeters (Netherlands), Michael Schulz (Germany), Kazuyo Tachikawa (France), Rashieda Toefy (South Africa), and Jaroslaw Tyszka (Poland)

**Executive Committee Reporter:** Corina Brussaard

Report for WG138

*Note: This report is submitted late for the final year of the WG138 (2014-2015). The WG asked to submit this report later because the final activity took place in fall 2015 and because we hoped to complete a synthesis product in 2016. We are now submitting this annual report for 2014-2015 including information on publications and results that were achieved until summer 2017. This is the final annual report of the WG138. A final report for the entire funded period is being submitted at the same time.*

1. Name of group

SCOR/IGBP Working Group 138: Modern Planktonic Foraminifera and Ocean Changes

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

The main activity of the reporting period has been the Final Workshop & Short Course on Culturing of Planktonic Foraminifera held on Catalina Island, California, 30.8.-4.9.2015. It was co-organized by Howie Spero and Michal Kucera (both WG members) and attended by 10 WG members and associates and 38 early-career researchers and guests, including 17 PhD and MSc students. Due to substantial additional funding from NSF, we were able to facilitate the participation by a large contingent of U.S. early-career researchers, who were joined by colleagues from 11 countries. The meeting consisted of a short course on modern planktonic foraminifera, combining two days of lectures in the morning with four days of labwork in the afternoons, where participants were able to collect, cultivate, observe and manipulate live foraminifera collected on the site by the UC Davis team. The WG work was concentrated to the evenings and on the last two days, combining open discussions with talks by the participants. A detailed program of the meeting is attached to this report. Due to funding from SCOR and NSF, we were able to offer a uniquely attractive logistical arrangement and scientific and training program. The event was so popular (but capacity limited due to on-site logistical limitations) that we had to reject some applicants. The program containing hands-on training with living planktonic foraminifera, learning from a broad range of experts and networking within such large and international group is deemed by us as a once-in-a-decade opportunity. The meeting was received most enthusiastically by the early-career researchers and we are already seeing the results of the networking in new research projects, collaborations and joint publications.

Besides the final meeting, the WG members and associates made progress during the reporting periods in the envisaged individual publications, including method reviews and data syntheses. These are to a large degree published (due to the unusually long reporting period).

In parallel, Jelle Bijma and Michal Kucera pursued the envisaged eBook project with Copernicus. This is progressing slower than expected, due to differential rate of progress in the individual areas and substantial progress has fallen victim to our ambition to generate a comprehensive resource. We are not abandoning this project but realizing that the time horizon will be too long, we have decided to ask SCOR to sunset the WG now.

There are two positive developments that resulted from the efforts of the WG138 and are entirely in line with the envisaged terms of reference to identify research priorities and stimulate new projects.

First, a shiptime proposal (lead proponent Michal Kucera) for the German vessel METEOR for a cruise dedicated to solving remaining "mysteries" of the ecology of planktonic foraminifera, has been accepted and the cruise (M140) will take place in the central Atlantic between 11 August and 5 Sept. 2017, with 10 early-career researcher participants from six countries, that represent the broader WG 138 community. Further information for the cruise can be found in the expedition brochure: https://www.ldf.uni-hamburg.de/meteor/wochenberichte/wochenberichte-meteor/m139-m141/m139-141--expeditionsheft.pdf.

The principal aim of the cruise is to provide data and samples that are needed to characterise the biology and ecology of planktonic foraminifera, and their coupling with biogenic and mineral particle flux. To this end, the research will combine three approaches. Sampling of the water column by filtration and by plankton tows, combined with physical water property profiles and water sampling will be used to determine horizontal and vertical species distribution, diversity and physiology of planktonic foraminifera. The sampling will be carried out using a vertically resolving plankton sampler (modified multiple closing plankton net) along transects between the mooring stations and in a replicated full-day continuous sampling scheme. Plankton samples will be processed for genetic analysis, for TEM study of digestive content and symbiont content and the photosynthetic activity of the symbionts will be measured on board. Short-term particle flux and particle composition in the water column will be studied by deployment of drifting particle traps, marine snow catchers and in situ cameras. Long-term particle flux will be studied by analysis of samples from sediment traps. To resolve the short-term (reproduction related) component of shell flux, the sediment traps operate at 3-4 day resolution. To achieve this, we are using a serial design of 3 traps on one mooring, providing 120 cups per deployment.

Second, a project led by WG 138 associate Thibault de Garidel Thoron (CEREGE, France), aiming to synthesize data on species distribution and densities in the plankton over the last 50 years in an attempt to identify trends of population change due to anthropogenic stress, is progressing and will have its first formal meeting on 10-12 November 2017. A flyer is attached to this report.

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

In chronological order, all papers and other resources published in 2015 and later:

Jonkers, L., Kucera, M., 2015. Global analysis of seasonality in the shell flux of extant planktonic foraminifera. *Biogeosciences,* 12, 2207-2226. doi: 10.5194/bg-12-2207-2015.

Morard, R., Darling, K., Mahé, F., Audic, S., Ujiié, Y., Weiner, A., André, A., Seears, H., Wade, C., Quillévéré, F., Douady, C., Escarguel, G., de Garidel-Thoron, T., Siccha, M., Kucera, M., de Vargas, C., 2015. PFR²: a curated database of planktonic Foraminifera 18S ribosomal DNA as a resource for studies of plankton ecology, biogeography, and evolution. *Molecular Ecology Resources*, 15, 1472–1485. doi:10.1111/1755-0998.12410

The above is associated with an online resource, acknowledging SCOR: http://pfr2.sb-roscoff.fr/

Spezzaferri, S., Kucera, M., Pearson, P.N., Wade, B., Rappo, S., Poole, C., Morard, R., Stalder, C., 2015. Fossil and genetic evidence for the polyphyletic nature of the planktonic foraminifera "*Globigerinoides*", and description of the new genus *Trilobatus*. *PLoS ONE,* 10(5): e0128108. doi:10.1371/journal.pone.0128108.

Caromel, A.G.M., Schmidt, D.N., Fletcher, I., Rayfield, E.J., 2015. Morphological change during the ontogeny of the planktic foraminifera. *Journal of Micropalaeontology*, 35: 2-19. doi:10.1144/jmpaleo2014-017.

Morard, R., Escarguel, G., Weiner, A., André, A., Douady, C. J., Wade, C. M., Darling, K. F., Ujiié, Y., Seears, H. A., Quillévéré, F., de Garidel-Thoron, T., de Vargas, C., Kucera, M., 2016. Nomenclature for the nameless: a proposal for an integrative molecular taxonomy of cryptic diversity exemplified by planktonic foraminifera. *Systematic Biology*, 65(5):925-940. doi: 10.1093/sysbio/syw031.

Weiner, A.K.M., Morard, R., Weinkauf, M.F.G., Darling, K.F., André, A., Quillévéré, F., Ujiie, Y., Douady, C.J, de Vargas, C., Kucera, M., 2016. Methodology for single-cell genetic analysis of planktonic foraminifera for studies of protist diversity and evolution. *Frontiers in Marine Science*, 3:255. doi: 10.3389/fmars.2016.00255.

Siccha, M., Kucera, M., (accepted). A curated database of planktonic foraminifera census counts in marine surface sediment samples (ForCenS). *Scientific Data*. SDATA-17-00102A.

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

The terms of reference of WG138 state: The main goal of the proposed WG is to synthesize the existing knowledge of modern planktic foraminifera, to build on this knowledge for identifying priority research and to transfer expertise to the generation of young researchers.

Specifically, we aim to:

1. Synthesize the state of the science of modern planktonic foraminifera, from pioneering to ongoing research including as a peer-reviewed publication in an open-access journal (**deliverable 1**).

*The WG138 efforts allowed the community working on genetic studies on planktonic foraminifera to get together and produce a comprehensive synthesis of existing genetic resources (Morard et al., 2015), devise a scheme on implementing stable nomenclature to genetically delimitated taxa (Morard et al., 2016) and provided a comprehensive synthesis and*

*analysis of methods used to obtain genetic information from single-cell extractions (Weiner et al., 2016). In addition, the WG138 effort facilitated the development of a new comprehensive database on the distribution of species identified by their shells in surface sediments (Siccha and Kucera, accepted).*

2. Provide guidelines (cookbooks) in terms of species identification, experimental setup for culture studies, laboratory treatment prior to geochemical analysis (**deliverable 2**).

*Advanced draft version of a revised taxonomy including essential formal taxonomic amendments (Spezzaferri et al., 2015) now exists and includes an identification key which has passed several rounds of review (including during the Catalina meeting) and is already starting to be in use (cited and implemented in e.g. Meilland J., Fabri-Ruiz S., Koubbi P., LoMonaco C., Cotte C., Hosie G.W., Sanchez S., Howa H., 2016. Planktonic foraminiferal biogeography in the Indian sector of the Southern Ocean: Contribution from CPR data. Deep-Sea Research I, 110, 75–89.)*

3. Establish an active Web-based network in cooperation with ongoing (inter)national research programs and projects to guarantee an open-access world-wide dissemination of results, data and research plans (**deliverable 3**).

*An online resource has been developed associated with the synthesis of data on single-cell DNA extraction and sequencing of planktonic foraminifera: http://pfr2.sb-roscoff.fr/*

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**).

*Jelle Bijma and Michal Kucera pursued the envisaged eBook project with Copernicus in the form of two meetings at the headquarters of Copernicus. This project is progressing slower than expected.*

5. WG activities planned for the coming year. Limit 500 words

The WG is formally sunsetting, but we still keep our ambition to work on the eBook and the community that resulted from the WG 138 will continue pursuing collaborative research projects, such as that associated with the dedicated cruise M140 and the FORCIS project (see details under 2) or other projects inspired by and related to the WG 138 activities and lead by colleagues from the wider WG 138 community (for example automated identification of foraminifera: https://research.ece.ncsu.edu/aros/foram-identification/)

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

All terms of reference of the WG have been met, except the envisaged comprehensive eBook as a resource containing authoritative reviews of all aspects of modern planktonic foraminifera

taxonomy, ecology and biomineralisation. We are not abandoning this project, but its time horizon will be longer than expected, due to our ambition to be comprehensive (we have not been successful in populating every aspect of the synthesis with potential authors).

7. Any special comments or requests to SCOR. Limit 100 words.

We thank SCOR and IGBP for their support over the funding period and beyond and kindly ask the committee to sunset the WG138.

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

*Additional information submitted with this report:*

- *Program of WG138 final meeting*
- *FORCIS workshop flyer*

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# SCOR/IGBP Working Group 138
# Modern Planktonic Foraminifera and Ocean Changes

Co-chairs: Gerald Ganssen (Amsterdam) and Michal Kucera (Bremen)

Promoting community building, knowledge synthesis and knowledge transfer on modern planktonic foraminifera

Final report 2011 – 2017

**SCOR/IGBP Working Group 138:** Timeline

**29 August – 1 September 2011, Amsterdam, The Netherlands**
Kick-off meeting and Focus symposium for early career researchers organised by Gerald Ganssen and Michal Kucera

*Ganssen, G.M., Kucera, M., 2012. SCOR/IGBP working group on modern planktonic foraminifera kicked off. PAGES news, 20(1): 6.*

**24 – 27 June 2013, Prague, Czech Republic**
Workshops on Collection Methods and Taxonomy (in association with TMS spring meeting) organised by Michal Kucera

**19 – 24 January 2014, Concepción, Chile**
SCOR/IGBP WG138 @ FORAMS 2014, including keynote lectures by Howard Spero and Michal Kucera and a SCOR special session on Ecology of planktonic foraminifera: from present to past co-chaired by WG members Kate Darling and Michal Kucera

**26 June 2014, NIOZ, Texel, The Netherlands**
Workshop on Foraminifera Geochemistry, (in association with TMS spring meeting) organised by Lennart de Nooijer

**30 August – 4 September 2015, Santa Catalina Island, California, USA**
Final Workshop & Short Course on Culturing of Planktonic Foraminifera organised by Howard Spero and Michal Kucera

**SCOR/IGBP Working Group 138:** Products

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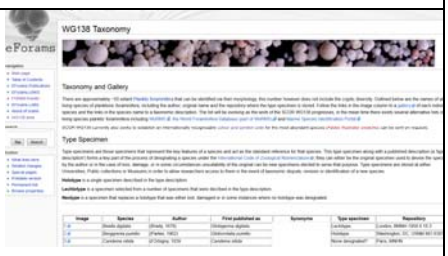
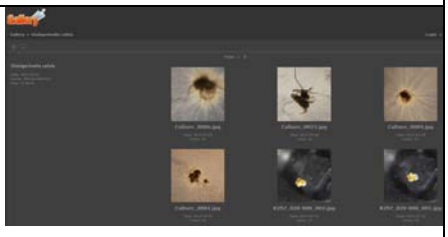
| **Documentaries**<br><br>• A Foram's Tale - Culturing process https://www.youtube.com/watch?v=6MakjP6MkdE<br>• A Foram's Tale - Documentary https://www.youtube.com/watch?v=xfZ_9UWcAB8<br>• A Foram's Tale (Short version) for 2012 Ocean Sciences Meeting https://www.youtube.com/watch?v=EldBtOjGBpw<br>• A Foram's Tale – Documentary of Focus symposium (not available on youtube) |  |
| **Website with resources**<br>http://www.eforams.org/index.php/WG138_Startpage |  |
| **Gallery of images:**<br>http://foraminiferaimagedatabase.marum.de/gallery2/main.php |  |

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| **PFR2: DNA library with curated taxonomy:** http://pfr2.sb-roscoff.fr/ |   |

**SCOR/IGBP Working Group 138:** Publications

Publications acknowledging SCOR support
(WG members and associates in bold)
(WG-associated early career researchers are highlighted in green)


Gajardo, N., **Marchant, M.,** 2012. Variaciones estacionales de los foraminíferos planctónicos durante 2005-2006 frente a Iquique (20ºS) y Concepción (36ºS), Chile. Lat. Am. J. Aquat. Res., 40(2): 376-388.

Gajardo, N., González, H.E., **Marchant, M.,** 2013. Characterization of El Niño, La Niña, and normal conditions through planktonic foraminifera (2006–2007) in the southeastern Pacific. Ciencias Marinas (2013), 39(3): 253–264.

Gajardo, N., **Marchant, M**., Hebbeln, D., 2013. Variación temporal de los afloramientos costeros frente a Chile central (36ºS; 74ºW), mediante los isótopos estables de oxígeno de foraminíferos planctónicos, durante El Niño 2006. Gayana 77(1): 10-20.

**de Nooijer, L.J., Spero, H.J., Erez, J., Bijma, J.,** Reichart, G.J., 2014. Biomineralization in perforate foraminifera. Earth Science Reviews, 135, 48–58.

Jonkers, L., **Kucera, M.,** 2015. Global analysis of seasonality in the shell flux of extant planktonic foraminifera. *Biogeosciences,* 12, 2207-2226. doi: 10.5194/bg-12-2207-2015.

Morard, R., **Darling, K.,** Mahé, F., Audic, S., Ujiié, Y., Weiner, A., André, A., Seears, H., Wade, C., Quillévéré, F., Douady, C., Escarguel, G., de Garidel-Thoron, T., Siccha, M., **Kucera, M**., de Vargas, C., 2015. PFR²: a curated database of planktonic Foraminifera 18S ribosomal DNA as a resource for studies of plankton ecology, biogeography, and evolution. *Molecular Ecology Resources*, 15, 1472–1485. doi:10.1111/1755-0998.12410

Siccha, M., **Kucera, M.,** (accepted). A curated database of planktonic foraminifera census counts in marine surface sediment samples (ForCenS). *Scientific Data*. SDATA-17-00102A.

Spezzaferri, S., **Kucera, M.,** Pearson, P.N., Wade, B., Rappo, S., Poole, C., Morard, R., Stalder, C., 2015. Fossil and genetic evidence for the polyphyletic nature of the planktonic foraminifera "*Globigerinoides*", and description of the new genus *Trilobatus*. *PLoS ONE,* 10(5): e0128108. doi:10.1371/journal.pone.0128108.

Caromel, A.G.M., **Schmidt, D.N.,** Fletcher, I., Rayfield, E.J., 2015. Morphological change during the ontogeny of the planktic foraminifera. *Journal of Micropalaeontology*, 35: 2-19. doi:10.1144/jmpaleo2014-017.

Morard, R., Escarguel, G., Weiner, A., André, A., Douady, C. J., Wade, C. M., **Darling, K. F.,** Ujiié, Y., Seears, H. A., Quillévéré, F., de Garidel-Thoron, T., de Vargas, C., **Kucera, M.,** 2016. Nomenclature for the nameless: a proposal for an integrative molecular taxonomy of cryptic diversity exemplified by planktonic foraminifera. *Systematic Biology*, 65(5):925-940. doi: 10.1093/sysbio/syw031.

Weiner, A.K.M., Morard, R., Weinkauf, M.F.G., **Darling, K.F.,** André, A., Quillévéré, F., Ujiie, Y., Douady, C.J, de Vargas, C., **Kucera, M.**, 2016. Methodology for single-cell genetic analysis of planktonic foraminifera for studies of protist diversity and evolution. *Frontiers in Marine Science*, 3:255. doi: 10.3389/fmars.2016.00255.

Selection of further publications by WG members and associates in the reporting period:

Allen, K**, Hoenisch, B, Eggins, S**, Haynes, Laura L.; Rosenthal, Yair; Yu, Jimin, 2016, 'Trace element proxies for surface ocean conditions: A synthesis of culture calibrations with planktic foraminifera', Geochimica et Cosmochimica Acta, vol. 193, pp. 197-221.

Allen, KA , **B Hönisch, SM Eggins,** J Yu, **HJ Spero**, H Elderfield, 2011. Controls on boron incorporation in cultured tests of the planktic foraminifer *Orbulina universa*. Earth and Planetary Science Letters 309 (3), 291-301.

Birch, H., Coxall, H. K., Pearson, P. N., **Kroon, D.** & O'Regan, M. May, 2013, Planktonic foraminifera stable isotopes and water column structure: Disentangling ecological signals. Marine Micropaleontology. 101, p. 127-145.

Dueñas-Bohórquez, A. , da Rocha, R. E. , Kuroyanagi, A. , **de Nooijer, L. J. , Bijma, J**. and Reichart, G. J., 2011. Interindividual variability and ontogenetic effects on Mg and Sr incorporation in the planktonic foraminifer *Globigerinoides sacculifer*, Geochimica et Cosmochimica Acta, 75 (2), pp. 520-532 .

Fehrenbacher, JS , AD Russell, CV Davis, AC Gagnon, **HJ Spero,** JB Cliff, Zihua Zhu, Pamela Martin, 2017. Link between light-triggered Mg-banding and chamber formation in the planktic foraminifera *Neogloboquadrina dutertrei*. Nature Communications 8, 15441.

Feldmeijer, W., Metcalfe, B., Brummer, G.J.A. & **Ganssen, G.M.**, 2015. Reconstructing the depth of the permanent thermocline through the morphology and geochemistry of the deep dwelling planktonic foraminifer *Globorotalia truncatulinoides*. *Paleoceanography, 30* (1), 1-22. doi: 10.1002/2014PA002687

**Ganssen, G.M., Peeters, F.J.C.,** Metcalfe, B., Anand, P., Jung, S.J.A., **Kroon, D**. & Brummer, G.J.A., 2011. Quantifying sea surface temperature ranges of the Arabian Sea for the past 20 000 years. Climate of the Past, *7*, 1337-1349. doi: 10.5194/cp-7-1337-2011

Gibson, KA , RC Thunell, ML Machain-Castillo, J Fehrenbacher, **HJ Spero,** Kate Wejnert, Xinantecatl Nava-Fernández, Eric J Tappa, 2015. Evaluating controls on planktonic foraminiferal geochemistry in the Eastern Tropical North Pacific, Earth and Planetary Science Letters 452, 90-103.

Henehan, MJ, JWB Rae, GL Foster, **J Erez,** KC Prentice, **M Kucera,** Helen C Bostock, Miguel A Martínez-Botí, J Andy Milton, Paul A Wilson, Brittney J Marshall, Tim Elliott, 2015. Calibration of the boron isotope proxy in the planktonic foraminifera *Globigerinoides rube*r for use in palaeo-CO2 reconstruction. Earth and Planetary Science Letters 364, 111-122.

Henehan, MJ , GL Foster, JWB Rae, KC Prentice, **J Erez,** HC Bostock, Brittney J Marshall, Paul A Wilson. Evaluating the utility of B/Ca ratios in planktic foraminifera as a proxy for the carbonate system: A case study of *Globigerinoides ruber*. Geochemistry, Geophysics, Geosystems 16 (4), 1052-1069, 2015.

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Howes, E., Kaczmarek, K. , Raitzsch, M. , Mewes, A. , Bijma, N. , Horn, I. , Misra, S. , Gattuso, J. P. and **Bijma, J.**, 2017. Decoupled carbonate chemistry controls on the incorporation of boron into *Orbulina universa* , Biogeosciences, 14 , pp. 415-430 .

**Hönisch, B.** , Allen, K. A. , Russell, A. D. , **Eggins, S. M. , Bijma, J. , Spero, H. J.** , Lea, D. W. and Yu, J. 2011. Planktic foraminifers as recorders of seawater Ba/Ca, Marine Micropaleontology, 79 (1), pp. 52-57.

**Hönisch, B.**, Katherine A Allen, David W Lea, **Howard J Spero, Stephen M Eggins,** Jennifer Arbuszewski, Yair Rosenthal, Ann D Russell, Henry Elderfield, 2013. The influence of salinity on Mg/Ca in planktic foraminifers–Evidence from cultures, core-top sediments and complementary δ 18 O. Geochimica et Cosmochimica Acta 121, 196-213.

**Hyun, S.,** Kimoto, K., Cho, S-H., 2013. Occurrence of modern planktonic foraminiferal species and their seasonal variations around the Jeju Island, Korea. Ocean and Polar Research, 35, 181-191 (Korean with English abstract).

Johnstone, H.J.H., Lee W., and **Schulz, M.**, 2016. Effect of preservation state of planktonic foraminifera tests on the decrease in Mg/Ca due to reductive cleaning and on sample loss during cleaning. Chemical Geology, 420, 23-36. doi:10.1016/j.chemgeo.2015.10.045

Keul, N. , Langer, G. , Thoms, S. , **de Nooijer, L.** , Reichart, G. J. and **Bijma, J**., 2016. Exploring foraminiferal Sr/Ca as a new carbonate system proxy , Geochimica et Cosmochimica Acta. doi:10.1016/j.gca.2016.11.022

Kuroyanagi, A , RE da Rocha, **J Bijma, HJ Spero,** AD Russell, **SM Eggins**, H Kawahata, 2013. Effect of dissolved oxygen concentration on planktonic foraminifera through laboratory culture experiments and implications for oceanic anoxic events. Marine Micropaleontology 101, 28-32.

Marshall, BJ , RC Thunell, **HJ Spero,** MJ Henehan, L Lorenzoni, Y Astor, 2015. Morphometric and stable isotopic differentiation of *Orbulina universa* morphotypes from the Cariaco Basin, Venezuela, Marine Micropaleontology 120, 46-64.

Martinez-Botí, M., Mortyn, P. G., **Schmidt, D. N.,** Vance, D. & Field, D. B. Jul 2011. Mg/Ca in foraminfera from plankton tows: evaluation of proxy controls and comparison with core-tops. Earth and Planetary Science Letters. 307, p.113 – 125

Naik, SS , SP Godad, **PD Naidu,** V Ramaswamy, 2013. A comparison of *Globigerinoides ruber* calcification between upwelling and non-upwelling regions in the Arabian Sea. Journal of Earth System Science 122 (4), 1153-1159.

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Vetter, L, R Kozdon, JW Valley, CI Mora, HJ **Spero,** 2014**.** SIMS measurements of intrashell δ 13 C in the cultured planktic foraminifer *Orbulina universa*, Geochimica et Cosmochimica Acta 139, 527-539

**SCOR/IGBP Working Group 138:** Initiated new network projects

1) An expedition lead by Michal Kucera on the German vessel METEOR dedicated to solving remaining "mysteries" of the ecology of planktonic foraminifera will take place in the central Atlantic will take place between 11 August and 5 Sept. 2017, with 10 early-career researcher participants from six countries that represent the broader WG138 community. The cruise has been organized by the WG138 community and motivated by WG138 efforts. The results will provide the basis for substantial advancement in the understanding of planktonic foraminifera ecology.
https://www.ldf.uni-hamburg.de/meteor/wochenberichte/wochenberichte-meteor/m139-m141/m139-141--expeditionsheft.pdf.

The principal aim of the cruise is to provide data and samples that are needed to characterise the biology and ecology of planktonic foraminifera, and their coupling with biogenic and mineral particle flux. To this end, the research will combine three approaches. Sampling of the water column by filtration and by plankton tows, combined with physical water properties profiles and water sampling will be used to determine horizontal and vertical species distribution, diversity and physiology of planktonic foraminifera. The sampling will be carried out using a vertically resolving plankton sampler (modified multiple closing plankton net) along transects between the mooring stations and in a replicated full day continuous sampling scheme. Plankton samples will

be processed for genetic analysis, for TEM study of digestive content and symbiont content and the photosynthetic activity of the symbionts will be measured on board. Short-term particle flux and particle composition in the water column will be studied by deployment of drifting particle traps, marine snow catchers and in situ cameras. Long-term particle flux will be studied by analysis of samples from sediment traps. To resolve the short-term (reproduction related) component of shell flux, the sediment traps operate at 3-4 days resolution. To achieve this, we are using a serial design of 3 traps on one mooring, providing 120 cups per deployment.

2) The international network FORCIS lead by WG138 associate Thibault de Garidel Thoron (CEREGE, France) has been established, aiming to synthesize data on species distribution and densities in the plankton over the last 50 years in an attempt to identify trends of population change due to anthropogenic stress. Its first meeting takes place in November 2017 in Aix en Provence.

**SCOR/IGBP Working Group 138:** Reflection on deliverables

The main goal of the proposed WG was to synthesize the existing knowledge of modern planktic foraminifera, to build on this knowledge for identifying priority research and to transfer expertise to the generation of young researchers.

We believe we met all of these objectives: the efforts of the WG facilitated several key synthesis products, including a benchmark synthesis and analysis of planktonic foraminifera seasonality (Jonkers and Kucera, 2015), their distribution in the sediments (Siccha and Kucera, accepted) and their genetic diversity (Morard et al., 2015, 2016; Weiner et al., 2016). It helped to identify key open questions in their biomineralisation (de Nooijer et al., 2014) and stimulated the development of revised taxonomy and of standardized identification key (work in progress). The identified gaps in knowledge have been used to formulate and realise new projects and networks (see previous section) and the first meeting in Amsterdam and final meeting on Catalina Island brought together much of the international community of students and young postdocs. The legacy of WG138 will live in the form of several documentaries, explaining the importance of planktonic foraminifera and showing how the research on these organisms is carried out.

In addition to the progress on individual research and syntheses of individual types of data, the WG138 community envisaged to deliver a comprehensive eBook as an open resource containing authoritative reviews of all aspects of modern planktonic foraminifera taxonomy, ecology and biomineralisation. To this end, we have made an agreement with a publisher (Copernicus) and are setting up the structure of the eBook and working on the modalities of including content. The time horizon of this enterprise be longer than expected, due to our ambition to be comprehensive (we have not been successful in populating every aspect of the synthesis with potential authors) and so whilst we are not abandoning the project, this particular deliverable has not yet been met.

# Workshop on foraminiferal response to multiple climatic stressors

Living planktonic foraminifera, marine protists that build a carbonate shell, play a key role in the ocean and in enabling a better understanding of ocean processes.

**(1)** they play a critical role in marine carbon pumps, through organic and mineral export of carbon;

**(2)** their assemblages are widely used for paleo-ecological reconstructions, e.g. in the CLIMAP study of LGM temperatures, or the Pliocene compilation, PlioMap;

**(3)** the geochemical composition of their shells is widely recognized as a good marker of past climatic change;

**(4)** they are one of the most extensively studied taxa in the open ocean to inform the relationship between morphological and genetic diversity, and to study evolution and adaptation processes at long time scales.

Fundamental to solving the response of these protists to natural (biotic and abiotic) and anthopogenic (e.g. warming, acidification, stratification changes) forcings is good documentation of the spatial and temporal distribution of living planktonic foraminifera. To date, there are no standards or centralized sources for reporting abundance information, and to our knowledge no significant effort has been made to rectify this. Within the SCOR WG 138 on planktonic foraminifera, some guidance has been provided on the taxonomical framework, but no compilation has been achieved.

We plan to change this at the first FORCIS workshop in Aicx en Provence, in the French biodiversity analysis and synthesis centre (FRB-CESAB) in collaboration with Labex OT Med. All micropaleontologists interested in modern planktonic foraminifera, and willing to contribute their own datasets are welcome to participate in this new collaborative endeavour.

*Objectives of the workshop:*

**#1** to put together the standards to define the database;
**#2** to assemble a first version of the database with the help of OT-Med and CESAB; and
**#3** to write a proposal to be submitted to the EU – COST and/or CESAB call for international collaborations.

**Registration:** 15th of october

**Grants for early career scientists**

Labex OTMed supports the funding of 2 to 3 early career scientists from Mediterranean countries willing to attend the workshop. Those grants will support travel and accommodation costs, and will be limited to 500€ per scientist. PhD students and post-docs (less than 2 years after PhD defense) can apply by sending a CV and a letter of motivation explaining their choice to attend the workshop to garidel@cerege.fr.

**Deadline for grants: 30th of September**.

**Venue** : CESAB, Centre de Synthèse et d'Analyse de la Biodiversité (Centre for the synthesis and analysis of biodiversity)
Technopôle de l'Environnement Arbois Méditerranée
Getting here : http://www.cesab.org/index.php/en/localisation

**Provisional schedule :**
Wednesday 8th November :

| | |
|---|---|
| 2 pm | welcome |
| 2.30 pm | Introductory talks |
| 3 to 6 pm | Short presentation talks |
| *7 pm* | *Tour in Aix en Provence* |

Thursday 9th November

| | |
|---|---|
| 9 to 12 am : | Discussions on data-base structure (ontology) |
| 1.30 to 3.30 pm : | Taxonomic framework |
| 4 to 6 pm : | Technical assignments |
| Dinner | |

Friday, 10th November

| | |
|---|---|
| 8.30 to 12 am : | Writing session |
| 1.30 to 4 am: | Writing session |
| 3 to 4 pm: | Wrap-up session |

**Accommodation**
*Hotels nearby : (15 minutes walk or 5 minutes bus ride)*

Hotel Best Western de l'Arbois
http://www.hotelarbois.com/fr/

Hotel Appartcity – La Duranne
https://www.appartcity.com/fr/appart-hotel/aix-en-provence-la-duranne-a-la-duranne.html

*Hotels downtown (25 minutes bus ride)*

Hotel Saint Christophe
http://www.hotel-saintchristophe.com/

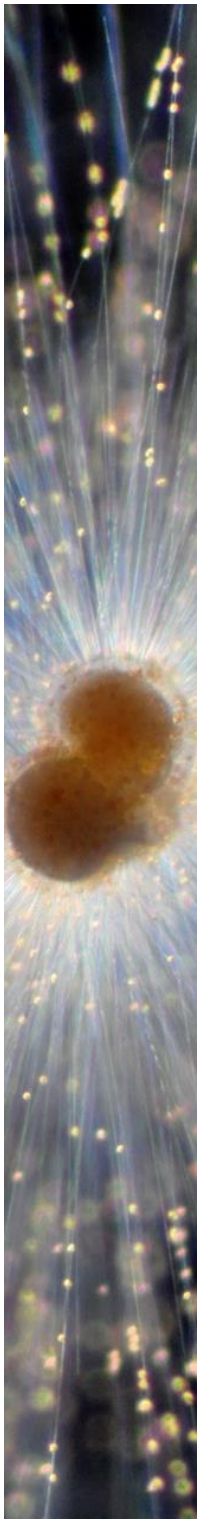
Hotel Cardinal
http://www.hotel-cardinal-aix.com/en/

Find all practical matters on your stay (accommodation, tourism, etc…) here
http://www.aixenprovencetourism.com/en/plan-your-trip/search-accommodation/

**Sponsors :** This meeting is supported by the Labex OTMed, the FRB-CESAB and CEREGE.

**Contacts :**
T. de Garidel-Thoron, CEREGE, garidel@cerege.fr, +33-685-027-143
X. Giraud, CEREGE, giraud@cerege.fr

SCOR/IGBP Working Group 138:
Planktonic foraminifera and ocean changes



# Final Workshop & Short Course on Culturing of Planktonic Foraminifera

## Second Circular & Meeting Program
## July 21, 2015

**Costs:** As advertised, the majority of on-site costs (all meals, coffee breaks, accommodation, bench fees and charter transportation) will be covered upfront – you will not be asked to pay for these items. The costs above do not cover soft drinks and alcoholic beverages. Please note that Wrigley Marine Station is a 20-30 minutes hike to the nearest shop – we highly recommend that you bring all you need, including all toiletries, with you. Please also note that due to water shortage in California, no laundry facilities are available for participants.

**Venue:** Wrigley Marine Science Center (https://dornsife.usc.edu/wrigley/) is located on a scenic bay overlooking the Pacific Ocean. It is surrounded by pristine waters protected as a nature reserve and thus featuring spectacular marine wildlife, offering excellent opportunities for underwater photography. There will be ample time available during the meeting to explore the coast. There is easy access to hiking, swimming and kayaking. Kayaks, mask, snorkels, fins and wet suits are available at no charge. If you prefer you own snorkeling equipment, or use masks with prescription glasses, please bring these with you. Unfortunately, scuba diving will not be available for participants of the workshop.

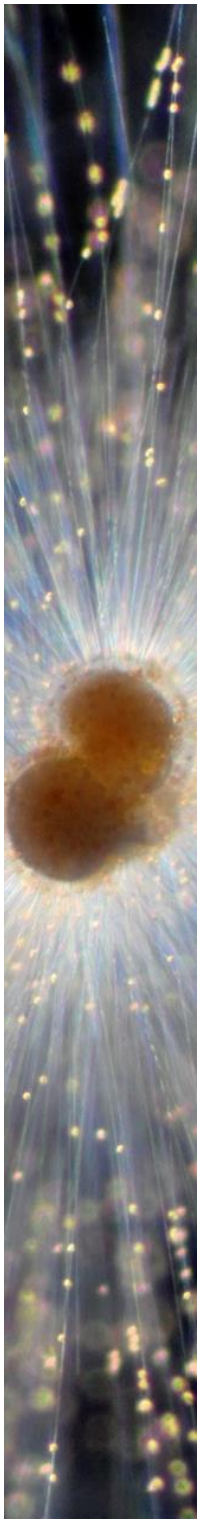
Accommodation and meals will be all on site, within ~200m of the lecture theatre, labs and the cafeteria. Accommodation will be in comfortable shared apartments. While towels will be provided, we suggest you bring your own 'beach' type towel for waterfront activities. Alternatively, you can buy a 'souvenir' towel in Two Harbors. Meals will be served in the cafeteria of the station, which also has a lounge area for informal meetings. Meal times are set.

All participants MUST bring their own water bottles. Tap water is not potable, but there is free potable water provided on the station. You are advised to bring sturdy shoes for hiking (the hiking trials could be demanding and the vegetation is rich in cactus). When working in the wet lab, your clothing and shoes may get in contact with seawater, so bring suitable comfortable open shoes and T-shirts/shorts.

**Weather:** The temperature in August ranges from 15°C in the night (you will need long-sleeve fleece and trousers) to 18°C in the morning, reaching 24-28°C and strong sun during the day. You will need strong sunglasses, sunhat and sunblock. Water temperature will be a pleasant 20-22°C.

