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

2-2

1. Name of group

Hydrothermal Energy Transfer and its Impact on the Ocean Carbon Cycles (WG135)

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

Finalization of the second review paper, including e-mail exchange with the authors that included several WG members and two young scientists that attended the 3rd WG meeting (EGU Vienna)

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

The review entitled 'Hydrothermal energy transfer and organic carbon production at the deep seafloor Nadine Le Bris, Mustafa Yücel, Anindita Das, Stefan M. Sievert, Loka Bharathi PonnaPakkam, Peter R. Girguis was submitted to *Frontiers in Marine Sciences* (18/07/ 2018).

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

Terms of reference

WG135 had three key goals:

• **synthesizing 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.**

This goal has been partly achieved with the second review in which the drivers and controls of 'carbon fixation at hydrothermal systems' has been considered. The paper structure was first discussed in Vienna during the 3rd meeting of the WG. The meeting was combined with an EGU session in 2014 (BG7.2 Hydrothermal energy transfer and its relation to ocean carbon cycling: from mechanisms and rates to services for marine ecosystems) convene by WG chairs.

The manuscript just submitted to *Frontiers in Marine Sciences* reviews key factors in hydrothermal ecosystem productivity, including A) the diverse mechanisms governing energy transfer among biotic and abiotic processes; B) the tight linkages among these biotic and abiotic processes; C) the nature and extent of spatial and temporal diversity within a variety of geological settings; and D) the influence of these and other factors on the turnover of microbial primary producers, including those associated with megafauna. This review proposes a revised consideration of the pathways of the biological conversion of inorganic energy sources into biomass in different hydrothermal habitats on the seafloor. We propose a conceptual model that departs from the canonical conservative mixing-continuum paradigm.

Inventories of different geochemical drivers of the 'the transfer of phytoplankton-limiting micronutrients from these systems to the open ocean' were already considered by WG members within the GEOTRACES programme (German C.R. et al. 2016 Hydrothermal impacts on trace elements and isotope ocean biogeochemistry. *Phil. Trans. R. Soc. A* **374**: 20160035) or included in specific reviews lead by WG members (Gartman, A., Yücel, M., Luther, G.W., 2014. An Introduction to the Major Chemical Components Released from Hydrothermal Vents, in: *Reference Module in Earth Systems and Environmental Sciences*. Elsevier.).

• integrating these findings into conceptual models of energy transfer and carbon cycling through hydrothermal systems which would lead to quantification of primary production and assessment of the contribution of these systems to the global carbon cycles.

A first WG paper provided an attempt to model plume processes related to the export of iron in plumes. It addressed an overlooked aspect of this cycling related to the deep-sea carbon pool, by considering the deposition of organic adsorbed on precipitating iron oxides. *German, C.R., Legendre, L.L., Sander, S.G., Niquil, N., Luther, G.W., Bharati, L., Han, X., Le Bris, N., 2015. Hydrothermal Fe cycling and deep ocean organic carbon scavenging: Model-based evidence for significant POC supply to seafloor sediments. Earth and Planetary Science Letters 419, 143–153.* This paper was produced after discussion at the second meeting in Hangzhou (China) where a dedicated subgroup established a conceptual frame for the processes related to iron biogeochemistry in plumes.

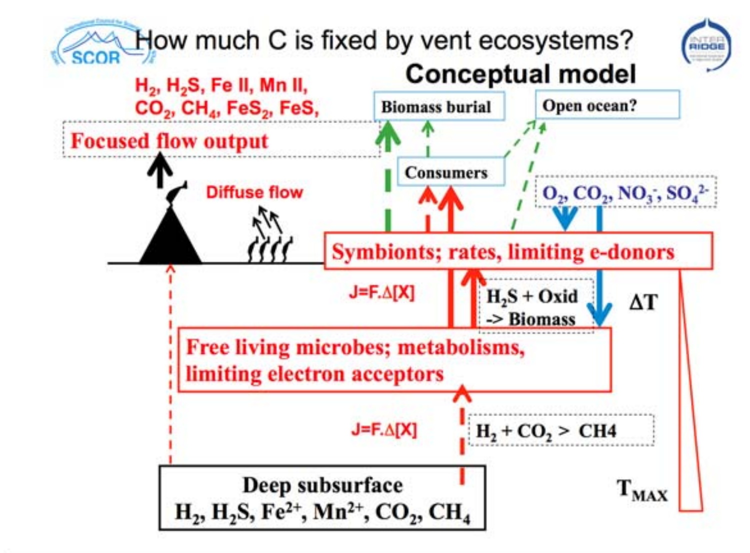

Figure 1: Conceptual model drafted at the 2nd WG meeting in Hangzhou (China) and discussion at the 3rd meeting

At this meeting, the bases for a modelling work of primary productivity at and below the seafloor were discussed and a conceptual scheme was drafted (Figure 1). The needs to synthesize the available knowledge to quantitatively constrain the model were discussed at the 3rd meeting in Vienna. The structure of the review paper has been discussed on this basis and later reorganized to focus mostly on seafloor components.

• **identifying 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.

The papers produced from the WG have identified critical gaps in the current understanding of geochemical, metabolic and ecological regulations that drive the efficiency of energy and micronutrient transfer from the geothermal source to ecosystems and emphasized the need for a global coordinated effort in the deep-ocean. In particular, Important knowledge gaps in the assessment of stabilized iron forms that can undergo long-range transport, as confirmed by GEOTRACES, are likely linked with the variability of iron and organic ligands at vents, in space and in time. This emphasizes the need to better understand the geochemistry and biogeochemistry of elements in distal plumes accounting for the different iron sources at vent fields.

On another hand, little is known about the temporal evolution of vent ecosystems in response to changes in their geochemical environment, to the exception of rare long-term study sites and observatories. The mechanistic understanding and modeling of organic carbon production is confronted to a huge lack of quantitative data about the temporal dynamics of such systems. Expanding studies beyond areas equipped with large seafloor infrastructures is a necessity if we are to extrapolate hydrothermal carbon budgets from regional settings to ocean basin scales. Rapid advances in the exploration of hydrothermal vent ecosystems and the diversity of geochemical contexts in space and time are requesting enlarged effort in investigation of the functional and dynamic basis of these ecosystems on the ocean floor.

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

The WG has ended its activities with the submission of the 2nd review paper.

Follow up with InterRidge and DOOS (under GOOS) might be considered. The availability of cost-effective underwater technologies could support a global coordinated effort on vent system, to be developed within the frame of future deep-ocean observation programmes.

Quantitative modeling could hence be supported by a better assessment of growth efficiencies of dominant microbes under realistic habitat conditions, based on combined in vivo experiments with in situ experiments and observations, accounting for the role of dominant invertebrate species in microbial-based processes.
The context of deep-sea mining is shedding new light on the need to better appreciate the functional role of these ecosystems at the deep seafloor. Chemosynthetic organic carbon production rates will deserve further assessment at local to regional scales.