**Organiser:** Howard Spero, University of California Davis, hjspero@ucdavis.edu
**Program**: Michal Kucera, MARUM, University of Bremen, mkucera@marum.de

SCOR/IGBP Working Group 138:
Planktonic foraminifera and ocean changes



# Final Workshop & Short Course on Culturing of Planktonic Foraminifera

## Second Circular & Meeting Program

| | Sunday 30.8. | Monday 31.8. | Tuesday 1.9. | Wednesday 2.9. | Thursday 3.9. | Friday 4.9. |
|---|---|---|---|---|---|---|
| 7:30-8:00 | | Breakfast | Breakfast | Breakfast | Breakfast | Breakfast |
| 8:30-9:00 | | Introduction | Lecture 4 | Talks 1-3 | Talks 7-9 | Closing Session |
| 9:00-9:30 | | Lecture 1 | Lecture 5 | | | |
| 9:30-10:00 | | Break | Break | Break | Break | Break |
| 10:00-10:30 | | Lecture 2 | Lecture 6 | Talks 4-6 | Talks 10-15 | Checking out |
| 10:30-11:00 | | Lecture 3 | Lecture 7 | | | |
| 11:00-12:00 | Depart 14:30; Arrive ~16:30 | Discussion | Discussion | SCOR WG | | |
| 12:00-13:00 | | Lunch | Lunch | Lunch | Lunch | Lunch |
| 13:30-15:30 | | Labwork | Labwork | Labwork | Labwork | Shuttle boat to San Pedro right after lunch |
| 16:00-17:30 | | Free time | Free time | Free time | Free time | |
| 18:00-18:30 | Welcome Dinner; orientation | Dinner | Dinner | Dinner | Dinner | |
| 19:00-20:00 | | Keynote 1 | Keynote 2 | Posters | Social evening | |
| 20:00 - | | SCOR WG | SCOR WG | SCOR WG | | |

Keynote – 35 minutes plus 5 minutes for discussion
Lecture – 25 minutes plus 5 minutes for discussion
Talk – 15 minutes plus 5 minutes for discussion
Posters – A0 vertical layout. Please put posters up in the dining room on Monday evening.

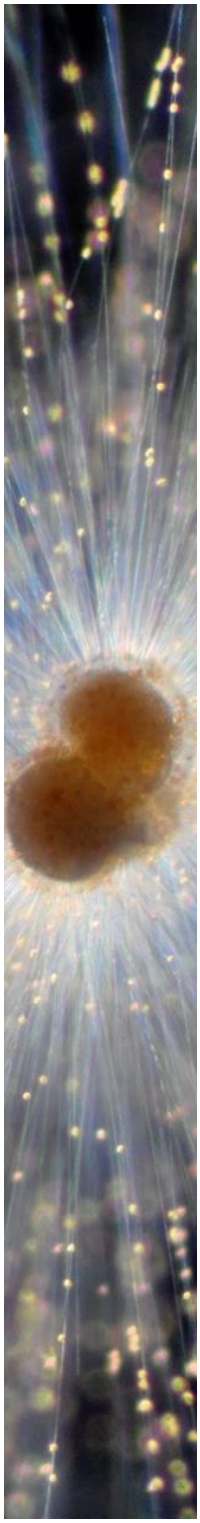
**Discussions**: serve to collective consider the key open questions and identify need for knowledge transfer. On 1.9. an extensive discussion on geochemistry and proxies is expected, guided by the "12 key open questions" document that has been distributed among the participants.

**Labwork** on each day will include in different groups: collection of plankton, sorting and identification, setting up cultures, observations and imaging of feeding, growth. In parallel on every day there will be a taxonomy workshop – you are most welcome to bring your own specimens or samples to discuss.

**Free time** includes opportunity to explore the coast or hike in the mountains.

**SCOR WG** informal meetings take place each evening and serve to coordinate future publications and other WG products, as well as to discuss strategy for future joint work on the topic of ecology, biology and geochemistry of planktonic foraminifera.

# SCOR/IGBP Working Group 138:
# Planktonic foraminifera and ocean changes



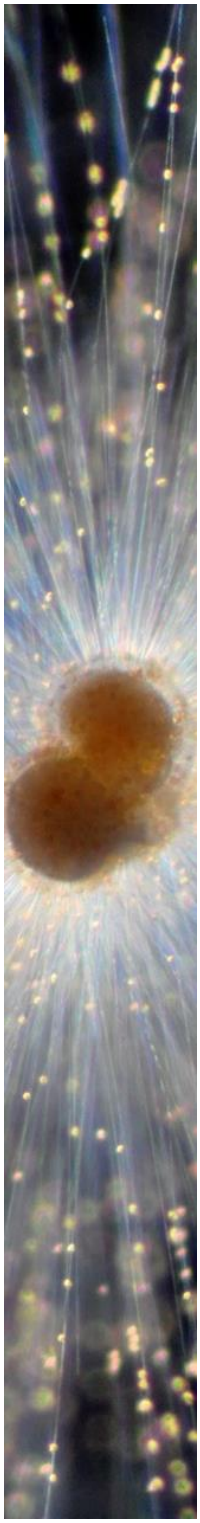


## Second Circular & Meeting Program

| | | | |
|---|---|---|---|
| Keynote | 1 | Zachos, James C. | Major advances and challenges in Cenozoic paleoceanography as inferred from marine microfossils |
| Keynote | 2 | Bijma, Jelle | Biomineralization as the basis to understand proxy incorporation |
| Lecture | 1 | Kucera, Michal | The diversity of modern planktonic foraminifera |
| Lecture | 2 | Spero, Howard J. | Laboratory culturing and the study of living planktonic foraminifera |
| Lecture | 3 | Brummer, Geert-Jan | Sampling of planktonic foraminifera by plankton tows and sediment traps |
| Lecture | 4 | Tyszka, Jarosław | Shell morphogenesis from the planktonic foraminiferal perspective |
| Lecture | 5 | Zeebe, Richard E. | Seawater carbonate chemistry and foraminifera |
| Lecture | 6 | Gagnon, Alexander | The role of cation transport during biomineralization in foraminifera |
| Lecture | 7 | Hönisch, Bärbel | Shell geochemistry and proxies |
| | | | |
| Talk | 1 | Weiner, Agnes K. M. | Genetic diversity and species concepts in foraminifera |
| Talk | 2 | Morard, Raphaël | The potential of Next Generation Sequencing to constrain the global biodiversity of planktonic foraminifera |
| Talk | 3 | Ivanova, Elena | Planktonic foraminifera biogeography: what can we learn from the Russian data and publications? |
| Talk | 4 | Edgar, Kirsty M. | Modelling approaches to understand planktic foraminiferal ecology in our past, present and future oceans |
| Talk | 5 | Bird, Clare | Towards understanding the microbiome of planktonic foraminifera |
| Talk | 6 | Brombacher, Anieke | Disentangling synergistic climate drivers on the anagenetic evolution and extinction of planktonic foraminifera |
| Talk | 7 | Weinkauf, Manuel F. G. | Stabilisation and disruption as indicator of terminal stress and extinction in planktonic foraminifera |
| Talk | 8 | Naidu, P. Divakar | Planktonic foraminifera as a tracer of monsoon in the geological past |
| Talk | 9 | Hathorne, Ed | Can individual foraminifer shell Mg/Ca provide information about past seawater temperature variability? |
| Talk | 10 | Kozdon, Reinhard | Getting the big picture from a small spot: Multi-proxy, multi-instrument *in situ* measurements in foraminifera |
| Talk | 11 | Metcalfe, Brett | Depth, growth or season: Investigating oxygen and carbon isotope distributions in coretop sediments from the North Atlantic |
| Talk | 12 | Mikis, Anna | The use of individual planktonic foraminifera from sediment traps to assess seasonal variability along the West Antarctic Peninsula |
| Talk | 13 | Davis, Catherine V. | Effects of seawater pH on respiration and calcification in cultured *Globigerina bulloides* |
| Talk | 14 | Fehrenbacher, Jennifer S. | Insights into the ecology and controls on trace metal geochemistry in the planktic foraminifer *Neogloboquadrina dutertrei* from laboratory culture experiments |
| Talk | 15 | Meilland, Julie | Planktonic foraminifera individual protein-biomass affected by trophic conditions in the southern Indian Ocean |

SCOR/IGBP Working Group 138:
Planktonic foraminifera and ocean changes

# Second Circular & Meeting Program



| | | | |
|---|---|---|---|
| Poster | 1 | Aze, Tracy | Testing Cope's rule in planktonic foraminifera |
| Poster | 2 | Bonnin, Elisa A. | Systematic sub-micron Na/Ca banding in *Orbulina universa* and *bilobata* |
| Poster | 3 | Branson, Oscar | Atom-scale insights into POM function |
| Poster | 4 | Burke, Janet | Exploring variation in modern planktonic foraminiferal test porosity |
| Poster | 5 | Edgar, Kirsty M. | Can shared evolutionary history open the vital-effect "black box"? |
| Poster | 6 | Le Kieffre, Charlotte | Carbon integration and transfer by the photosynthetic symbiotic dinoflagellates of the planktonic foraminifer *Orbulina universa* observed by TEM-nanoSIMS techniques |
| Poster | 7 | Marchant, Margarita | Planktonic foraminifera in the Humboldt current and upwelling regime off Chile |
| Poster | 8 | Marchitto, Thomas M. | Mg/Ca measurements on individual planktonic foraminifera using a 'wet chemistry' approach |
| Poster | 9 | Osborne, Emily B. | Planktonic foraminiferal shell thickness as a carbonate ion concentration proxy |
| Poster | 10 | Rebotim, Andreia | Environmental control on vertical distribution of planktonic foraminifera in the eastern North Atlantic |
| Poster | 11 | Siccha, Michael | New global database of planktonic foraminifera census counts in surface sediments |
| Poster | 12 | Tyszka, Jarosław | Planktonic foraminifera as agents in eVolutus model |
| Poster | 13 | Venancio, Igor M. | Lunar cyclicity in planktonic foraminifera shell fluxes in the southwestern Atlantic |
| Poster | 14 | Weimin, Si | Mosaic evolution of middle-Miocene *Globorotalia* (*Fohsella*) lineage |
| Poster | 15 | Withacre, Katherine | Status of amino acid geochronology applied to foraminifera |
| Poster | 16 | Ezat, Mohamed M. | A 135 kyr record of subsurface $pCO_2$, nutrient levels and ventilation in the Norwegian Sea |
| Poster | 17 | Praetorius, Summer K. | North Pacific deglacial hypoxic events linked to abrupt ocean warming |
| Poster | 18 | Zamelczyk, Kasia | Planktonic foraminifera response to climate and ocean chemistry changes during the past two millennia in the Fram Strait |

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

**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.

**Co-chairs:** Sylvia Sander (New Zealand), Kristen Buck (USA), and Maeve Lohan (UK)

**Other Full Members:** Kathy Barbeau (USA), Ronald Benner (USA), Martha Gledhill (UK), Katsumi Hirose (Japan), Ivanka Pizeta (Croatia), Alessandro Tagliabue (UK), and Rujun Yang (China-Beijing)

**Associate Members:** Philip Boyd (New Zealand), Ken Bruland (USA), Peter Croot (UK), Jay Cullen (Canada), Thorsten Dittmar (Germany), Christine Hassler (Australia), Rick Keil (USA), James Moffett (USA), François Morel (USA), Micha Rijkenberg (Netherlands), Mak Saito (USA), Barbara Sulzenberger (Switzerland), and Stan van den Berg (UK)

**Executive Committee Reporter:** Colin Devey

1. Name of group

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

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

1. Special Session at the 2016 ASLO/TOS/AGU Ocean Sciences Meeting in New Orleans, Louisiana
2. Second special issue, *Frontiers in Marine Science/Chemistry*, completed May 2017

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

In 2017, a series of 21 peer-reviewed articles were published in a second special issue at *Frontiers in Marine Science/Chemistry* related to activities of this SCOR WG. An editorial for this special issue is currently being written by the WG chairs and will acknowledge SCOR support for this effort.

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

1. To inform the Ocean Sciences community of this WG and related objectives via a widely distributed publication in *Eos* or analogous journal.

The initiation of this SCOR Working Group, including the terms of reference and overall objectives of this working group, was announced in two publications in 2012:

S.G. Sander, K.N. Buck, and M.C. Lohan. 26 June 2012. Improving understanding of organic metal-binding ligands in the ocean. *Eos*, 93(26): 244.

K.N. Buck, M.C. Lohan, and S.G. Sander. July 2012. Metal-binding organic ligands. IUPAC *Chemistry International*, 34(4): 23.

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.

Databases for metal-binding ligand measurements have been compiled by members of the working group for Co (Mak Saito), Cu (Jim Moffett), Fe (Alessandro Tagliabue) and Zn (Maeve Lohan). The iron-binding ligand database is the most developed and an additional database for the raw titration data (Micha Rijkenberg) used to calculate iron-binding ligands has also been initiated. A compilation review of iron-binding ligands based on these databases was published in the *Frontiers in Marine Science* special issue for this working group (http://journal.frontiersin.org/article/10.3389/fmars.2016.00221/full).

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 ligands.

A large intercalibration of the interpretation techniques routinely used for determining ligand concentrations and conditional stability constants from titration data was conducted, and results were published (Pizeta et al. 2015) in the first WG139 special issue. Powerful new interpretation tools developed by participants in this working group were also presented in the special issue and evaluated in the intercalibration, all of which are now freely available to download from the SCOR WG139 website (http://neon.otago.ac.nz/research/scor/achievements.html).

For field-based intercalibration efforts, large volumes of filtered seawater have been collected for this purpose from the Gulf of Mexico and from the Southern Ocean, initial analyses of these samples for dissolved metals are underway in the host lab, and samples for ligand analyses will be made available to the community in late summer 2017.

A manual detailing intercalibration results and best practices for measurements is in the planning stages. This manual is expected to be continually updated and will be made publicly available online at the SCOR WG 139 website.

4. To identify how best to incorporate published and future data into biogeochemical models.

The working group discussed several aspects of incorporating ligands into models, including how analysts can provide ligand concentrations, their sources and sinks and complexation kinetics such as the variability in conditional stability constants of iron, how to distinguish between different iron-binding ligand classes, and if trace metals compete for the same class of ligands. A paper published by Volker and Tagliabue (2015) in first special issue examined how organic iron-binding ligands could be represented in a biogeochemical ocean model. This effort is ongoing and will be part of a new SCOR Working Group, WG151: Iron Model Intercomparison Project.

5. To debate the nature of sampling strategies and experimental approaches employed in laboratory and field efforts from different communities in workshops and meeting discussions to foster cross-fertilization of ideas across groups, capitalize on joint expertise between specialties and ultimately 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.

This working group met annually from 2012-2014 coinciding with the February Ocean/Aquatic Sciences Meetings. Notes from each of these meetings are posted on our website. The co-chairs of this Working Group have also chaired a special session related to the working group at each of the conferences in 2012-2014, 2016. A Town Hall Meeting during the 2014 Ocean Sciences meeting was attended by 47 people and served to highlight accomplishments of the working group to date and to engage broader community participation in working group activities. These meetings have fostered discussions on the need for improved modeling of trace metal speciation in seawater and have led to a new SCOR Working Group, WG145: Modeling Chemical Speciation in Seawater to Meet 21st Century Needs. Several members of SCOR WG139 are also members of WG145 and the new model will incorporate trace metal-organic ligand interactions across marine environments.

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. It will also include a series of recommended downloadable digital products on multiple platforms for interpreting ACSV data.

A final two-day symposium was held for SCOR WG139 in Sibenik, Croatia. This symposium was open to the broader scientific community and was used as a platform to recommend future approaches to ligand measurements and highlight results from intercalibration and field activities. A total of 51 people attended the symposium, including 24 students and postdocs, who were each allotted time to present their research results in the field of ligand biogeochemistry. Twenty of the 51 symposium attendees also participated in a training workshop held the day before the symposium. This workshop was held at the Martinska Marine Station in Sibenik, and consisted of hands-on training in analyzing samples for metal-binding ligands and in using the state-of-the-art interpretation techniques developed (in part) through the activities of the working group.

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 modelling 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.

A webpage has been created for this SCOR working group (http://neon.otago.ac.nz/research/scor/). An email list for the WG members and another for those interested in following the working group's activities is hosted at the Bermuda Institute of Ocean Sciences (scorwg139members@bios.edu and scorwg139all@bios.edu). The 'all' email list for this SCOR WG currently has 188 followers and will remain active for continued use in discussing accomplishments and activities of the working group.

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.

A website for this SCOR WG has been created and is currently being maintained at the University of Otago (http://neon.otago.ac.nz/research/scor/).
The first special issue resulting from this WG's activities was published in July 2015 in *Marine Chemistry*, and included 28 research articles plus an editorial (http://www.sciencedirect.com/science/journal/03044203/173).
The second special issue will be published in *Frontiers in Marine Science/Chemistry* in June 2017 with a total of 21 research articles and an additional editorial (http://journal.frontiersin.org/researchtopic/3981/organic-ligands---a-key-control-on-trace-metal-biogeochemistry-in-the-ocean#articles). This second special issue will be published as an open-access e-book in summer 2017 and will be made available from the SCOR WG 139 website.

5. WG activities planned for the coming year. Limit 500 words

WG139 activities are expected to continue in the coming year. These include continued progress on the best practices manual for ligand measurements, and completion of speciation analyses on the intercalibration samples collected from the Gulf of Mexico and Southern Ocean.

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

WG139 has met most of their goals under each of the original Terms of Reference and will continue to make progress on remaining goals moving forward. The field-based intercalibration activities have proven challenging due to the logistics of achieving funding for shiptime and collection, verification and distribution of samples. Samples for these efforts have, however, now been collected and are in the process of verification for total dissolved metal concentrations prior to distributing to participants for analyses.

7. Any special comments or requests to SCOR. Limit 100 words.

| |
|---|
| Thank you for your support! |

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

### 2.1.4 WG 141 on Sea-Surface Microlayers *Burkill* (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:** 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),
Robert Upstill-Goddard (UK), and Svein Vagle (Canada)

**Executive Committee Reporter:** Peter Burkill

1. Name of group

**SCOR Working Group 141 Sea Surface Microlayers (SML)**

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

- SCOR SML Working Group members (Cunliffe, Landing, Wurl & Zappa) have been engaged in the preparation and execution of the multi-disciplinary SML research cruise on the R/V *Falkor* (Schmidt Ocean Institute) in 2016. The cruise started in Darwin, Australia and finished in Guam, sampling the SML and underlying water at over 17 stations, performing on-board ship experiments and aerial ROV deployments. The research cruise interlinked exchange of bio-limiting trace elements and organic compounds between the atmosphere and the sea surface (Landing), technological advancement of *in situ* techniques to characterize sea surfaces (Zappa), new parameterization for air-sea exchange of climate-relevant gases and heat (Wurl), and assessed the sea surface as a unique habitat for complex microbial communities (Cunliffe). The cruise was used as a 'hand-on' teaching platform for several PhD students and allowed for the continued refinement of the *'Guide to best practices to study the ocean's surface'* (see TOR 1). See https://schmidtocean.org/cruise/study-of-the-sea-surface-microlayer/.


- SCOR SML Working Group has initiated a special issue in the journal *Elementa: Science of the Anthropocene.* The journal was selected because it is a trans-disciplinary, open-access journal committed to the facilitation of collaborative, peer-reviewed research. The SML special issue will report the latest research on the sea surface microlayer. The deadline was extended to 14 March 2017 (originally 28 February 2017). A list of committed contribution includes at least 12 papers from SCOR group members and others.

- Following the Ocean Surface Microlayer and Biogeochemical Feedbacks in the Earth System conference organized by GEOMAR/Kiel University in July 2015, several members of SCOR SML Working Group have written a perspectives and option paper on the SML (see section 3). The paper promotes the move towards an integrated understating of the SML and suggests future research directions.

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

- Anja Engel, Hermann W. Bange, Michael Cunliffe, Susannah M. Burrows, Gernot Friedrichs, Luisa Galgani, Hartmut Herrmann, Norbert Hertkorn, Martin Johnson, Peter S. Liss, Patricia K. Quinn, Markus Schartau, Alexander Soloviev, Christian Stolle, Robert C. Upstill-Goddard, Manuela van Pinxteren & Birthe Zäncker (2017) The Ocean's Vital Skin: Toward an Integrated Understanding of the Sea Surface Microlayer. *Frontiers in Marine Science* 4:165. doi: 10.3389/fmars.2017.00165

- Inter-collaborative Study on the Sea-Surface Microlayer and Air-Sea Interaction http://www.iioe-2.incois.gov.in/IIOE-2/Germany.jsp

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

- 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.

  ✓ COMPLETED. The *'Guide to best practices to study the ocean's surface'* was published online in September 2014. To ensure that the document will be accessible beyond the lifetime of the SCOR SML WG, the document will be held by the Plymouth Marine Science Electronic Repository (managed by the Marine Biological Association), ensuring a permanent and free download link. http://plymsea.ac.uk/6523/

- TOR 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 opinion/position paper in a peer-reviewed journal and will support future international projects concerning the SML and ocean change.

  ✓ PARTIALLY COMPLETE. The recent publication including members of the SCOR SML WG in *Frontiers in Marine Science* (see section 3) fulfills TOR 2. A second short communication published in the upcoming special issue in the journal *Elementa: Science of the Anthropocene* will complete TOR 2.

- TOR 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.

  ✓ COMPLETED. The working group has been engaged in several major meetings;
  - Special session at Ocean Sciences Meeting 2016 in New Orleans 'Linking the Ocean with the Atmosphere - Exploring the Importance of the Ocean-Atmosphere Interface and Near Surface Waters in Global Scale Processes' (February 2016).
  - Session at Surface-Ocean/Lower Atmosphere Study (SOLAS) Open Science Conference in Kiel, Germany on 'Microbial life at the air-sea interface' (September 2015).
  - The Ocean Surface Microlayer and Biogeochemical Feedbacks in the Earth System conference, GEOMAR/ Kiel University, Germany (July 2015).

- TOR 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.

  ▪ IN PROGRESS. The special issue in the journal *Elementa: Science of the Anthropocene* deadline for submission of manuscripts was the 14 March 2017; 13 papers under review now.

5. WG activities planned for the coming year. Limit 500 words

- Publication of the *Elementa: Science of the Anthropocene* special issue (TOR 2 & TOR 4).
- A post-SML cruise meeting will be held in summer/autumn 2017 to co-compare the multi-disciplinary data sets and synthesize an integrated understanding of the SML and the role of the SML in global scale processes. Part of the meeting will consider the refinement of the *'Guide to best practices to study the ocean's surface'* based on sampling experiences from the cruise and any updates to the best practice sampling document will be made if needed.

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

- Due to the undefined and probably widely varying thickness of the SML, finding a consensus definition of the SML is challenging. Hunter's (1997) original definition seems to be most appropriate. We have re-iterated Hunter's definition in a short communication paper submitted to the special issue.

7. Any special comments or requests to SCOR. Limit 100 words.

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

### 2.1.5 WG 142 on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders (2012) *Burkill*

**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.

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

**Other Full Members:** Herve Claustre ( France), Denis Gilbert (Canada), Wajih Naqvi (India), Steven Riser (USA), Virginie Thierry (France), Bronte Tilbrook (Australia), Hiroshi Uchida (Japan), and Xiaogang Xing (China-Beijing)

**Associate Members:** Steve Emerson (USA), Katja Fennel (Canada), Hernan Garcia (USA), Nicolas Gruber (Switzerland), Dong-Jin Kang (Korea), Satya Prakash (India), and Osvaldo Ulloa (Chile)

**Executive Committee Reporter:** Peter Burkill

1. Name of group

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

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

The last in-person meeting of SCOR WG 142 was held on Feb. 27, 2016 and a report of that meeting is included in the 2016 Annual Report. The WG has focused on reporting its major findings since that time. The working group published two recommendations (Bittig et al., 2015, 2016) through the Argo Data Management System. The first recommends that all profiling floats make air oxygen measurements to track sensor accuracy and possible drift. That recommendation enables measurements of such high quality that it required the second recommendation on the conversion of oxygen concentrations between various units. This ensures that errors in unit conversion are not a problem if the recommendations are followed.

The committee is now preparing a manuscript (Bittig et al., in preparation) that summarizes the protocols for successful operation of oxygen sensors on profiling floats. This manuscript is largely competed and undergoing final review by authors. We also note that the efforts of WG142 are being successfully transferred to a broader community, including operators of gliders (Nicholson and Feen, 2017, Air calibration of an oxygen optode on an underwater glider. Limnol. Oceanogr.: Methods, 15: 495–502. doi:10.1002/lom3.10177). The committee work has also played a seminal role in planning for a global array of Biogeochemical-Argo floats (Biogeochemical-Argo Planning Group, 2016; Johnson and Claustre, 2016), as well as the development of data processing protocols for the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) profiling float array (Johnson et al., 2017). The contributions of the Working Group are acknowledged in each of these publications.

The next meeting of the WG is tentatively set for the Argo Data Management Team meeting in Hamburg, Germany during late November 2017. A focus of this meeting would be passing much of the Working Groups findings on to the Argo Data Management Team.

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

Biogeochemical-Argo Planning Group (2016), The scientific rationale, design and Implementation Plan for a Biogeochemical-Argo float array. Eds., K. S. Johnson and H. Claustre. doi:10.13155/46601.

Bittig, H. C., Körtzinger, A., Johnson, K. S., Claustre, H., Emerson, S., Fennel, K., et al. (2015). SCOR WG 142: Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders. Recommendation for oxygen measurements from Argo floats,

implementation of in-air measurement routine to assure highest long-term accuracy. doi:10.13155/45917.

Bittig, H. C., Körtzinger, A., Johnson, K. S., Claustre, H., Emerson, S., Fennel, K., et al. (2016). SCOR WG 142: Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders. Recommendations on the conversion between oxygen quantities for Bio-Argo floats and other autonomous sensor platforms. doi:10.13155/45915.

Bittig, H. C., A. Körtzinger, C. Neill, E. van Ooijen, J. N. Plant, J. Hahn, K. S. Johnson, B. Yang, and S. R. Emerson. In preparation. (Almost) everything you always wanted to know about oxygen optodes but were afraid to ask. Frontiers in Marine Science.

Johnson, K.S., and H. Claustre. (2016), Bringing biogeochemistry into the Argo age. Eos, 97, https://doi.org/10.1029/2016EO062427. Published on 8 November 2016.

Johnson, K. S., et al. (2017), Biogeochemical sensor performance in the SOCCOM profiling float array, J. Geophys. Res. Oceans, 122, doi:10.1002/2017JC012838.

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

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.).

The Working Group activities have been remarkably successful in influencing community understanding of the role of air oxygen calibration. This includes a publication that summarizes the improvements of air oxygen calibrations on a large array of U.S, and Canadian profiling floats (Johnson, Kenneth S., Joshua N. Plant, Stephen C. Riser and Denis Gilbert. 2015. Air oxygen calibration of oxygen optodes on a profiling float array. Journal of Atmospheric and Oceanic Technology. 32, 2160-2172.), as well as publications summarized in the 2016 report. The publication by Bittig et al. will bring the Working Group's effort on oxygen sensors to completion.

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.

These metrics are encapsulated in the Bittig (2015, 2016) recommendations and further expanded on in the Bittig (in preparation) manuscript.

3. Collaborate with Argo and other data centers to implement these procedures in their standard routines.

Working Group members have attended every Argo Data Management Team meeting since 2012 and reported on Working Group findings. These reports have shaped the ADMT document, "Processing Argo Oxygen Data at the Data Assembly Center Level".

4.Disseminate procedures widely to ensure rapid adoption in the community. Develop ideas for capacity building in this context.

The Working Group activities have been highlighted in several publications (Biogeochemical-Argo Planning Group, 2016; Bittig et al., in prep., Johnson and Claustre, 2016; Johnson et al., 2017), as well as numerous presentations.

5. WG activities planned for the coming year. Limit 500 words

The primary effort is to finish development of Working Group publications and extend these efforts to sensors for nitrate and pH, as outlined in Johnson et al. (2017).

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

None.

7. Any special comments or requests to SCOR. Limit 100 words.

We greatly appreciate the opportunity to have participated in this Working Group and we believe that it has been extremely successful.

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

### 2.1.6 WG 143 on Dissolved $N_2O$ and $CH_4$ measurements: Working towards a global network of ocean time series measurements of $N_2O$ and $CH_4$ *Turner* (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.

**Co-chairs:** Herman Bange (Germany) and Sam Wilson (USA)

**Other Full Members:** Mercedes de la Paz Arándiga (Spain), Laura Farias (Chile), Cliff Law (New Zealand), Wajih Naqvi (India), Gregor Rehder (Germany), Philippe Tortell (Canada), Rob Upstill-Goddard (UK), and Guiling Zhang (China-Beijing)

**Associate Members:** John Bullister (USA), Jan Kaiser (UK), Annette Kock (Germany), Sunyoung Park (Korea), Andy Rees (UK), and Alyson Santoro (USA)

**Executive Committee Reporter:** John Turner

1. Name of group

Working Group #143: Dissolved N2O and CH4 measurements: Working towards a global network of ocean time series measurements of N2O and CH4

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

1. Intercalibration cruise for continuous and discrete measurements of methane and nitrous oxide. The expedition was organized by Gregor Rehder (Leibniz-Institute for Baltic Sea Research) and took place in the Baltic Sea from 15 to 22 October 2016.

2. Second intercomparison of seawater samples collected from the North Pacific Ocean with discrete samples collected from two depths and distributed to twenty laboratories globally.

3. Two webconferences: 17 January 2017 and 10 May 2017. The webconferences are occurring every 2-4 months throughout 2017 to maintain momentum with the data exchange and analysis from the intercalibration cruise and the exchange of seawater samples.

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

1. Technical Report: The production of Methane and Nitrous Oxide Gas Standards for Scientific Committee on Ocean Research (SCOR) Working Group #143. The Technical Report is attached separately to this email for posting onto the SCOR website (see http://www.scor-int.org/Publications/SCOR_WG_143_Technical_Report.pdf).

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

*1. Conduct an intercalibration exercise between the time series programs (for methane and nitrous oxide)*
This is completed, with data analysis and publication pending. We have conducted three intercomparison exercises of discrete seawater samples and one intercomparison of underway equilibrator systems. We are receiving the data for the most recent intercomparisons and will start formally analyzing the data next month when at least half the datasets will have been received.

*2. Establish the appropriate standards to be used by the scientific community*
This is completed and the Technical Report is posted at http://www.scor-int.org/Publications/SCOR_WG_143_Technical_Report.pdf. Gas standards have been manufactured by John Bullister at NOAA PMEL and distributed to twelve groups around the globe. Every recipient is working with other scientists in their own respective countries to cross-calibrate their own standards, where necessary.

*3. Recommend the analytical reporting procedures to be used for N2O and CH4*
An outcome of the Terms of Reference #1 will include best practice recommendations for sample collection and analysis as well as data reporting. This activity has not occurred yet, but will be completed by the end of 2017.

*4. Establish framework for an N2O/CH4 ocean time series network and write a global oceanic N2O/CH4 summary paper for publication in an open-access journal.*
This task is still pending. The GEOMAR group (H. Bange, A. Kock, D. Arevalo) will take the lead for this. Manuscript writing will start when the terms of references 1-3 are completed. Potential open-access journals for publication of the SCOR WG overview paper include *Biogeosciences*, *Ocean Science*, *Frontiers in Marine Science*, or *Environmental Research Letters*.

Further, SCOR WG#143-related articles that include results of the SCOR WG#143 include the following:

1) A manuscript about the MEMENTO database is currently being written by Annette Kock for submission to *Earth System Science Data*.
2) An overview article about the application of cavity-enhanced absorption spectroscopy for measurements of dissolved trace gases (including N2O and CH4) in ocean science is currently in preparation for the open-access journals *Ocean Science* or *Frontiers in Marine Science*.

5. WG activities planned for the coming year. Limit 500 words

1. Data synthesis and manuscript writing for the intercomparison of methane and nitrous oxide in seawater.

2. Cruise report for the Baltic Sea expedition

3. The two activities will be facilitated by continuing to hold webconferences every 2-3 months. We are using a BlueJeans webconferencing unit which is working very well for everyone calling in from around the world. Our next webconference is in July 2017, and then two more before the end of the calendar year (September and December).

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

Our final year as a Working Group is a crucial one as we need to synthesize the data and produce a scientific publication on the findings with all the working group members as coauthors. We do not foresee any barrier to this being achieved, but it will take the remainder of the year which is the formal ending for us as a working group. We are in very good shape for this to be a high-quality document, as we have conducted three intercomparison exercises of discrete samples and also distributed common gas standards to participating lab groups.

One of the hold-ups for the working group was the delay in the synthesis of gas standards which meant that the Year 2 for the Working Group was very quiet.

7. Any special comments or requests to SCOR. Limit 100 words.

We have already requested to use the remainder of our budget to have a final face-to-face meeting piggy-backing on the Ocean Sciences meeting in Portland on 11-16 February 2018. It is possible that we also hold an additional meeting in 2017 for a subgroup of people who compared underway equilibrator systems (5 laboratory groups). This would be most productive if it was a face-to-face meeting and we are looking into possibilities for hosting this.

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

### 2.1.7 WG 144 on Microbial Community Responses to Ocean Deoxygenation *Miloslavich* (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 (USA)

**Other Full Members:** Sean Crowe (Canada), Virginia Edgcomb (USA), Veronique Garcon (France), Steven Hallam (Canada), Klaus Juergens (Germany), Elsabe Julies (Namibia), Phyllis Lam (UK), Nagappa Ramaiah (India), and Osvaldo Ulloa (Chile)**Associate Members:** Mark Altabet (USA), Annie Bourbonnais (Canada), Karen Casciotti (USA), Francis Chan (USA), David Conley (Sweden), Robinson (Wally) Fulweiler (USA), Jung-Ho Hyun (Korea), David Karl (USA), John Kaye (USA), SWA Naqvi (India), Nancy Rabalais (USA), Mak Saito (USA), Frank Stewart (USA), Matt Sullivan (USA), and Jody Wright (Canada)

**Executive Committee Reporter:** Patricia Miloslavich

# 2016 Annual report for SCOR Working Group 144: Microbial Community Responses to Ocean Deoxygenation

Report for the period September 2015 – December 2016

## Executive Summary

SCOR Working Group 144 *Microbial Community Responses to Ocean Deoxygenation,* is wrapping up its activities after three years. Our first unofficial inaugural meeting was held at the ASLO Ocean Sciences meeting in Hawaii in late February 2014. At that meeting, we planned a practical workshop, which was held at Saanich Inlet/UBC in British Columbia, Canada 13-18 July 2014. The workshop included a short cruise, incubation experiments and sample collection, and was hosted by WG members Sean Crowe and Stephen Hallam. The report of that workshop can be found at the WG 144 website (http://omz.microbiology.ubc.ca/index.html).

The second official meeting of WG-144 took place on 30 August–4 September at the Leibniz Institute for Baltic Sea Research in Warnemünde, Rostock, Germany and was hosted by WG member Klaus Jürgens. WG 144 submitted a proposal to the Schmidt Ocean Institute to request ship time for a cruise to one of the Pacific OMZs in 2018. We have been notified that the full proposal will not be funded.

The third official meeting was held in Goa, on India 2-5 Dec. 2016. The 2016 SCOR workshop was joint with The International Symposium on Microbial Responses to Ocean Deoxygenation, held to honor Wajih Naqvi. Dr. Naqvi is an associate member of SCOR WG 144, the former director of the National Institute of Oceanography in Goa, and world leader in research in the chemistry of oxygen minimum zones. A special issue of *Deep-Sea Research* containing the symposium papers is planned.

## International Symposium on Microbial Response to Ocean Deoxygenation

The main event of year three of SCOR WG 144 was the International Symposium on Microbial Responses to Ocean Deoxygenation, which was held at the National Institute of Oceanography in Goa, India in December 2016. The symposium focused on SCOR OMZ topics and was held in Goa to honor Wajih Naqvi. Naqvi is a leader in the field of chemical oceanography of OMZ systems and served as director of the National Institute of Oceanography in Goa for about a decade. Ward and Ramaiah were co-conveners of the symposium. The program of speakers is attached (Appendix I).