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 sadly missed Katrina Edwards, who has been very supportive of the WG during the first 3 years and contributed to the discussions for the structuring of the review. The subseafloor sub-theme of the WG was largely lead by her and did not continue its activities after her decease.

In the first 3 years of the WG activity, several members of the WG have been engaged in large national efforts dedicated to the exploration of mid-ocean ridges and back-arcs (particularly in the United States, Japan, Germany, partly within international programmes as GEOTRACES and IODP). This context that included the leadership of major expeditions at deep-sea vents did not allow organizing a large, co-constructed with the ocean biogeochemistry community.

The intensification of research in relation to microbial carbon fixation on the seafloor and expansion of the use of new generation molecular techniques have profoundly changed our knowledge of chemosynthetic primary producers in the last 10 years. Molecular microbiology studies have identified a much larger diversity of metabolic pathways and more complex links with putative environmental drivers of carbon fixation, than considered when the WG started considerably complicated the task of assessing their biogeochemical role in the deep ocean.
The final review attempted to integrate this rapidly expanding knowledge with the state of the art of vent habitat geochemistry and the (limited) knowledge of ecosystem dynamics.

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

Though they are not strictly products of the WG activities, numerous initiatives were developed in international collaboration among WG members. We can cite particularly:

- The recent Gordon conference ‘Biogeochemistry of Marine Interfaces held on July 8-13, 2018 in Hong Kong chaired by Sylvia Sanders and Louis Legendre included a special theme on hydrothermal vents, extending the discussions of the WG in a biogeochemical oceanography context.

- Several review papers published by WG members on the geochemistry of vent fluids, related thermodynamic energy budgets and microbial primary producers.

  German, C.R., Seyfried, W.E., 2014. Hydrothermal Processes, in: Treatise on Geochemistry. Elsevier, pp. 191–233.
  German CR et al. 2016 Hydrothermal impacts on trace element and isotope ocean biogeochemistry. Phil. Trans. R. Soc. A ***374****: 20160035.*
  Gartman, A., Yücel, M., Luther, G.W., 2014. An Introduction to the Major Chemical Components Released from Hydrothermal Vents, in: Reference Module in Earth Systems and Environmental Sciences. Elsevier.

Nakamura, K., Takai, K., 2015. Geochemical Constraints on Potential Biomass Sustained by Subseafloor Water–Rock Interactions, in: Ishibashi, J., Okino, K., Sunamura, M. (Eds.), Subseafloor Biosphere Linked to Hydrothermal Systems. Springer Japan, Tokyo, pp. 11–30.
A. Thomas, T.R., Das, A., Ponnapakkam Adikesavan, L., 2018. A Review on the Phylogeography of Potentially Chemoautotrophic Bacteria from Major Vent and Seep Fauna and Their Contribution to Primary Production. Geomicrobiology Journal 35, 612–634. https://doi.org/10.1080/01490451.2018.1440035

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.

2.1.2 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

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

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

Template for Annual SCOR Working Group Reports to SCOR

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

- WG members participating in the RV *Falkor* cruise Air⇅Sea met in Wilhelmshaven (Germany) for a post-cruise workshop. Preliminary data presented, and plans for publications were discussed. Currently, three papers have been published and one manuscript is in revision.
- An In-person meeting with some WG members was held during the 2018 Ocean Science Meeting in Portland. We discussed a second *Falkor* cruise investigating heat exchange processes across slicks. The cruise is planned for the last quarter of 2019.

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

- Wurl, O., Bird, K., Cunliffe, M., Landing, W. M., Miller, U., Mustaffa, N. I. H., Ribas-Ribas, M., Witte, C., Zappa, C. J. 2018. Warming and inhibition of salinization at the ocean's surface by cyanobacteria. *Geophys. Res. Lett.* 45 doi: 10.1029/2018GL077946
- Wurl, O., Ekau, W., Landing, W.M., Zappa, C.J. 2017. Sea surface microlayer in a changing ocean – A perspective. Elem Sci Anth. 5:31. DOI: http://doi.org/10.1525/elementa.228

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.

COMPLETED. The recent publication including members of the SCOR SML WG in *Elementa* fulfills TOR 2 by providing SML's role in a changing ocean as well reiterate the definition proposed earlier by Hunter (2005).

•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).
- Special session at ocean Sciences Meeting 2018 in Portland 'Ocean Biogeochemistry and Air-Sea Interactions' (February 2018).

•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.

COMPLETED. The working group has published a special issue in the journal *Elementa: Science of the Anthropocene*. A total of 11 papers have been published in the special issue 'The Sea Surface Microlayer - Linking the Ocean and Atmosphere' (https://collections.elementascience.org/sea-surface-microlayer). The special issue is interdisciplinary with a wide range of topics, including new technology, soot and aerosol particles, biogeochemistry, role of bubbles, trace elements, microbiology and rheology.

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

None. Final report of WG 141

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 TORs has been achieved

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

We thank SCOR for the support of our working group over the last 5 years. It has been an amazing opportunity to push the SML into a greater awareness within the ocean science community. We especially acknowledge the support of SCOR of the expedition Air↓↑Sea with the RV *Falkor*, which was initiated by WG members. It should be also noted that the WG member Prof Talib Latif (Malaysia) is now a Committee member of Surface Ocean - Lower Atmosphere (SOLAS).

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

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

2-16

1. Name of group

SCOR Working Group #143: Oceanic methane and nitrous oxide

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

1. Quarterly webconferences
We continued to hold webconferences every 3-4 months throughout 2017-2018 to help expedite data analysis.

2. In-person meeting at Portland, Oregon
We had a one-day workshop on Sunday 11 February prior to the Ocean Sciences conference. The workshop focused on the content of our final report which will be turned into a manuscript for a peer-reviewed journal.

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 a draft manuscript which describes the inter-comparison exercise. The manuscript will be submitted to the *Biogeosciences* journal by June 2018.

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. The inter-comparison of discrete seawater samples is the basis for our manuscript 'A global inter-comparison of oceanic methane and nitrous oxide measurements' which will be completed by June 2018.

2. Establish the appropriate standards to be used by the scientific community
This is completed and the Technical Report has been published on the SCOR website. 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
The manuscript 'A global inter-comparison of oceanic methane and nitrous oxide measurements' will include some good practice recommendations for sample collection and analysis as well as data reporting. This will be completed by June 2018.

4. Establish framework for an N_2O/CH_4 ocean time series network and write a global oceanic N_2O/CH_4 summary paper for publication in an open access journal. There are different components to this Terms of Reference 1. The production and distribution of common gas standards will benefit the framework for methane and nitrous oxide measurements. This has been completed. 2. The intercomparison work identified several key steps to methane and nitrous oxide analyses that need to be taken into consideration when conducting the measurements. This forms part of the forthcoming *Biogeosciences* manuscript. 3. There will be an OCB workshop at Lake Arrowhead Conference Center in October 2018. This workshop specifically asks the question '*Where are the critical locations in the global oceans to measure dissolved methane and nitrous oxide in order to document long-term changes to the oceans as a source of these greenhouse gases?*' Therefore, in addition to existing measurements, where should new or increased measurements be located? This information will comprise the workshop report and will become part of any open-access peer reviewed publication that is produced following the event. 4. The GEOMAR group (H. Bange, A. Kock, D. Arevalo) will take the lead writing a manuscript about the MEMENTO database for submission to *Earth System Science Data*. The MEMENTO database is the current data portal for the methane and nitrous oxide measurements.

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

We would like to extend the WG#143 timeline to September 2019 so that the community of scientists is maintained for the duration of two more events outlined below. We have received funding to hold an OCB workshop at Lake Arrowhead Conference Center in October 2018. At this point, we hope to have the *Biogeosciences* manuscript peer-reviewed and nearing publication. The website address is https://web.whoi.edu/methane-workshop/. SCOR WG#143 has an abstract accepted for the OceanObs'19 conference in Honolulu, Hawaii with the title "A harmonized N_2O ocean observation network for the 21st century". The OceanObs'19 Program Committee has invited an overview paper (open access) in combination with another submission titled 'Constraining the oceanic uptake and fluxes of GHG by building a certified ocean network of stations'.

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 at this time. Thank you to Ed Urban and SCOR for supporting the activity of WG#143 during the past four years. It has been extremely helpful to the progress of methane and nitrous oxide measurements in the ocean

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

2-20

1. Name of group

Microbial Community Responses to Ocean Deoxygenation WG-144

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

SCOR-WG-144 did not hold any meetings in 2017. A workshop that had been tentatively planned for January 2018 did not materialize due to lack of funding. The main activities of our last year focused on publication of a special issue of *Deep-Sea Research*, with Bess Ward as the Special Issue Editor. Eight papers have completed the review process and have been sent to production. At least four additional manuscripts are in the final stages of review and editorial decisions are pending. This is a little later than planned, but the final result will be a respectable contribution.

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

A special issue in *Deep-Sea Research* is nearing completion.

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

i. The Saanich Inlet workshop was completed as planned during the first year of the program.

ii. The Warnemünde meeting was held as planned during the second year of the program and a white paper was drafted. Although a final version was expected at the Goa workshop, that did not occur and the leader of that effort, Klaus Jürgens, has let it be known that he will not be pursuing the project to publication.

iii. The Goa workshop, originally planned for the fourth year of the program, was moved to the third year and was successfully completed in December 2016. In addition to SCOR funds, OCB and NIO also contributed substantially to the cost of the workshop and enabled the participation of many international scientists. The special journal issue planned for the output of the Goa workshop is in progress at DSR II and will be completed this year (2018).

iv. The workshop in Chile was an ambitious addition to the original plan, but it did not occur, due to funding and time limitations.

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

SCOR-WG-144 has completed its planned objectives and its activities will end with the publication of the DSR II special issue.

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 planned publication of a methods-oriented white paper that was to be the outcome of the Warnemünde workshop during the second year of the WG did not materialize because the leader of the effort decided not to pursue it. Many of the group members and other colleagues had contributed text, so this was quite disappointing. No amount of encouragement or pressure from the rest of the group could change the outcome, short of someone else taking over and that did not happen.

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.

2.1.8 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 past year has seen progress on a broad front, with the start in November 2017 of the 3-year NERC/NSF project that supports the WG aims (PIs Clegg, Benway and Dickson); the first new experimental measurements contributed by our collaborating laboratories (NMIJ, Japan and GEOMAR, Germany); and the establishment of collaboration with other relevant projects and international organisations. We are making increasing use of telephone and video meetings to ensure effective collaboration between the WG, NERC/NSF project and the collaborating laboratories.

<u>NERC/NSF project</u>

- Work is underway on software development, including the propagation of uncertainties in speciation calculations. The initial focus of the experimental and modelling work is on TRIS buffers in artificial seawater, which will contribute to the development of a traceable pH scale for seawater in collaboration with national standards laboratories.

<u>Experimental measurements</u>

- Collaboration with national standards laboratories on TRIS buffers in artificial seawater is underway. The Japanese laboratory NMIJ has contributed a full set of Harned cell data for TRISHCl/HCl mixtures
- Initial measurements on TRIS solubilities have been completed at GEOMAR (Germany)
- A database has been established to archive the experimental data generated by the NERC/NSF project and the collaborating laboratories. The database currently comprises the new NMIJ data together with relevant published data from the literature. The database is managed by David Turner.

<u>New collaborations</u>

- We have initiated collaboration with two projects relevant to the seawater pH scale. PIs Bob Byrne (U South Florida), Wei-Jun Cai (U. Delaware), and Regina Easley (NIST) attended the 2018 WG meeting as guests and outlined their project plans. These groups, together with collaborating laboratories, took part in a video conference in December 2017.
- Contact has been established with pH-monitoring programmes (GOA-ON, IOC), and also with the SCOR/IAPSO/ICPWS Joint Committee on Seawater Properties.

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

A report summarising the results of the SurveyMonkey web questionnaires has been published on the website marchemspec.org (http://marchemspec.org/publications/).

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.

Documentation of the current status of the Pitzer models for seawater is now complete as an internal document that will be used as a basis for model development. The first new experimental measurements that contribute to model development have been completed and a database established.

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.

A new WG website has been developed (marchemspec.org) to document our progress, and to make available internal (non-refereed) reports. This site was publicised at the 2018 Ocean Sciences meetings by way of a handout.

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 results of the SurveyMonkey web questionnaires on user requirements have been summarised in a report published on the WG website at http://marchemspec.org/publications/.

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.

Coding of the calculation engine is now underway.

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

Publications

Following the SurveyMonkey web questionnaires on user requirements for the software package, a paper is being prepared outlining the plans for the software. It is planned to submit this paper to the *Frontiers in Marine Science* Special Topic "Best Practices in Ocean Observing" in autumn 2018. This paper will invite further feedback from potential users, which can then contribute to the final design. This paper will be followed up by a webinar on a relevant host organisation such as GOOS.

Collaboration

- Simon Clegg and Andrew Dickson will attend a workshop organised by the SCOR/IAPSO/IAPWS Joint Committee on Seawater in Prague in September 2018, to discuss the potential for collaboration on the question of seawater pH.
- The potential for collaboration with the University of Belgrade, who have the capacity to contribute new isopiestic measurements, is being investigated.

Experimental measurements

- A Harned cell intercalibration is now underway, coordinated by Andrew Dickson's laboratory. The participating standards laboratories are NIST (USA), LNE (France), PTB (Germany) and NMIJ (Japan)
- The coordinated programme of new experimental measurements in the NERC/NSF project and collaborating laboratories will continue.