It was a truly international gathering, with participants from India, Japan, Chile, Denmark, France, Germany, Canada, UK and USA. The visitors were housed at the International Center, which was very pleasant, and transportation was provided to NIO for the meeting. The symposium was funded through a combination of sources: NIO contributed the housing and food for all attendees. WG member Nagappa Ramaiah served as the local host and worked tirelessly in the months preceding the symposium to secure Indian Government support for it,

and to schedule the scientific and cultural sessions and activities. SCOR supported the travel of some of the non-U.S. attendees. A grant from the Ocean Chemistry and Biogeochemistry Program (US NSF) supported the travel for U.S. participants. Many of our European colleagues paid for their own travel to India. Most of the Indian participants also traveled at their own expense (many, but not all of them, were located at NIO). The list of attendees at the symposium is attached (Appendix II).


Goa Symposium attendees in front of the seminar building at NIO.

We plan to publish a symposium volume as the major output from the Goa Symposium. Ward submitted a proposal to *Deep-Sea Research* (DSR II) for a Special Issue on Ocean Deoxygenation in December 2016 immediately after the meeting. The proposal was accepted, with Ramaiah, Crowe, Edgcomb and Ward as editors. All of the editors received training from EVISE in how to handle the manuscript submission and review process. To date, nine manuscripts have been submitted and are under review. Several more manuscripts have been promised and are underway, so we expect a total of about 15 papers for the Special Issue. DSR II estimates a time line from initial submission to publication of about 1.5 years so we expect to publish some time in 2018. A tentative list of authors and titles, compiled at the time of the symposium, is attached (Appendix III).

Immediately after the Goa symposium, Hallam, Crowe and Jurgens prepared a Correspondence for *Nature* on the urgency of the issue of ocean deoxygenation. The letter was submitted to *Nature* in February 2017.

SCOR-WG-144 Goa Meeting, 3 Dec 2016

WG-144 Members Attending

Sean Crowe
Virginia Edgcomb
Stephen Hallam
Veronique Garcon
Klaus Jürgens
Nagappa Ramaiah
Osvaldo Ulloa
Bess Ward

The annual meeting of SCOR SG-144 took place on 4 December at NIO in Goa, India. The main items of business were as follows.

**1. Update on the Warnemünde meeting:** As outlined in last year's report, a white paper is planned to provide guidelines for experimental design, sampling and analysis of oxygen-depleted waters in order to minimize artefacts and to maximize comparability between studies. The outline and tentative authorship for the sections remains as initially planned:

1. Introduction and Goals (Jürgens)
2. OMZ models: General considerations, models and data (Garcon, Oschlies)
3. Incubation-independent sampling: Chemistry (nutrients, gases, sulfur compounds, stable isotopes etc.) (Schulz-Vogt, Revsbech, Bange, Bottcher)
4. Incubation-independent sampling: Biology (viruses, prokaryotes, protists, DNA/RNA, transcripts) (Brum, Lam, Edgcomb, Ramaiah, Hallam, Ulloa, Jürgens)
5. Incubation-dependent sampling: Activities, rates, processes (Ward, Thamdrup, Ramaiah, Jürgens, Crowe, Lam, Brum, Edgcomb)
6. Identification of core parameter/measurements to characterize OMZs: (Lam, Revsbech)
7. Current status of in situ incubation/fixation systems: (Edgcomb, Taylor)
8. Genomic data and sample archiving: (Hallam, Ulloa)

Klaus Jürgens is the lead author on the white paper and he has received draft contributions from several of the authors. The discussion focused on how to move the project forward. Renewed efforts are needed to obtain text from those who have not yet contributed, but it might be wise to proceed with the materials in hand. Jürgens was urged to proceed to compile the material he has already received and to edit it into a publishable document.

**2. *Falkor* ship time proposal:** Ward submitted an Expression of Interest to the Schmidt

Ocean Institute in December 2015 to request ship time on the R/V *Falkor*. The goal of the cruise was to develop and demonstrate in situ devices for unperturbed measurement of biogeochemical processes, and assessment of microbial community composition and activity in the ocean. The expression of interest was approved for further development and a full proposal was prepared by Hallam and Crowe for work in the North Pacific and submitted in June 2016. We were notified in November 2016 that the proposal would not be funded. The main reason for the lack of success appears to be uncertainty about the new in situ devices that we planned to deploy.

**3. Hands-on workshop in Chile:** For January 2018, we are planning a workshop to be held in conjunction with ECODIM in Concepcion, Chile. At the minimum, the SCOR members will attend and the students of the ECODIM course will be the "beneficiaries" of a hands-on workshop applying the best practice methods we have described in the Warnemünde white paper. We will plan to use the Concepcion research vessel for day trips to collect samples and will perform the incubations and some analysis at the Concepcion lab. (Update on the Chile workshop: This endeavor is somewhat beyond the means and the time frame of the original WG 144 mandate. In the absence of serious fundraising and buy-in from our Chilean collaborators, it seems unlikely that this event will take place.)

Progress towards goals of the Terms of Reference

The Saanich Inlet workshop was completed as planned during the first year of the program. The Warnemünde meeting was held as planned during the second year of the program and the white paper is in draft form at this time and although final version was expected at the Goa workshop, which has still not progressed. The Goa workshop, originally planned for the fourth year of the program, was moved to the third year and was successfully completed. The special journal issue planned for the output of the Goa workshop is in progress at DSR II. The workshop in Chile has been moved to the fourth year and planning and fundraising for that event are still underway. However, given the lack of funds and the expense of the effort, it seems likely that this event will not take place.

Schedule of Sessions

**International Symposium on Microbial Responses to Ocean Deoxygenation December 03-05, 2016**

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Day 1; Dec 3, 2016, Saturday

| | |
|---|---|
| Registration | 08.30-09.00 |
| **Inaugural Session +Distinguished Lecture by Dr SWA Naqvi** | **09.00-10.45** |
| **Tea Break** | **10.45-11.15** |

| **Session I** | **Biogeochemical Processes** | **11.20-13.10** |
|---|---|---|
| Time | Presenting Author | Title of the Presentation |
| 11.20-11.45 | Bess Ward | **Biogeochemistry and Nitrogen Cycling in Oxygen Minimum Zone Regions of the Ocean** |
| 11.45-12.10 | Hermann Bange | **Trace Gases in Low Oxygen Environments in the Open and Coastal Oceans** |
| 12.10-12.30 | Karen Casciotti | **Paired N and O Isotopic Analysis of Nitrate, Nitrite, and Nitrous Oxide from the Arabian Sea Oxygen Deficient Zone** |
| 12.30-12.50 | Damodar Shenoy | **Variation of Dissolved Oxygen in the Oxygen Minimum Zone of the Arabian Sea** |
| 12.50-13.10 | Arvind Singh | **Time-series Analysis of Dissolved Oxygen and Inorganic Nutrients in the Eastern Arabian Sea** |
| **13.10-14.00 Lunch** | | |
| **Session II** | **Biogeochemical Processes** | **14.00-15.50** |
| Time | Presenting Author | Title of the Presentation |
| 14.00-14.25 | Donald E. Canfield | **The Bay of Bengal, an Oxygen Minimum Zone at a Tipping Point** |
| 14.25-14.50 | Bo Thamdrup | **The Biogeochemistry of Golfo Dulce, an OMZ-like Coastal Basin** |
| 14.50-15.10 | Siby Kurian | **Fate of Organic Matter in the OMZ Sediments of Central West Coast of India during late Holocene** |
| 15.10-15.30 | Aurélien Paulmier | **Remineralization versus Preservation in the Oxygen Minimum Zone off Peru** |
| 15.30-15.50 | Aninda Mazumdar | **Sediment Pore Fluid Chemistry in the Oxygen Minimum Zone of the Eastern Arabian Sea** |
| **15.50-16.50** | **Tea Break + Poster Session (7 Posters)** | |

| **Session III** | **Biogeochemical Processes** | **16.50-18. 00** |
|---|---|---|
| Time | Presenting Author | Title of the Presentation |
| 16.50-17.15 | Virginia Edgcomb | **Evidence for needed New Sampling Technology for *In Situ* Water Sample Collection and Preservation** |
| 17.15-17.40 | Allan Devol | **An N-isotope Mass Balance of the Eastern Tropical North Pacific Oxygen Minimum Zone** |
| 17.40-18.00 | Carolyn Buchwald | **Using Natural Abundance Stable Isotopes of Nitrate and Nitrite as Tracers for Nitrogen Cycling in the Eastern Tropical North Pacific** |

**Poster Presentations for Day 1:**

| Poster | Presenting Author | Title of the Presentation |
|---|---|---|
| D1-P1 | Jovitha Lincy V J | **Prevalence of 'Candidatus' Bacterial Communities, the Major Component of "Microbial Dark Matter" from the Bay of Bengal, Oxygen Minimum Zone** |
| D1-P2 | Larissa D Menezes | **Diversity of Chemolitotrophic Bacteria in the Oxygen-depleted Waters of the Northern Indian Ocean** |
| D1-P3 | Kausar F Bepari | **Dynamics of Dimethylsulphide and Associated Sulphur Compounds at the Sediment Water Interface: An Experimental Approach** |
| D1-P4 | Svetlana Fernandes | **A Comparative Study of Sulfur-Carbon-Iron Systematics in Sediments Underlying the Perennial and Seasonal OMZs of the Arabian Sea, West Coast of India** |
| D1-P5 | Rishmita Mukherjee | **Bacterioplankton Abundance, Community Composition, Oxygen and other Physico-Chemical Parameters from Sundarban Estuaries** |
| D1-P6 | AV Chandrasekhararao | **Phytoplankton Response to the Contrasting Physical Features in the Eastern Arabian Sea during late North East Monsoon** |
| D1-P7 | Genevieve Fernandes | **Influence of pH change on Bacterial Community Structure in the OMZ of the Bay of Bengal: a Microcosm Study** |

**Day 2; December 4, 2016, Sunday**

| **Session IV** | **Microbial Ecology and Communities** | **09.00-13.05** |
|---|---|---|
| Time | Presenting Author | Title of the Presentation |
| 09.00-09.25 | Steven J. Hallam | **Size Matters: Describing Changes Associated to Filter Size Cutoff in the Microbial Community Structure of a Seasonally Anoxic Fjord, Saanich Inlet.** |
| 09.25-09.45 | Sean Crowe | **High Affinity Microbial Sulfide Uptake and Marine Sulfur Cycling** |
| 09.45-10.05 | Steven/Monica | **TBA** |
| 10.05-10.25 | Parvathi Ammini | **Responses of Viruses in the Deoxygenated Waters of the Northern Indian Ocean** |
| 10.25-10.45 | Mandar Bandekar | **Temporally Stable but Diverse Bacterial Community in the Arabian Sea Oxygen Minimum Zone** |
| 10.45-11.05 | Andrew Babbin | Bess Ward Presented Title: **Anaerobic nitrite oxidation exceeds fixed nitrogen loss in the Pacific oxygen deficient zones** |
| **11.05-11.25** | **Tea** | |
| 11.25-11.45 | Koji Hamasaki | **Distribution and Phylogeny of Anaerobic Anammoniu-Oxidizing (Anammox) Bacteria in a Water Column of the Central Pacific Ocean** |
| 11.45-12.05 | | |
| 12.05-12.25 | Montserrat Aldunate | **Nitrogen Assimilation in *Prochlorococcus* Inhabiting the Anoxic Marine Zone of the Eastern Tropical South Pacific.** |
| 12.25-12.45 | Mónica Beltrán | **Exploring Methanotrophic Community Composition and Dynamics along Redox Gradients in a Seasonally Anoxic Fjord, Saanich Inlet.** |
| 12.45-13.05 | Samir Damare | **A comparison of Bacterial Communities from the OMZs of the Arabian Sea and Bay of Bengal** |
| **13.05-14.00 Lunch** | | |

| **Session V** | **Omics of Deoxygenated Waters** | **14.00-15.45** |
|---|---|---|
| Time | Presenting Author | Title of the Presentation |
| 14.00-14.25 | Klaus Jürgens | **Prokaryotic Activities in the Suboxic Zone of the Black Sea as revealed by a Metatranscriptomic analysis** |
| 14.25-14.45 | Osvaldo Ulloa | **Metabolic Potential of Uncultivated Microorganisms from Anoxic Marine Zones as revealed by Single-cell Genomics** |
| 14.45-15.05 | Amal Jayakumar | **Diversity, Distribution and Gene Expression of Diazotrophs (*nifH*) in Oxygen Deficient Waters** |
| 15.05-15.25 | Michael Beman | **Carbon and Nitrogen Cycling Processes, Genes, and Organisms along Oxygen Gradients within and across (model) Oxygen Minimum Zones: Consistent, Inconsistent, or Consistently Inconsistent?** |
| 15.25-15.45 | G V M Gupta | **Variation in Deoxygenation and its Controlling Factors over the Western Indian Shelf** |
| **15.45-16.00** | **Skalar Presentation** | |
| **16.00-16.45** | **Tea + Poster Session (5 posters)** | |

| **Session VI** | **Modelling** | **16.45-17.50** |
|---|---|---|
| Time | Presenting Author | Title of the Presentation |
| 16.45-17.10 | Véronique Garçon | **Multi-scale Interactions in the OMZ off Peru: AMOP Observations and Modelling** |
| 17.10-17.30 | Laura A. Bristow | **Putting the Puzzle Pieces together: How Substrate Kinetics and Oxygen Inhibition Control N Loss in Oxygen Minimum Zones** |
| 17.30-17.50 | Andreas Oschlies | **Patterns of Deoxygenation - How Reliable are Model Projections? Presented via Video Conferencing** |

**Poster Presentations for Day 2:**

| Poster | Presenting Author | Title of the Presentation |
|---|---|---|
| D2-P1 | Amara Begum Mulla | **Nitrate-Reducing Bacterial Diversity from the Arabian Sea Oxygen Minimum Zone** |
| D2-P2 | Jovitha Lincy V J | **Exploring Sediment Bacterial Diversity of the Arabian Sea Oxygen Minimum Mone through Phylogenomics** |
| D2-P3 | Jasmine Gomes | **Denitrification Potential of Culturable Bacterial Population from a Seasonal Hypoxic Coastal location** |

| | | |
|---|---|---|
| D2-P4 | Mandar Bandekar | **Molecular Detection of Nitrite Reducing (*nirS*) and Anammox (*hzo*) Bacteria from the Arabian Sea Oxygen Minimum Zone** |
| D2-P5 | Ujwala Amberkar | **Phylogenetic Diversity of Culturable Bacteria from the Coastal Sediments of Oxygen Minimum Zone in the Arabian Sea and their Role in Nitrate Reduction** |

**Day 3, December 5, 2016, Monday**

| **Session VII** | **Societal Impacts of Marine Deoxygenation** | **09.00-10.50** |
|---|---|---|
| Time | Presenting Author | Title of the Presentation |
| 09.00-09.25 | Gordon T. Taylor | **Lessons from a Natural Laboratory for Ocean Deoxygenation: The Cariaco Basin** |
| 09.25-09.50 | Sudhakar Maratadu | **Consequence of Ocean Deoxygenation on Bioresources in Areas Beyond National Jurisdictions** |
| 09.50-10.10 | Judith Gonsalves | **Ecological Characterization of Microbial Groups as Drivers and Responders in the Oxygen Minimum Zone of the Arabian Sea** |
| 10.10-10.30 | Venkatesan Ramasamy | **Challenges to have Real Time Ocean Data Collection - Microbial Deterioration of Structures** |
| 10.30-10.50 | Ramaiah Nagappa | **Coastal Hypoxia and Blue Economy** |
| **10.50-11.40** | **Tea + Poster Session (6 posters)** | |
| **11.40-13.00** | **Valedictory Function and Closing** | |

**Poster Presentations for Day 3:**

| Poster | Presenting Author | Title of the Presentation |
|---|---|---|
| D3-P1 | Anirudh Ram | **Impact of Hypoxia/Anoxia in a Tropical Indian Estuary receiving Urban Wastewater** |
| D3-P2 | Bhagyashri Naik | **Variation in Phytoplankton at the CaTS Time Series Site (Off Goa): Implication to DMS Production** |
| D3-P3 | Jabir T Vipindas T V | **Nitrogen Fixation by Sulfate Reducing Bacterial Communities of a Tropical (Cochin) Estuary** |
| D3-P4 | Mamatha S S | **Role of Nitrate Reducers in Bioremediation of Waste Water from Shrimp Pond** |
| D3-P5 | Mangesh Gauns | **Spatial Discrepancy of Mesozooplankton over the Continental Realm in the Eastern Arabian Sea Preceding the Arrival of Southwest Monsoon** |

| D3-P6 | Asha Devi | **Micro and Mesozooplankton Community Dynamics in Eastern Arabian Sea Ecosystems** |
|---|---|---|

| **International Symposium on Microbial Response to Ocean** | | | | |
|---|---|---|---|---|
| SCOR Goa attendees list | | | | |
| | | | | |
| **Speakers** | | | | |
| **Senior Scientists** | | **Institution** | | **Country** |
| Parvathi | Ammini | NIO | | India |
| Mandar | Bandekar | NIO | | India |
| Hermann | Bange | GEOMAR | | Germany |
| Don | Canfield | Southern Denmark University | | Denmark |
| Karen | Casciotti | Stanford University | | USA |
| Allan | Devol | University of Washington | | USA |
| Judith | Gonsalves | NIO | | India |
| G V M | Gupta | CMLRE | | India |
| Koji | Hamasaki | AORI | | Japan |
| Amal | Jayakumar | Princeton University | | USA |
| Siby | Kurian | NIO | | India |
| Sudhakar | Maratadu | CMLRE | | India |
| Aninda | Mazumdar | NIO | | India |
| Aninda | Mazumdar | NIO | | India |
| Wajih | Naqvi | NIO | | Indai |
| Andreas | Oschlies | GEOMAR | | Germany |
| Aurelien | Paulmier | CNRS | | France |
| Venkatesan | Ramasamy | NIOT | | India |
| Damodar | Shenoy | NIO | | India |
| Gordon | Taylor | Stonybrook SUNY | | USA |
| Bo | Thamdrup | Southern Denmark University | | Denmark |
| | | | | |
| **Junior/Early Career** | | | | |
| Montserrat | Aldunate | Universidad Concepcion | | Chile |
| Mike | Beman | UC Merced | | USA |
| Laura | Bristow | MPI- | | Germany |
| Carly | Buchwald | Dalhousie | | Canada |
| Samir | Damare | NIO | | India |
| Joitha | Lincy | | | India |
| Arvind | Singh | | | India |
| Parvathi | Venu | NIO | | India |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Poster Presentations** | | | | | | |
| Uujwala | Amberkar | NIO | | India | | |
| Kausar | Bepari | NIO | | India | | |
| AV | Chandrasekhara | NIO | | India | | |
| Asha | Devi | CMLRE | | India | | |
| Genevieve | Fernandes | NIO | | India | | |
| Svetlana | Fernandez | NIO | | India | | |
| Mangesh | Gauns | NIO | | India | | |
| Jasmine | Gomes | NIO | | India | | |
| Joitha | Lincy | NIO | | India | | |
| S S | Mamatha | NIO | | India | | |
| Larissa | Menezes | NIO | | India | | |
| Rishmita | Mukherjee | University of Calcutta | | India | | |
| Amara | Mulla | NIO | | India | | |
| Bhagyashri | Naik | NIO | | India | | |
| Anirudh | Ram | NIO | | India | | |
| Jabir T | Vipindas T V | CUSAT | | India | | |
| Monica | Beltran Torres | UBC | | Canada | | |
| | | | | | | |
| **SCOR WG-144 members** | | | | | | |
| Sean | Crowe | UBC | | Canada | | |
| Veronique | Garcon | CNRS | | France | | |
| Ginny | Edgcomb | WHOI | | USA | | |
| Jung-Ho | Hyun | Hanyang University | | Korea | unable to attend | |
| Elsabe | Julies | University of Namibia | | Namibia | unable to attend | |
| Klaus | Jurgens | Leibniz Institute for Baltic Sea | | Germany | | |
| Stephen | Hallam | UBC | | Canada | | |
| Phyllis | Lam | Southampton | | UK | unable to attend | |
| Osvaldo | Ulloa | Universidad Concepcion | | Chile | | |
| Nagappa | Ramaiah | NIO | | India | | |
| Bess | Ward | Princeton University | | USA | | |

Partial list of authors and tentative/draft titles of papers to be included in the DSR II Special Issue on Ocean Deoxygenation

1. Carolin Löscher, Don Canfield et al.: on $N_2$ fixation in the Bay of Bengal.
2. Hannah Lutterbeck, Hermann W. Bange et al: Nitric oxide (NO) in the oxygen minimum zone off Peru
3. Ryuki Shishikura, Shotaro Suzuki, Takuhei Shiozaki, Tomotaka Nakamura, Yuichi Suwa, Koji Hamasaki: Distribution of anaerobic ammonium-oxidizing (anammox) bacteria in a water column of the central Pacific Ocean
4. Arvind Singh and Anna Godhe: Time-series analysis of dissolved oxygen and inorganic nutrients in the eastern Arabian Sea
5. Parvathi A, Jasna V, Aparna S, Aswathy VK, Muraleedharan KR, Gireesh Kumar TR, Pradeep Ram and Sime-Ngando T: Is lysogeny a survival strategy for viruses in the deoxygenated waters of Arabian Sea oxygen minimum zone?
6. M. Hannig, S. Beckmann, G. Lavik, G. Jost, M. Labrenz, K. Jürgens: Impact of experimental bottle incubations on the composition and activity of marine denitrifying bacterial communities
7. Mandar Bandekar, Ram Murti Meena and N Ramaiah: Predominant denitrification via Annamox and DNR in Arabian Sea Oxygen Minimum Zone
8. Jasmine Gomes, Mandar Bandekar, Rakhee Khandeparker, Ram Murti Meena and N Ramaiah: Diversity of Denitrification bacterial community from a seasonally hypoxic tropical coastal region: qPCR based approach
9. Laura Bristow, Cory Padilla, Neha Sarode, Frank Stewart, Bo Thamdrup: Size fractionation of microbial nitrogen transformations in the tropical anoxic basin Golfo Dulce
10. Kausar F. Bepari, Sidhesh Borker, Anil K. Pratihary and Damodar M. Shenoy: Dynamics of dimethylsulphide and associated sulphur compounds at the sediment water interface: An experimental approach
11. Analiza Maria D'souza and Mangesh Gauns: Spatial changes in mesozooplankton over the continental realm in the eastern Arabian Sea preceding the arrival of southwest monsoon
12. Matthew Forbes, Jagruti Vedamati, Brian Peters, and Karen Casciotti: Nitrous oxide cycling in the Eastern Tropical South Pacific as inferred from isotopic and isotopomeric data
13. C.R. Asha Devi, Vimalkumar, K.G., Padmakumar, K.B., Lathika Cicily Thomas, Maneesh, T.P., Anilkumar Vijayan, Gupta, G.V.M and Sudhakar, M: Understanding the microzooplankton mediated food web of the winter- spring *Noctiluca* bloom in the perennial oxygen deficient North Eastern Arabian Sea Ecosystem
14. Monica Torres Beltran, Taylor Sehein, Steven Hallam and Virginia Edgcomb: Parasitic protest interactions and dynamics along oxygen gradients in a seasonally anoxic fjord: Saanich Inlet, British Columbia
15. Gordon Taylor: Microbial community response to ocean deoxygenation in the Cariaco Basin
16. Amal Jayakumar, A. P. Rees. P. J. Kearns, J. L. Bowen and B. B. Ward. Biogeography of denitrification on the basis of nosZ gene community composition

17. Aurelier Paulmier, et al.: Remineralization versus preservation in the Oxygen Minimum Zone off Peru
18. Carly Buchwald et al.: Using Natural Abundance Stable Isotopes of Nitrate and Nitrite as Tracers for Nitrogen Cycling in the Eastern Tropical North Pacific

Others expected to contribute but who have not yet committed:

Stephen Hallam, Sean Crowe, Montserrat Aldunate, Osvaldo Ulloa, Michael Beman

### 2.1.8 WG 145 on Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC) (2014) *Sicre*

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, Cd, Co, Mn, and Zn). Current capabilities and limitations for oceanographic and biogeochemical calculations will be defined, and future needs established. 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.
2. 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.
3. 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.
4. 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.

**Chair:** David Turner (Sweden)

**Vice-Chairs:** Simon Clegg (UK) and Sylvia Sander (New Zealand)

**Other Full Members:** Heather Benway (USA), Arthur Chen (China-Taipei), Andrew Dickson (USA), Vanessa Hatje (Brazil), Maite Maldonado (Canada), Alessandro Tagliabue (UK), and Rodrigo Torres (Chile)

**Associate Members:** Eric Achterberg (Germany), Yuri Artioli (UK), Parthasarathi Chakraborty (India), Peter Croot (Ireland), Martha Gledhill (Germany), Giles Marion (USA), Peter May (Australia), Frank Millero (USA), Ivanka Pizeta (Croatia), Darren Rowland (Australia), Pavel Tishchenko (Russia), Stan van den Berg (UK), Wolfgang Voigt (Germany), Christoph Völker (Germany), Feiyue Wang (Canada), and Mona Wells (China)

**Executive Committee Reporter:** Marie-Alexandrine Sicre

1. Name of group

WG145: Chemical Speciation Modelling in Seawater to meet 21st Century Needs

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

The major effort in the past year has been devoted to seeking research funding for carrying out the fourth term of reference. Group members Simon Clegg, Andrew Dickson and Heather Benway have been awarded a research grant within the NERC/NSF (UK/US) joint program. This project is closely aligned with the Working Group objectives and will run for 3 years, with an expected start date in July 2017. In addition, four laboratories have offered to fund and carry out complementary measurements: GEOMAR (Kiel, Germany) and the national standards laboratories in France, Germany and Japan.

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

Turner, D.R., E.P. Achterberg, C.-T.A. Chen, S.L. Clegg, V. Hatje, M.T. Maldonado, S.G. Sander, C.M.G. van den Berg, M. Wells. 2016. Toward a Quality-Controlled and Accessible Pitzer Model for Seawater and Related Systems. *Frontiers in Marine Science* 3: doi:10.3389/fmars.2016.00139.

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

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, and Zn). Current capabilities and limitations for oceanographic and biogeochemical calculations will be defined, and future needs established. 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.*

The Working Group's review has been published in *Frontiers in Marine Science*, see section 3 above.

2) *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.*

The Working Group's overview of current model status and development needs has been published, see section 3 above. The WG's plans have been presented at a Town Hall meeting at Ocean Sciences 2016, where the WG also co-sponsored a session.

3) *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.*

The Working Group considers that the functionality should be based on user's needs, and has therefore taken steps to consult with user communities. User needs were discussed at the 2016 Town Hall, and were followed up by a Survey Monkey questionnaire aimed at academic users (thanks to Ed Urban for help with this). A second Survey Monkey aimed at users outside the academic community was started in April 2017.

4) *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.*

This term of reference involves significant effort, both in program code development, and in new measurements. External funding has now been secured through the NERC/NSF grant described under section 2 above

5. WG activities planned for the coming year. Limit 500 words

The NERC/NSF research project is expected to start in July 2017. The initial focus of the work will be a full characterization of the chemistry of TRIS buffers in artificial seawater over the full range of relevant salinities and temperatures. These buffers are used for calibration of seawater pH, a measurement that is central to monitoring and understanding of ongoing ocean acidification. New measurements complementing those made by the U.S. project partner will be carried out at GEOMAR (Kiel, Germany) and at the French, German and Japanese national standards laboratories.

Once the second Survey Monkey aimed at non-academic users has been completed, an analysis and summary of the results of both surveys will be prepared for publication.

The next WG meeting is planned for February 2018 in conjunction with the Ocean Sciences Meeting.

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

The Working Group has made good progress with the first three terms of reference. Research funding for the fourth term of reference has been secured for the period 2017-2020, which

means that the Working Group would need to continue its activities beyond the planned 4-year period in order to complete the Terms of Reference. Since the major effort during the past year has focused on fundraising, the Working Group will not meet during 2017. The Working Group asks SCOR to reallocate the funding for a 2017 meeting to later years so that the WG can meet to discuss priorities and review progress through the period of the NERC/NSF project.

7. Any special comments or requests to SCOR. Limit 100 words.

### 2.1.9 WG 146 on Radioactivity in the Ocean, 5 decades later (RiO5) *Smythe-Wright* (2014)

**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.

**Co-chairs**: Ken Buesseler (USA) and Minhan Dai (China-Beijing)

**Other Full Members:** Michio Aoyama (Japan), Claudia Benitez-Nelson (USA), Sabine Charmasson (France), Roberta Delfanti (Italy), Pere Masqué (Spain), Paul Morris (Monaco), Deborah Oughton (Norway), and John Smith (Canada)

**Associate Members:** Andy Johnson (USA), Reiner Schlitzer (Germany), Gary Hancock (Australia), José Godoy (Brazil), Nuria Casacuberta (Switzerland), Jordi Vives i Batlle (Belgium), Vladimer Maderich (Ukraine), and Sandor Muslow (Chile)

**Executive Committee Reporter:** Denise Smythe-Wright

**Note:** The 2017 Meeting of WG 146 will occur after the background papers for the SCOR meeting are distributed, so a report from WG 146 will be distributed later.

### 2.1.10 WG 147: Towards comparability of global oceanic nutrient data (COMPONUT) (2014) *Sicre*

**Terms of Reference**

1. To establish mechanisms to ensure comparability of oceanic nutrient data in collaboration with International organisations such as ICES and PICES.
2. To assess the homogeneity and stability of currently available RMs/CRMs: The group needs 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 practices, including sample preservation protocols, 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.

**Co-chairs:** Michio Aoyama (Japan) and E. Malcolm S. Woodward (UK)

**Other Full Members:** Susan Becker (USA), Karin Bjorkman (USA), Anne Daniel (France), Claire Mahaffey (UK), Hema Naik (India), Raymond Roman (South Africa), Bernadette Sloyan (Australia), and Toste Tanhua (Germany)

**Associate Members:** Karel Bakker (Netherlands), Minhan Dai (China-Beijing), Andrew Dickson (USA), Akiharu Hioki (Japan), Alex Kozyr (USA), Akihiko Murata (Japan), TaeKeun Rho (Korea), Sophie Seeyave (UK), Jonathan Sharp (USA), Winnie van Vark (Netherlands), and Takeshi Yoshimura (Japan)

**Executive Committee Reporter:** Marie-Alexandrine Sicre

Annual SCOR Working Group 147 Report to SCOR

By Michio Aoyama and Malcolm Woodward on 22 June 2017

1. Name of group

SCOR WG#147 "Towards comparability of global oceanic nutrient data"

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words (873words)

We held the WG#147 second annual meeting in Qingdao, China, in September 2016, alongside the CLIVAR annual meeting, where our SCOR group contributed to a poster cluster presentation. There were 7 Full Members, 3 Associate Members and 4 observers present at the meeting. During this second annual meeting, we confirmed and congratulated TaeKeun as he had been accepted onto the official Associate Member list for WG #147, following the resignation of Jonathan Sharp.
We had two teleconferences with all Full and Associate members, on Feb. 2016 and July 2016, respectively.
During the meeting/teleconferences and follow up discussions after the second meeting, we made recommendations and decided on the actions and future anticipated progress as outlined below. The actions for the WG into 2017 are described in section 5.

1. **Follow up questionnaire of the IOCCP-JAMSTEC inter-laboratory comparison study in 2014/15:**

It was agreed that we should write to all the laboratories that did not do well in the last intercomparison exercise in an effort to help them improve their analysis. This was given general approval by all members. We would also write to all of the labs who did not report any results in the last exercise, telling them there would be another exercise in 2017/18, but asking them why they did not submit results in 2015. It was noted that there were cross agreements with results from the last intercomparison exercise: 30 labs were in good agreement with the values. Dr. Aoyama prepared a questionnaire covering the above discussions and sent it out for comment to labs on the 2015 list. In June 2017, we had received only 8 replies, so we will ask the labs again to reply with the information.

2. **About the SCOR- JAMSTEC CRM's:**

The Website went live in November 2016 and JAMSTEC started to provide nutrient CRMs with the SCOR-JAMSTEC logo, and these were available to the global scientific community. At the time of this report, June 2017, 16 laboratories in 12 countries ordered 314 bottles of CRMs over the first 8 months.
There was a long discussion on the certification and methods of carrying this out, which was at NMIJ, KANSO and JAMSTEC. Based on these discussions, details of certification and SI traceability of the CRMs were up on the website at JAMSTEC, http://www.jamstec.go.jp/scor/.
A description of the specification for the CRMs is below.

1) SCOR-JAMSTEC CRMs are certified reference materials (CRM) for inorganic nutrients in seawater. These were produced by the KANSO Company Ltd. on a commission basis, using the state-of-the-art facility at KANSO, and this certified reference material has been produced using autoclaved natural seawater on the basis of a quality control system under ISO Guide 34 (JIS Q 0034).
2) The certified values are arithmetic means of the results of a randomly selected sub-set of 30 bottles from each batch (measured in duplicates), and analysed by KANSO, and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), using the classical colorimetric analytical methods (continuous flow analysis, CFA method).
3) For metrological traceability of the CRMs, the certified values of nitrate, nitrite, and phosphate of SCOR-JAMSTEC CRM are traceable to the International System of Units (SI) through an unbroken chain of calibrations, JCSS, CERI and NMIJ solutions, each having stated uncertainties. The certified values of silicate for the SCOR-JAMSTEC CRMs are traceable to the International System of Units (SI) through an unbroken chain of calibrations, Merck KGaA and NIST SRM3150 solutions, each having stated uncertainties.

After much discussion it was decided we would not move into coastal water CRMs, but that we would advise KANSO to look into producing, in the future, high-salinity ~ 39psu, Mediterranean/Black Sea waters as it would be advantageous to many laboratories to have a Med reference material.

**3. Continuation of WG#147 at the end of the 3 years of SCOR funding – thoughts and options:**

It is very important for the global community that the production of the Reference materials is continued, and also that the International Intercalibration exercises should also continue as they are an important guide to how well laboratories are improving their analytical quality globally. It is crucially important to improve the quality of analysis around the world, and the subsequent data outputs, and hence inputs to global databases.
Generally, it was agreed that is very important that the work of this group needs to be continued in some format. Informal discussions have continued with SCOR how this may be achieved into the future once the 3 years of International working group status has expired.

**4. Poster cluster session at the CLIVAR Open Science conference, 2016:**

WG #147 submitted a poster 'cluster' session at the CLIVAR Open Science conference "Charting the course for climate and ocean research" (Qingdao, China) in September 2016. We had 15 posters at the site and 14 of them can be viewed at the SCOR WG 147 web page at: http://www.scor-int.org/SCOR_WGs_WG147.htm.

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

Poster Cluster Community White paper entitled "Comparability of Oceanic nutrient data" has been published. This was presented to the CLIVAR Open Science conference, 2016 and now is at SCOR WG 147 web page at http://www.scor-int.org/SCOR_WGs_WG147.htm.

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words (831words)

ToR 1: To establish mechanisms to ensure comparability of oceanic nutrient data in collaboration with International organisations such as ICES and PICES.

WG 147 collaborated with JAMSTEC and has provided SI traceable CRMs of nutrients for the global community since November 2016. WG 147 also collaborated with IOCCP and JAMSTEC to conduct the IOCCP-JAMSTEC Inter-laboratory calibration exercise of CRM/RMNS in 2014/15. There will be a further international calibrations exercise in 2017/2018.

ToR 2: To assess the homogeneity and stability of currently available RMs/CRMs: The group needs to determine whether the current producers are achieving a level of precision within and between laboratories which is comparable to or better than 1 %.

In the IOCCP-JAMSTEC Inter-laboratory calibration exercise of CRM/RMNS in 2014/15, NMIJ CRM, KANSO CRM and KIOST RM were used. The results of the KANSO CRMs, of which the analytical concentrations were the highest among the samples, and with homogeneities of 0.2 %: the consensus standard deviation in terms of percentage for nitrate was 1.5%, for phosphate was 1.6% and for silicate was 1.2%. This indicated that a level of precision among 30 core laboratories who reported values were in agreement close to 1% for nitrate, phosphate and silicate. These results also confirmed that the homogeneity of currently available KANSO CRMs should be better than 1% because consensus of standard deviation in terms of percent is an expanded uncertainty of homogeneity of the CRMs, and analytical precision of the core laboratories.

For MOOS-3 by NRC Canada, Dr. Aoyama confirmed an unacceptable decrease of phosphate and nitrate concentrations of 7 bottles of MOOS-3 in 2015. For nitrate the certified value was 22.31 +- 0.30 μmol $kg^{-1}$, however, the measured values actually ranged from 11.03 to 17.90μmol $kg^{-1}$. For phosphate, the certified value was 3.430 +- 0.060 μmol $kg^{-1}$; however, the measured values ranged from 3.030 to 3.245μmol $kg^{-1}$. For silicate, measured values were within the certified value and the stated uncertainty. Filamentous fungi was found in several bottle of MOOS-3. This was reported to the manufacturer and the MOOS-3 samples were not used as part of the global intercalibration exercise.

ToR 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.

No specific progress during this period. A part of this ToR3 might be included in the updated GO-SHIP nutrients manual, discussed in ToR 6.

ToR 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 practices, including sample preservation protocols, particularly targeted towards developing countries.

WG 147 is currently arranging an 'International training workshop on Nutrient analysis', which will be held at the NIOZ laboratory in November 2017. This is being co-organised by NIOZ and PML. Generous sponsorship has been awarded from grant applications through both SCOR & POGO. This workshop is specifically for nutrient scientists from developing countries, who will have the opportunity to work alongside and learn techniques from a group of the world's leading nutrient chemists, who are members of SCOR 147. Extra funding for the trainers and lecturers, and also for the actual running of the workshop, has also been obtained separately by the WG 147. We are also very grateful to have co-sponsorship from JAMSTEC, PML and NIOZ. The plan is to have a nutrient training workshop for the successful applicants from developing countries for the first 4 days of the week, and then have a specific workshop on silicate analysis, where the 'experts'/'trainers' will stay on to continue this effort. We will also try to target all the developing countries who submitted results to the last intercalibration exercise and more specifically those who were over 10% in error from the mean values of others and away from the consensus means of the majority.

The workshop Website is being hosted by NIOZ under their Marine Matters pages with the 'Flyer' being sent to potential applicants at the end of June 2017: The deadline for the applications is early August 2017, with the successful applicants being informed by the end of August.

ToR 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.

WG 147 collaborated with IOCCP and JAMSTEC and helped to conduct the IOCCP-JAMSTEC Inter-laboratory calibration exercise of CRM/RMNS in 2014/15. WG 147 will collaborate with the IOCCP-JAMSTEC Inter-laboratory calibration exercise of CRM in 2017/18 through the WG network of the global nutrients community.

ToR 6: To update the GO-SHIP nutrient measurement manual, which was originally a product of the IOC-ICES SGONS, (Study Group on Nutrient Standards).

WG 147 has drafted a new manual which is an update of the GO-SHIP nutrient measurement manual, and this draft was sent to Members for comments in February 2017. WG 147 is continuing this work to finalise this update.

ToR 7: To publish reports on this WG's activities and workshops.

Updates have been communicated to the other WG members and for the workshop the advertisement/flyer will be sent globally.

5. WG activities planned for the coming year. Limit 500 words (486words)

1. **The third and final annual meeting will be held at OSM 2018, at Portland, USA, in February 2018.**
After discussions it was decided that the most apt meeting to end with would be the Ocean Sciences Meeting at Portland in February 2018. Agreement would be sought from Ed to extend the end dates of the WG until after that meeting (Note: Malcolm consulted Ed and this was agreed).

**2. NIOZ training workshop in November 2017:**
The WG 147 workshop in November 2017, organized by NIOZ and PML will be financially sponsored by SCOR & POGO, with co-sponsorship by JASMTEC for the nutrient CRMs, and PML and NIOZ. The plan is to have a nutrient training workshop for developing country scientists for the first 4 days of the week, and then have a specific workshop on silicate analysis, where the 'experts'/'trainers' will stay on to continue this effort. We have already secured some funding from SCOR for 5000 Euros and from POGO for 8250 Euros to support travel etc. for scientists from developing countries. Plus we have £7000, through WG 147 activities, to support the trainers/ experts/workshop. We will also try to target all the developing countries who submitted results to the last intercalibration exercise, and more specifically those who were identified as being greater than 10% from the norm for their analytical results, with the aim to improve those laboratories analysis and data quality output. The first call of this workshop was done in June 2017 and the web site of this workshop is at NIOZ web site at **https://www.nioz.nl/en/education/marine-studies**

**3. Production of new lots of CRMs:**
We have already decided to provide the final two nutrient concentration levels which fit Atlantic waters. This will happen during the ZIPLOc north Atlantic cruise, at sea between June and August 2017, Malcolm and Claire will collect the seawater materials for the Atlantic deep and mid-depth waters, which will complete the remaining 2 lots of Atlantic waters for CRMs production, making 3 lots of CRMs (low, medium and high nutrient concentrations) available to all global scientists for both Atlantic and Pacific waters.

**4. GO-SHIP manual revision:**
A draft of a new updated manual was completed by Susan Becker (Scripps Institution) in Feb. 2017 and this is in discussion now within the group. Once the document is worked on and agreed by SCOR WG 147, it was suggested there could be a public consultation/review phase with the draft document up on the GO-SHIP Website as well as the IOCCP nutrients web page. The suggested name for the Manual is "The precise and accurate determination of dissolved inorganic nutrients in seawater; CFA Methods and Laboratory practice".
(Note : See the Susan Becker GO-SHIP poster presentation, which is the outline of the new manual at http://www.scor-int.org/Working_Groups/WG147/Poster_3.pdf).

**5. A workshop at OSM 2018:**
We have submitted a proposal for a session at OSM 2018: “Biogeochemistry and Nutrients in open ocean waters: Sustainable Ocean Observations and Time Series Efforts" This is to highlight and finalise the outputs of the working group and to invite other scientists to submit talks and posters also.

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words (144 words)

To establish mechanisms to ensure comparability of oceanic nutrient data, production and distribution of nutrients CRMs are one of the key issues. WG 147 has tried to have a UV cleaning system to pasteurize the resource seawater collected from the deep and mid-layer water column in order to stop any biological activity within the seawater during the transfer from ship to CRM producer in Japan. It has taken much longer than expected, and it is NOT finalized yet. This made a delay about one year from original schedule of CRM production. We decided instead to carry out pasteurization instead, plus 0.2 micron filtration, and will collect the final resource seawater in June-August 2017. Therefore, two lots of CRMs will be available around January-February in 2018 for purchase, and after we get these Atlantic level CRMs, SCOR-JASMTEC CRMs will cover the whole range of nutrient concentrations from the world oceans.

7. Any special comments or requests to SCOR. Limit 100 words.

WG#147 would like to request to get permission to use SCOR logo on SCOR-JAMSTEC CRMs after WG 147’s third and final meeting.

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

### 2.1.11 WG 148 on International Quality Controlled Ocean Database: Subsurface temperature profiles (IQuOD) *Shapovalov* (2015)

**Terms of Reference**

1. To develop, implement and document algorithms for assignment of "intelligent" metadata – i.e. an informed guess as to likely values for missing information – for temperature profiles where crucial metadata is missing.
2. To evaluate and document the most effective combination of automated quality control (AutoQC) procedures for temperature profile observations. International collaboration will be required for the design and coordination of benchmarking experiments using high quality reference datasets.
3. To establish and implement a set of optimal automated quality control procedures, by reaching international community consensus and using the knowledge gained in the benchmarking tests from ToR-2 (above); to produce and publish a reference guide for best practices in automated quality control of ocean temperature profiles; and to develop and freely distribute an open-source quality control software toolkit to promote wide and rapid adoption of best practices by the oceanographic community.
4. To examine and document the feasibility of machine learning and other novel computational methods for enhanced quality control, to potentially minimize labor costs associated with human expert quality control procedures.
5. To develop, implement and document internationally agreed best practice methods for assignment of uncertainty estimates to each temperature observation.
6. To freely disseminate (interim) versions of the IQuOD global temperature profile database (and added value-products) as it evolves over the next 3 years, in user-friendly file formats.
7. To share knowledge and transfer skills in instrumentation, regional oceanography, quality control procedures and data stewardship with international scientists in both developed and developing nations.

**Co-chairs:** Catia Domingues (Australia) and Matt Palmer (UK)

**Other Full Members:** TVS Udaya Bhaskar (India), Tim Boyer (USA), Marcela Charo (Argentina), Christine Coatanoan (France), Viktor Gouretski (Germany), Shoichi Kizu (Japan), Alison Macdonald (USA), and Ann (Gronell) Thresher (Australia)

**Associate Members:** Lijing Cheng (China-Beijing), Mauro Cirano (Brazil), Rebecca Cowley (Australia), Sergey Gladyshev (Russia), Simon Good (UK), Francis Bringas Gutierrez (USA), Katherine Hutchinson (South Africa), Gabriel Jorda (Spain), Sergio Larios (Mexico), and Toru Suzuki (Japan)

**Executive Committee Reporter:** Sergey Shapovalov

1. Name of group

**IQuOD - SCOR Working Group 148** (since April 2016)

**International Quality Controlled Ocean Database: Subsurface temperature profiles**

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

3.

- Email exchange (various)
- 6 video-conference meetings with 3-5 participants (via Skype, Zoom or Webex)
- 1 in-person meeting (Diggs, Cowley, Domingues, King, Maze | 14/03/2017, Hobart, Tasmania)
- 3 oral presentations by Domingues at the CLIVAR Open Science Conference: "Charting the course for climate and ocean research", 18-25 September 2016, Qingdao, China.
  - Global Synthesis and Observations Panel meeting (on IQuOD)
  - Townhall on sustained observations (including IQuOD)
  - CLIVAR Scientific Steering Group (including IQuOD)
- 6th Session WCRP Data Advisory Council (WDAC) presentation by P-P Mathieu (including IQuOD) https://www.wcrp-climate.org/WDAC-6/presentations/3a1.CLIVAR_WDAC6.pdf
- 1 oral presentation on IQuOD by Domingues at the 24th Session of the IOC Committee on International Oceanographic Data and Information Exchange (IODE), 27-31 March 2017, Kuala Lumpur, Malaysia
- 1 oral presentation on IQuOD by Palmer at the 9th Session of the JCOMM Ship Observations Team meeting, 27-31 March 2017, London, United Kingdom
- Annual IQuOD workshop with 46 participants (hosted by Suzuki, Kizu and Ishii) 1st SCOR-IQuOD WG 148 along with 5th XBT Science Team workshop, 3-7 October 2016, JAMSTEC, Tokyo, Japan

Agendas:
http://tokyo2016.xbt-japan.org/document/4th_iquod_agenda.pdf
http://tokyo2016.xbt-japan.org/document/XBT_Science_Agenda.pdf

4. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

- IQuOD website (Ricardo Domingues webmaster): http://www.iquod.org
- Annual workshop report
  1st SCOR-IQuOD WG 148, 3-7 October 2016, JAMSTEC, Tokyo, Japan
  http://www.iquod.org//documents/iquod_4thWkshp_meeting_report_final.pdf
- 24th session IODE report (including summary IQuOD activities | keyword IQuOD)
  27-31 March 2017, Kuala Lumpur, Malaysia
  http://www.iode.org/components/com_oe/oe.php?task=download&id=34433&version=1.0&lang=1&format=1
- Github software repository (led by S. Good, B. Mills and G. Castelao)
  https://github.com/IQuOD
  - Automated Quality Control (from various international groups) benchmarking framework
  - Machine learning for XBT data
  - Wodpy
- Peer-reviewed journal articles in preparation:
  - Cowley et al. on observational uncertainties
  - Palmer et al. on intelligent metadata for XBT measurements

5. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

Our major aim for 2016/2017 was to carry out a number of activities for the delivery of the first IQuOD interim product (IQuOD v0.1). This interim product has now been implemented by Tim Boyer as part of the next World Ocean Database version and is currently in the verification phase.

Major activities included:

- ✓ **Duplicates**: exact duplicates flagged (led by Thresher and King)
- ✓ **Intelligent-metadata**: "first cut" algorithms for unknown XBTs, advancing the work of Cowley et al. (2013) and coded in open-source Python (Palmer et al. draft in preparation)
- ✓ **Uncertainty**: "first cut" random error attached to each discrete observation (Cowley et al. draft in preparation)
- ✓ **Format**: ASCII and netCDF ragged array (CF compliant) (led by Boyer, Coatanoan and Hidas)
- **GDAC**: distribution via US NCEI (currently under verification phase at NCEI for format and data presentation, led by Boyer)

ftp://ftp.nodc.noaa.gov/pub/WOD/SELECT/iquod
Other potential distribution sites: UK MetOffice, French Coriolis, and Australian IMOS.

Terms of reference:

1. **To develop, implement and document algorithms for assignment of "intelligent" metadata – i.e. an informed guess as to likely values for missing information – for temperature profiles where crucial metadata is missing.**

   First-cut algorithms developed by Palmer et al. and implemented by Boyer for unknown XBT observations (a major platform type over the historical period). Draft paper in preparation for peer-reviewed journal (Palmer et al.).

2. **To evaluate and document the most effective combination of automated quality control (AutoQC) procedures for temperature profile observations. International collaboration will be required for the design and coordination of benchmarking experiments using high quality reference datasets.**

- About 50 AutoQC tests implemented on IQuOD's github repository
- AutoQC benchmarking code is ready to run.
- Some high-quality reference datasets made available for benchmarking exercise.
- Preliminary work completed on developing software to find the optimum set.

The above activities are being led by Good, Mills and Castelao.

3. **To establish and implement a set of optimal automated quality control procedures, by reaching international community consensus and using the knowledge gained in the benchmarking tests from ToR-2 (above); to produce and publish a reference guide for best practices in automated quality control of ocean temperature profiles; and to develop and freely distribute an open-source quality control software toolkit to promote wide and rapid adoption of best practices by the oceanographic community.**

   Activities to complete the above TORs are to be undertaken over 2017-2018/2019-2020.

4. **To examine and document the feasibility of machine learning and other novel computational methods for enhanced quality control, to potentially minimize labor costs associated with human expert quality control procedures.**

   Gui Castelao has started development of a prototype web-based site to quality control ocean temperature/salinity profiles using machine learning (https://expertqc.castelao.net)

   Bec Cowley supervised a summer student (Austin, January 2017) to explore machine learning techniques for quality control of XBT data, with a focus on hit-bottom events

(as an initial test). Outputs depend on probability distributions and decision tree. Some promising/preliminary results were obtained (e.g., false positive detection rate ~1%).

Bec Cowley and Edward King are exploring the possibility to adapt & adopt the SQUIDLE web-based platform (https://squidle.acfr.usyd.edu.au/). Some initial discussions have been carried out with Stefan Williams and Ariell Friedman (March, 2017)

Guillaume Maze is a new IQuOD member since March 2017 and will contribute with his proved expertise in machine learning for quality control of modern ocean data.

5. **To develop, implement and document internationally agreed best practice methods for assignment of uncertainty estimates to each temperature observation.**

   First-cut table for random uncertainty for various platform types developed by Cowley et al. and implemented by Boyer. Draft paper in preparation for peer-reviewed journal (Cowley et al.).

6. **To freely disseminate (interim) versions of the IQuOD global temperature profile database (and added value-products) as it evolves over the next 3 years, in user-friendly file formats.**

   First interim product IQuOD v0.1 has been implemented by Boyer as part of the next release of the World Ocean Database. Implementation is currently under verification phase. Public release to be expected during 2017.

7. **To share knowledge and transfer skills in instrumentation, regional oceanography, quality control procedures and data stewardship with international scientists in both developed and developing nations.**

   Knowledge transfer activities have centered on the workshop in Tokyo.
   Other activities to progress during 2017-2018/2019-2020, possibly with joint involvement from CLIVAR, SCOR and IODE.

6. WG activities planned for the coming year. Limit 500 words

- A session on "Scientific data rescue of ocean data with a focus on climate analysis" proposed for the AGU Ocean Sciences meeting (Ocean Data Management Theme) to be held during 11-16 February, 2018, Portland, Oregon, USA. Chairs: Tim Boyer (NESDIS/NOAA), Catia Domingues (UTAS), Rebecca Cowley (CSIRO), Matt Palmer (UK Met Office). Session ID#: 28722.

- Annual IQuOD-SCOR WG148 workshop.
  Tentative: April 2018 @ UK Met Office (piggy-backing on EGU meeting), being organized by Matt Palmer.
  Major objectives:
- AutoQC benchmarking exercise
- Refinements to i-metadata, uncertainty and duplicates flagging
- Coordinating machine learning activities
- Discussion of potential outreach activities

7. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

Progress on AutoQC activities are being transferred from Amazon cloud server to a virtual machine with docker install (to be set up at the UK Met Office) due large number of sensitivity tests and large data volumes.

IQuOD v0.1 verification phase is taking longer than expected due to some continued discussions, but is very near completion. A virtual meeting will take place in the next 2-3 weeks to expedite progress.

We are seeking potential funding options to help support/speed up some programming tasks.

8. Any special comments or requests to SCOR. Limit 100 words.

1. If feasible, SCOR representative to facilitate a request for joint sponsorship from IAPSO for SCOR WG 148 during IAPSO-IAMAS-IAGA meeting in Cape Town in late August 2017.

2. Suggestions for effective dissemination strategies for public release IQuOD v0.1 for maximum impact with ocean observational/reanalyses/modelling communities.

3. Virtual meeting/email exchange with SCOR representative to discuss potential avenues for developing capacity-building activities related to WG148/IQuOD activities, jointly with IODE (Claudia Delgado, training coordinator) and CLIVAR (Nico Caltabiano).

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

### 2.1.13 WG 149 on Changing Ocean Biological Systems (COBS): how will biota respond to a changing ocean? (2015) *Miloslavich*

**Chair:** Philip Boyd (Australia)

**Other Full Members:** Aurea Ciotti (Brazil), Sinead Collins (UK), Kunshan Gao (China-Beijing), Jean-Pierre Gattuso (France), Marion Gehlen (France), David Hutchins (USA), Christina McGraw (Australia), Jorge Navarro (Chile), and Ulf Riebesell (Germany)

**Associate Members:** Haimanti Biswas (India), Sam Dupont (Sweden), Katharina Fabricius (Australia), Jonathan Havenhand (Sweden), Catriona Hurd (Australia), Haruko Kurihara (Japan), Gorann Nilsson (Norway), Uta Passow (USA), Hans-Otto Pörtner (Germany), and Marcello Vichi (Italy)

**Terms of Reference**

1. Assess the current status of emerging research themes 1-3 by reviewing the literature to assess the dominant research foci, their relative coverage, and identify any major gaps and/or limitations. Publish this review in an open-access peer-reviewed journal.
2. Raise awareness across different scientific communities (evolutionary experimental biologists, ecologists, physiologists, chemists, modelers) to initiate better alignment and integration of research efforts.
3. Co-ordinate thematic transdisciplinary sessions to attract and assemble experts from other fields such as paleoceanography and marine ecotoxicology to learn from the successful approaches their fields have developed to address multiple drivers.
4. Develop a multi-driver Best-Practice Guide (BPG, or other tools) as one potentially valuable way to help this research field move forward in a cohesive manner.
5. Mentor early career scientists in the design process for complex multiple driver manipulation experiments, familiarize them with BPG, and teach them practical methodologies for the analysis of their experimental findings.
6. Publish a series of short articles in both the scientific media and with scientific journalists to disseminate the challenges and opportunities surrounding multiple drivers and ecosystems.
7. Engage with policy-makers and science communication experts to produce a glossary of terms and an implementation guide for policy-makers to better understand the role of multiple drivers in altering marine living resources and ecosystem services.

**Executive Committee Reporter:** Patricia Miloslavich

Template for Annual SCOR Working Group Reports to SCOR

1. Name of group

WG149 Changing Ocean Biological Systems (COBS)

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

There have been three meetings of WG members since our first annual report in mid-2016.

The Ocean Acidification International Coordination Centre (OA-ICC) co-organized a technical meeting of this Working Group at the IAEA in Monaco, 12-14 June 2017, focusing on the development of best practices for multiple-stressor manipulation experiments on marine organisms (our ToR #4). IAEA funding along with SCOR funding (for the 2nd annual WG149 meeting in nearby Villefranche-sur-mer in 15-16 June 2017) enabled most of the Full and Associate members to attend these two events. Several early-career researchers were also invited to the IAEA meeting to provide feedback on the development of a Best Practice Guide (BPG).

The 2nd annual WG meeting on 16-17 June continued discussions on the BPG, but also focused on other terms of reference, and in particular TOR #1, 2, 3 and 5.

The third meeting took place in Gothenberg on 22-25 June, when WG members Philip Boyd, Sinead Collins and Sam Dupont met (joined by David Hutchins and Marcello Vichi by video link) to finalise the development of the BPG theme 2 – the www-based Virtual Marine Scientist 2 (for which the group raised > 30 K USD to fund the coding of this VMS2). Sam Dupont has subsequently met with the programmer, who will commence work on this development in September 2017.

There have been ongoing email discussions throughout 2016-2017 to develop the Review manuscript for ToR1.

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

We have set up and maintained the following website for WG149.
https://scor149-ocean.com/

It is linked to the SCOR website http://www.scor-int.org/SCOR_WGs_WG149.htm
And features a new topical publication every 3 months, and also houses a suite of links to closely related projects. It will be updated again in a few weeks. We have also recently

contributed a short meeting report to the IAEA which summarized our June 2017 in Monaco (see above).

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

1. Assess the current status of emerging research themes 1-3 by reviewing the literature to assess the dominant research foci, their relative coverage, and identify any major gaps and/or limitations. Publish this review in an open-access peer-reviewed journal.

   We have finalised the figures and most of the text (now in a penultimate draft for a Research Review for *Global Change Biology* (we made a pre-submission enquiry in late 2016 which was successful). The Review is entitled

   Experimental approaches to assess the biological ramifications of multiple drivers of global ocean change

   We will submit this manuscript by mid-August 2017.

2. Raise awareness across different scientific communities (evolutionary experimental biologists, ecologists, physiologists, chemists, modelers) to initiate better alignment and integration of research efforts.

   The above manuscript (for ToR1) has 10 sub-sections which integrate many of the above themes in ToR 2. Our WG comprises expertise across all of the above themes and so we were able to incorporate state-of-the-art knowledge about each theme and how best to better link them. Furthermore, our WG membership are publicising the holistic approach being taken by WG149 within their own communities.

3. Co-ordinate thematic transdisciplinary sessions to attract and assemble experts from other fields such as paleoceanography and marine ecotoxicology to learn from the successful approaches their fields have developed to address multiple drivers.

   In the last 12 months we have set up reciprocal links to a wide range of other projects that are tackling aspects of changing ocean biological systems (https://scor149-ocean.com/partners/). They include the fisheries-based Nereus Program - Predicting Future Oceans, and the IOC $GO_2NE$ programme on hypoxia. We also recently featured an end-to-end foodweb paper on the website (https://scor149-ocean.com/#meetings-section) to again try to learn more from other research fields. We have a successful working relationship with the IMBER programme and recently submitted a joint session with IMBER entitled:

'Multiple stressors at multiple scales'

to the 4th Symposium on the Effects of Climate Change on the World's Oceans (June 2018 in Washington D.C.). We will find out about the session in early August 2017.

4. Develop a multi-driver Best-Practice Guide (BPG, or other tools) as one potentially valuable way to help this research field move forward in a cohesive manner.

   The group has taken a three-tiered approach to develop a web-based best practice resource which will be made available to the global community by summer 2018: (1) initial decision support to navigate through this complex research topic via flow charts and questionnaires; (2) a "Virtual Marine Scientist" experimental design tutorial to assist researchers with the selection and refinement of the most suitable design for their research question(s) and locale(s); and (3) a series of webinars by field-leading scientists to enable researchers to further hone their skillset. A course book that provides links between each of these three strands, along with other information, will also be available as an open-access pdf.

   Strands 1 and 3 will be developed inter-sessionally with Katharina Fabricius and Jon Havenhand leading strand 1; Strand 2 being led by Boyd, Dupont, Vichi and Collins; Strand 3 by Christina McGraw and Marion Gehlen. The pdf 'course book' is being structured by Boyd, Jean-Pierre Gattuso and Ulf Riebesell.

5. Mentor early career scientists in the design process for complex multiple driver manipulation experiments, familiarize them with BPG, and teach them practical methodologies for the analysis of their experimental findings.

   The IAEA – through the OA-ICC – will fund a further workshop in Monaco in mid-2018. This workshop will be used to roll out the multiple drivers BPG to early-career scientists. As of 2017, we will hold our 3rd annual workshop several days after this Monaco workshop, which will maximize the WG participation in this hands-on training event on how to get the most from the www-based BPG.

   We also plan to roll out the BPG in North America in mid-July at the early-career Gordon Research Seminar which precedes the Ocean Global Change Gordon Research Conference.

   National representatives of WG149 will be encouraged to publicise the BPG at events in their countries – for example, Boyd will give a presentation on the Principles behind the BPG at the 5th annual Ocean Acidification workshop in September in Hobart, Australia. Christina McGraw gave a similar presentation at the recently held New Zealand 10th annual Ocean Acidification workshop

5. WG activities planned for the coming year. Limit 500 words

| |
|---|
| A workshop in Monaco in mid-2018 to introduce the multiple drivers BPG to early-career scientists.<br><br>Mid-2018 - our 3rd annual workshop several days after the Monaco workshop.<br><br>Introduction to the BPG in North America in mid-July 2018 at the early-career Gordon Research Seminar which precedes the Ocean Global Change Gordon Research Conference.<br><br>Potential joint IMBER/SCOR WG149 session at the 4th Symposium on the Effects of Climate Change on the World's Oceans (June 2018 in Washington D.C.) |

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

| |
|---|
| No |

7. Any special comments or requests to SCOR. Limit 100 words.

| |
|---|
| Thanks to Ed Urban and SCOR for continued support of the WG in 2016-2017 and also for assistance with holding funds raised to develop the multiple driver BPG. |

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

### 2.1.14 WG 150: Translation of Optical Measurements into particle Content, Aggregation and Transfer (TOMCAT) (2015) *Burkill*

**Chair:** Sari Giering (UK)

**Other Full Members[1]:** Klas Ove Möller (Germany), Sünnje Basedow (Norway), Lionel Guidi (France), Morten Iversen (Germany), Andrew McDonnell (USA), Adrian Burd (USA), Catarina Marcolin (Brazil), Sandy Thomalla (South Africa), and Tom Trull (Australia)

**Associate Members:** Emma Cavan (UK), Uta Passow (USA), George Jackson (USA), Nathan Briggs (France), Dhugal Lindsay (Japan), and Lou Darroch (UK)

**Terms of Reference[2]**

1. Compare current devices that optically measure particles and document the advantages and disadvantages of each device.
2. Inter-calibrate the outputs of different devices and/or highlight calibration difficulties.
3. Define key parameters to use for interpretation of the optical information and decide which measurements are most important for characterizing particle export.
4. Improve techniques/algorithms for the conversion of optical observation into fluxes.
5. Decide on how to best analyse the increasingly larger data sets.
6. Develop software examples and codes, placed on a public repository.
7. Deposit optical particle data in an internationally recognised database that can be actively added to as new data is collected (to allow for large scale analysis and future data exchange)
8. Advise on future methods to maximize data collection and interpretation

**Executive Committee Reporter:** Peter Burkill

[1] SCOR has asked the group to add another Full Member from a developing country and move one of the following Full Members to Associate Member status.
[2] SCOR has asked that the group streamline its terms of reference.

1. Name of group

**WG 150 - Translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT)**

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

**Meeting**
Our first workshop/meeting was held on 12-14 Sept. 2016 at the National Oceanography Centre, Southampton, UK. 11 Members attended, and the meeting was a combination of presentations and discussions, addressing four main topics:

1. Current technologies – what is 'out there' (advantages/disadvantages), how do they compare, what can we do for intercalibration?
2. From image to flux estimates – what is the state of the art, how can we improve these efforts?
3. Global data sets, data repository and standardization – what is the best way to collate data, share code, make recommendations?
4. Next steps for TOMCAT – get the ball rolling for the review paper(s), opportunities for intercalibration, data repository and software codes

A full agenda of the 3-day meeting can be found on our website: https://tomcat-scor.org/activities/1st-tomcat-workshop/

***Eos* Meeting Report**
Our meeting report was published in *Eos*. Citation: Giering, S. L. C. (2017), Optical sensors can shed light on particle dynamics in the ocean, *Eos*, 98, https://doi.org/10.1029/2017EO072123. Published on 2 May 2017.

**Literature Review**
We since have been working on a literature review, currently entitled: "Particles in the ocean - what can we learn from optical devices?" The thorough review explores the cutting-edge technologies that are currently available—including some of their exciting discoveries—and highlight the potential for future research and development. We aim to submit the review by the end of July.

**Conference Session**
We have submitted a conference session to the Ocean Sciences Meeting, 11-16 Feb. 2018 with the title "We shed light: optical and imaging insights into the biological carbon pump", chaired by Emma Cavan, Sari Giering, Emmanuel Laurenceau-Cornec and Andrew McDonnell. We will receive information about the status of our proposal in early July 2017.

**Website**
Our website is now online and is regularly updated: www.tomcat-scor.org. We have an average of 20 visitors per month (since May 2016) from a total of 17 countries.

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

**Website:** www.tomcat-scor.org

***Eos* meeting report:** https://eos.org/meeting-reports/optical-sensors-can-shed-light-on-particle-dynamics-in-the-ocean (Giering, S. L. C. (2017), Optical sensors can shed light on particle dynamics in the ocean, Eos, 98, https://doi.org/10.1029/2017EO072123)

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

**TOR:**

1. **Review current devices that optically measure particles, and document the capabilities and limitations of each device.**

   We reviewed and discussed current devices during the meeting in September and are now documenting and discussing their capabilities and limitations within the literature review, which will serve as a benchmark for future optical work.

2. **Make vocabularies more transparent and interoperable using international standards.**

   We discussed and made a list of key terms and essential variables. We are working on formal definitions now. We are currently looking into ways of making these freely accessible (it looks like we would have to pay for a wiki).

3. **Define key parameters for interpretation of optical information, and recommend which optical measurements are useful for characterizing particle type, interactions and export.**

   As above. We discussed the key variables, but will refine our recommendations within the literature review and in the future. This will include an effort to secure funding for dedicated modelling and the organization of autumn schools to disseminate this knowledge.

4. **Evaluate various techniques and algorithms for the conversion of optical observation into particle type, size, concentration, mass, composition, and fluxes,**

**and recommend ways of improving our understanding of the relationships between these properties.**
We will focus on this step after we retrieve the calibration data (target summer/autumn 2018).

5. **Promote sharing of software examples and codes, placed on a public repository.**

   As above. We will focus on this step after we retrieve the calibration data (target summer/autumn 2018).

6. **Improve the visibility and usage of data by hosting an inventory of published datasets.**

   We are currently discussing the options with the British Oceanographic Data Centre and potential need for financial support. In addition we promote TOMCAT during conferences and meetings and have received increasing interest.

5. WG activities planned for the coming year. Limit 500 words

**Fieldwork**
We will be carrying out intercalibrations between in situ camera system, LOPC and backscatter sensors during the UK COMICS cruises (http://comics.ac.uk/) in the Southern Ocean (Nov-Dec 2017) and Benguela (Apr-May 2018).

**Autumn school**
We are planning an international autumn school, likely hosted at the National Oceanography Centre, Southampton, in late 2018. We will secure external financial support for catering, travel and subsistence of participants (particularly focusing on early-career researchers and developing countries).

**Conference Session**
We plan to host a dedicated session during the Ocean Science Meeting in Feb 2018. We will further promote TOMCAT's work here and advertise the autumn school.

**Publication of essential variables**
We will finalize the list of essential variables and publish these freely available online.

**First example codes**
We will decide on a public depository and publish the first set of example data and codes.

**Next meeting**

The next meeting is planned in conjunction with Ocean Sciences Meeting, 11-16 Feb. 2018, in Oregon, US. Most members will be able to attend.

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

We had a delay in our working group by approximately 6 months owing to a later first meeting than planned and a delay in the cruises planned for intercomparison. Nonetheless, overall we believe we are on target.

7. Any special comments or requests to SCOR. Limit 100 words.

We would welcome some support/advice on how to increase capacity building and involvement of developing countries.

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

### 2.1.15 WG 151: Iron Model Intercomparison Project (FeMIP) (2016) *Devey*

**Co-chairs:** Alessandro Tagliabue (UK) and Stephanie Dutkiewicz (USA)

**Other Full Members:** Tatiana Ilyina (Germany), Kazuhiro Misumi (Japan), Fanny Monteiro (UK), J. Keith Moore (USA), Yeala Shaked (Israel), Marcello Vichi (South Africa), Christoph Völker (Germany), Mustafa Yücel (Turkey)

**Associate Members:** Olivier Aumont (France), Alex Baker (UK), Philip Boyd (Australia), Fei Chai (China-Beijing), Peter Croot (Ireland), Christel Hassler (Switzerland), Eun Young Kwon (Korea), Jun Nishioka (Japan), Maite Maldonado (Canada), Mark Moore (UK), Andy Ridgwell (USA), Benjamin Twining (USA)

**Terms of Reference**

- To identify best practices for minimum complexity representations of the iron cycle in models, with options given for more advanced aspects, and publish the guidance in a peer-reviewed paper.
- To develop tools for a wide variety of platforms to validate global model results in a standardised way and make these available via a peer-reviewed publication and a website.
- To facilitate a focussed intercomparison of iron models to constrain the impact of varying residence times and a consensus dust deposition scheme and publish the results in a peer-reviewed journal.
- To review how to represent biological interactions in the iron cycle, the linkages to key phytoplankton species and the interactions with zooplankton and bacteria, as well as broader connections with other biogeochemical cycles and publish the results in a peer-reviewed journal.

**Executive Committee Reporter:** Colin Devey

1. Name of group

Iron Model intercomparison project (FeMIP), SCOR WG 151

2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). Limit 1000 words

WG151 formally began its activities in January 2017. We decided to wait until the February 2018 Ocean Sciences meeting to hold our first in-person meeting. In the meantime, we have set up an FeMIP "slack group" (an online platform for group work, which is facilitating the interaction between Full and Associate members. All Full and Associate members have joined the FeMIP slack group, which has become the primary focus for WG activities. We do not engage in discussion via email.

3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

https://femip.slack.com active by invitation since 25 January 2017

WordPress WG website will be active by Dec. 2017 (Action item for co-chair Tagliabue)

4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one. Limit 1000 words

Objective 1: Three main processes of importance in modelling the ocean iron cycle have been identified by discussion: external input, biological cycling (incl. uptake and regeneration) and speciation/scavenging (incl. ligand aspects). Each main process has been assigned a WG champion who is, alongside observational WG members, collating information on the ways in which models represent these processes and how they reflect understanding from an observational standpoint. Outcomes will be delivered here by July and discussed within the objective 1 slack channel with input from all Full and Associate members.

Objective 2: The main issues regarding the development of model assessment tools have been identified, linked to the choice of assessment platforms, choice of the assessment metrics, value of additional metrics, and format of model inputs have been discussed within the objective 2 slack channel. Work is now moving forward to develop test cases for model skill metrics for the different platforms (volunteers have come forward from the WG to represent all major programming platforms).

Objective 3 and Objective 4 to be discussed at the kick off meeting in February 2018.

5. WG activities planned for the coming year. Limit 500 words

During the coming year, we will be moving forward on objectives 1 and 2. Alessandro Tagliabue and Marcello Vichi are heading up O1 and O2 activities, respectively. Results from O1 and O2 to be presented at Feb 2018 meeting and publicised during a Town Hall session during Ocean Sciences 2018.

Outcome of O1 is planned to be a publication and release of code for different process closures.

Outcome of O2 is planned to be a release of evaluation tools and consensus values via the website, plus a companion paper.

Champions and preliminary plans will be developed for O3 and O4 during the kick off meeting.