Model development

- The review of current Pitzer models, together with the accumulating new experimental measurements, will be used to develop the first phase of the WG's speciation model, for TRIS buffer in artificial seawater
- Further development will focus on the priorities identified in the web questionnaires: trace metals including organic interactions (see next point); coastal and estuarine waters including low salinities
- The potential for including natural organic matter in the speciation model will be explored in collaboration between David Turner and Martha Gledhill (Associate Member), who has been awarded a grant from DFG in Germany for new experimental studies

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 timetable for the WG has been dependent on securing research funding, which was successful through the NERC/NSF project that will run from November 2017 – October 2020. Complementing this project, collaborating laboratories are contributing new experimental data from their own funding. Given the timing of the NERC/NSF project, we anticipate that we will be able to fulfil the terms of reference by the end of 2020. We would like to keep the WG active until that time so that the software package can be released as a SCOR project. We would like to use the limited funding remaining for this WG to finance, in part, a final WG meeting at the 2020 Ocean Sciences meeting in San Diego. We plan to make a major effort to highlight the WG's work at that meeting (e.g., Town Hall, Scientific Session, Tutorial). We are therefore not requesting any funding for the 2018/2019 financial year.

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

Final report of SCOR Working Group #146: Radioactivity in the Ocean, 5 decades later (RiO5)

By Ken O. Buesseler and Minhan Dai

June 2018

SCOR WG 146 held three meetings to discuss WG activities, the first one was held on 15-17 July 2015 in Woods Hole, USA, second one was held on 4-7 June 2016 in Xiamen, China, and the last one was held on 9-11 August 2017 in Aix-en-Provence, France.

SCOR WG 146 has fulfilled all the Term of References. Some actions being taken are summarized below along the Terms of Reference:

ToR#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 which will be useful to both the scientific community and the public.

The WG has updated the data base via the IAEA's MARiS portal (https://maris.iaea.org).

ToR#2&3: Summarize and publish review papers in peer review journals on these global radionuclide datasets and provide examples of how these can help improve our understanding of ocean processes and contaminant fate and transport. Identify gaps in scientific knowledge in relation to radioactivity in the marine environment and publish the results in a perspectives paper in Eos or elsewhere.

A review paper was published:

Buesseler, K., M.H. Dai, M. Aoyama, C. Benitez-Nelson, S. Charmasson, K. Higley, V. Maderich, P. Masqué, D. Oughton and J. N. Smith. 2016. Fukushima Daiichi-Derived Radionuclides in the Ocean: Transport, Fate, and Impacts. *Annual Review of Marine Science* 9:1-31.

ToR#4: Bring together academic, nuclear industry and national laboratory expertise for an international symposium on radionuclides in the ocean.

- Due to financial difficulties in orgnising an international symposium, the WG decided to dissemble this ToR into mutiple events with lower costs to serve simlar purposes, which included special sessions organised in international conferences and desinated public engagement and lectures.
- At the Goldschmidt 2017 conference in Paris, France, Paul Morris along with other colleagues organised a session entitled "Insights into Ocean Processes Through the Application of Radioactive Tracers".
- Ken Buesseler and Pere Masque co-chaired a session on "Radionuclides in the Ocean" at the Goldschmidt 2015 conference in Prague, Czech Republic on 16-21 August 2015.
- Michio Aoyama co-organized a session "Geoscience processes related to Fukushima and Chernobyl nuclear accidents" at EGU General Assembly 2015 in Vienna, Austria on 12–17 April, 2015.

- A series of public educational events were delivered in Xiamen on June 8-11, 2016, including demonstrations and hands on activities about radioactivity and radiation with the students in 3 local middle schools and 1 science museum, as long as a panel discussion (with 4 talks) for public audience and the media.

ToR#5: Provide a warehouse of education materials to assist in the education and training of the next generation of marine radiochemists and radioecologists.

A series of e-lectures on: 1) Introduction to radiochemistry; 2) U - Th Series Radionuclides in Marine Systems; 3) Cosmogenic and Artificial Radionuclides in marine Systems; and 4) Marine Radioecology have been submitted for publication to *Limnology and Oceanography* e-lectures. All of the lectures have been accepted with some minor revisions.

The WG held the first training course in Xiamen, China on June 8-10, 2016 and the second training workshop on August 13, 2017, in conjunction with the Goldschmidt conference in Paris, France. A training course building on RiO5 has been scheduled to be held in Puerto Rico on 21-23 February 2019 as a post-RiO5 event.

ToR#6: Develop web□based tools to enhance public understanding of radioactivity, in particular in the ocean.

The on-line methods "Cookbook" for radionuclides was developed (https://cmer.whoi.edu/). This is a resource for all where we could readily share our past and current step-by step methods used for measuring radionuclides in largely (but not exclusively) marine samples.

Since the Terms of Reference have been fulfilled, there is nothing more the WG needs to do, we request to disband this WG.

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 Reports to SCOR
By Malcolm Woodward and Michio Aoyama, May 2018.

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

Numerous email contacts have occurred over the year, along with telephone and 'skype' type meetings between the co-chairs and members.

1. One of the main exercises in 2017 was an International nutrient training workshop. This was organized by NIOZ and PML and was funded by POGO, SCOR, NIOZ, PML and JAMSTEC. The POGO-SCOR workshop "International Training Workshop for Nutrient Analysis" was held at The Royal Netherlands Institute for Sea Research (NIOZ) in November, 2017. The purpose of the workshop was to give technicians from developing countries, who work in the field of marine nutrients, the possibility to become familiarized with the latest techniques in seawater nutrient analysis. It is increasingly important to produce internationally comparable nutrient data and therefore essential that institutes around the world share as much as possible their knowledge on nutrient measurement methods. This training was set up to show people how to produce reliable data and to how to gain international accuracy through the use of Certified Reference Materials (CRMs). The disadvantage of a practical course is that the number of participants is limited. From 235 application letters, only 9 participants were able to join this workshop due to funding and space considerations. The participants who joined were chosen for their potential capacity building and were all from different institutes and different countries.

In total, 13 lectures were presented by mainly the Members of this SCOR Working Group. Lectures covered the role of nutrients in the oceans in general, statistics, how to make proper calibrations, the use of nutrient reference materials and internal lab standards, worldwide nutrient inter-comparison exercises and much more. These theoretical lectures were followed by the practical part of the workshop. In the laboratory, 3 different Continuous Flow Analysers were set up and then several runs could be performed so that the participants could learn through hands-on practice. Different groups covered different issues and at the end of the practical session the results were presented to the other groups. Also, some basic lab practices, such as weighing, making stock standards, handling pipettes and preparing reagents were carried out. The informal character of these practical sessions made communication much easier and stimulated question asking and the exchange of information. All participants went home with a lot of information and were all invited to join the 2017/2018 Global Nutrient Inter-comparison exercise. The workshop was very successful and had very good feedback from the attendees.

2. We held the third and final annual meeting of the Working Group #147 as part of the Ocean Sciences Meeting (OSM) held in Portland, Oregon in February 2018. Thanks to Ed Urban for his help in organising the venue which was at the Courtyard Portland Downtown/Convention Center, close to the Convention Centre itself. The meeting was held alongside the OSM conference. We had 2 sessions, on Wednesday, 14 Feb and Thursday, 15 Feb.