6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties Limit 200 words

None.

7. Any special comments or requests to SCOR. Limit 100 words.

None

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.

### 2.1.16 WG 152: Measuring Essential Climate Variables in Sea Ice (ECV-Ice) (2016) *Turner*

**Co-chairs:** Daiki Nomura (Japan), François Fripiat (Belgium), and Brent Else (Canada)

**Other Full Members:** Bruno Delille (Belgium), Mar Fernandez-Méndez (Norway), Lisa Miller (Canada), Ilka Peeken (Germany), Janne Markus Rintala (Finland), Maria van Leeuwe (Netherlands), and Fan Zhang (China-Beijing)

**Associate Members:** Katarina Abrahamsson (Sweden), Jeff Bowman (USA), James France (UK), Agneta Fransson (Norway), Delphine Lannuzel (Australia), Brice Loose (USA), Klaus Meiners (Australia), Christopher J. Mundy (Canada), Hyoung Chul Shin (Korea), and Jean-Louis Tison (Belgium)

**Terms of Reference**

- Publish synthetic reviews compiled from measurements demonstrating large, unresolved discrepancies, with a special emphasis on primary production, gas concentrations and fluxes. These detailed reviews will draw on both the literature and unpublished studies to evaluate the strengths and weaknesses related to each methodology.
- Design and coordinate intercalibration experiments to evaluate different methods for key parameters. In addition to organizing field experiments, we will pursue use of ice tank facilities and stimulate and support applications for funding, at both national and international levels, to further facilite the experiments. If successful, manuscripts will be written and the outcomes will be presented in the guide of best practice to support the recommendations.
- Design intercomparison studies to facilitate validation and adoption of new technologies for assessing the complexity and heterogeneity of sea ice at various spatial and temporal scales.
- Create a guide of best practices for biological and biogeochemical studies in the sea-ice environment. This will be accomplished using a web-based forum for compiling and disseminating the outcomes of past and new intercomparison studies.

**Executive Committee Reporter:** John Turner

**1. Name of group**

Working Group 152, Measuring Essential Climate Variables in Sea Ice (ECV-Ice)

**2. Activities since previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions).** Limit 1000 words

**Virtual meeting #1**: 26 October 2016, 23:00-24:00 UTC through Skype. Fripiat, Else, Miller and Nomura. We discussed working plan.

**Virtual meeting #2**: 1 February 2017, 23:00-24:00 UTC through Skype. Fripiat, Else and Nomura.We discussed agenda for first ECV-Ice meeting at Scripps institute of Oceanography.

**In-person meeting #1**: 3-5 April 2017, BEPSII and ECV-Ice Meeting, Scripps institute of Oceanography. Total 23 people: 11 ECV-ice members: Fripiat, Nomura, Else, Miller, Rintala, Bowman, France, Fransson, Lannuzel (Skype), Meiners, Mundy. We finalized working plan (see minutes in appendix A or at https://onedrive.live.com/?authkey=%21AA6LGarO1noXp6g&cid=AE56CCC94525FE05&id=AE56CCC94525FE05%21392&parId=root&o=OneUp).

**3. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support**

**Peer-reviewed journal articles #1:** Roukaerts A., Nomura D., Fripiat F., Hattori H., Dehairs F. No significant effect of the melting protocol for the assessment of biomass and nutrients in sea ice (Saroma-ko lagoon, Hokkaido, Japan), In preparation.

**Web pages:** B. Delille and M. Thomas will set up a webpage, related to the website of BEPSII. Bruno Delille is currently in Antarctica. To be done in the upcoming months.

**4. Progress toward achieving group's terms of reference. List each term of reference separately and describe progress on each one.**

This working group gathers international experts on chemical and biological measurements in sea ice to design and coordinate required intercomparison and intercalibration experiments. The group is synthesizing the results of past experiments, identifying what types of new experiments are needed, and supporting the community in executing those experiments.

**Term of reference (TR) #1: Publish synthetic reviews compiled from measurements demonstrating large, unresolved discrepancies.**

We have started to collect various datasets (raw data, methodologies and associated protocols for data correction, instruments, and sampling design) for each target parameter (sea ice-air $CO_2$ flux, ocean-air $CO_2$ fluxes in the seasonal ice zone, primary production, light transmission, etc.) from the global polar sea-ice and ocean research communities.

Planned reviews include:

- Sea ice-air gas fluxes. Coordinating lead authors: D. Nomura and B. Else. Data are currently being collated, to be presented during the next annual meeting.
- Air-sea gas flux parameterizations in the marginal ice zone. Coordinating lead authors: B. Loose and B. Else. Data are currently being collated, to be presented during the next annual meeting.
- Primary production. Coordinating lead authors: F. Fripiat, M. Fernandez-Méndez and C.J. Mundy Data are currently being collated, to be presented during the next annual meeting.
- Light transmission through sea ice. Coordinating lead author: J. Ehn. A plan to collate available data will be discussed during the upcoming year.

**TR #2: Design and coordinate intercalibration experiments to evaluate different methods for key parameters.**

We have started to seek funding for various intercalibration experiments (gas concentrations, primary production, trace metals, etc).

**Gas concentrations**

- Date: summer 2018
- Location: University of East Anglia (UEA) ice tank facility
- Participants: B. Delille (lead), M. Kotovich, L. Miller, B. Else, M. Thomas, J. France, D. Nomura, A. Fransson, K. Ambrahamsson, E. Damm, J. Verdugo, C. Uhlig, J.-L. Tison, etc.

The purpose is to compare all the techniques available to date to measure gas concentration in sea ice (sampling, processing, storage, analysis): peepers, sackholes, ice crushing, equilibrating method, melting-refreezing method, bulk melt for DIC/TA. The following gases will be tested ($N_2O$, $CH_4$, $CO_2$), but with a special emphasis on $pCO_2$.

EUROCHAMP 2020 transnational access funding is available to cover facility access and travel for 1-3 international participants. Additional funding is being pursued for more participants.

**Primary production**

- Date: Spring 2019
- Location: Cambridge Bay (Canada)
- Participants: Brent Else (co-lead), F. Fripiat (co-lead), J. Stefels, M. Van Leeuwe, J. Bowman, C.J. Mundy, J.-M. Rintala, M. Fernandez-Mendez, F. Deman, A.-J. Cavagna, D. Nomura, etc.

The purpose of this experiment is to compare all the techniques available to date to measure primary production (GPP, NPP, NCP) in sea ice (2-3 weeks): biomass/chl-a accumulation, under-ice eddy covariance, under-ice microelectrodes, isotopic tracer incubations ($^{14}C$ & $^{13}C$), O2:Ar ratio, PI curve, and PAM fluorescence. We will also

assess the most suitable tracer incubation protocols for general metabolic rate determinations in sea ice (e.g., bacterial production, nutrient transformations). That is, how to collect a representative in-situ sea-ice microbial community and to ensure tracer homogenization within the brine network prior incubation (e.g., direct vs. buffered melting, …). It was also noted that the experiment could be extended to include other inter-calibrations. Other suggested intercalibration include bacterial production, DNA/RNA, bacterial abundance, light measurements, nutrients, biomass, taxonomy, storage of ice cores for later analysis. A special emphasis will be also dedicated to solve the nutrient-chlorophyll paradox in productive sea ice. We are open to accommodating this, although we may run into logistical problems if there are too many people.

**Trace metals**

- Date: Fall 2017 and follow up in 2019
- Location: Ross Sea (PIPERS voyage) and TBD
- People involved: D. Lannuzel and A. Aguilar-Islas (co-leads), J. de Jong, etc.

To test the existing methods and devices to sample, process, store, and analyze trace metal concentrations in sea ice. An initial experiment will most likely take place in the Ross Sea during a voyage in austral fall 2017. Duplicate cores will be collected using 3 different coring devices. Based on the results from this first experiment, the group will decide where and when the next phase of the experiment will take place.

**TR #3: Design intercomparison studies to facilitate validation and adoption of new technologies for assessing the complexity and heterogeneity of sea ice at various spatial and temporal scales.**

Because we were not able to identify opportunities for true international intercalibrations, we have not yet begun to focus on this activity. New technologies will be tested alongside conventional techniques for calibration.

**TR #4: Create a guide of best practices for biological and biogeochemical studies in the sea-ice environment.**

Based on the information available at this time, we will start to create a guide of best practices hosted on the ECV-Ice website as a living document. The first entry will be the Miller et al. (2015) methodological review from SCOR WG 140, and the results of additional methods evaluations and intercalibrations will be added, as they become available.

**5. WG activities planned for the coming year**.

**Virtual meetings**: two planned for summer/fall 2017. Fripiat, Else, Miller and Nomura. We will discuss planning of the upcoming intercalibration experiments as part of TR #1 and the next in-person meeting. We will also update advancements in TR #2.

**Intercalibration experiment on primary production and gas concentrations:** We will examine a small intercalibration experiment at the Saroma-ko Lagoon, Hokkaido, Japan in

winter 2018 during the field course of the International Antarctic Institute (IAI) organized by Hokkaido University and the University of Tasmania. A small amount of funding will be available for this intercalibration experiments from JSPS research fund from Nomura. Therefore, few ECV-ice members will join and examine the intercalibration experiment.

**In-person meeting**: June 2018, ECV-Ice Meeting with BEPSII, MOSAiC and CATCH during the 2018 SCAR/IASC POLAR 2018 Conference, in Davos, Switzerland. ECV-Ice members and others. We will discuss review progress on the Terms of reference (present the data collations (TR #2), pursue the elaboration of intercalibration experiments (TR #1 and #3), including reviewing results of primary production experiment in Saroma and finalizing plans for the gas concentration experiment at UEA.

**Intercalibration experiment on gas concentrations:** We will conduct an intercalibration experiment at the UEA ice-tank facility in summer 2017. EUROCHAMP 2020 funding will available for this intercalibration experiment. The funding will cover travel expenses for 1-3 international participants, and the costs of operating the facility. We will run at least one ice growth experiment (~10 days). If feasible, a second experiment at a different temperature will be conducted.

**6. Is the group having difficulties expected in achieving terms of reference or meeting original time schedule? If so, why, and what is being done to address the difficulties**

At this point, we appear to be on track, with a number of activities to forward the terms of reference.

**7. Any special comments or requests to SCOR.**

We would like to express heartfelt thanks for financial and technical supports. We would be very interested in any advice SCOR could provide on additional possible sources of support for more scientists to be able to directly participate in the intercalibration experiments.

**8. Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.**

Please see attached minutes (Appendix A) from the first ECV-Ice annual meeting in La Jolla, California, on April 3-5, 2017.

Minutes SCOR-WG ECV-ice meeting April 3-5, 2017, San Diego
Scripps institution of Oceanography

Participants:
ECV-ice members : François Fripiat, Daiki Nomura, Brent Else, Lisa Miller, Janne-Markus Rintala, Jeff Bowman, James France, Agneta Fransson, Delphine Lannuzel (Skype), Klaus Meiners, Christopher J. Mundy.

Others: Melissa Chierici, Florian Deman, Marie Kotovich, Marion Lebrun, Lynn Russel, Jacqueline Stefels, Nadja Steiner, Letizia Tedesco, Martin Vancoppenolle, Bonnie Raffel, Oliver Legge, Max Thomas, Ana Aguilar-Islas.

Monday April 3

François Fripiat, Daiki Nomura & Brent Else:

Welcome with a brief introduction on the goals (terms of reference and deliverables) that we would like to achieve with this working group in the upcoming four years. The aim of this first meeting was to start the working group, to attribute tasks and leadership, and to elaborate an agenda. This meeting has been organized jointly with the BEPSII research community (CLIC, SCAR, and SOLAS). Here only the tasks related to ECV-ice will be described.

*Task group 2-3: Intercalibration experiments and validation of new technologies.*

**Primary production and ancillary biogeochemical parameters:**

*Target Date/Location*: Cambridge Bay (Canada) has been discussed as a good location, because we know there will be sea ice there, and there should be good access to logistics (accommodations, laboratory space) and the new Canadian high Arctic Research Station. Saroma-Ko (Japan) is another potential location. It may be less expensive, but ice is less reliable. We focused most of our discussion assuming Cambridge bay. We'll attempt to do this experiment in 2019 (late March-early April), in order to target the sea-ice algal bloom in an ascending phase.

*Funding*: Brent Else thinks we can get good in-kind support from POLAR (they may provide accommodation/laboratory space at no cost). We would still need funds for some logistics (guides, fuel, food), but Brent Else has some ideas of where we could get funding for this in Canada. Everyone would have to find money to get themselves/equipment there. COST-action is one potential avenue for European supports. In order to be attractive for a COST-action and to promote our capacity building, we'll try to organize a sea-ice training school together with the intercalibration experiment in Cambridge Bay (last week). The link with the upcoming MOSAIC field trip (i.e., support in the sampling design) will be clearly highlighted in the COST-action. NSF could possibly provide support for Americans.

*Experimental design*: The purpose of this experiment is to compare all the techniques available to date to measure primary production (GPP, NPP, NCP) in sea ice (2-3 weeks): biomass/chl-*a* accumulation, under- ice eddy covariance, under-ice microelectrodes, isotopic tracer incubations ($^{14}C$ & $^{13}C$), $O_2$:Ar ratio, PI curve, and PAM fluorescence. We will also assess the most suitable tracer incubation protocols for general metabolic rate determinations in sea ice (e.g., bacterial production, nutrient transformations). That is, how to collect a representative in-situ sea-ice microbial community and to ensure tracer homogenization within the brine network prior incubation (e.g., direct vs. buffered melting, …). It was also noted that if we are doing this, there are many things we could ‘’intercalibrate’’. We open to accommodating this, although we may run into logistical problems if there are too many people. Other suggested intercalibration include: bacterial production, DNA/RNA, bacterial abundance, light measurements, nutrients, biomass, taxonomy, storage of ice cores for later analysis. A special emphasis will be also dedicated to solve the nutrient-chlorophyll paradox in productive sea ice.

*People involve*: Brent Else (co-lead), François Fripiat (co-lead), Jacqueline Stefels, Maria Van Leeuwe, Jeff Bowman, C.J. Mundy, Janne-Markus Rintala, Mar Fernandez-Mendez, Florian Deman, Anne-Julie Cavagna, and Daiki Nomura. We can always add people to this list, and we should of course not restrain ourselves to people who are in ECV-ice/BEPSII (although BEPSII research community probably covers pretty much everyone).

*What to do next*: Brent Else will ask around POLAR to assess their interest in this program, and look into potential funding avenues for Canada. Jacqueline Stefels will look if COST-action is suitable to fund short- term scientific missions and training schools outside Europe. François Fripiat will draft the overall experimental set-up. Klaus Meiners will contact Andrew McMinn to see if he is interested to take part (under-ice microelectrodes).

**Gas concentration:**
*Target Date/Location*: We'll attempt to this experiment in 2018. Possibly in summer (Late June, early July), possibly timed to coincided with the next BEPSII/ECV-ice/MOSAIC meeting in Davos. We'll use the ice- tank facility at the University of East Anglia (James France).

*Funding*: Eurochamps funding is available for this intercalibration experiments. The funding will cover travel expenses for 1-3 international participants, and the costs of operating the facility. We will likely run one ice growth experiment (~10 days), although we could do longer (e.g. we could do two 10-day experiments, perhaps at different temperatures). The application for funding should be led by a European participant (we volunteered Bruno Delille to do this). Most participants (e.g. North American) will need to find their own funding get themselves and their equipment to University of East Anglia.

*Experimental design*: The purpose is to compare all the techniques available to date to measure gas concentration in sea ice (sampling, processing, storage, analysis): peepers, sackholes, ice crushing, equilibrating method, melting-refreezing method, bulk melt for DIC/TA. The following gases will be tested ($N_2O$, $CH_4$, $CO_2$) but with a special emphasis on $pCO_2$. The basic goal will be to grow ice to about 30cm thickness (at -18°C), and then collect samples for the various methods. After that, the ice will be melted, and we could do another sampling point in the warm ice. We could then (if we want) run another test where we grow ice to 30cm (at -30°C) and do another sample collection point, to perhaps get ice with lower permeability.

*People involve*: Bruno Delille (lead), Marie Kotovich, Lisa Miller, Brent Else, Max Thomas, James France, Daiki Nomura, Agneta Fransson, Katarina Ambrahamsson, Ellen Dam, Josefa Verdugo, Christane Uhlig and Jean-Louis Tison. We can always add people to this list, and we should of course not restrain ourselves to people who are in ECV-ice/BEPSII (although BEPSII probably covers pretty much everyone)

*What to do next*: Determine timelines for Eurochamp application. Schedule a conference call to further specify experimental design. Submit the Eurochamp application.

**Trace metals:**
*Experimental design*: To test the existing methods and devices to sample, process, store, and analyze trace metal concentrations in sea ice. An initial experiment will most likely take place in the Ross Sea during a voyage in austral fall 2017. Duplicate cores will be collected using 3 different coring devices.

*People involved*: Delphine Lannuzel and Ana Aguilar-Islas (co-leads), Jeroen de Jong.

*What to do next*: To continue discussion to determine course of action following the 2017 Ross Sea experiment.

Tuesday April 4
*Task group 1: Synthetic review on existing methodological discrepancies.*
To write review on existing methodological discrepancies. The upcoming year will be mainly dedicated to collect the various dataset (raw data, used methodology, used instruments, data correction, and sampling design), with the goal to perform the data analysis and comparison the year after the second ECV-ice meeting (summer 2018). The following topic has been targeted as priorities:

**Sea Ice-Air $CO_2$ fluxes:**
Several intercomparison have already been made at several locations (e.g., Barrow, McMurdo Sound, and North of Svalbard) between chamber and eddy covariance techniques, giving results that differ by up to an order of magnitude. In addition to the different spatial scales of the two methods, specific technical limitations of both methods impact the measurements. These methodological gaps are still not yet fully understood and effort will be made in the ECV-ice working group to develop a mechanistic understanding.

*People involve*: Daiki Nomura (co-lead), Brent Else (co-lead), Bruno Delille, Lisa Miller, Kristina Brown, Katarina Ambrahamsson.

*What to do next*: Daiki Nomura is in charge to collect chamber's data and Brent Else the eddy covariance's data.

**Ocean-Air $CO_2$ fluxes in the seasonal ice zone:**
This intercomparison has been suggested by Brice Loose as differences is expected between eddy covariance and geochemical tracers (e.g., Rn). From what we're aware, no intercalibration experiments exist to date (i.e., tested at the same location). The goal here will be to collect the data and see if clear differences are reported between methodologies.

*People involve*: Brice Loose (lead), Brent Else, and John Prytherch.
*What to do next*: Brice Loose is in charge to collect the data and ask to John Prytherch if he is interested to participate.

**Primary Production:**
Sea-ice primary production measurements are scarce, span three orders of magnitude, and have used numerous, distinctively different methods ranging from in-situ sensors to in-vitro isotope labeling studies, for which largely varying results are reported. From what we're aware, no intercalibration experiments exist to date (i.e., tested at the same location). The goal here will be to collect the data and see if clear differences are reported between methodologies.

*People involved*: François Fripiat (lead), C.J. Mundy, Florian Deman, Mar Fernandez-Mendez, Maria Van Leeuwe, Anne-Julie Cavagna, and Janne-Markus Rintala.

*What to do next*: François Fripiat and Florian Deman will be dedicated to collect the data in Antarctic sea ice, C.J. Mundy the Arctic fast ice, and Mar Fernandez-Mendez the Arctic pack ice (to ask her).

**Light transmission through sea ice:**
As being a key parameter to assess primary production and no clear protocol exists to date, it has been suggested that a review should be written.

*People involve*: Jens Ehn (lead), Bonnie Raffel, C.J. Mundy, Klaus Meiners, and James France What to do next: This will be initiated only after the next ECV-ice meeting in 2018.

Wednesday April 4

*Website*

It has been decided to merge ECV-ice with BEPSII website. François Fripiat sent an email to Max Thomas and Bruno Delille to keep us inform about the upcoming updates on the BEPSII website.

*Scientists from emerging countries*

SCOR recommended to add 1-2 associated members from emerging countries. Marcello Vichi (University of Cape Town) is interested to be an associated member.

*Capacity building*

Together with the intercalibration experiment in Cambridge Bay, we'll look to the possibility to train people from the Arctic communities in order to repeat small intercalibration experiments (e.g., nutrients or biomass) at different seasons and locations. The associated sea-ice training school will allow us to pass this consolidated expertise to new scientists interested in sea ice. We'll try to allocate some funds to support the venue of young scientists coming from emerging countries.

*What to do next*: To first check if it is possible in term of funding to perform an intercalibration experiment in Cambridge Bay.

## 2.2 Working Group Proposals

### 2.2.1 Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS) Burkill

# Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (proposed acronym: P-OBS)

**1.** Summary/Abstract

Measurements to characterize life in the ocean—including its composition, abundance, and changes in distribution—are fundamental to our understanding of marine ecosystems. The abundance of many fish species, sea birds, and marine mammals is critically tied to fluctuations in the abundance of smaller planktonic organisms. Similarly, plankton mediate the cycles of many chemical elements in the ocean that are critical for life, including oxygen, nitrogen, phosphorus, carbon, and many others.

The primary goal of this proposed SCOR Working Group (WG) is to identify measurements that can expand the number of observations of biological stocks, diversity, and rates or fluxes of planktonic organisms. The objective is to identify methods and technologies that can be incorporated into large-scale sampling programs such as GO-SHIP and OceanSITES as well as other similar programs from around the world. Emphasis of the WG would be on methods and technologies that can be implemented in the *short term* without disruption to established observing programs, and identifying gaps and opportunities that can significantly increase the number of routine and sustained observations of life in the ocean in the longer term. A document produced by this WG will identify the rationale for each measurement, associated costs and human investment (e.g., technical expertise and time needed), and data collection, quality control (QC), and data archival protocols.

**2.** Scientific Background and Rationale

### 2.1 Why do we need sustained biological observations?

Oceanic plankton, the base of the marine food web, are extremely under-sampled. Their diversity, abundance, and variability are largely unknown at high spatial and temporal resolution. There is a need to establish a baseline of distribution and phenology (change in seasonal timing) in different regions of the ocean. As of today, there is still no clear consensus regarding the processes responsible for phytoplankton and zooplankton phenology. There are incompatible top-down and bottom-up arguments brought to describe the same phenomena (e.g., the North Atlantic spring bloom, or changes in the abundance and make-up of phytoplankton and zooplankton in any region).

Higher-resolution information on changes in phytoplankton and zooplankton is fundamental to constrain ecosystem and biogeochemical models. These models are used to forecast the success and recruitment of organisms such as fish, the efficiency of food webs in cycling elements and transferring energy from one trophic level to another, and understanding and forecasting of water quality and other changes that affect rates and composition of biological stocks. These models require proper parameterization of plankton and their functions at appropriate temporal and spatial resolution, and are important because they help develop fundamental understanding about life in the ocean and its biogeochemical consequences. Models are the only way to evaluate large-scale processes such as the potential expansion of hypoxic areas in the ocean, the modulation of air-ocean exchange of gases (e.g., oxygen, carbon dioxide), and the amount of organic matter that may be sinking to the bottom of the ocean, where food for deep ocean life is otherwise limited. Models are also a powerful tool to predict the response of plankton to climate change, with possible feedbacks to the ecological and biogeochemical functioning of the ocean.

**2.2** Emerging technologies to maximize investments in ocean observing

Large investments have been made in long-term ocean measurement infrastructure (e.g., Global Ocean Observing System, GOOS). These include the development of long-term ecological monitoring stations, coordination for repeated observations on ship lines, sustained moorings, deployment of autonomous vehicles, and various other remote data-collection technologies, such as cabled observatories. Many of these are deployed over large geographical domains and are intended for long-term observations. Important developments in technologies to measure physical and chemical parameters (e.g., salinity, temperature, oxygen, pH, currents) have meant that these parameters tend to make up the majority of the observations collected from automated platforms today. Adding the capability to measure biological parameters (e.g., stock, diversity, rates and fluxes) to these existing platforms and programs would fill critical gaps in our knowledge of ecosystem function. Linking such multidisciplinary measurements to ocean color radiometry, other remote sensing technologies, and other global observing systems (e.g., BGC- Argo, CPR surveys) will assist in better characterizing and explaining synoptic changes of life in the ocean. Developments in biological and bio-optical sensors, including genetic analyses, automated microscopy and flow cytometry, provide a pathway for the development and implementation of biological observations as part of global and regional ocean observing systems.

**2.3** Benefits:

SCOR can foster progress in a number of areas by convening a Working Group focused on developing a strategy for automated, sustained, and widespread plankton observations. Specifically:

Science: increased biological data are critical to quantify variability of known plankton in space and time, discover and quantify new life forms, constrain models, and better characterize processes leading to ecosystem changes.

Society: data on plankton are critical to quantify marine food webs, detect harmful algal/cyanobacterial blooms, and sustain ecosystem services such as fisheries and nutrient cycling.

Observing systems: increasing the value of these assets to science and society, including developing markets of technology and information transfer. The outcomes from our WG will benefit many other national and international programs (e.g. OOI, bioGEOTRACES) that have similar platforms and interest in sampling biological properties.

Conservation: Establishment of ecosystem-based approaches to marine resource management critically depends on sufficient data to quantify ecosystem members and functions.

Ultimately, developing the strategy to incorporate plankton observations into global observing systems, using well-described and robust protocols, facilitates the development of technology and incorporation of observations in a framework spanning from viruses to fish.

**2.4** The challenge:

We propose to develop sets of detailed recommendations to augment existing, large-scale sampling programs with feasible observations of phytoplankton and zooplankton. The recommendations will be prioritized based on science and information content. A strategy will be developed to prioritize the technology so that observations can be ramped up by the systematic incorporation into various Global Ocean Observing System elements. The assessment will include realistic costs and the requirement for capacity development.

The incorporation of biological measurements into regional ecosystem status and trend assessments is not trivial. Scientists, modelers, and resource managers are often not aware of the data available, methods of collection, or other limitations of biological measurements (Everett et al., 2017). Hence, it is critical that data disseminated follow standardized protocols for collection and quality control. Dissemination is incomplete without adequate metadata. Recommendations for the community also need to include suggestions for data repositories, descriptions of what the data represent, and examples of how such data have been used. These examples will help promote the collection of additional observations and will facilitate the application of ocean biology information in research, management, and sustainable development.

This SCOR WG would address the following goals:

1. Provide recommendations to GO-SHIP and OceanSITES regarding instrumentation and water-sample analysis that should be added to their protocols together with their scientific relevance and resource requirements (both in funds and people time). The recommendations would be broadly applicable to other national, regional, and global observing systems.
2. Deliver the appropriate protocol and provide appropriate points of contact for each recommended measurement.
3. Identify databases to curate the data and the associated requirements.

4. Identify synergies with other programs (e.g., BGC-Argo, spaced-based measurements, Continuous Plankton Recorder surveys) to provide complementary measurements and cross-validation.
5. Build capacity in the access to, and use of, biological oceanographic datasets

**2.5** The Role of SCOR

SCOR is uniquely positioned to provide credibility, weight, and support to this international and diverse group of experts to trace a viable path to increased observations of life in the ocean.

**3.1** Terms of reference

***General*:** To identify best practices (technologies and sampling protocols) and technical feasibility to incorporate plankton measurements into global ocean observing platforms (initially GO-SHIP and for expansion into the mooring array of OceanSITES).

***Specific:***

1. Identify current technologies (sensors as well as water sample analysis) that can be integrated into existing observing infrastructure to provide input and guide studies of plankton for marine ecosystem and biogeochemistry studies.
2. Provide the necessary details associated with every technology/measurement proposed (e.g., power, cost, and human effort).
3. Document potential applications, including science case studies and lists of publications, and document measurement protocols. Develop adequate protocols when these are not available.
4. Identify synergies with specific measurements done from other observing programs (e.g., BGC-Argo, space-based measurements, Continuous Plankton Recorder surveys) to provide cross-calibration and a better representation of the 4-D distribution of the parameter measured.
5. Identify technological limitations and/or gaps, and identify areas of priority investments to develop and implement the required observation technologies and tools for specific needs.
6. Increase awareness of the availability of biological oceanographic datasets internationally and identify barriers to their access and use, particularly in developing nations.

4.0 Work Plan

The group is planning to convene three times by meeting in conjunction with major ocean science conferences so that some Full Members will be able to self-fund their travel costs and to maximize the likelihood that Associate Members will attend.

**Month 1-6: Sep. 2017-Feb. 2018.** Focus on planning; Find champions to review existing measurements (Bio-optics, flow-cytometry, genetics, Bio-Acoustics, imaging, HPLC). Contact experts for input and references.

**Month 6:** Kick off meeting (in conjunction with the Ocean Sciences 2018). Draft an *Eos* article advertising the WG (Deliverable a). Work on chapters associated with above measurements.

**Month 6-14**: Setup of website with content. Submit *Eos* article. Prepare presentations for OceanObs'19 about adding plankton measurements to GO-SHIP. Work on chapters for manual, website content and identify gaps and people in the community able to contribute relevant expertise. Draft of manual to GO-SHIP.

**Month 14**: 2nd meeting (in conjunction with the OceanObs'19). Preset draft of manual to GO-SHIP, ask community for feedback. Outline work on OceanSITES manual. Identify community members who could contribute their relevant expertise.

**Month 14-27**: Answer feedback by month 20Final editing of manual for plankton measurements for GO-SHIP (Deliverable b). Identify gaps in OceanSITES manual.

**Month 27 or 32:** 3rd (final) meeting (in conjunction with Fall AGU or Ocean Sciences 2020 or spring EGU). Capacity-building workshop for early-career researchers (deliverable e). Final editing of OceanSITES manual (deliverable c) and website (deliverable d). Work on Report to SCOR office.

**5.1** Deliverables

a. An *Eos*-type article after the first meeting reporting to the community about the activity and inviting input.
b. A manual with the protocols for plankton measurements on board research vessels (initially GO-SHIP but expandable to Ships of Opportunities).
c. A manual with the protocols for plankton measurements with research buoys (initially OceanSITES but expandable to other programs, including cabled observatories).
d. A website where our findings will be disseminated. The website will include information on ALL the specifics outlined above.
e. A workshop supporting capacity-building for early career researchers.
f. Present progress at conferences associated with the meetings.

We will contact scientific societies and scientific agencies (e.g. IOC) to see if they will be willing to publish the reports we will produce (including assignment a doi), so that the reports' future use could be tracked.

6.0 Capacity Building

The product of this working group will allow observing systems and programs throughout the world to identify measurements that can be added to their infrastructure. The deliverables will help the community understand the expanded scope of the science that the observations will

support, the cost and effort associated with the measurements, databases where data could/should be submitted to, and experts available for consultation.

We plan a specific capacity-building workshop for early career researchers (ECRs) in conjunction with the Ocean Sciences meeting in 2020, particularly encouraging participation from developing nations. The workshop will support broader awareness of the availability of bio-oceanographic datasets, and identify specific communication and infrastructure gaps limiting their wider dissemination. We will approach SCOR requesting support for attendance by two ECRs from developing nations, from its grant for travel of developing country scientists. The WG will also ask SCOR to encourage its national committees (from developing and developed countries) to send their early-career scientists to the workshop. The workshop will be modeled on the ECR workshop held at the SCOR-sponsored Goa symposium in December 2015, which was assisted by one of the WG co-chairs (Anya Waite).

**7.1** Working Group composition

**7.2 Full members (responsible to produce the deliverables)**

| Name | Gender | Place of work | Expertise |
|---|---|---|---|
| Emmanuel Boss (co-chair) | M | University of Maine, USA | Optical oceanography and the use of optics to study ocean biogeochemistry and ecology, in-situ observing systems, BGC-Argo, Ocean Color, Sea-going. |
| Anya Waite (co-chair) | F | Alfred Wegener Institute, Germany | Ocean biogeochemistry; particle dynamics; marine food webs; biophysical coupling; mesoscale dynamics; Sea-going. |
| Silvia Acinas | F | Spanish National Research Council, Spain | Microbial ecology, flow cytometery, microbial genomics, Sea-going. |
| Ilana Berman-Frank | F | Bar-Ilan University, Israel | Phytoplankton photosynthesis and eco- physiology, aquatic microbial ecology, biological oceanography, marine N2 fixation, in-situ flow cytometry, Anthropogenic impacts, Sea-going |
| Marcela Cornejo | F | Pontificia Universidad Católica de | Biological rates and biogeochemistry, seagoing. |
| Katja Fennel | F | Dalhousie University, | Coupled physical- biogeochemical and ecosystem modeling, Data assimilation. |
| Heidi Sosik | F | Woods Hole Oceanographic Institution | Phytoplankton ecology and photophysiology, automated flow cytometry, automated microscopic imaging, ocean color, biological oceanography, single cell to ecosystem. Sea-going. |

| | | | |
|---|---|---|---|
| Sandy Thomalla | F | Southern Ocean Carbon and Climate Observatory CSIR, South | Biological carbon pump and primary productivity and their relation to physical and biogeochemical controls. Sea-going. |
| Julia Uitz | F | CNRS, Laborato ire d'Ocean | Phytoplankton functional types, optics, HPLC, Ocean Color, BGC-Argo. Sea- going. |
| Hidekatsu Yamazaki | M | Tokyo University of Marine Science and Technology, | Bio-Physical interaction, Optical measurements of plankton/aggregates, Microstructures. Sea-going. |

**7.3 Associate members**

| **Name** | **Gender** | **Place of work** | **Expertise** |
|---|---|---|---|
| Sonia Batten | F | SAHFOS, Canada | Plankton dynamics, Continuous Plankton Recorder, Ship of Opportunity plankton sampling, Global Alliance of CPR Surveys (GACS) Chair. |
| Jørgen Berge | M | UiT The Arctic University of Norway | Arctic marine biology, polar night, zooplankton, organisms associated with the Arctic sea ice, effects of climate change |
| Herve Claustre | M | CNRS, Laboratoire d'Oceanographie | Phytoplankton ecology and pigments. Co-chair BGC- Argo. Sea going. |
| Johannes Karstensen | M | GEOMAR \| Helmholtz Centre for Ocean Research, | Physical interaction with biogeochemical, biological and meteorological processes. Co-chair OceanSITES. |
| Frank Muller-Karger | M | University of South Florida, US | Phytoplankton dynamics, marine biodiversity, marine policy, public outreach, in- situ observing systems, ocean color, coastal and pelagic, Sea-going. |
| Anthony Richardson | M | CSIRO, Australia | Climate change ecology, plankton dynamics and ocean observations. |
| Bernadette Sloyan | F | CSIRO, Australia | Physical Oceanography, Climate, air-sea flux, GO- SHIP co-chair, in-situ observing systems, Sea- going. |
| Rik Wanninkhof | M | NOAA, Miami, USA | Chemical Oceanography, Climate, air-sea flux, GO- SHIP co-chair, in-situ observing systems, Sea- going. |

**7.4 Working Group contributions**

Emmanuel Boss: 20 years of using commercial instrumentation on ships and fixed platforms. Physical-Biological interactions from micro-scale to basin scales.

Anya Waite is a biological oceanographer with extensive laboratory and field experience in integrating and interpreting large multidisciplinary datasets across arrays of biological and physical sensors, field sampling at a wide range of time and space scales as well as analytical experience in flow cytometry, image analysis, confocal and conventional microscopy.

Silvia Acinas is a microbial ecologist who is coordinator of the prokaryotic consortium of the Tara Oceans expedition and responsible also for microbial genomics analyses of the Malaspina 2010 global circumnavigation. Her team has been involved of deliver alternative approaches for exploring diversity and community structure of microbial communities and analyses of marine microbial metagenomics.

Ilana Berman-Frank has extensive experience on phytoplankton ecophysiology and specifically on marine $N_2$ fixation focusing for the past 15 years on the contribution of diazotrophs to production in the eastern Mediterranean Sea (EMS) and northern Red Sea. Has recently set up the first deep-moored station in the Levantine Basin (1500 m depth) to measure production and export and targeted as an ocean observatory platform to provide data for the ultraoligotrophic EMS.