The agenda was:

<u>Session 1</u>
Opening: Summary of our collaborations: Recent progress how to promote CRM use: SCOR-JAMSTEC CRM distribution, current status and future: NIOZ workshop: Discussion on new GO-SHIP nutrients manual: Ocean Obs'19 Community White Papers

<u>Session 2</u>
Discussion of new GO-SHIP nutrients manual (cont.): Freezing Nutrients issues: Silicate SI traceability: IOCCP-JAMSTEC IC current status and future: Final report of our activity to SCOR: The Future, how do we continue the good work of WG #147?

The participants of the meeting were Michio Aoyama, Malcolm Woodward (co-Chairs), Toste Tanhua, Karin Bjorkman, Susan Becker and Claire Mahaffey (Full members), and Karel Bakker , Andrew Dickson, Akihiko Murata and Tae-Keun Rho (Associate members) plus Cassie Schwanger who was an active Observer.

A good constructive meeting took place. One important decision was the agreement to submit a Community White Paper to the OceanObs'19 meeting. This was submitted by the March 15 deadline and entitled: "The importance of high quality inorganic macro-nutrient data and how to get them". The authors were the attendees of the AGM meeting, and this will effectively continue the work of this Working Group beyond the 3-year boundary that has now been reached.

It was confirmed the SCOR-JAMSTEC CRMs are now available for purchase, and the provision of the final 400 litres of seawater to produce the Atlantic High and Medium CRMs was collected during summer 2017 by Malcolm Woodward on board the RRS James Cook. Much of the meeting centered about discussions concerning the updating of the GO-SHIP Nutrient manual, being led by Susan Becker from Scripps.

Further drafts have been circulated and changes made and a near-final draft should be circulated to the Group in May. The ideas discussed were to maybe publish through an online journal, and also to make the document available to the global community for comment before finally publishing the new Manual.

At the Ocean Sciences Meeting, the Working Group initially had its own Session assigned, but this was then merged into 2 Sessions: BN43A: Biogeochemistry and Nutrients in Open-Ocean Waters: Sustainable Ocean Observations from Profiling Floats and Time Series I:

and BN44B: Biogeochemistry and Nutrients in Open-Ocean Waters: Sustainable Ocean Observations from Profiling Floats and Time Series II. Working Group Members acted as Session Chairs, Co-chairs and Moderators, plus we presented 7 Posters and one session talk. Also as part of the OSM, SCOR and WG #147, 200 empty bottles of the SCOR-JAMSTEC CRM was distributed from the SCOR booth to publicise and promote CRM use. We also distributed forms for labs to apply to receive free CRMs as part of the SCOR WG 147 Activity. After the OSM, then 25 laboratories would receive a set of low and high CRMs. This promotion was funded by SCOR.

3. The IOCCP-JAMSTEC International Intercalibration exercise was carried out over the winter of 2017/2018, with final results submitted by participating labs in February 2018. The results have not yet been finalized or fully analysed, and a subsequent report will be published about this exercise. The Working Group members agreed that that this exercise should be continued every 2 years into the future, if possible.

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

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

The WG#147 has collaborated with JAMSTEC, and has now been providing SI traceable Nutrient CRMs for the global community since November 2016, and the final Atlantic water High and Medium concentration CRMs have just recently become available. At the 3rd WG147 meeting, we discussed how to continue the distribution and sale of the SCOR-JAMSTEC CRMs, and considering the possibility of JAMSTEC stopping supporting the current distribution system. We discussed about a new system which would be supported by international bodies such as IOCCP and others. WG147 has already been in close collaboration with IOCCP and JAMSTEC to conduct the IOCCP-JAMSTEC Inter-laboratory calibration exercise of CRM/RMNS in 2017/18.

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 2017/18, NMIJ CRM, KANSO CRM and KIOST RM were used. The results of this exercise have not yet been finalised and will be published once complete.

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.

A part of this ToR3 will be included in the updated GO-SHIP nutrients manual, discussed in ToR6.

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 organised the 'International training workshop on Nutrient analysis', which was held at the NIOZ laboratory in November 2017. This was co-organised by NIOZ and PML. Details of this very successful Workshop are outlined above in Section 2.

ToR 5: To continue regular global inter-comparison studies, following on from the previous exercises in 2003, 2006, 2008, 2012 and 2015/16, 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 2017/18. The 8 scientists from developing countries who attended the training workshop were also invited to participate in the International Intercalibration exercise.

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).

WG147 has a near final draft of the updated GO-SHIP nutrient manual, and this draft is out for comment to the authors. WG147 are 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 Intercalibration exercise and GO-SHIP manual will be published when completed.

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

Even though the 3 year funding for the group has ended through SCOR there are a number of activities that will continue on into 2018 and 2019 and beyond.

1. The OceanObs White paper has been submitted and the authors will work together on this and continuing promoting the WG#147 aims through that meeting in 2019.

2. The results of the 2017/2018 International Intercalibration exercise will be published later in 2018. Further exercises are planned to take place probably in 2019 and beyond.
3. The updated GO-SHIP nutrient Manual will continue to be finalized over 2018 and hopes to be finally published before the end of the year.

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

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

We would like to request from SCOR to have continued support for the distribution of the SCOR-JAMSTEC nutrient CRMs bottles. These were produced through the efforts of the SCOR Working group #147 as a very positive output, making cheaper CRMs available to the global community. These bottles have been produced with the SCOR name on them, and we would request the support to continue the distribution of these bottles up until they are sold out, or the 6-year certification expires.

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

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

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

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

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

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[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.

Template for Annual SCOR Working Group Reports to SCOR

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 at Ocean Science Meeting
Our meeting was held on 14 Feb. 2018 at the Ocean Sciences Meeting, Portland, Oregon. 13 Members attended, and the meeting addressed the following topics:

1. Progressing the literature review
2. Potential for special issue in *Frontiers* (incl. linking with other OSM BCP sessions); publications needed to establish TOMCAT methods
3. Data bank – data sharing – how can we move collaboration forward
4. The two conversions that are clearly missing: Image-to-Carbon & Image-to-sinking speed; how to increase efforts to solve these
5. Capacity building (including inviting scientists from developing countries and future workshops)

Conference Session
During the Ocean Sciences Meeting (OSM), 11-16 Feb. 2018, we hosted a session entitled “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 had 8 talks and 10 posters, and the overall session was rated very highly based on the feedback (~100 scientists in audience).

Special Issue
We have started a Research Topic (special issue) in *Frontiers in Marine Sciences* called “We Shed Light: Optical Insights into the Biological Carbon Pump” following on from the session at OSM. 35 contributors have been confirmed and 12 abstracts accepted so far. The anticipated submission deadline is the 19 Apr. 2019.

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 highlights the potential for future research and development. Progress on the review has been slow mainly due to busy schedules. We aim to submit the review as part of the special issue.

Capacity building - Training workshop
TOMCAT will deliver part of a 12-day training course on "Analytical methods in marine biogeochemistry" from 1–12 Oct. 2018 at the National Oceanography Centre. This training course is part of the SOLSTICE programme funded by the Global Challenges Research Fund (GCRF). We are expecting participants from Tanzania, Kenya, South Africa, Malaysia and Belize.

Capacity building – Postgraduate training
In an effort to bring TOMCAT methods to South Africa, Sari Giering is supervising a PhD student based at the Nelson Mandela University, South Africa, in how to convert optical data into particle fluxes.

Community White Paper
Members of TOMCAT are actively involved in shaping a Community White Paper on Observational Needs as part of OceanObs'19, led by Fabien Lombard.

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

Research topic: https://www.frontiersin.org/research-topics/7817/we-shed-light-optical-insights-into-the-biological-carbon-pump

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

TORs:

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

   We are now documenting and discussing the capabilities and limitations of current devices 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 future. This will include the Research Topic in Marine Sciences and the OceanObs’19 Community White Paper. Knowledge is also disseminated as part of person-specific capacity building (supervision of graduate students in developing countries) and workshops (training schools for participants from developing countries). We are also in the process of organizing a ring trial to compare identification methods and definitions.

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 have retrieved some intercalibration data. We will focus on the analysis within the next year (target summer 2019).

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

   As above. We will focus on this step within the next year (target summer 2019).

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

   We are currently discussing the options with different platforms. For example, EcoTaxa is a web application dedicated to the visual exploration and the taxonomic annotation of plankton images, and it has the potential to be extended or used as a template for marine snow images.

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

Training school
We are providing training as part of the “Analytical methods in marine biogeochemistry” workshop, hosted from 1-12 Oct. 2018 at the National Oceanography Centre, UK. This training workshop is exclusively for participants from developing countries.

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 for early 2019. Details have yet to be confirmed.

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

Overall we believe we are on target.

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.

2.1.14 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 but we decided to wait until the February 2018 Ocean Sciences meeting to hold our first in-person meeting.

This meeting duly took place on the Sunday prior to Ocean Sciences and had an excellent turn out of 24 participants. During the meeting there was a combination of reporting from objectives and communication of associated science from participants. There was lively discussion about how best to deliver the terms of reference.

It was also noted that there were a number of groups not included in the list of Full and Associate members (due to selection criteria) that were very interested in our efforts. We have invited additional people to the slack communication platform and we might also consider creating an email list for important announcements.

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

None yet

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: We had reports from the three subgroups that had been working prior to the kick off meeting on external input, biological cycling (incl. uptake and regeneration) and speciation/scavenging (including ligand aspects). Parallel to that, a table has been created that documents the development of complexity in iron cycle models. Moving forward, there will be a video conference held during 2018 (convened by AT) to plan the publication of a review article, with recommendations given for the optimal closures.

Objective 2: Marcello Vichi (MV) presented a detailed report on his efforts to bring together skill metrics. It was decided that a number of WG participants should share model output with him to enable the preparation of example cases. Candidates were found to translate scripts into Matlab, python, R and ferret. Moving forward, there will be a video conference held during 2018 (convened by MV) to plan the way forward further.

Objective 3: This was the first time we had convened to discuss this topic. We focused specifically on identifying the important aspects associated with how different models deal with dust deposition and identifying a way to explore their significance. After some discussion, we identified (i) Natural vs Anthropogenic, (ii) fixed vs variable solubility, (iii) the time scale of deposition, (iv) the depth scale of deposition, and (v) dust as a scavenger of iron as the key aspects. Andy Ridgwell offered to run simulations with his GENIE model to allow a relatively straightforward way to assess their impact (noting that GENIE is a relatively light and easy to run model). Keith Moore took the lead on this objective and will contact Natalie Mahowald to obtain daily forcing data to use for these experiments.

Objective 4: There was some initial discussion of objective 4, but we ran short of time to get more into the details of this.

For all these slack is proving to be a useful forum for exchange.

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

Finalise Objectives 1 and 2.

Conduct experiments for Objective 3

Organise a meeting, virtual or physical to discuss how to move Objective 4 forwards.

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

2.1.15 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**: 17 August 2017, 6:00-7:00 UTC through Skype. François Fripiat, Brent Else, and Daiki Nomura. We discussed about the updates and working plan for the different tasks.
- **Virtual meeting #2**: 22 November 2017, 22:00-23:00 UTC through Skype. François Fripiat, Brent Else, and Daiki Nomura. We discussed the updates and working plan for the different tasks.
- **Virtual meeting #3**: 30 November 2017, 14:30-15:30 UTC through Skype. François Fripiat, Christopher J. Mundy, Karley Campbell and Florian Deman. To discuss the collation of primary production measurements in sea ice. The data have been collected for both the Arctic and Antarctic.
- **Email discussion**: January-February 2018 through email. James France, Brent Else, Daiki Nomura, Bruno Delille, Lisa A. Miller, Francois Fripiat. To discuss the Eurochamps application.
- **Virtual meeting #4**: 6 February 2018, 22:00-23:00 UTC through Skype. Daiki Nomura, Kazuhiro Yoshida, Brent Else, Brian Butterworth, Bruno Delille, François Fripiat, Christopher J. Mundy, Karley Campbell, Florian Deman. To discuss the sampling strategy during the intercalibration experiment for primary production in Saroma-Ko Lagoon (Japan, March 2018).
- **Intercalibration experiment**: March 2018, Saroma-Ko Lagoon, Japan. Intercalibration experiment for primary production (dark and light O_2 and DIC incubations, ^{13}C incubations, biomass accumulation, variable fluorescence, O_2 optode incubation, O_2:Ar ratio, and under-ice eddy covariance) and air-sea ice CO_2 flux (chamber and eddy covariance techniques). Participants: Daiki Nomura, Kazuhiro Yoshida, Emiliano Cimoli, Masaaki Kiuchi, Koji Suzuki, Dong Yan, Naoya Kanna, Yusuke Kawaguchi, Brian Butterworth, Bruno Delille, Karley Campbell, Florian Deman, Ryuichi Shibusawa, Toru Hirawake.
- **Virtual meeting #5**: 20 April 2018, 5:00-6:00 UTC through Skype. François Fripiat, Brent Else, and Daiki Nomura. We discussed the agenda for the second annual ECV-ice meeting, which will be held at the POLAR 2018 conference in Davos (June 2018).
- **Virtual meeting #6**: 20 April 2018, 14:30-15:30 UTC through Skype. Christopher J. Mundy, Karley Campbell and Florian Deman. To discuss how to interpret and present the data collation of primary production measurements in sea ice at the second ECV-ice annual meeting, which will be held at the POLAR 2018 conference in Davos (June 2018).

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 article #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), submitted in *Polar Biology*.
- **Peer-reviewed journal article #2:** Meiners K.M., Vancoppenolle M., et al. Chlorophyll-a in Antarctic land- fast sea ice: a synthesis of historical ice-core data, to be submitted in *Journal of Geophysical Research*.
- **Peer-reviewed journal article #3:** Butterworth, B., Else, B.G.T. (in review). Long-term tower-based eddy covariance measurements of carbon dioxide flux over sea ice in the Canadian Arctic. Submitted to *Atmospheric Measurement Techniques*, manuscript no. amt-2018-158.
- **Web page:** https://sites.google.com/view/ecv-ice/.