Marcela Cornejo is a biogeochemical oceanographer with interest in carbon, nitrogen and phosphorus cycles in the surface and subsurface waters and the main physical and biological driving factors such as upwelling, phytoplankton bloom, and the shallowing of the oxygen minimum zone. Her work is mainly focused in the upwelling regions and the mesoscale structures.

Katja Fennel has developed and applied numerical models of marine ecosystems and biogeochemistry for over two decades with particular focus on the cycling of nitrogen, carbon and oxygen. In addition, she has developed and applied methods for the assimilation of observations into models in order to improve their predictive capabilities.

Heidi Sosik is a plankton ecologist with extensive experience developing automated instrumentation, in particular submersible flow cytometry and imaging-in-flow cytometry; developing open-source analysis workflows and web-service based information systems to advance accessibility and use of the big data streams resulting from these technologies; serving as coastal ocean observatory science director; and promoting long-term ecological research in the oceans.

Sandy Thomalla is a biogeochemical oceanographer whose research focuses on using bio-optical approaches to parametrize the particle field (dominated by phytoplankton). The primary objective of her work is to develop and apply emerging techniques to derive optimized and regionally robust information from autonomous platforms and satellite ocean colour products in the Southern Ocean.

Julia Uitz is a biogeochemical oceanographer with strong interest in deriving information on phytoplankton diversity based on optical observations from a variety of research platforms such as vessels, profiling floats or ocean color satellites. Her research has mostly focused on the global open ocean and more recently on specific atypical regions (Mediterranean Sea, Southern Ocean).

Hidekatsu Yamazaki is a physical oceanographer. His research interests focus on examining the physical environment of phytoplankton and zooplankton. He is also investigating the relationship between turbulence and other phenomena (internal waves, ocean currents).

8.0 Relationship to other international program and SCOR working groups

GO-SHIP & OceanSITES– We will provide recommendations to GO-SHIP and OceanSITES regarding instrumentation and water-sample analysis that should be added to their protocols together with their scientific relevance and resource requirements (both in funds and people time). Associate Members Sloyan and Wanninkhof are the co-chairs of GO-SHIP and Associate Member Karstensen is the co-chair of OceanSITES.

SOLAS – data to be collected would directly link atmospheric measurements done on research vessels and buoys to plankton-related parameters and rates, providing data to constrain processes at the interface of ocean and atmosphere (Boss is on SOLAS SSC).

IOCCG - data to be collected will provide validation for algorithms using space-based measurements. (Boss is on the IOCCG SSC).

BGC-Argo – Synergies with BGC-Argo are in providing a platform to deploy floats where relevant biogeochemical parameters are collected near to the deployment location to assess measurement accuracy (e.g., many SOCCOM floats have been deployed from GO-SHIP cruises and POC and HPLC pigments have been collected in conjunction as well as oxygen, nitrate, and carbonate chemistry). When float trajectory are in vicinity of cruise tracks or moorings, cross- calibration can be done to assess presence and magnitude of sensor drift. Proposed WG Associate Member Claustre is the co-chair of BGC-Argo.

Global Alliance of CPR Surveys (GACS) – Synergies with GACS are in relating our proposed plankton measurements to their past and present efforts in quantifying global plankton biomass and diversity and lesson learned in curation and dissemination of data. Associate member Batten is the chair of GACS.

SCOR WG 150, translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT) – Optical technologies that will be evaluated by this WG (optical sensors, automated microscopes, cameras) are the same TOMCAT is reviewing. Proposed WG Full Member Thomalla is also a member of WG 150.

Appendix: 5 relevant publication by each Full Member

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### 2.2.2 Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change Shapovalov

Title:
Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change

**Acronym:** EBUS

Summary/Abstract

Eastern Boundary Upwelling Systems (EBUS) (California, Humboldt, Benguela and Canary Current System) are characterized by complex dynamical processes spanning a wide range of spatio-temporal variability due to the strong coupling between the ocean and atmosphere. They are among the most productive marine ecosystems in the world supporting some of the world's major fisheries, yet occupying only 0.1% of the global surface. Trade winds drive coastal upwelling, which brings cold and nutrient-rich waters to the surface, where favorable light conditions sustain high phytoplankton growth. Below the surface, Oxygen Minimum Zones develop due to high organic matter export. When these waters upwell, they release $CO_2$ and $N_2O$, potent greenhouse gases, to the atmosphere. Locally, the mesoscale low-level atmospheric circulation is affected by air-sea-land interactions, which impact the upwelling and productivity, while remote forcing can modulate upwelling at timescales from intraseasonal (*e.g.* Kelvin waves) to interdecadal (*e.g.* gyre circulation) and longer. EBUS are natural laboratories for studying the breadth of interactive processes between land, ocean and atmosphere at the regional scale. This SCOR WG will focus on the integration of existing knowledge on EBUS to formulate a strategic recommendation white paper for setting up regional observational systems and climate modeling approaches to monitor and understand physical and biogeochemical ocean- atmosphere interactions. These observational systems will be instrumental in improving the performance and reliability of climate models in these socio-economically relevant regions of the world ocean. This WG will also review and critically evaluate the different "hard science" approaches that are pursued with respect to the socio-economic benefits they could bring.

Scientific Background and Rationale

The Eastern Boundary Upwelling Systems (EBUS) are the most productive areas of the world's oceans (Pauly and Christensen, 1995), supporting large populations of commercially important fish species (Bakun et al., 2015). In these regions the equatorward alongshore winds drive offshore Ekman transport of the surface layers of the ocean and, cold, nutrient-rich deeper waters outcrop to re-establish the geostrophic equilibrium in eastern boundaries, developing the so-called Coastal Upwelling Systems. These areas (California, Peru-Chile, Benguela and Canary Current, Sumatra-Java Systems) are characterized by equatorward alongshore boundary currents, poleward undercurrents, filaments, squirts, mesoscale eddies and internal waves, also driven, triggered and modulated by the local-to-regional wind field (e.g., Chelton et al., 2007).

These processes interact at different timescales influencing a wide variety of processes including marine fishery production (e.g., Mbaye et al., 2015), phytoplankton cell size (e.g. Van der Lingen et al., 2009), plankton and fish community structure (e.g. Van der Lingen et al., 2006) and biogeochemical cycling (e.g. Woodson and Litvin, 2015). High biological productivity in the surface layer drives elevated rates of downward vertical flux of organic matter that in combination with sluggish circulation results in the development of the Oxygen Minimum Zones (OMZs). The four EBUS display varying levels of OMZ development from the shallow, anoxic Peru-Chile system to the deeper hypoxic California system (Chavez and Messié, 2009). Low-oxygen areas strongly influence the distribution of macroorganisms that are displaced by oxygen-poor conditions. Deoxygenation may also modify plankton regimes that can have profound consequences on ecosystem structure (e.g. Gomes et al., 2014). Extreme anoxic events can reduce habitat (for instance in Peru-Chile by creating a shallow habitat leading to increased catchability) or increase mortality (rock-lobster walkouts in the Benguela are well documented). Specific biogeochemical processes (denitrification, anammox, methanogenesis) which only occur at low oxygen concentrations influence global ocean nutrient cycles as well as production of greenhouse gases (e.g. Stramma et al., 2010). The impact of oceanic trace gases on atmospheric chemistry is also yet to be determined (e.g. Rees et al., 2011).

The basic forcing mechanisms are similar across the different EBUS and establish similarities in physical dynamics and ecosystem structure, and progress has been achieved in understanding the EBUS dynamics from an integrative and comparative perspective (e.g., Pegliasco et al., 2015; Capet et al., 2014; Lachkar and Gruber, 2012; Gruber et al. 2011; Chavez and Messié, 2009; Capet et al., 2008; Carr and Kearns, 2003). However, owing to differences in the relative strength of the potential stressors (e.g. the strength of the equatorial oceanic teleconnection or subtropical pressure system), a unified view is yet to be established and challenges to understanding the sensitivity of individual EBUS to climate variability and change remain (e.g. Wang et al., 2015; Bakun et al., 2015; Mackas et al., 2006). From a global climate perspective, some EBUS are also thought to influence large-scale climate modes. For instance, the EBUS in the Indian Ocean, the Sumatra-Java upwelling system, is relatively less studied, although it plays an important role in the development of the Indian Ocean Dipole (Saji et al., 1999). The difference in their latitudinal positions implies that some EBUS or EBUS sub-components are more wind- driven (those at high-latitudes) while others experience more tropical oceanic teleconnections, although the Benguela EBUS is also influenced by the Agulhas leakage. Therefore while commonalities in the nature of the forcing have suggested that a common theory of the circulation and its role on biogeochemical properties (e.g. OMZs) could be drawn, the characteristics of the forcing (amplitude, frequency, persistence, asymmetry) linked to inherent non-linearities of the systems call for a revision of this paradigm. In addition, progress in regional modeling has shed light on potentially important processes that were only inferred until recently (e.g. effect of the wind-drop off on upwelling dynamics (Capet et al., 2004; Renault et al., 2015, 2016); current-wind coupling (Chelton et al., 2007); eddy-induced transport (Bettencourt et al., 2015; Vergara et al., 2016; Gruber et al., 2011; Rossi et al., 2008) and that are, so far, difficult to tackle only with observations or from global models. The latter in particular still suffer persistent warm biases (Richter, 2015; Zuidema et al., 2016) that have limited our predictive capability of the EBUS evolution at various timescales (intraseasonal to

climatic timescales) (Cabré et al., 2015; Stramma et al., 2012). While most regional modeling studies have been process-oriented, some long-term regional hindcast simulations are becoming available (Dewitte et al., 2012; Franks et al., 2013; Combes et al., 2015) and regional model simulations with data assimilation are becoming available (Neveu et al., 2016). Although not yet including all relevant processes (e.g. air-sea coupling at the mesoscale) and mostly limited to the physical component of the system, they however allow the investigation of processes at low-frequency time scales and within a climate framework, overcoming some of the limitations of the observational studies and modeling studies based on low-resolution global models. So far the focus has been on the four major EBUS (California, Canary, Humboldt, Benguela). However it is also of interest to contrast the EBUS with the weak upwelling/less productive eastern boundary current systems such as the Iberian Current and Leeuwin Current systems, so as to better understand transient processes in the context of global warming.

The challenge for better understanding EBUS dynamics as a whole has spurred, in recent years, a number of joint efforts from an observational and modeling perspective, e.g., the international CLIVAR program VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Study) was implemented to develop and promote scientific activities leading to an improved understanding of the South Eastern Pacific coupled ocean-atmosphere-land system on diurnal to interannual timescales (Mechoso et al., 2014). VOCALS also motivated research on the Benguela upwelling system (e.g. European projects MEECE and PREFACE). The transdisciplinary AMOP (*Activities of research dedicated to the Minimum of Oxygen in the eastern Pacific)* project was launched to investigate the mechanisms leading to the formation of the OMZ off Peru and its variability from hourly to centennial timescales. The German initiative SFB754 '*Climate-Biogeochemistry Interactions in the tropical Ocean*' addressed the relatively newly recognized threat of ocean deoxygenation, its possible impact on tropical OMZs and implications for the global climate biogeochemistry system. The recently initiated TPOS 2020 project (http://tpos2020.org/) aims at designing a future tropical Pacific observing system including monitoring the Eastern boundary and addressing coastal upwelling dynamics (Takahashi et al., 2014). A CLIVAR/SOLAS/IMBER Research Focus on upwelling systems has also been initiated recently that is aimed at making progress in our understanding of EBUS dynamics from physics to fisheries.

These observing programs along with recent progress in regional coupled modeling offer a new perspective for understanding EBUS and can revitalize the intercomparison approach. In particular, the perspective of long-term regional simulations (not just climatological) is an asset for addressing temporal and spatial scale interactions (upscaling, rectification processes) and their sensitivity to low-frequency changes in the environmental conditions, providing material for revisiting the interpretation of historical data. The on- going international effort for intensifying the ocean observing systems (e.g. Argo, IOCCP, SWOT mission, Sentinel missions) in order to address small spatial scales of variability also sets favorable conditions for documenting quantitatively the continuum of small scales (from mesoscale to submesocale) and its impact on the ecosystem dynamics. In that sense the context is favorable for launching a working group on related issues. Its aims will be in particular to stimulate the interactions between the modelers and experts in observations interested in EBUS.

There are a number of regional processes in EBUS that modeling studies suggest to be key but that have been undocumented by observations (e.g. impacts of coastal mesoscale atmospheric jets, transports of water properties by eddies, deep zonal oceanic jets, air-sea interactions at mesoscales, etc). This calls first for more quantitative evaluations of the role of such processes in EBUS dynamics from integrated modeling platforms, i.e., that take into account the complexity of feedbacks and scale interactions, and within a climate perspective, i.e., from long-term (multidecadal) simulations. Second, it motivates the design of dedicated observing programs in order to document these processes in nature and in return evaluate the realism of the coupled models. The socio-economic importance of EBUS (0.1% of global ocean area that sustains 20% of the world's fish catch) further urges the investigation of the role of these regional processes in the biogeochemistry of the OMZs. This is a prerequisite for improving our predictive capabilities of the evolution of marine ecosystems in these key economic regions and for anticipating changes in the nature of extreme events (e.g. hypoxia). This will require the design and implementation of efficient and cost effective observing systems, which are motivated by adequate scientific objectives. The activities that will be carried out within this proposed working group are thus also oriented towards providing guidance for the design of such observation systems based on modeling and process studies and synthesis of existing knowledge. It will build upon current initiatives both at national and international levels (e.g. TPOS2020, GOOS IMSOO (Implementation of Multi-Disciplinary Sustained Ocean Observations) panel on Oxygen Minimum Zones) while providing a synthetic view through looking at all upwelling systems.

The EBUS WG will address the knowledge gaps outlined above by making recommendations as to how better and more cost-effectively observe these regions in both the ocean and atmosphere simultaneously. It will first provide a comprehensive evaluation of current knowledge regarding control mechanisms, impacts on biogeochemical cycles and feedbacks derived from all published observational and modeling approaches, and will then develop a strategic recommendation white paper to fill these gaps. This WG will thus have material for conducting a socio-economic exercise to review and critically evaluate the different "hard science" approaches that are pursued with respect to the socio-economic benefits they could bring (at what scales, what level of complexity on the physics, what level of complexity on the ecosystem, what precise applications, what are the enduring challenges, inter alia)**.** While the latter is not in the main scope of the WG, the objective is to take advantage of the rich networks of collaboration of the WG participants to identify relevant experts during the course of the project, and invite them to collaborate on a recommendation paper. As well this will be coordinated with relevant programs (CLIVAR RF on EBUS, GEF (Global Environment Facility), Future Earth Oceans KAN, etc).

To achieve these goals, a unique group of early career scientists and more senior scientists, all experts in different EBUS of the world ocean and involved in relevant national and international programs, has been invited to participate in this working group. This group is composed so as to cover issues of both observations and modeling, and gather scientists originating from a range of developed and developing countries and disciplines, which shall ensure communication of

the outcomes to the wider research community, and alignment with national and global research platforms.

## Terms of Reference

1. **Synthesize existing knowledge** on the different physical mechanisms occurring over different time scales (i.e., diurnal, intraseasonal, interannual, decadal, multidecadal) and their implications on water column properties, biogeochemical cycles, biodiversity/ecosystem structure and functioning and the regional climate, to identify the key feedback processes, establish similarities, differences and the knowledge gaps.
2. **Conduct a regional database initiative** to hold a web-based platform for graphically querying integrated information of observational systems (e.g. including data access, available timescale, papers published, associated databases) and numerical outputs (e.g. including configuration details as well as associated scientific production and responsible scientists together with their contact details) as well as protocols for measuring key properties and indicators in EBUS. Such a database will be used in particular to explore the processes that are difficult to tackle with just observational datasets (e.g. submesocale processes and their role in structuring the biological environment)
3. **Produce a** comparative analysis from modeling validated/published results, presented as a **high impact factor review paper**. While such an analysis will have mostly a regional focus, it will also attempt to address subregional scales building upon past and on-going research programs on specific upwelling centers (e.g. Bay of Hann near Dakar (Senegal), Bay of Monterey (USA), Bay of Concepcion (Chile)), which will help linking to the socio-economic exercise (see Term of Reference 5).
4. **Provide a strategic recommendation brief** for setting up regional observational systems to monitor and understand physical and biogeochemical ocean-atmosphere interactions. These observational systems will be designed so as to be instrumental in improving the performance and reliability of climate models in these socio-economically relevant regions of the world ocean. Such a recommendation brief will also address needs for fostering interactions between the observational and modeling communities (e.g. coordinated experiments with common forcing; recommendations on resolution of specific processes or a specific scale, etc).
5. **Conduct a socio-economic exercise** to review and critically evaluate the different hard science approaches that are pursued with respect to the socio-economic benefits they could bring, that will provide useful information about scales, level of complexity on the physics and on the ecosystem, precise applications, among others. This document, prepared as a report (printed and online) for diverse target audiences including the scientific community, policy-makers and stakeholders, will present the basis on which to assess changes across EBUS and will be useful for governance activities.

## Working plan

### Year 1 (2018)

The first year will be focused on organizing the working group and assembling the information needed to achieve terms of references 1, 2 and 3. This will be discussed initially via email and

coordinated at **a first meeting** where full and associate members will attend together with their PhD students, postdocs or early career scientists (at least one each). The meeting will be developed in two parts, the first where full and associate members will (1) agree on a clear plan of the strategies required to achieve the goals and
(2) organize the structure of the **peer-reviewed publication** that will be submitted and published in an open-access journal at the end of the first year (Deliverable 1). The second part will be devoted to capacity building and activities in which early career scientists will be involved, and would look for to be linked with the IMBER early career Network of socio-ecologists and CLIVAR and SOLAS initiatives. The first meeting will be organized four months after the SCOR WG is implemented.

Year 2 (2019)
The second year will be dedicated to organizing the **regional database initiative** and **summer school**. This will be developed in a **second meeting**/workshop where full and associate members will attend together with some invited stakeholders from the scientific community and decision-makers. Following the second meeting, **a summer school** will be organized either in Senegal and/or Peru involving PhD students and early career scientists mostly from Africa and South America, having the objective to 'Provide an overview of the main processes occurring in EBUS (including physical, biogeochemical, biological, fish and fisheries processes and trends), in order to understand ocean-atmosphere interactions, combining lectures and hands-on sessions, and practical lessons' as well as 'to identify potential students to integrate the capacity building strategy' (i.e., create an early career network from alumni of the summer school). All experts and younger scientists will participate giving lectures and tutorials. The WG will request funding from SCOR and other sources to facilitate the participation of students and early-career scientists. Classes given during the summer school will be recorded and available from the SCOR WG EBUS webpage that will be provided and supported by the Computational Geophysical Fluid Dynamic Laboratory at IGP (Geophysical Institute of Peru).

The **regional database initiative** (Deliverable 2) will be developed in close collaboration with the early career scientists, with the aim to involve graduate students from different developing countries and disciplines (some of them identified in the summer school) to prepare a web based graphical platform where the compilation of regional observational systems and numerical simulations will be available for the scientific community and stakeholders. Also, it will serve as material for preparing and submitting a **high impact factor review paper** (Deliverable 3) compiling modeling results**,** addressing the comparison between EBUS, and establishing the strengths and weaknesses of regional coupled models, and directions for the future.

Year 3 (2020)
The third year will be oriented towards organizing the **Open Science Conference** composed of three parts:

- *Day 1*: Objective 'Organize the strategic recommendation brief to be presented as a short paper to the Executive Panel (i.e. defined as a representative group of decision makers, stakeholders and scientific experts from different areas)', where only full and associated

members will participate.

- *Days 2-3*: Objective 'Bring together all interdisciplinary and multidisciplinary ocean and atmospheric science communities involving modelers and observationalists studying EBUS and related topics'.
- *Day 4*: Executive Panel. Objective 'Bring together decision makers, stakeholders and the scientific community to present and highlight the main findings, suggest first priority topics, offer suitable and cost-effective alternatives to approach solutions to further understand EBUS dynamics'. It will be developed just after the Open Science Conference.

During this year **a strategic recommendation brief** (Deliverable 4) on how to best set up regional observational systems to monitor and understand physical and biogeochemical ocean-atmosphere interactions in the EBUS will be presented. Note that the Executive Panel discussion will feed the strategic recommendation brief.

Year 4 (2021)

The fourth year will be focused on **preparing the report** of the socio-economic exercise (Deliverable 5) which will be developed in a meeting where full and associate members will attend, together with some invited stakeholders from the scientific community and decision-makers. In addition, the **final report** of the SCOR WG will be delivered.

## Deliverables

*Deliverable 1*. **A multidisciplinary synthesis peer-reviewed publication**, with the existing knowledge about the different physical and biogeochemical mechanisms developed over different time scales on EBUS as well establishing similarities and differences**.**

*Deliverable 2*. **A web-based platform,** where graphically the EBUS databases will be queried and useful information about measurements and protocols

*Deliverable 3*. **A high impact factor review paper** (e.g., Nature Geoscience)**,** wherein a comparative analysis based on modeling results from both the ocean and atmosphere is presented

*Deliverable 4*. **A short recommendation paper for stakeholders and policy makers** where a strategic recommendation on how to more cost effectively design and improve regional observational systems with the overarching goal to improve the performance and reliability of global climate models.

*Deliverable 5*. **A report** where a socio-economic exercise for EBUS is conducted.

## Capacity Building (How will this WG build long-lasting capacity for practicing and understanding this area of marine science globally)

The WG is planning to hold an international summer school focused on PhD students and young post-docs mainly (but not exclusively) from Africa and South America and other developing countries. The objective will be to provide the young scientists with an integrative

view of the land-atmosphere-ocean continuum in their modeling coupled physical/biogeochemical approach. The basics of atmospheric physics and chemistry and associated coupled and modeling platforms will be presented. An introduction to regional weather and climate systems off the EBUS will be given, as well as basic concepts in physical oceanography and biogeochemistry and hands-on practicals with the ROMS-BIOEBUS[1] modeling platform. Statistics applied to climatology and challenges of regional climate downscaling for performing regional climatic projections will be taught. We will try to explore a new, innovative capacity-building concept: the Network of Early Career Scientists (NECS). This will combine traditional capacity- building of individual early career scientists with a new level of institutional networking. The ultimate goal is to build long lasting capacity through training and by interconnecting the next generation of scientists, and to develop enduring institutional interactions that will help address the scientific challenges facing the EBUS. We will also encourage and facilitate other training and professional development workshops and programs, such as those funded by the Marie Skłodowska Curie Innovative Training Network. Funding for sustaining our NECS will be sought from a range of sources and stakeholders supporting training and networking measures worldwide. We will collaborate with START, IAI, POGO and APN, so that their fellowship schemes and other mechanisms can be used for capacity development.

Several of the scientists involved in the consortium are dedicated to supervise students from southern countries, therefore this WG proposal will also serve as a platform for networking and increasing the critical mass of young researchers hence reinforcing capacity in oceanic sciences in these developing countries. The co-chair of the Working Group is a female early career scientist originating from a developing country, thus guaranteeing the attention given to capacity building and to gender equity.

Additionally, the web-based platform will be the key element to build a young multidisciplinary team from different disciplines and countries to work on EBUS to provide synthetic material for students and local researchers from the developing countries, as well as for decision-makers around the world. In this sense, since the database will provide comprehensive information including observational and numerical data as well as their respective owners and associated scientific production, students and local researchers would be in direct contact with the ocean science community reinforcing their capacity building in these topics and at the same time initiating and expanding their international collaborations.

[1] This model is chosen for its relative versatility and simplicity, which is convenient for capacity building.

Working Group composition

Full Members

| Name | Gender | Place of work | Expertise relevant to proposal |
|---|---|---|---|
| 1. Francisco Chavez (United States of America) | Male | Monterey Bay Aquarium Research Institute, USA | Biological Oceanography/ California, Peru |
| 2. Enrique Curchitser (United States of America) | Male | Institute of Marine and Coastal Sciences, Rutgers University, USA | Physical oceanography Modeling / CLIVAR |
| 3. Boris Dewitte (France) | Male | IRD-LEGOS, CEAZA-Chile | Physical Oceanographer, EBUS Dynamics, Air-sea interactions, ENSO dynamics |
| 4. Ruben Escribano (Chile) **Co-chair** | Male | Department of Oceanography, Universidad de Concepción, Chile | Biological Oceanography, Chile/ IMBeR/CLIVAR |
| 5. Sara Fawcett (South Africa) | Female | Department of Oceanography, University of Cape Town, South Africa | Biogeochemical Oceanographer |
| 6. Salvador Lluch-Cota (Mexico) | Male | Programa de Ecología Pesquera. CIBNOR-CONACYT, México | Fishery/Socio-economist ecology |
| 7. Baye Cheikh Mbaye (Senegal) | Male | Laboratoire de Physique de l'Atmosphère et de l'Océan Simeon Fongang (LPAOSF), University Cheikh Anta Diop of Dakar (UCAD), Senegal | Physical/biological Oceanography - Senegalese- Mauritanian coastal upwelling within the Canary upwelling system off North-West Africa |
| 8. Ivonne Montes (Peru) **Co-chair** | Female | Instituto Geofísico del Perú (IGP) | Physical Oceanographer, biogeochemical coupled modeling and dynamics of the Peru/Chile System |
| 9. Andreas Oschlies (Germany) | Male | Helmholtz-Zentrum für Ozeanforschung Kiel (GEOMAR) | Physical Oceanography, Marine Biogeochemical Modeling |
| 10. Parv Suntharalingam (UK) | Female | University of East Anglia (UEA) | Oceanographer, biogeochemical modeling/SOLAS |

Associate Member

| Name | Gender | Place of work | Expertise relevant to proposal |
|---|---|---|---|
| 1. Edward Allison (United States of America) | Male | School of Marine & Environmental Affairs, University of Washington, USA | Interdisciplinary marine scientist focus on climate, social science and resource management |
| 2. Javier Aristegui (Spain) | Male | Instituto de Oceanografía y Cambio Global (IOCAG) at the University of Las Palmas de Gran Canaria (ULPGC) | Biological Oceanography/ Canary Current EBUE |
| 3. Xavier Capet (France) | Male | CNRS-LOCEAN, Paris | Physical Oceanographer - modeler |
| 4. Iris Kriest (Germany) | Female | Helmholtz-Zentrum für Ozeanforschung Kiel (GEOMAR) | Biogeochemical modeller |
| 5. Eric Machu (France) | Male | IRD – LPAO-SF, ESP, Université Cheikh Anta Diop, Dakar Sénégal | Oceanographer, structuration of plankton communities from coupled approaches (observation & modeling) |
| 6. Beatriz Yanicelli (Chile) | Female | Centro de Estudios Avanzados de Zonas Aridas (CEAZA) | Oceanographer, Chile Coastal Upwelling System |
| 7. Damodar Shenoy (India) | Male | National Institute of Oceanography, Goa, India | Biogeochemistry/Bay of Bengal/Arabian Sea |
| 8. Ryan Rykaczewski (USA) | Male | University of Southern California | Biological Oceanography of EBUS – California System/CLIVAR |
| 9. Lynne Shannon (South Africa) | Female | Marine Research Institute, University of Cape Town | Fishery/Socio-economist ecosystem EBUE |
| 10. Ming Feng (Australia) | Male | CSIRO Marine and Atmospheric Research | Physical oceanographer specialized in the Leeuwin Current dynamics |

## Working Group contributions

The full and associated members involved in this SCOR WG have been invited due to their field of expertise and past works, coming from various countries and disciplines; these are:

**Dr. Francisco Chavez** has published extensively on climate variability and EBUS, worked for many decades on the California and Humboldt EBUE, and has broad interests in oceanography, biogeochemistry, ecology, modeling, and new technology. He has led several synthesis efforts, edited multiple special issues and is active in national and international programs.

**Dr. Enrique Curchitser** is a physical oceanographer with interests in the dynamics of eastern boundary currents and shelf circulation and coupled bio-physical and numeric modeling. He is leading the CLIVAR Eastern Boundary Upwelling Research Focus that is trying to better understand the very large biases that climate models have in EBUS.

**Dr. Boris Dewitte** is a physical oceanographer involved in numerous projects dedicated to the study of Humboldt Current System; with wide experience on ENSO events and their impacts. He is currently a member of the CLIVAR Scientific Steering Group and of the Task Team "Eastern Boundary" of the international program TPOS2020. He was an associate member of the SCOR group 128 on Natural and Human-Induced Hypoxia and Consequences for Coastal Areas (2006-2008).

**Dr. Ruben Escribano** is a biological oceanographer who specializes in zooplankton, was active in the GLOBEC program and is presently on the IMBeR Scientific Steering Committee, working extensively on the Humboldt.

**Dr. Sara Fawcett** is dedicated to understanding the complex relationships between biogeochemical fluxes (particularly nitrogen) and primary productivity in the ocean, with implications for past and future climate, ecosystem structure and function, ocean fertility, and global biogeochemical cycles.

**Dr. Salvador Lluch-Cota** has interests in climate variability and change and its effects on living marine resources; he was one of the six lead authors of the IPCC chapter on Ocean Systems. He has worked extensively in the California Current System particularly off Baja California, Mexico and has led synthesis efforts to uncover and better understand the variability of small pelagic fish in Atlantic and Pacific EBUS.

**Dr. Baye Cheikh Mbaye** is specializing in the Senegalese-Mauritanian coastal upwelling within the Canary upwelling system off North-West Africa. His main focus is to analyze how both physical and biological factors affect the survival of fish early life stage (eggs and larvae), and how this ecological understanding could help improve policies for marine conservation and fisheries management of eastern boundary upwelling systems; his approach integrates both modeling and observation (remote sensing).

**Dr. Ivonne Montes** is specialized on coupled physical-biogeochemical modeling applied to Eastern boundary current system (Guinea Gulf, Mexico and Peru/Chile) to study the role of the

ocean in climate, the investigation of processes maintaining the Oxygen Minimum Zone off Peru, and the impact of remote and local air-sea interactions over the upwelling systems.

**Dr. Andreas Oschlies** is an expert on marine biogeochemical Modeling dedicated to study the physical, biogeochemical, and ecological constraints on the oceanic carbon uptake and its climate sensitivity as well as interested on mixing processes and their representation in numerical models.

**Dr. Parv Suntharalingam** is focused on biogeochemical cycles of climatically important species in the atmosphere and ocean.

## Relationship to other international programs and SCOR Working groups

This EBUS theme is an integral part of the integrated topics in the new SOLAS Science Plan 2015-2025[2] . Moreover, CLIVAR (Climate and Ocean: Variability, Predictability and Change), IMBeR (Integrated Marine Biosphere Research) and SOLAS have a joint Research Focus on Upwelling systems. In addition, there is a strong link between this SCOR WG proposal and the new initiative from IOC-UNESCO called $GO_2NE$ (Global Ocean Oxygen NETwork), an interdisciplinary network concerned about the low oxygen concentrations in both the open ocean and coastal areas, which will be involved in the regional database initiative. This working group is also timely since it fits with the concerns of the program TPOS2020 that is aimed at designing the future of the observing system in the Pacific (http://tpos2020.org/). Interactions with the Task Team "Eastern Pacific" of the TPOS2020 program will be encouraged during the course of the SCOR group. It will also link with the GOOS IMSOO (Implementation of Multi-Disciplinary Sustained Ocean Observations) panel on Oxygen Minimum Zones. This SCOR WG will also have the opportunity to start with standards, datasets and comparative analysis of the oxygen deficient systems being generated by the SCOR Working Group 144 on Microbial Community Responses to Ocean Deoxygenation, developed for the world ocean to the wider oceanographic and Earth system science communities and the public.

This SCOR WG will also strive to integrate in its synthesis outcomes of relevant regional modeling and observational projects (e.g. CORDEX) through collaborations of its members.

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*By inversions we mean inversions to obtain information on the properties of materials in the ocean and the atmosphere (gas, particles, dissolved materials, drops etc') as well as at the interface (waves, bubbles). By properties we mean concentration, composition, size and shape, lifetime, optical properties.

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Appendix (For each Full Member, indicate 5 publications related to proposal)

**Dr. Francisco Chavez**


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2-108

**Memorandum to:** Dr Ed Urban Executive Director

Scientific Committee on Oceanic Research College of Earth, Ocean, and Environment Robinson Hall

University of Delaware Newark, DE 19716 USA

Kiel, 11 April 2017

**Subject:** SOLAS support for SCOR Working Group on 'Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change'

Dear Ed,

With this letter SOLAS expresses strong support for the proposal to establish a SCOR Working Group on 'Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change', submitted by Ivonne Montes, Ruben Escribano and others. The proposal is a response to the need for integrating existing knowledge on EBUS to formulate a strategic recommendation white paper for setting up regional observational systems to monitor and understand physical and biogeochemical ocean-atmosphere interactions. This is a frontier issue scientifically and one of the scientific priorities for SOLAS as detailed in the SOLAS 2015- 2015 Science Plan and Organisation. Observational systems will be instrumental in improving the performance and reliability of climate models in these socio-economically relevant regions of the world ocean.

The SOLAS International Project Office (IPO), as you know, has limited financial resources with which it must support activities across the full scope of the SOLAS science plan. As a result, there are insufficient resources available for SOLAS to fund the proposed activity. SOLAS will support the group to the best of its ability, ensure access to the communications and organisational capabilities of the IPO, and help link the Working Group's activities to other ongoing SOLAS planning activities and scientific meetings. We expect that regular communiqués on the group's activities can be published via the SOLAS report series and E-news.

The international team assembled for this Working Group is well qualified to carry out its mission and we hope that SCOR will be able to support the proposal. We look forward to this becoming one more area in which SOLAS and SCOR can continue our productive cooperation.

With very best regards,

Dr. Véronique Garçon
Chair, SOLAS Scientific Committee Steering

Dr. Emilie Brévière
Executive Director,
SOLAS International Project Office

**The Surface Ocean – Lower Atmosphere Study (SOLAS) International Project Office**

GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany Tel: +49 431 600 4153 | solas@geomar.de | www.solas-int.org

Integrated Ma IMBeR

www.imber.info

Robinson Hall, University of Delaware Newark, DE 19716 USA

Dr. Ed Urban
Executive Director

15 April 2017

Scientific Committee on Oceanic Research
College of Earth, Ocean and Environment

Dear Ed,

I am writing to confirm that IMBeR strongly supports the proposal for a SCOR Working Group on ‘’*Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change*”, which would be co-chaired by Ivonne Montes, a physical oceanographer working at the Instituto Geofisico del Perú, and Rubén Escribano, a biological oceanographer at the University of Concepción, Chile.

The objectives of EBUS, to synthesise, compare, make accessible and recommend future observational and modelling approaches to monitor and understand the physical and biogeochemical feedbacks occurring in eastern boundary upwelling systems align well with the IMBeR research goal as outlined in the Science Plan and Implementation Strategy (2016-2025). In particular, this includes the IMBeR objectives to improve the quantitative understanding of ocean variability and change in order to provide the basis for scenarios, projections and predictions of the future, and to enable the acquisition and provision of evidence-based advice for marine managers, policy makers and other end-users for sustainable marine governance. IMBeR also has a commitment to supporting early career researchers, so we would be particularly pleased to link the EBUS summer school participants with our Early Career Network of socio-ecologists, which developed from our own series of biennial ClimEco summer schools.

If funded, IMBeR will support the SCOR working group in terms of ensuring networking opportunities within the IMBeR community, for example through collaboration with the CLIVAR/SOLAS/IMBeR upwelling Working Group, and access to the logistical and organizational expertise of the IMBeR International and Regional Project Offices in Bergen and Shanghai. The interdisciplinary activities of the IMBeR Human Dimensions and Continental Margins Working Groups would be a particular source of expertise for the EBUS socio-economic exercise.

We look forward to the opportunity to work closely with this potential new SCOR Working Group.

IMBeR International Project Office (IPO)
Institute of Marine Research

P.O. Box 1870 Nordnes
5817 Bergen

Norway

Tel: +47 953 65 708

E-mail: imber@imr.no

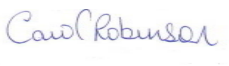
Chair: Carol Robinson

Centre for Ocean and Atmospheric Sciences
School of Environmental Sciences University of East Anglia, Norwich NR4 7TJ United Kingdom

Tel: +44 1603 593174

E-mail: carol.robinson@uea.ac.uk

Yours sincerely,



Dr. Carol Robinson

Chair, IMBeR Scientific Steering Committee

### 2.2.3 International Network for the Study of How Organisms Respond to Environmental change (INSHORE) Miloslavich

Proposal for a SCOR Working Group to form the International Network for the Study of How Organisms Respond to Environmental change

**Acronym: INSHORE**


## Abstract

Climate change and ocean acidification are the greatest global threats facing the world's ecosystems, significantly altering the structure and functioning of coastal systems around the globe[1,2]. The financial cost of not undertaking adaptive management in coastal areas is estimated at $1 trillion by 2100[3]. In this era of unprecedented anthropogenic pressures, limitations in basic and applied knowledge on the distribution of organisms, and the paucity of multiple stressor research programmes impedes our ability to predict change and responsibly manage coastal systems.

INSHORE will use an interdisciplinary approach to understand and predictively model responses of ecosystem engineer species, including commercially farmed and Non-Indigenous Species to climate change and ocean acidification (OA). The Working Group will focus on ten species of mussels; *Mytilus edulis* and *Mytilus galloprovincialis* (Europe), *Brachydontes pharaonis* (invasive to Mediterranean Europe), *Mytilus californianus* and *Mytilus trossulus* (USA), *Septifer virgatus* (China & Hong Kong), *Perna viridis* (China & Hong Kong), *Mytilopsis sallei* (invasive to Hong Kong), *Perna perna* (South Africa) and *Mytilus chilensis* (Chile).

The Working Group objective is to develop an integrative framework and modelling tool that can be applied internationally to coastal marine ecosystems. This will be achieved by 1) creating a global database of relevant ecological, biological and environmental datasets 2) developing a biophysical 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 research community in an integrated scientific approach.


Scientific Background and Rationale

Global climate change is now the milieu within which all biological, ecological and socio-ecological interactions must be positioned. Understanding and predicting impacts of climate change and OA on the physiology, abundance and distribution of species have been highlighted as a 'grand challenge' for physiologists worldwide[4], with a recognized need amongst the international research community to understand the organism's role in organism–environment linkages and how organisms respond to change.

The importance of a quantitative understanding of biological and physiological impacts of global climate change and OA, and resultant changes to distributions and abundances of species

within the marine environment is clear, with an emphasis on predicting “winners” and “losers” among commercially, ecologically and culturally important species. Understanding how these stressors will alter resilience and sustainability of ecosystems is a priority for marine scientists working across molecular to ecosystem scales.

Species and ecosystems respond to 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], however, decadal-scale increases in mean climate are not the proximate drivers of organismal survival. Instead, vulnerability is through mortality or sub-lethal performance; species’ distributions respond more directly to shorter-term variation in environmental conditions including extreme 'climatic' events and anomalies[7]. Consequently, predictions may have little relevance for individual species, nor be appropriate for ecosystem status assessments at local to regional scales. 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 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, subsequently altering sublethal responses for a species[9]. To avoid potential misinterpretations we propose that expectations of how climate and OA are likely to affect ecologically important species should be based on ecologically-functional trait-based metrics over appropriate spatio-temporal scales[10-12]. Such predictions should emphasize how multiple stressors interact to drive local-scale processes, and acknowledge the importance of biological responses and interactions in determining patterns of vulnerability over multiple spatio-temporal scales.

INSHORE will employ a multidisciplinary 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. We will scale up from organismal to biogeographic processes, identifying biological mechanisms underpinning the responses of ecosystem engineer species to climate change and OA, and link organism physiological performance to changes in population abundances and productivity. INSHORE will develop a dynamic energy budget model (DEB) and associated mechanistic species distribution model (SDM), and produce a methodological best practice guide for data collection and analysis to enhance our understanding of the most important and appropriate aspects of the responses of ecologically and commercially important coastal marine species to global change. INSHORE will focus on species of mussel to assist with future management objectives, and progress the ability to predict invasions of pest species in coastal areas across the globe.

Scientists cannot account for every possible combination of environmental conditions when forecasting ecological responses to global change. 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. To be effective, forecasts need to capture bio/eco-logically relevant stressor metrics[10-19], over appropriate spatio-temporal scales (10-100 km) applicable to the scientific research agenda and national and international policy drivers.

INSHORE will review existing climate and OA models alongside published experimental research and methodologies for climate change and ocean acidification 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 Biology*.

We will integrate detailed information on the mechanistic biology of species from experimental studies with molecular, physiological and ecological data, biogeographical time-series and environmental datasets using DEB and SDM models, sensu[15]. The DEB will use these data to simultaneously estimate impacts of temperature and pH on physiological performance, and the SDM will generate predictions of the impacts on the future biogeographic distributions of the target species. SDM outputs will be created at a regional scale (100s km) within areas of the Atlantic and Pacific oceans for which physiological, ecological, biogeographical and environmental data exist.

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 and are at high risk from multiple human-induced pressures, exhibiting some of the fastest responses to global change in any natural system.[12,18,19]

INSHORE comprise a multidisciplinary team of researchers with international track records on impacts of climate change and OA on marine species. Expertise spans time-series data collection and analysis (Mieszkowska, Krueger-Hadfield, Russell, Lima), biogeography, macroecology and population ecology (Mieszkowska, Helmuth, Harley, Williams, McQuaid, Broitman, Fawzi, Chan, Christopholetti), physiological experimentation (Russell, Sarà, Williams, Dong, McQuaid, Kroeker, Rilov) and modelling (Sarà, Helmuth, Williams, Mieszkowska), dynamic energy budget modeling (Sará, Helmuth, Williams), climate and OA modelling impacts modeling (Broitman, Helmuth, Lima, Fawzi, Harley). Some 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 climate change and OA impacts research via an integrated, international approach is timely given the major findings of the 2014 IPCC Report on Impacts, Adaptation and Vulnerability[22] that $CO_2$ emissions are driving unprecedented changes in global marine climate and ocean pH, and may be 'irreversible in terms of possible futures'. This knowledge gap with respect to marine ecosystems will be addressed within the sixth IPCC Assessment Report, involving contributions from the Working Group team, and is also identified within the EU Marine Strategy Framework Directive. Given these needs, this Working Group could be instrumental in leading a global, standardized approach to detecting, quantifying and predicting the impacts of climate change and OA 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 web-based platform 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 and ocean acidification 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

(1) Form an international Working Group with expertise in physical, ecological, and physiological sciences, to develop a Dynamic Energy Budget model and associated mechanistic Species Distribution Model for ten species of commercial or invasive priority for coastal

systems globally. The DEB model will calculate organismal performance across thermal and OA environments, and the results will be input into the mechanistic SDM, which will model current distributions and forecast future impacts of climate change and OA.

(2) Tailor these models to the target species. The group will utilize their extensive collection of scientific and monitoring datasets, and those collected by the wider global research community including data repositories (e.g. ICES, PICES, OBIS, EMODnet, Redmap) and time-series such as the UK MarClim (Mieszkowska) and Pacific PISCO dataset (Broitman) and the NOAA Mussel Watch data to create a dataset of biogeographic distributions, traits, lifecycle and population dynamics for the target species. Data will be entered into a purpose-built database and used to derive best practice methodologies and to develop the models for all ten target species.

(3) Based on the outcomes from (2) the climate impacts modeling experts in the Working Group and Associate Members will lead a review of existing global change impacts models with input on novel methodologies and parameters necessary to develop next-generation predictive models provided by the Working Group and Associate experts.

(5) A Dynamic Energy Budget Model will be run for each of the ten target species, incorporating species-specific physiological performances and tolerances, and data on distributional range shifts and abundances. DEB outputs will be integrated with the IPCC AR-5 scenario climate models input into mechanistic Species Distribution Models. These will provide quantitative assessments of the future biogeographic distributions, and identify areas within the species ranges where the species will become highly vulnerable to climate change and OA.

(6) The SDM 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. Australian Representative Network of MPAs, UK Marine Conservation Zones, 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 Marine Climate Change Impacts Partnership, Australian National Climate Change Research Facility).

Understanding the impacts of climate change and OA on core ecological processes is an essential first step to mitigating their influence on ecosystem functioning, productivity and carbon sequestration, safeguarding species and communities, and adapting to changes in biodiversity and ecosystem service provision[11,24]. INSHORE will work closely with SNCBs providing fit-for-purpose data informing national marine policies. Outputs will be disseminated through peer-reviewed publications and press releases via Research Councils of the partner nations and partner institutes. Knowledge exchange workshops, IPCC, and MCCIP report cards will communicate the findings to policy makers and NGOs, with public engagement via national citizen science projects on which Working Group members are PIs or collaborators (e.g., the UK Capturing Our Coast Project).

The INSHORE imeline is detailed in Table 1. The first Working Group meeting will be held in January 2018 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 existing

DEB model for *Mytilus galloprovincialis* will be showcased and the Working Group will test and validate the model using the metadatabase collated by the Working Group prior to this meeting (ToR 5, Deliverable 5).

The second Working Group meeting will be a three-day workshop and themed session held at the 'Twelfth International Temperate Reefs Symposium', January 2019 in Hong Kong and organized by Co-Chair Williams, from the conference host institute the University of Hong Kong, who will cover venue costs as an 'in kind' contribution. The workshop and themed session will be open to students from University of Hong Kong, SWIRE Institute of Marine Science and other conference participants. 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 (ToR 2, Deliverable 3), a review of existing climate models (ToR 3, Deliverable 4) and a best practice guide for climate change and OA impacts research drafted (ToR 4, Deliverable 4). Presentations on the state of climate impacts modeling and availability of datasets for climate and OA at ocean basin, national and regional scales will be given by Broitman, Helmuth, Lima, Kroeker, Harley, Fawzi, Lundquist and Mieszkowska who are world- leaders in this field. Ecological responses to multiple stressors will be presented by Williams, Krueger-Hadfield, Harley, McQuaid, Helmuth, Chan and Christofolettii. Williams, McQuaid, Dong, Sarà, Rilov and Mieszkowska will present work on molecular and physiological multiple stressors. Working Group discussions will include datasets to be incorporated into the new models and a time-line for remote participation and delivery of data to the modelers. An early career workshop will be held by the group alongside the Working Group workshop to allow international students and early career researchers to learn about the development of these new models, and potential applications to their own ecosystems and research.

Between workshops two and three the review manuscript of the status of the research field into climate change and OA impacts on ecosystem engineer species will be written by the Working Group using cloud file sharing and virtual group working methods successfully employed by some members for previous publications.

A third workshop will be held in January 2020 at the Centro de Estudios Avanzados en Zonas Áridas, Chile, hosted by Working Group member Broitman. The DEB and SDM models will be run for all ten target species, with an extensive QA process carried out for each model by the relevant experts within the Working Group. Model runs will be carried out at regional scales relevant to invasive species management strategies and harvesting of commercial species. Manuscripts will be written on DEB and SDM models for submission to open access journals by the end of 2020 (Deliverable 6).

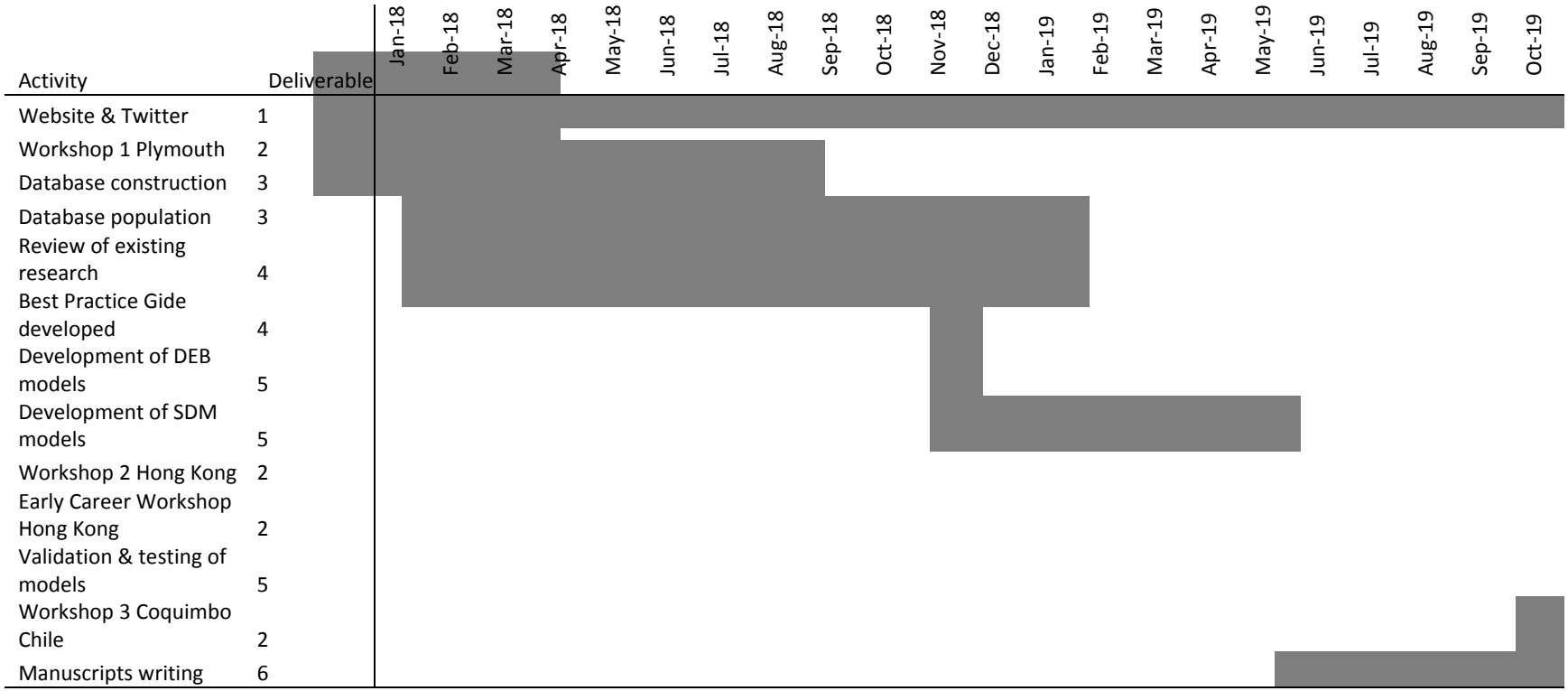
Deliverables

The Working Group will provide a mechanistic approach to understanding how coastal marine species of ecological and commercial value and/or invasive concern will respond to climate change and ocean acidification. This will develop new, biologically realistic predictions based on existing time-series and physiological data from the ICES community and high resolution (10-100 kilometers) environmental data.

Specific outputs:

1) Launch a website and Twitter account providing information on project activities, model outputs and links to related ICES activities.
2) Present Working Group expertise in climate change and OA research and promote 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 DEB and SDM models (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 journal *PLOS One*.
5) Develop novel DEB models and mechanistic SDMs and make the codes available to the international marine research community.
6) Publish model codes and outputs in international journals including open-access journals (e.g., *Ecological Modelling*, *Global Change Biology*, *PLOS Biology*) highlighting the roles of climate and ocean acidification in shaping and changing ecosystem engineer and commercially important species.
7) Provide project outputs to the IPCC 6$^{th}$ Assessment Report and governmental policy bodies for implementation in international policy drivers including OSPAR and MSFD via existing science-policy knowledge exchange roles of the team.

Table 1. Timeline of proposed INSHORE Working Group activities



**Capacity Building**

Understanding responses to climate change and ocean acidification requires the study of organisms at multiple levels of biological organization, from organismal physiology, population dynamics to species distributions. This integrated approach requires a multi-disciplinary research programme integrating global experts in physiological, ecological, experimental, monitoring and modelling disciplines.

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, Krueger-Hadfield, 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 increase this collaborative research base to the wider Working Group and Associate Group members. The SCOR funding would facilitate 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), and establish long-term collaborative links across the globe.

The group will present their contributions to an integrated multiple-stressor research perspective at the Eleventh International Temperate Reefs Symposium in Hong Kong, and host workshops to develop the integrated methodology and associated multiple stressor profiling model in Hong Kong, Chile, the UK and China. The Hong Kong conference will be attended by PICES and ICES member nation 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 attending this conference will be invited to interact with the global Working Group during an early career workshop that the Working Group will hold at this event.

Working Group members will give presentations on this project at their 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 DEB and SDM

model methodologies and codes 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.

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 national research grants on climate change and OA impacts on marine biodiversity. |
| 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 in Japan, China, Vietnam, Thailand, Malaysia, Singapore. |
| 3 Brian Helmuth | Male | Director, Sustainability Science and Policy Initiative.<br><br>Professor, College of Science, Northeastern University, USA | Ecological forecasting, physiological mechanistic responses to climate, thermal engineering technology, mathematical modeling. Species Distribution Modelling. Biomechanical modeling. |
| 4 Bernardo Broitman | Male | Director, Centro de Estudios Avanzados en Zonas Aridas, Santiago, Chile<br><br>Associate Professor, Facultad de Ciencias del Mar, Universidad Catolica del Norte, Chile. | 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 Stacy Krueger-Hadfield | Female | Assistant Professor, University of Alabama at Birmingham, USA | Intertidal population dynamics, Seascape genetics, microgeographic structure, connectivity of populations across biogeographic scales, invasive species. |
| 6 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. |
| 7 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. |
| 8 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. |
| 9 Yunwei Dong | Male | Professor, State Key Laboratory of Environmental Science, Xiamen University, China | Physiological and molecular (transcriptomics, proteomics) responses of intertidal invertebrates to multiple stressors. |
| 10 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. |

**Associate Members**

| Name | Gender | Place of work | Expertise relevant to proposal |
|---|---|---|---|
| 1 Fernando Lima | Male | Centro de Investigação em Biodiversidade e | Biogeography of intertidal organisms, climatic reconstruction and analysis, |
| 2 Kristy Kroeker | Female | UC Santa Cruz, USA | OA impacts on marine invertebrates. Forecasting and managing the emergent effects of |
| 3 Ronaldo Christofolettii | Male | Instituto do Mar, | Trophic interactions within intertidal ecosystems. |
| 4 Benny Chan | Male | Principal Scientist & Associate Professor, | Intertidal, supply-side and larval ecology, biogeography of tropical intertidal invertebrates. |
| 5 Gil Rilov | Male | Senior Scientist, National | Community biodiversity, biogeography, benthic-pelagic |
| 6 Bayden Russell | Male | Associate Professor, University of | Experimental assessment of physiological changes and resultant ecosystem functioning |
| 7 Carolyn Lundquist | Female | National Institute of Water and Atmospheric | Benthic ecology. Invertebrate larval dispersal. Restoration of shellfish habitats. |

**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 experimental 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.

**Krueger-Hadfield.** International research profile on population connectivity and marine ecosystem resilience, seascape genetics, biogeographic distributions of native and invasive species.

**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.

**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.

**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.

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.

INSHORE will establish links to the SCOR WG149 Changing Ocean Biological Systems (COBS) to continue the theme of multiple stressor impacts on the global oceans within the SCOR Network and the wider international research community.

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Appendix 1
Five key publications per Working Group Member (author and co-authors who are also WG members highlighted in bold):

Mieszkowska

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Williams

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Helmuth

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Broitman

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Krueger-Hadfield

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McQuaid

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# 2-128

Sarà


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### 2.2.4 Expanding Regional Application of Dynamic Ocean Management (ERADOM)



**ERADOM**

**Expanding Regional Application of Dynamic Ocean Management**

Prepared by co-chairs:

Alistair Hobday
CSIRO, Australia
Email: Alistair.Hobday@csiro.au

Stephanie Brodie
University of California Santa Cruz, USA
Email: sbrodie@ucsc.edu

## 1. Summary

Oceans are physically and biologically dynamic, yet strategies to manage oceans are often implemented at overly coarse spatiotemporal scales. Dynamic Ocean Management (DOM) is a management strategy that rapidly changes in space and time in response to changes in the ocean and its users. DOM is an emerging field of research that has been demonstrated to have wide application to ocean users around the globe. To date, DOM applications have rapidly expanded across a diverse range of timescales, biota, levels of data availability, and objectives, yet these applications have occurred as independent efforts which has resulted in limited application in regions lacking scientific and management capacity. Given ongoing sustainable ocean use challenges, approaches such as DOM are vital. This proposal aims to synthesize existing DOM applications, identify barriers to DOM implementation in areas with ocean use conflict, and develop a suite of tools to aid implementation of DOM. In addition to open-access primary publications, a major output of ERADOM will be a "How-To Guide" to facilitate implementation of DOM applications, particularly in novel regions. The working group outputs will enhance DOM uptake to minimize ocean conflict in the face of competing social, economic, and ecological objectives. The international experience required is expansive, and a SCOR working group provides the ideal mechanism to achieve our aims.

## 2. Scientific Background and Rationale

### *2.1 Dynamic Ocean Management*

Spatial management is one strategy to regulate ocean use and provide protection for vulnerable species and habitats. Traditionally, spatial management options are implemented as a static approach that seek to separate apparently incompatible activities, such as shipping, tourism, petroleum extraction, fisheries, and conservation zones. As an example, static boundaries for conservation purposes often need to encompass very large areas in order to ensure year-round protection for highly mobile and migratory species. With increasing pressure and ocean activities, this may be inefficient as some activities (e.g. fishing, shipping) can be excluded from areas at times when the protection is not needed, as the focal species needing protection is absent (Agardy *et al.* 2003). Seismic testing, as part of petroleum industries, is another activity that may need to be separated from fishing or tourism activities, but is not a permanent feature of the seascape (Carroll *et al.* 2016). There is often resistance to placing restrictions on ocean activities that provide significant economic and social benefits - evidence-based scientific solutions are needed to resolve often competing objectives. There is a clear need in both developed and developing economies for scientific development of management tools that offer flexibility and efficiency in ocean management.

Dynamic Ocean Management (DOM) is one such approach that allows management strategies to rapidly change in space and time in response to changes in the ocean and its users (Maxwell *et al.* 2015). DOM can offer a flexible alternative that allows trade-offs between competing objectives (e.g. harvest or conserve) to be met, and has potential application around the globe (Dunn *et al.* 2014). To date, the new field of DOM research has covered a diverse range of biota (e.g. from scallops to tuna to turtles (Maxwell *et al.* 2015)), objectives (e.g. conservation outcomes to industry adaptation to climate variability (e.g. Spillman & Hobday 2014)), spatiotemporal scales (e.g. from real-time observations to seasonal and decadal forecasts (e.g. Tommasi *et al.* 2017)), and levels of data availability (e.g. data poor to fishery-independent to satellite telemetry (e.g. Hazen *et al.* 2016)). To realize wider benefits there is a need to develop scientific capability and support for those seeking DOM as a solution to local resource use conflicts.

This need is also particularly urgent as climate change is affecting the distribution of marine activities (e.g. Arctic shipping) and species (e.g. range change). New and more variable environmental conditions are already creating novel challenges for ocean-users and managers (Pecl *et al.* 2017). DOM offers a strategy to allow ocean-users and managers to adapt to the challenges of a changing ocean. Historically DOM has been implemented on a near real-time basis, but improvements in ocean forecasting on time scales of weeks to decades offer additional opportunities to develop approaches to resolve ocean conflicts (Tommasi *et al.* 2017). For example, seasonal forecasting of ocean conditions and animal habitats has been used as a decision-support tool in marine industries adapting to climate variability (Hobday *et al.* 2016).

There is opportunity to clarify, expand, and integrate more timescales and more applications under the definition of DOM, and as such likely improve future users understanding and uptake of DOM.

### *2.2 The Challenge*

To date, published literature indicates that application of DOM has mostly been in developed nations. While reviews and syntheses on DOM and seasonal forecasting have been published (e.g. Hobday *et al.* 2014; Lewison *et al.* 2015; Maxwell *et al.* 2015), these reviews focus on DOM examples from developed nations. There is currently limited knowledge on if, or what, DOM strategies are appropriate in emerging economies, and how science can support these efforts.

There may be barriers that limit the uptake of DOM across new regions and in developing nations. Although investigation of barriers is required as part of the proposed working group activities, they are likely to include: 1) Knowledge - limited knowledge transfer between researchers and managers/policymakers (Cvitanovic *et al.* 2015); 2) Fiscal – potential DOM applications are expensive to research and implement (Hobday *et al.* 2014); 3) Expertise – DOM approaches can be diverse and complex, and difficulties can arise from limited expertise and issues with data (e.g. scarcity, biases, quality) ; 4) Communication - communication between users and managers needs to be possible and occur at timescales relevant to the management approach (e.g. cell phones, printed maps, email, website access).

### *2.3 The ERADOM initiative*

Our vision is to provide a means to increase uptake of DOM globally. To do so we aim to understand and overcome barriers to DOM uptake by identifying and individually addressing the barriers, such as: 1) Knowledge – reviewing how existing DOM applications have become operational, which will inform guidelines on how to increase knowledge transfer and improve operationalization (Objective 1); 2) Fiscal – providing code and guidelines on how to access freely-accessible data sources, thus reducing many of the initial and ongoing costs of DOM (Objectives 2 and 3); 3) Expertise – creating a How-To Guide that provides instructional information on how to develop and apply DOM applications (Objectives 2, 3, and 4); 4) Communication – reviewing existing DOM applications and the levels of communication required to maintain an operational product (Objective 1). We will draw upon the existing knowledge of international partners, and seek to support and encourage implementation DOM in new regions and new applications.

### *2.4 Why a SCOR working group?*

The work proposed here aims to understand the barriers to implementation of dynamic ocean management in areas with ocean use conflict. We seek to enable uptake of DOM by those seeking approaches that complement traditional spatial management approaches, particularly in areas where implementation of extensive static management areas, such as closed areas, will

lead to considerable social and economic harm. This SCOR effort will bring together an interdisciplinary group of scientists with an established track record in development and application of DOM to unify disparate approaches and tools. A primary goal is to understand the success of existing applications and package the tools to allow wider uptake where useful. To date, perhaps as DOM is an emerging research field, independent efforts have been the norm which limits DOM applications in areas that may have limited capacity. Thus, a primary goal is to develop a "How-To Guide" to explain DOM as a management choice. The breadth of international collaboration proposed here is unique, yet without SCOR funding is unlikely to be realized. We believe the working group deliverables will support enduring DOM uptake, minimize ocean conflict, and support sustainable social, economic, and ecological objectives.

## 3. Terms of Reference

**Objective 1:** Review and synthesize the current state of operational ecology, including identifying how existing dynamic ocean management tools have become operational, and to publish the results in a peer-reviewed journal.

**Objective 2:** Develop a code library that provides freely accessible and easy ways to connect environmental data sets and specific local data sets.

**Objective 3:** Create a How-To Guide for dynamic ocean management, drawing on the general code library (Objective 2), which encompasses both operational (Objective 1) and research (Objective 4) aspects, and provide this Guide as an online open-access and updatable resource.

**Objective 4:** Demonstrate the applicability of the How-To Guide by creating case studies of dynamic ocean management in developing nations, including a data poor case study, and publish these case studies in a peer-reviewed journal.

## 4. Working plan

To deliver Objective 1 we will review and synthesize how existing dynamic ocean management applications transitioned from a research output to an operational tool. An operational tool is one that is ready or being used in a real-time application. The transition from a research output to an operational tool is often an obstacle when attempting to implement DOM. The synthesis will aim to include examples from developing nations and artisanal fisheries. This will help to summarize what formats DOM takes across a broad spectrum of ocean users, and will inform the scope of the proceeding objectives. As a part of this objective we will review levels of stakeholder involvement in planning and implementation of existing DOM applications, and identify barriers to DOM uptake. The synthesis will help new projects plan for and achieve the transition from a research output to an operational product, and ultimately support a greater implementation of DOM. The results of Objective 1 will be published in a peer-reviewed open access journal.

To deliver Objective 2 we will use the group's knowledge, experience, skills, and existing code to develop a code library. The code library will focus on ways in which to connect environmental data sets, environmental forecasts, and local data sets, and will be written in R language but can be expanded to include other software (e.g. Matlab, ArcGIS) should the need arise. The code library will be developed in conjunction with Objectives 3 and 4 so as to ensure useful linkages between code, the How-To Guide (Objective 3), and case studies (Objective 4). The code library will be hosted on a freely accessible public platform, such as an R vignette or on Github, and will be maintained beyond the lifetime of the SCOR working group.

Objective 3, entitled the How-To Guide, will be a guidance document to provide instructional information on how to apply DOM. The Guide will have a simplistic core structure, with complexity added incrementally to ensure that all levels of user-experience are able to effectively and constructively use the Guide. The Guide will be centered around 1) a decision tree (e.g. (Dunn, Boustany & Halpin 2011)); and 2) an idealized workflow (e.g. (Hobday *et al.* 2014)). The decision tree will step through various spatiotemporal scales of management interest, and will ultimately identify DOM approaches that best suit specific applications. The workflow will show an idealized step-wise approach to achieving DOM that will reference leaves on the decision tree. Each step within the workflow will be expanded upon, with a description of potential data sources and methods. For example, issues surrounding species data (e.g. data poor fisheries, data with inherent biases) will be summarized and potential solutions suggested.

The workflow will form the backbone of the How-To Guide, and will be targeted towards overcoming the barriers to DOM implementation. For example, the Guide will describe ways in which to source freely accessible environmental products for multiple time scales (e.g. historical, real-time, forecast); and outline methods for building species distribution models using freely accessible software (e.g. R, Maxent) and/or existing global habitat models (e.g. raquamaps).

The Guide will: integrate results from Objective 1 using examples of how to operationalize and communicate DOM; draw on the general code library (Objective 2); and outline examples of how to use the Guide to implement DOM (Objective 4). The Guide will be an online, updatable resource and will allow for updates as information changes and new products become available (e.g. links to access new global or regional environmental products; or links to new operational DOM tools and applications). We will explore options for an existing organization to host the Guide location (e.g. https://www.openchannels.org/; http://www.copernicus.eu/), which will extend the reach of this guide, as well as provide a long-term location beyond the lifetime of the SCOR working group.

To deliver Objective 4 we will seek additional partners to identify and collaborate on case studies in regions where DOM has not yet been applied. We will use the How-To Guide to implement a stepwise approach to creating DOM for these case studies, ultimately ending with an application of DOM that can be transitioned to an operational stage. Potential regions for case studies include southern Africa, south-east Asia, and South America, and working group members from these regions will help to cultivate collaborations. Collaborations will focus on a

two-way knowledge exchange to ensure that knowledge of existing DOM applications in developing nations (part of Objective 1) is integrated into the How-To Guide (Objective 3). Case studies, in collaboration with regional partners from participating countries, will be published in a peer-reviewed open access journal and also integrated into the How-To Guide and code library.

**Month 1:** 1st WG meeting. The meeting will include planning for the entire project with a focus on Objective 1 and 4. Task oriented sub-groups will be organized to progress Objective 1 during and after the meeting. The meeting will aim to be held in a region where creation of a first case study can be supported (Objective 4), sub-groups will be allocated to progress Objective 4.

**Months 2 - 11:** Continue work on Objective 1 and submit to a peer-reviewed journal within this period. Continue work on Objective 4.

**Month 12: 2nd** WG meeting – discuss framework for Objectives 2 and 3. Use framework to create sub-groups to progress work during and after the meeting. The meeting will aim to be held in a region where creation of a second case study can be supported (Objective 4), as such sub-groups will be allocated to progress Objective 4.

**Month 13 - 23:** Continue work on Objectives 2, 3, and 4.

**Months 24:** 3rd WG meeting – discuss and plan the finalization of Objectives 2, 3, and 4. The meeting will aim to be held in a region where creation of a third case study can be supported (Objective 4), as such sub-groups will be allocated to progress Objective 4.

**Months 25 - 36:** Release code (Objective 2) and How-To Guide (Objective 3) as freely accessible resources online. Continue work on Objective 4 and submit to a peer-reviewed journal.

**5.** Deliverables

1. Publish a review/synthesis paper on operationalizing dynamic ocean management and stakeholder involvement (Objective 1)
2. Release a code library as a freely accessible resource (e.g. R vignette; Github) (Objective 2)
3. Release the DOM How-To Guide as a freely accessible online resource (Objective 3)
4. Collaboration with developing nations by completing case studies of dynamic ocean management implemented using the stepwise approach in the How-To Guide. To be published open-access in a peer-reviewed journal (Objective 4).
5. Coordinate a session and/or Town Hall meeting at an international conference to showcase the application and capacity of the website and the How-To Guide.

## 6. Capacity Building

Dynamic ocean management has immense potential for current and future ocean management globally. However, one of the barriers to uptake of DOM is limited knowledge on how to create and implement DOM applications. The vision of our proposal is to remove the barriers to DOM implementation, and create better communication and applicability between researchers and stakeholders.

We believe our proposed code library and How-To Guide will be important in supporting global uptake of DOM. The WG will actively build capacity by seeking participants from developing nations in which to identify and create case studies for these regions. The working group meetings will be hosted in developing nations which will ultimately foster international collaborations into the future and also foster wider uptake of the How-To Guide and DOM by association. Furthermore, collaborations with these regions may identify existing DOM applications that are novel, and our proposed objectives will ensure such novel applications are communicated. Such collaborations are critical to developing and strengthening skills and expertise, which will ultimately support wider uptake of DOM. The proposed How-To Guide has global applications, and the online, updatable resource will ensure the WG outputs are recorded globally accessible into the future, and long lasting.

## 7. Working Group composition

### *7.1 Full Members*

| **Name** | **Gender** | **Place of work** | **Expertise relevant to proposal** |
|---|---|---|---|
| 1 Alistair Hobday (co-chair) | M | Commonwealth Scientific and Industrial Research Organisation, | Dynamic ocean management; Ecological forecasting; climate adaptation |
| 2 Stephanie Brodie (co-chair) | F | University of California Santa Cruz, | Spatial ecology; ecological forecasting |
| 3 Mark Payne | M | Technical University of Denmark, | Statistical modelling; oceanography; fisheries. |
| 4 Lynne Shannon | F | University of Cape Town, **South Africa** | Ecosystem dynamics; fisheries management |
| 5 Sei-Ichi Saitoh | M | Hokkaido University, **Japan** | Fisheries science; biological oceanography; remote sensing |
| 6 Priscila Lopes | F | Universidade Federal do Rio Grande do Norte, **Brazil** | Fisheries research; ecosystem services |
| 7 Kylie Scales | F | University of the Sunshine Coast, | Spatial ecology; dynamic ocean management; statistical modelling; remote sensing |

| | | | |
|---|---|---|---|
| 8 Jon Lopez | M | AZTI-Tecnalia, **Spain** | fisheries ecology; statistical modelling; bycatch |
| 9 Desiree Tommasi | F | National Oceanic and Atmospheric Administration, **USA** | Biological oceanography; dynamic ocean management |
| 10 Jean-Noel Druon | M | European Commission, **Italy** | Spatial fisheries management; remote sensing |

*7.2 Associate Members*

| **Name** | **Gender** | **Place of work** | **Expertise relevant to proposal** |
|---|---|---|---|
| 1 Jason Hartog | M | Commonwealth Scientific and Industrial Research Organization, | Ecological forecasting; dynamic ocean management |
| 2 Claire Spillman | F | Bureau of Meteorology, **Australia** | Seasonal forecasting; dynamic ocean management; remote sensing |
| 3 Michael Jacox | M | University of California Santa Cruz, | Oceanography; ocean modeling; remote sensing |
| 4 Kristin Kaschner | F | University of Freiburg, **Germany** | Spatial ecology; Conservation biology |
| 5 Haritz Arrizabalag | M | AZTI-Tecnalia, **Spain** | Fisheries management; population dynamics |
| 7 Daniel Dunn | M | Duke University, **USA** | Dynamic Ocean Management |
| 8 Marta Coll | F | Institute of Marine Science, **Spain** | Ecosystem functioning; Fisheries; Conservation biology. |
| 9 Ryo Kawabe | M | Nagasaki University, **Japan** | Fisheries management; animal behaviour |
| 10 Emmanuel Chassot | M | Institute of Research for Development, **Seychelles** | Population dynamics; fisheries ecology |

## 8. Working Group contributions

**Alistair Hobday**: lead developer of DOM applications, seasonal forecasting and adaptation approaches for fisheries and conservation. Expertise in risk assessment, climate change, management and policy.