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

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.

a. Published and unpublished datasets, using various methodologies, have been collated for primary production both in the Arctic and Antarctic sea ice: incubations (^{13}C, O_2, ^{14}C), under-ice microelectrode, and biomass accumulation rates (F. Fripiat, C.J. Mundy, F. Deman, and K. Campbell). The different methods will be compared and a mechanistic understanding of the observed discrepancies will be elaborated. C.J. Mundy still needs to gather biomass accumulation rates in the Arctic. Together, this dataset represents the largest compilation of primary production rates so far in sea ice. It will be presented and discussed at the second ECV-Ice annual meeting in Davos (June 2018).
b. Published and unpublished datasets have been collated to compare gas flux measurements over sea ice using chamber and eddy covariance techniques (D. Nomura and B. Else). These two methods give results that differ by up to an order of magnitude. A paper has been drafted and submitted by B. Butterworth & B. Else that summarizes published chamber and eddy covariance measurements, in comparison to a new eddy covariance technique. It will be presented and discussed at the second ECV-Ice annual meeting in Davos (June 2018). We will attempt to develop mechanistic understandings of the observed discrepancies.

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

A COST-action proposal (Lead: J. Stefels, University of Groningen) was submitted in September 2017, on "European Network on sea-ice biogeochemistry". In this framework, it was planned to perform two intercalibration experiments for method standardization: (i) Ice Chamber experiment on calibration of the carbonate system (at University of East Anglia-Roland von Glasgow Air-Sea-Ice Chamber, accessible through Eurochamps 2020 transnational access funding); and (ii) sea-ice primary production intercalibration experiment (optional locations: Svalbard, Villum Research Station). Unfortunately, the proposal was rejected. Several ECV-Ice members were associated: Bruno Delille, Francois Fripiat, Maria Van Leeuwe, Agneta Fransson, Katarina Abrahamsson, and James France.

An intercalibration experiment (two weeks; Lead: D. Nomura) was conducted in Saroma-Ko lagoon (Japan) in March 2018 to evaluate different methodologies assessing sea-ice primary production (dark and light O_2 and DIC incubations, ^{13}C incubations, O_2:Ar ratio, biomass accumulation, variable fluorescence, O_2 optode, and under-ice eddy covariance) and air-sea ice CO_2 flux (chamber and eddy covariance techniques). Participants: Daiki Nomura, Kazuhiro Yoshida, Emiliano Cimoli, Masaaki Kiuchi, Koji Suzuki, Dong Yan, Naoya Kanna, Yusuke Kawaguchi, Brian Butterworth, Bruno Delille, Karley Campbell, Florian Deman, Ryuichi Shibusawa, Toru Hirawake. The experiment was successful and the preliminary results will be discussed at the second ECV-Ice annual meeting in Davos (June 2018).

An intercalibration experiment for trace metals in sea ice was performed during PIPERS (USA, April-June 2017), and the samples are currently being analyzes in different laboratories. Participants: D. Lannuzel, A. Aguilar-Islas, J. de Jong. The results will be compared in the upcoming year and discussed at the third ECV-Ice annual meeting (location TBD).

An intercalibration experiment was planned in fall 2018 at the University of East-Anglia. The purpose was to use the Roland Von Glasgow Air-Sea-Ice Chamber facility to compare all the techniques available to date to measure gas concentrations in sea ice (sampling, processing, storage, and analysis). An application to Eurochamps 2020 transnational access funding has been written (Lead: B. Delille). In the meantime, James France, who was supposed to host this experiment, has been appointed for a new faculty position in another institution. Accordingly, this experiment will be delayed, at least until fall 2018. The procedure will be discussed at the second ECV-Ice annual meeting in Davos (June 2018). Participants: Bruno Delille, Marie Kotovich, Lisa Miller, Brent Else, Max Thomas, James France, Daiki Nomura, Agneta Fransson, and Jean-Louis Tison.

At the second ECV-Ice meeting in Davos (June 2018), we will discuss (logistic, funding) the possibility to perform a large-scale intercalibration experiment in Cambridge Bay, in the new Canadian High Arctic Research Station, operated by Polar Knowledge Canada (POLAR). Members of ECV-Ice met with POLAR at the 2018 Arctic Change meeting, where the idea was met with positive feedback. In principle, the infrastructure exists to do the experiment, if we can find funding for various participants to attend. We will attempt to do this experiment in 2019-2020 (late March-early April), in order to target the sea-ice algal bloom in an ascending phase.

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.

We will try to merge as much as possible the future intercalibration experiments with emerging technologies.

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.
   Limit 500 words

- **Virtual meetings**: Expect to meet 2-3 times to discuss updates and working plans for the different Terms of Reference. F. Fripiat, B. Else, and D. Nomura. 2-3 meetings expected to discuss about each data collation related to TR1 (primary production and sea ice-air CO_2 exchange).
- **Intercalibration experiment at the University of East Anglia-Roland von Glasgow Air-Sea-Ice Chamber on the calibration of the carbonate system:** We will conduct an intercalibration experiment at the UEA ice-tank facility in fall 2018. 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.
- **In-person meeting in 2019**: TBD at the second ECV-Ice meeting in June 2018 (SCAR/IASC POLAR 2018 Conference, Davos, Switzerland). ECV-Ice members and others. We will discuss review progress on the Terms of reference, pursue the elaboration of intercalibration experiments (TR2 and 3)), including reviewing results of primary production experiment in Saroma and the gas concentration experiment at UEA.

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

Except for the difficulties related to the intercalibration experiment at the University of East Anglia (because of the new faculty position of James France), the group is on track to achieve the terms of references.

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

None

2.1.16 WG 153: Floating Litter and its Oceanic TranSport Analysis and Modelling (FLOTSAM) (2017) *Smythe-Wright*

Chair: Stefano Aliani (Italy)

Vice-Chairs: Nikolai Maximenko (USA), Kara Lavender Law (USA), and Erik van Sebille (Netherlands)

Other Full Members: Bertrand Chapron (France), Irina Chubarenko (Russia), Atsuhiko Isobe (Japan), Victor Martinez-Vicente (UK), Peter Ryan (South Africa), Won Joon Shim (South Korea), and Martin Thiel (Chile)

Associate Members: Melanie Bergmann (Germany), Yi Chao (USA), Baylor Fox-Kemper (USA), Denise Hardesty (Australia), Tobias Kukulka (USA), Laurent Lebreton (New Zealand), Christophe Maes (France), and Miguel Morales Maqueda (UK)

Terms of Reference

- 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 marine litter in the open ocean.
- Improve awareness of the scientific understanding of marine debris, based on better observations and modelling results.