**Stephanie Brodie**: marine ecologist with experience in species distribution modelling and seasonal forecasting. Her research has included working with data poor fisheries and citizen science programs.

**Mark Payne**: marine ecologist researching climate change and climate variability on marine life. Experience with forecasting and projecting distributions of multiple trophic levels and across multiple scales.

**Lynne Shannon**: expert in ecosystem dynamics and the application of the ecosystem approach to fishing in an African case study (Benguela upwelling system, South Africa) in an international context. Brings ecological indicator and food web modelling expertise to the group.

**Sei-Ichi Saitoh**: fisheries scientist with experience in remote sensing and species distribution modelling. He has researched fisheries ecology across multiple trophic levels.

**Kylie Scales:** marine ecologist, with expertise in spatial ecology, species distribution modelling, biologging, remote sensing, and DOM applications in the California current system. Her work is primarily focused on understanding the influence of heterogeneity and variability in the physical environment on habitat use by migratory marine vertebrates.

**Priscila Lopes**: ecologist working on interdisciplinary approaches to small-scale fisheries. Her work has focused on understanding fishers' behavior and their socio-ecological resilience to changes (e.g.: changes in fish stocks or in management), socioeconomic incentives to fisheries and to (non-)compliance, and also on providing solutions to co-management using local ecological knowledge and the ecosystem services approach. Her work relies on existent fishing databases and on direct contact with fishers from small villages in different environments (oceanic, coastal, semi-arid and Amazonian).

**Jon Lopez**: fisheries ecologist working on tropical tunas and has been involved in several EU projects of bycatch mitigation and tuna and tuna-like behavior and ecology, using both fisheries (VMS, logbooks, etc.) and unconventional data (local ecological knowledge, alternative acoustics platforms, etc.). He is currently member of various ICCAT and IOTC working groups, including the subcommittee on ecosystems and FAD groups, among others, and works towards the sustainability of tropical tuna fisheries.

**Desiree Tommasi:** fisheries oceanographer whose interdisciplinary research centers on understanding the impacts of climate variability on marine ecosystems and the development of environmentally-informed fisheries management frameworks. Her current work uses management strategies evaluations to assess the value of integrating seasonal to multi-annual climate forecasts into fisheries management decisions.

**Jean-Noel Druon**: marine ecologist working on dynamic and ecosystem-based management of fisheries. He has expertise in habitat modelling and ocean monitoring across multiple spatial scales.

**9.** Relationship to other international programs and SCOR Working groups

*9.1 IMBeR Activities*

Science Plan and Implementation Strategy: Our proposed WG directly relates to the IMBeR SPIS, specifically Theme 4 "Responses of Society". Our proposed WG deliverables will help clarify what human institutions can do to mitigate or adapt to anthropogenic impacts on ocean systems.

Working Groups: Our proposed WG complements two of the IMBeR working groups - the Capacity Building Task Team and the Human Dimensions Working Group (HDWG). Firstly, our proposed collaborations aim to enhance research capabilities in developing nations, and secondly our proposed deliverables can be informed by the integrated assessment framework developed by the HDWG.

Regional Programmes: The Climate Impacts on Top Ocean Predators (CLIOTOP) is an IMBeR regional programme, and currently has two task teams on seasonal forecasting, and operational oceanography. We anticipate that the task team outputs can directly contribute to the proposed code library and How-To Guide. The links between these task teams and the proposed WG will be supported by concurrent membership of certain WG members (Hobday, Scales, Arrizabalaga, Lopez).

*9.2 WG149 Changing Ocean Biological Systems (COBS)*

The proposed WG compliments WG149 by focusing on dynamic strategies to support management and industry adaptation to a changing ocean. The proposed WG can directly use the WG149 glossary of terms and implementation guide (TOR 8) to better align language and ensure greater uptake and understanding of DOM by manager and policy makers.

*9.3 United Nations Sustainable Development Goal 14: Life Below Water*

The outputs of the proposed working group will be useful for, and directly contribute to the United Nations Sustainable Development Goal 14. Specifically, by facilitating the wider uptake of DOM globally we will support the 2020 targets of sustainable management (target 2), effective regulation of marine resources (target 4), and greater conservation of coastal regions (target 5). Our proposed collaboration with developing countries will also support increased economic benefits of ocean sustainability (target 7) and transfer of marine technology (target 8) to such countries.

*9.4 ICES and PICES Working Groups on Seasonal to Decadal Predictability*

Working groups within ICES and PICES are focusing on various levels of spatio-temporal ecosystem predictability. The ICES working group investigation of seasonal to decadal forecasts is directly relevant to this WG proposal, and links will be supported by concurrent membership (Payne and Jean-Noel). The PICES investigation into ocean products for use in

marine ecosystem predictions is relevant to the proposed WG and outputs can be integrated into the How-To Guide and case studies.

### *9.5 FiSCAO: Fish Stocks in the Central Arctic Ocean*

FiSCAO is an international collaborative group to ensure sustainable commercial harvest in new and existing areas of the pan-Arctic ecosystem. There is potential for the proposed WG outputs to directly inform current and future management in the pan-Arctic ecosystem, and support dynamic ocean management at the initial stages of new management regimes.

### *9.6 ICCAT, IATTC, and IOTC groups on Ecosystems and Bycatch*

ICCAT, IATTC, and IOTC Regional Fisheries Management Organizations are responsible of the conservation and management of tuna and tuna-like species in the Atlantic, Pacific, and Indian Oceans, including target and non-target species. The application of DOM in regions of interest would provide key material to work towards the sustainability of both intentionally and unintentionally exploited resources.

## **10.** Key References


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**Appendix**

**Alistair Hobday**


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### 2.2.5 Floating Litter and its Oceanic TranSport Analysis and Modelling (FLOTSAM)

**Halpern**

Prepared by:

Chair: Stefano Aliani
Institute Marine Science CNR, Italy
Email: stefano.aliani@ismar.cnr.it

Vice chair: Kara Lavender Law
Sea Education Association, USA
Email: klavender@sea.edu

Vice chair: Nikolai Maximenko
University of Hawaii, USA
Email: maximenk@hawaii.edu

Vice chair: Erik Van Sebille
Utrecht University, Netherlands
Email: e.vansebille@uu.nl

## 1. Summary

In October 2015, the G7[3] Science Ministers highlighted marine debris as a major ocean health issue. A number of international working groups have focused on ocean plastics, although the amount of plastic floating at the sea surface remains an open question, including knowledge about its origins, where it is accumulating, and its transport pathways. It is a complex oceanographic problem for a variety of reasons, including challenges in sampling in situ and remotely, as well as in modelling at a variety of space and time scales.

In this working group (WG) we plan to address the problem of floating litter in the open ocean at global scale by disentangling coastal processes (with their short timescales) from the open ocean low-frequency processes. The major objectives of this WG are to:

- identify gaps in our knowledge of the near-surface ocean dynamics that may affect litter distribution and transport;
- improve future marine litter modelling capabilities;
- evaluate existing and emerging remote sensing technologies that can be applied to detect marine litter in the open ocean;
- improve awareness of the scientific understanding of marine debris, based on better observations and modelling results.

[3] https://www.bmbf.de/files/English_version.pdf and http://www.icsu.org/news-centre/news/pdf/Report%20to%20G7%20SMins%20on%20FOSs.pdf

Bringing together scientists with expertise in plastic marine debris with those focused on ocean observations, remote sensing, and numerical modelling will create a powerful collaboration for the understanding of marine debris.

We propose one chairperson and 3 vice chairs, each responsible for a specific objective. There are 10 Full members and 9 Associated members from a total of 13 different countries.

## **2.** Background and motivation for the working group

### **2.1** The importance of environmental plastic pollution and current knowledge gaps

Contamination by man-made debris is increasingly reported in marine habitats around the world. An estimated 70-80% of marine litter is made of plastic polymers, and that percentage is probably much higher at the sea surface of the open ocean. Because they do not readily biodegrade, plastics may persist in the marine environment for years to decades or longer, longer than the time-scales of many of the ocean processes typically considered in physical oceanography. An estimated ~8 million metric tons of mismanaged plastic waste entered the oceans from land in 2010 (Jambeck et al. 2015), with additional sources including natural disasters (Maximenko et al., 2015) and accidents (Trinanes et al., 2016), and inputs are expected to rise with the continued acceleration in global plastics production (Plastics Europe 2016).

Marine litter poses a variety of environmental and socioeconomic risks, which will be mitigated only with a substantial, sustained and integrated effort from individuals, industry, governments, and intergovernmental organizations at local to regional and global scales. In October 2015 the G7 Science Ministers highlighted marine litter, especially plastics, as a major ocean health issue, and the International Association for the Physical Sciences of the Ocean (IAPSO) and the Scientific Committee on Oceanic Research (SCOR) published conclusions regarding those issues and recommendations for future action by G7 countries (Thompson and Maximenko, 2016).There is no single solution; rather, a variety of local and regional solutions will be required to effect change (Hardesty et al. 2017).

Marine litter occurs all over the world from densely inhabited to remote areas, from the seafloor to surface waters. However, our knowledge of the abundance and distribution of plastic in the open ocean is limited, with most prior work having focussed on floating microplastics (millimeter-sized particles and smaller) measured with plankton nets.

Floating microplastic debris is found in seas around the world, from oceanic subtropical gyres (e.g. the so-called ‘garbage patches’) where concentrations exceed 600,000 pieces per $km^2$ (Law et al. 2010), to inner seas (e.g. Suaria et al. 2016, Chubarenko et al. 2016, Chubarenko and Stepanova, 2017) to more remote regions such as the waters of the Arctic (Cozar et al., 2017, Bergmann et al., 2016) and the Antarctic (Barnes et al., 2010; Ryan et al., 2014), where far fewer plastic particles are observed. It has become clear that humanity's discarded litter is spreading throughout our seas and oceans (e.g., Pham et al., 2014; Jambeck et al., 2015; GESAMP, 2016) and ocean models of surface transport predict that marine debris should ultimately be expected everywhere (Van Sebille et al., 2015).

A number of international working groups have focused on ocean plastics, but the focus is often on impacts of plastics to marine organisms and ecosystems. With the goal to assess the risks of plastic debris, they frequently highlight the need for increased knowledge about its abundance, distribution and transport. A necessary step is to get an estimate of the amount of plastic in the ocean, including knowledge about its origins, where it is accumulating, and its transport pathways. This is a complex problem for a variety of reasons, including challenges in sampling, both in situ and remotely, as well as in modelling.

If 8M tons of plastic are added to the ocean annually and plastic is expected to be around for decades or even centuries, why don't we find these large amounts in the ocean (e.g. Ryan, 2015)? Estimates of floating litter to date only tally up to order of 100,000 tons of floating microplastics (Cozar et al, 2014, Eriksen et al. 2014, van Sebille et al., 2015), with only an order of 10,000 tons removed by coastal clean-ups.[4] What missing knowledge can explain this multiple order of magnitude mismatch? Emerging research in physical oceanography may help elucidate marine debris distribution patterns and transport processes. Bringing together scientists with expertise in plastic marine debris with those focused on ocean observations, remote sensing, and numerical modelling in a single SCOR working group will create a powerful collaboration that will advance our understanding of marine debris in the open ocean.

## **2.2** The Challenge

The major challenge of this WG is to explain the distribution patterns, trends, and pathways of plastics in the open ocean.

Limitations of our understanding of the transport of floating plastics result from technical gaps as well as gaps in our knowledge of the near-surface ocean dynamics. These gaps include:

- coarse vertical and time resolution of debris modelling
- high-frequency processes and their non-linear interactions (Stokes drift, inertial oscillations, diurnal cycle in the upper-ocean stratification),
- lack of data on critical parameters (e.g. fluxes) that could support next-generation models of plastics at sea, and limited observations of surface currents (remote or in situ) that could help calibrate/validate such models.

In addition, there is a dearth of knowledge on the typical features of marine debris, including floating lifetime, settling, fragmentation, degradation, and ingestion by organisms, which may alter the debris properties affecting its transport. Questions to be addressed include:

- How variable is marine litter composition in time?
- How big are the differences in the composition between different regions?
- What characteristics of plastic debris should be used in models (different degradation and fragmentation rates for different polymers, average particle size, etc.)?

[4] http://www.oceanconservancy.org/our-work/marine-debris/2016-data-release/2016-data- release-1.pdf

- How does the composition of microplastics correspond to the composition of macroplastics?
- How do the dispersion and physics that apply to floating debris differ between macroplastic, microplastic and nanoplastic?
- What are the roles and impacts of the biological pump on transfer of pollutants to deep waters at different scales?
- What are the temporal trends in composition of microplastics associated with changes in macroplastic production?

Drift models have been used to describe marine litter distribution and transport, but improvements are required to adequately simulate pathways of marine debris ranging in size from microplastics to large objects. This includes improved models of ocean motion and definition of the dynamics of buoyant objects in a turbulent sheared flow, together with characterization of properties of plastic debris.

Distribution of floating marine litter has been studied since the 1970s using plankton net tows and visual selection of plastic particles in collected samples. Preliminary efforts have been made to standardize collection procedures and sample analysis protocols. Yet global, or even regional, in situ sampling at high resolution is not feasible, which calls for development of remote sensing instruments. At present, only optical data are readily available and they are only capable of detecting very large debris items.

Prospective satellites and airborne sensors may be able to measure various indices related to plastics and other types of floating debris and quantify their abundance on the ocean surface. The scientific recognition on this topic is still in its infancy and the key issues to be addressed and the full potential of remote sensing are still to be fully discussed in the scientific community. In 2016, the European Space Agency (ESA) released a call for proposals on remote sensing of Marine Litter (RESMALI). In the same year, the US National Aeronautics and Space Administration (NASA) sponsored a workshop on Mission Concepts for Marine Debris Sensing[5] and included marine debris research in the scope of NASA's Interdisciplinary Research in Earth Science (IDS) program.[6] Satellite remote sensing can best contribute to the marine debris field through new missions to measure surface velocities, as well as implementation of existing and development of new sensors (optical, hyper-spectral, SAR, etc.) to track larger objects or detect the presence and quantify the concentration of smaller particles.

In the proposed WG we plan to:

- address the problem of floating litter at the global scale by disentangling coastal processes (with their short timescales) from the open ocean low-frequency processes.
- improve the application of ocean circulation models to the drift of debris at sea.
- assess and promote the use of remote sensing tools to study floating debris at sea.

[5] http://iprc.soest.hawaii.edu/NASA_WS_MD2016/

[6] https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=498140/solicitationId=%7BE4A477E6-5A41-B75E-5DA8-61724BC35768%7D/viewSolicitationDocument=1/A.28%20IDS%20Amend%2034.pdf

**2.3** Why a SCOR Working Group?

This is the first effort to address the problem of marine litter in a SCOR WG. The proposed focus on debris in the open ocean from the physical oceanography perspective is new and makes this WG unique. The presence of a scientifically sound and competent voice on the topic is needed to fill knowledge gaps. By focusing expertise and resources into an international community effort, we will be able to deliver much-needed knowledge of marine debris in offshore waters that are mostly out of our sight, but in the heart of the global ocean.

We have already seen capability and willingness in the scientific community working on marine debris to work together in international WGs – some of the proposed members of this SCOR WG are also members of other, non-physics, international WGs – and we see SCOR as the proper environment to transform these recommendations into a more detailed, effective and cutting-edge improvement in knowledge.

This SCOR working group will assemble a diverse set of ocean scientists to work jointly towards delivering a set of clear objectives that will have wide impact and resonance across the larger ocean scientific communities.

These communities are diverse and include physical oceanographers specializing in relevant dynamics and using in situ observations and remote sensing, experts in marine plastic debris and modellers who attempt to synthesize the theory and the data and summarize the overall knowledge of the marine system.

Because of the broad involvement from several different disciplines and because of the specific focus on the marine litter problem, the multi-disciplinary and international work we propose would be difficult to support through national agencies, private foundations or other international organizations.

## **3.** Terms of reference

(Objective 1) Identify gaps in our knowledge of the near-surface ocean dynamics that may affect litter distribution and transport.
**Vice Chair: Kara Lavender Law**

Gaps that will be explored will include, but not be limited to, improved mixed layer parameterizations and refined vertical and time resolution of ocean circulation models, inclusion of high-frequency processes and their non-linear interactions (Stokes drift, inertial oscillations, and diurnal cycle in the upper-ocean stratification). The WG will address the absence of data on critical parameters (e.g., fluxes) that are needed to support next-generation models, as well as the shortage in observations of surface currents (remote or in situ) that could help calibrate/validate models. We will also discuss marine litter parameters that can characterize non-homogenous distribution and behaviour, floating lifetime, settling, fragmentation, degradation, and ingestion by marine life that can increase the power of debris

drift modelling. The results of WG discussions will be presented in a synthetic paper in an open-access, peer-reviewed journal publication.

(Objective 2) Improve future marine litter modelling capabilities.
**Vice Chair: Erik Van Sebille**

The group will select a set of software and computing platforms (e.g., Python, R, Matlab, Ferret etc.) and models (MITgcm, MOM, POM, NEMO, ROMS, etc.) in order to identify a platform to lead the development of new tracking tools, taking into account the very rapid development of ultra-fine-resolution global ocean hydrodynamics simulations (which will reach 1/60° global resolution within the foreseeable future). The group will then agree on a common set of model metrics and diagnostics required to evaluate model performance, as well as a reference database from the observations. Platform leaders will be responsible for writing the code, which will be tested against a common model. Open-source scripts and codes will be made available to the ocean science community.

(Objective 3) Evaluate existing and emerging remote sensing technologies that can be applied to marine litter in the open ocean.
**Vice Chair: Nikolai Maximenko**

The working group will identify parameters important for understanding and modeling of the dynamics of marine litter that can be derived from variables measured by present satellite missions and from emerging remote sensing technologies. Inter-calibration of remote and in situ observations will be discussed in the context of a consolidated marine debris observing system.

(Objective 4) Improve awareness of the scientific understanding of marine debris, based on better observations and modelling results.
**Chair: Stefano Aliani**

The working group will aim to advance awareness on the topic through open sessions at scientific meetings and through the WG webpage. Open access scientific papers will be delivered as well as outreach actions through the media.

## **4.** Work Plan

To deliver Objective 1,
we will identify gaps in knowledge of the near-surface ocean dynamics that may affect litter distribution and transport. We will utilize expertise within the working group to discuss key aspects of the state of plastic debris in the open ocean, especially focusing on those critical gaps in knowledge to understand the global distribution and transport of marine plastics. This will be expedited by close dialogue between modellers and observationalists within the working group.

A peer-reviewed paper will be published in an open-access journal to report WG recommendations for studying plastics in the ocean from a multidisciplinary perspective.

To deliver Objective 2,
we will discuss governing equations in a unified mathematical notation and default parameter values or ranges necessary for parameterization, and test these across a subset of models. As part of this effort, we will produce consensus initialization fields that can be used by the global ocean modelling community, as well as open-source scripts and codes dedicated to marine litter modelling.

To deliver Objective 3,
we will review existing and emerging remote sensing technologies that can be used to measure marine debris floating on the ocean surface or distributed in the upper ocean. We will also review relevant activity of national space agencies, as well as published research reports utilizing remotely sensed data to study marine debris, and we will formulate requirements for future satellite missions.

To deliver Objective 4,
we will synthesize and publish our findings to improve awareness of scientists, the public, and policymakers. We will create a website and start social media dissemination. An open session at relevant international conferences dedicated to students, young scientists, journalists and NGO will be organized. This information will be helpful input to achieving the pollution sub-goal of Oceans 2030 Sustainable Development Goal #14.

*Timeline*

We expect that our Working Group will start working in September 2017, right after receiving the decision from SCOR.

As a part of our activity, we plan to hold annual WG meetings. To maximize impact of this SCOR WG and optimize costs for Associated Members, we will combine funding available from SCOR with other sources and will hold group discussions during other ocean science-related meetings.

<u>Month 1-6: Sep 2017 - Feb 2018</u>
Web meetings with Chair and Vice Chairs to define details and plans of year 1 activity. Discussions on web page design and subgroups (SG) structure.

<u>Month 7-12: Mar - Aug 2018</u>
The first SCOR working group meeting will focus on drafting an optimal roadmap to progression of all tasks. This meeting will involve all members in planning activities; selected experts will be tasked and sub-groups will be assembled.

Our first meeting could be linked to the Sixth International Marine Debris Conference (6IMDC) that will be held in San Diego, California, USA from March 12-16, 2018. Locations for future meetings will be set at that time.

A first Writing Team (WT1) will be set up to write the short presentation article of this WG. (Deliverable 1 in Section 5). A second WT (WT2) will prepare the text for a web site and web discussion platform available for accredited worldwide students (Deliverable 2) and launch the site.

Month 13-18: Sep 2018 - Feb 2019
The second working group meeting will be timed to coincide with the 2018 AGU Fall Meeting or other similar major conference. During the meeting, a special discussion session open to students will be organized. Preliminary results from sub-group activities will be presented and reviewed by the entire WG. The website will be update (Deliverable 3).

Months 19-24: Mar - Aug 2019
The WG will continue remote work on all objectives.

Month 25-35: Sep 2019 - Jul 2020
The WG will finalize results and disseminate them to the broader scientific community. Remote discussion will continue on about the key processes controlling marine debris dynamics and phenomena identified in observations and models. Sub-groups write up the analysis of key processes. The website will be updated and meeting report written and submitted (Deliverable 4).

Month 36: Aug 2020
Final symposium. Co-sponsorship will be sought from other organizations identified in due course. The aim of the symposium will be to highlight progress made in the linking of observational work (satellite and in-situ) with modelling, and also including extending the theory of marine litter distribution and transport.
We will complete final website updates and submit the meeting report publication (Deliverable 5 and 6). We will present results at scientific meetings and submit papers to peer-reviewed scientific journals (Deliverable 7).

## **5.** List of Deliverables

(D1) Introduction of this SCOR WG in a short article in Eos or elsewhere. Contribution from WT1.

(D2) Construction of a website to manage contributions from all sub groups, including a web discussion platform for accredited worldwide students and experts. Contribution from WT2.

(D3) Annual meeting report (including session open to students) and update of the website.

(D4) Peer reviewed paper(s) to disseminate results of WG sub-groups. (D5) Annual meeting report and update of website.
(D6) Final symposium report and update of website.

(D7) Peer-reviewed papers and presentations at scientific meetings.

## 6. Capacity building

Skills and knowledge that will be shared in this WG pertain to a number of subjects: field sampling and marine instrumentation, data homogenization, oceanography, remote sensing and modelling. A large community of experts from different regions of the world will gather and share skills to enhance knowledge.

The partnerships include experts on plastics in the ocean as well as experts on specific ocean processes that affect ocean plastics. This results in a two-way capacity building between experts in oceanography and in plastic marine debris, and may encourage those who have not previously applied their ocean physics expertise to debris to continue this work beyond the WG itself. Our vision is also to broaden the dialogue between modellers and observationalists/ experimentalists by bringing together these groups in a focused forum of this working group.

A major tool for knowledge transfer will be through international workshops, a website and journal articles, but we expect to achieve longevity through fostering a new community of skilled ocean scientists from both developed and developing nations.

A global community of young scientist working on marine debris will be developed also via an open discussion session at one of the Ocean Sciences Meetings. We also believe that the open web discussion platform will enhance the development of a competent new generation of scientists working on open ocean marine debris.

A meeting will possibly be held in an emerging country, also including some basic training for local scientists. The POGO SCOR Visiting Fellowship program will be considered to support people from low-income countries to learn techniques related to marine debris in one of the institutions of WG members. We will also endorse the possibility for partners to include the POGO Fellowships for Shipboard Training in their activity at sea.

## 7. Composition of Working Group

This SCOR WG has 10 Full and 9 Associate members that combine together state-of- the-art skills in marine debris modelling and remote sensing as well as in situ experimental observations. Two associated members are experts in theoretical physical oceanography.
The Full Members are responsible for the delivery of the four objectives (each led by an assigned vice-chair) and the Associate Members provide important input from the complementary fields.

Our Full members represent 9 different nations, including emerging nations, with a total of 13 nations involved including Associated members. Moreover, we include one early career researcher as vice chair, and another as Associate member which will aid their career development.

We propose one chairman and 3 vice chairs from different disciplines, each of them being responsible for a specific WG objective.

**7.1** Partnership:

| Name | Gender | Place of work | Expertize | Status |
|---|---|---|---|---|
| Stefano Aliani | M | CNR ISMAR ITA | Chair – In situ observation | FULL |
| Nikolai Maximenko | M | Univ Hawaii USA | Vice chair Remote sensing | FULL |
| Bertrand Chapron | M | IFREMER FRA | Remote sensing | FULL |
| Victor Martinez-Vicente * | M | Plymouth Marine Lab UK | Remote sensing | FULL |
| Yi Chao | M | Remote Sensing Solutions, Inc. USA | Remote sensing | Assoc. |
| Erik van Sebille * | M | Univ. Utrecht NED | Vice chair modelling | FULL |
| Atsuhiko Isobe | M | Kyushu Univ JPN | modelling | FULL |
| Irina Chubarenko | F | Univ Moscow RUS | modelling | Assoc. |
| Laurent Lebreton * | M | modellinghouse NZL | modelling | Assoc. |
| Miguel Morales Maqueda | M | Univ Newcastle UK | modelling | Assoc. |
| Christophe Maes | M | LPO-IRD, Brest FRA | modelling | Assoc. |

| | | | | |
|---|---|---|---|---|
| Kara Lavender Law | F | Sea Education Association USA | Vice chair In situ observation | FULL |
| Peter Ryan | M | Univ Cape Town RSU | In situ observation | FULL |
| Won Joon Shim | M | KIOST KOR | In situ observation | FULL |
| Martin Thiel | M | UCN CHL | In situ observation | FULL |
| Melanie Bergmann | F | AWI GER | In situ observation | Assoc. |
| Denise Hardesty | F | CSIRO AUS | In situ observation | Assoc. |
| Tobias Kukulka | M | Univ Delaware USA | Theoretical physical oceanography | Assoc. |
| Baylor Fox-Kemper | M | Brown Univ USA | Theoretical physical oceanography | Assoc. |

* is for young scientists.

| **Observers/ stakeholders** | | | |
|---|---|---|---|
| Joao Sousa | IUCN | M | Joao.SOUSA@iucn.org |
| Georg Hanke | EU-JRC | M | georg.hanke@jrc.ec.europa.e |
| Nancy Wallace | NOAA | F | nancy.wallace@noaa.gov |
| Paolo Corradi | ESA | M | Paolo.Corradi@esa.int |

## **8.** Working group contributions

**Stefano Aliani** is in charge of the coordination as chair of this WG and of Objective 4. He has experience on observational data on marine litter distribution and in situ measurements of oceanographic processes. He is section head at Institute Marine Science of CNR in Lerici, Italy.

He led/participated to many cruises worldwide and has considerable experience in data collection. He is involved in developing new quality control methods and protocols for in situ marine litter assessment.

**Kara Lavender Law** is in charge of the objective on in situ observations of marine debris as vice chair (O1). She is Research Professor of Oceanography at Sea Education Association (SEA), where she has published analyses of SEA's two long-term data sets on floating open ocean microplastics. She carries out research on SEA's 30-year archive of microplastics to understand what the physical and chemical characteristics of the debris might reveal about the transformation and fate of ocean plastics. She is also the co-PI of the National Center for Ecological Analysis and Synthesis (NCEAS) Marine Debris working group, which has published on the input of plastics to the ocean from land-based waste; on the global abundance of floating plastics; and a critical review of the biological and ecological impacts of debris.

**Erik Van Sebille** is in charge of the objective (O2) on modelling of plastic litter pathways as vice chair. He is an Early Career Scientist who has won the 2016 Outstanding Young Scientist Award from the European Geosciences Union's Ocean Division, and has recently been awarded a European Research Council Starting Grant on a five-year project 'Tracking Of Plastic In Our Seas'. He has worked extensively with marine ecologists to map the risk of plastic to marine life, and has been part of the GESAMP Working Group on microplastics. He has testified for UK Parliament on the impact of microbeads on the marine environment, and the effects of a potential ban of these materials.

**Nikolai Maximenko** is in charge of objective on remote sensing of marine debris as vice chair (O3). He is an established Oceanographer with expertise in ocean circulation and air-sea interaction physical dynamics and develops applications, such as drift models of marine debris. In his research, he combines in situ observations with satellite products to study multi-scale ocean debris. Maximenko is a member of NASA Ocean Surface Topography, Ocean Salinity and Salinity Processes in the Upper Ocean Regional Study Science Teams.

**Bertrand Chapron** will provide his multi-year experience on the combined use of space- borne ocean remote sensing measurements. He is senior scientist at Ifremer, co- responsible for the ESA Sentinel 1 (a and b) algorithms and scientific validation of ocean (wind, wave and current) products, co- and/or principal investigator in several other ESA (SMOS salinity mission, OceanGasFlux, GlobCurrent), member of NASA and CNES science and definition teams (SWOT and CFOSAT, Altika missions), and working on potential future space-borne instrument to provide ocean surface currents (Doppler off- nadir altimeter SKIM, multi-azimuth optical glitter GLISTERO).

**Atsuhiko Isobe** will provide a numerical model of microplastics using observed data for validation. He has been the principal investigator of three plastic-debris research projects sponsored by the Environmental Research and Technology Development Fund of Ministry of the Environment, Japan, and conducted field surveys of macroplastics and microplastics, around East Asian seas, North/South Pacific, and the Southern Ocean. Also, he and his group have conducted numerical modeling for pelagic marine debris including microplastics in these research projects.

**Peter Ryan** has studied marine plastics since the 1980s. He will provide his multi-year experience on field and laboratory assessments of the abundance, distribution and composition of macrolitter at sea, as well as experiments on the rates of sinking through biofouling.

**Victor Martinez-Vicente will** contribute the working group with a review on current techniques for plastic litter detection from satellites. He is principal scientist in the RESMALI proposal submitted by Plymouth Marine Laboratory to the European Space Agency. He is an Early Career scientist that focuses on validation of satellite observations and on developing new products from remote sensing. To do so, he has developed in-situ and laboratory techniques for characterising the optical properties of particles in the ocean, leading to novel phytoplankton Carbon algorithms.

**Won Joon Shim** will provide his expertise on distribution of microplastics in water and sediment and their fate including weathering and fragmentation in the environments. He is a principal research scientist at Korea Institute of Ocean Science and Technology and currently co-leads a national research project for environmental risk assessment of microplastics in coastal zone including microplastic monitoring in multi-media.

**Martin Thiel** will provide his 15 years' experience on field and laboratory studies on marine litter, especially about its distribution and composition at sea. He will also contribute to capacity building through citizen science program Cientificos de la Basura ("litter scientists", www.cientificosdelabasura.cl) in which schools from the entire Chilean coast are participating in scientific research on marine litter. He is Professor of Marine Biology at Facultad de Ciencias del Mar, Universidad Católica del Norte (UCN).

## 9. Relationship to other programmes and SCOR working groups

### 9.1 Other SCOR Working Groups

This SCOR WG will interface well with current SCOR Working Group 149 (Changing Ocean Biological Systems - COBS) when they address the presence of multiple drivers altering marine living resources and ecosystem services. We will also interface on producing a glossary of terms and guide for policy-makers to better understand the role of plastics as one of the multiple drivers of change in biological systems.

We will also interface with SCOR Working Group 150 (Translation of Optical Measurements into particle Content, Aggregation & Transfer - TOMCAT) for the part about remote sensing of debris and polymer characterisation usually performed by FTIR or Raman spectroscopy.

### 9.2 Other Programmes

GESAMP WG40
GESAMP is the Group of Experts of the Scientific Aspects of Marine Environmental Protections and is sustained by UN, UNEP, FAO, UNESCO, IOC, UNIDO, WMO IMO IAEA and UNDP. Working Group 40 is about "sources, fate and effects of micro-plastics in the

marine environment – a global assessment". This SCOR WG is the obvious consequence of GESAMP recommendations when they address the importance to assess distribution and transport of microdebris. Some members of this WG are also members of GESAMP, and plan to bring those general recommendations into a more detailed and active stage.

SCAR
The Scientific Committee on Antarctic Research (SCAR) is a committee of International Council for Science dedicated to Antarctic science. Recently marine debris has been found in Antarctica. The source is necessarily from industrialized countries and this SCOR WG will interact with SCAR providing information about ocean transport and accumulation of debris, the ultimate challenge for Antarctic marine research. The possibility to create a SCAR WG dedicated to marine debris will be assessed as a product of this SCOR- WG.

MARPOL - IMO
MARPOL 73/78 is one of the most important international marine environmental conventions. It was developed by the International Maritime Organization in an effort to minimize pollution of the oceans and seas, including dumping, oil and air pollution. The objective of this convention is to preserve the marine environment in an attempt to completely eliminate pollution by oil and other harmful substances and to minimize accidental spillage of such substances. This WG will interact with IMO exchanging information on ship-based plastic pollution.

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Appendix 1 (5 papers per full member)

**Stefano Aliani**

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1) B.D. Hardesty, J. Harari, A. Isobe, L. Lebreton, N. Maximenko, J. Potemra, E. **van Sebille**, D. Vethaak, and C. Wilcox, **2017**. Using numerical model simulations to improve the understanding of microplastic distribution and pathways in the marine environment. *Frontiers in Marine Science*, 4:30.
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Appendix 2 (endorsements)

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
Office of Response and Restoration
Silver Spring, Maryland 20910

Dear Dr. Aliani,

I am writing in support of your proposal for a SCOR working group entitled, "Floating Litter and its Oceanic TranSport Analysis and Modelling" (FLOTSAM). Our mission at the Marine Debris Division of the National Atmospheric and Oceanic Administration (NOAA) is "to investigate and prevent the adverse impacts of marine debris" through research, education, and outreach, and we value collaboration and coordination with a multitude of stakeholders to achieve this mission.

The work proposed in the FLOTSAM working group addresses some of the fundamental questions about the distribution, transport, and fate of floating plastic marine litter, and is novel in bringing together scientists with expertise in physical oceanography theory, numerical modeling, and remote sensing, with others who have extensive experience collecting and analyzing environmental data on the abundance and behavior of plastics in the marine environment. This working group will engage researchers new to the study of marine litter, and as such has the potential to significantly advance our scientific understanding of this contaminant and, ultimately, to better inform intervention and prevention strategies.

We are pleased to support the FLOTSAM working group by serving as external advisors, and by helping to disseminate the scientific outcomes to the broader marine debris community.

Sincerely,

Nancy Wallace

Nancy Wallace
Director, Marine Debris Program
Office of Response & Restoration
National Ocean Service

University of East Anglia
Faculty of Science
School of Environmental Sciences

University of East Anglia
Norwich NR4 7TJ
United Kingdom

Email:@uea.ac.uk
Tel: +44 (0) 1603 593117

Web:www.uea.ac.uk

20 April 2017

To Whom It May Concern

On behalf of the European Office of Future Earth I would like to express our interest in the proposed by SCOR WG FLOTSAM (Floating Litter and its Oceanic TranSport Analysis and Modelling). The problem of marine debris is one of the major concerns for global sustainability,
and we would want to encourage research in this area.The WG will lead to improved knowledge on the distribution and fate of plastic in the open ocean, particularly by the focus on temporal trends in composition of rnicroplastics, associated with changes in macro-plastic production, and the use of modelling to project the effects of future changes in societal plastic use.This new knowledge will bring a direct benefit for the long term management of the oceans and their sustainability in line with the UN Sustainable development Goals.

I look forward to the output of the Working Group and I am sure that Future Earth can offer a variety of mechanisms to disseminate the outcome of the work of the group to a wide audience.

Yours sincerely

Professor Tim Jickells Director Future Earth Europe
Director Centre for Ocean and Atmospheric Sciences Email: T.Jickells@uea.ac.uk