Executive Committee Reporter: Denise Smythe-Wright

1. Name of group

Floating Litter and its Oceanic TranSport Analysis and Modelling (FLOTSAM)

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

WG153 was approved after the 2017 Annual Meeting in September in Cape Town, South Africa, and this is the first annual report.

A lot of the 9 months' initial activity has been concerned with the logistics of organization and communication, with large exchange of emails and Skype meetings. However, significant scientific progress has also been achieved through web conference discussions, scientific meetings and the first kickoff workshop. For example, well in advance of the workshop, a list of key questions was shared among partners using Google Drive; these documents were a common starting point to stimulate and to target face-to-face discussion. The WG has also been communicated to the scientific community and to media, as *National Geographic*, national newspapers and television (RAI and Sky).

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

A website has been created at http://scor-flotsam.it and regularly updated. It is hosted on GitHub and CNR servers and administrated by E. Van Sebille. WG 153 is also hosted in SCOR website (http://www.scor-int.org/SCOR_WGs_WG153.htm).

A session was convened by all SCOR WG 153 chairs (*Law, van Sebille, Maximenko, Aliani*) and another Full Member (*Won Joon Shim*) at the 2018 Ocean Sciences meeting in Portland, Oregon, USA, inviting presentations on the focus of the working group: Detection, Analysis and Modeling of the Distribution and Transport of Oceanic Debris.

FLOTSAM participants presented the outcome of the first WG153 workshop at the 6th International Marine Debris Conference in San Diego, CA, USA. (http://internationalmarinedebrisconference.org/). Four relevant sessions and one plenary were convened by participants of WG 153. Reports were delivered to NOAA and available soon in 6IMDC Session Summaries of Conference Proceedings:

- PLENARY SESSION of Wednesday, March 14, 8:30 - 10:00 AM *Kara Lavender Law*, Sea Education Association.
- Session Chairs: *Erik van Sebille*, Utrecht University; *Kara Lavender Law*, Sea Education Association TRANSPORT AND FATE OF MARINE DEBRIS IN THE OCEAN AND SHELF-SEAS: THEORY, MODELING AND OBSERVATIONS (double session)
- Session Chairs: *Nikolai Maximenko*, University of Hawaii; Delwyn Moller, Remote Sensing Solutions; *Bertrand Chapron*, IFREMER; *Paolo Corradi*, ESTEC; *Victor*

Martinez Vicente, Plymouth Marine Laboratory REMOTE SENSING OF MARINE DEBRIS IN THE OPEN OCEAN
- Session Chairs: Georg Hanke, European Commission Joint Research Centre Directorate D Sustainable Resources; *Stefano Aliani*, CNR-ISMAR QUANTIFICATION OF FLOATING MARINE MACRO LITTER
- Session Chairs: Chelsea Rochman, University of Toronto; Sang Hee Hong, Korea Institute of Ocean Science and Technology; *Won Joon Shim*, Korea Institute of Ocean Science and Technology; Jennifer Lynch, National Oceanic and Atmospheric Administration; Hideshige Takada, Tokyo University of Agriculture and Technology; Hrissi Karapanagioti, University of Patras THE CHEMISTRY OF PLASTIC MARINE DEBRIS (double session)

Abstracts have been accepted for special sessions on WG153 topics at IAPSO/IUGG Assembly in Montreal, 10-17 July 2019. The leading author was *Erik van Sebille*. http://iapso.iugg.org/

An abstract for a community white paper has been accepted at OceanObs'19 in Honolulu 16-20 September 2019 Leading author was *Nikolai Maximenko*. http://www.oceanobs19.net/.

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 WG made relevant progresses toward its objectives through a kickoff meeting, sessions at scientific congresses, email exchanges, and Skype calls.

TOR1 - Identify gaps in our knowledge of the near-surface ocean dynamics that may affect litter distribution and transport

During the workshop, participants discussed and agreed on a list of relevant oceanographic processes affecting marine litter distribution and transport. Coastal processes and open ocean processes were considered separately, giving priorities to coastal and open ocean according to scientific relevance and current level of knowledge. It was noted that the observations required for basic research are often different from those collected for monitoring/management purposes.

Processes that are relevant (at the present state of knowledge) have been listed and WG discussed what we know about these, how important they may be for marine debris studies, how easily the process can be measured. They have been separated in different categories: transport processes that accumulate vs. disperse (redistribution at the surface); processes that flux material to/from the surface, including sources and sinks; and processes that change the particle properties.

Observations required to understand the relevant processes have been discussed. Existing observations are based upon sampling surface ocean trawling nets (different mesh sizes may be a source of critical heterogeneity), bulk water sampling, visual surveys, ingestion of plastic by birds (and other organisms), and separation of samples by filtration (again mesh size may be relevant). Chemical characterization of polymers is a must to separate plastic from natural debris, especially at sizes smaller than ~300 um. All participants agreed that datasets must be comparable, which involves harmonization of methods, and data quality must include some basic information, for example, particle characterization (size, polymer type- smaller sizes) in order to achieve a plastic taxonomy. A Litterbase data facility has been introduced (http://litterbase.awi.de/) and other databases have been cited. The problem of QC/QA has been discussed, which is a necessary step toward the creation of time series, i.e., repeated transects over time. The role of citizen science as a source of global data was discussed also.

TOR 2 - Improve future marine litter modelling capabilities

The current state of modelling of marine debris was been discussed during the kick-off workshop and during internal Skype meetings. There was general agreement that many papers published in recent years were based upon transport models commonly used to describe other types of objects (oil or larvae) and no model is fully dedicated to marine debris. There is an ecosystem of possible models suitable for marine debris studies, but at present they are without proper parametrisation of key processes affecting debris. For example, the role of Stokes drift has been considered in recent papers, but more work is needed to achieve a full comprehension of its effect on marine debris and properly include in-model parametrisations and set ups. Other relevant processes should be included in model parametrisation and to disentangle coastal processes (with their short timescales) from open ocean low-frequency processes, effort is also required in nesting large scale and high-resolution models. Participants in the modelling subgroup have conducted regular web conferences.

TOR3 - Evaluate existing and emerging remote sensing technologies that can be applied to marine litter in the open ocean

Aspects related to remote and in situ observations were discussed at the kick-off meeting and a plan for next year's activities was agreed, including creation of a community white paper to be submitted in 2018. Some points have been highlighted to focus on the next decade of science. Outcomes of the meeting highlighted that remote sensing provides the bigger picture and that, very often, it's difficult to draw a line between remote sensing and other observations. New technologies are required for future remote observations, including new sensors, e.g. optical (visible spectrum) and IR. The IR range is very promising, as seawater is almost black, so even small particles of plastic would be very bright, but if surface of the plastics is wet it may block the signal. However, good possibility may come from spotting shorelines and possibly large objects sticking out of the water. Hand-held drones may be useful to observe accumulation hot spots to overcome the low resolution of satellites. Active Raman sensors require a powerful source of energy, which is good in the lab, but may not be good for the field and satellites. The SAR active sensor can get a height profile of large floating objects, get information about surface currents, waves and the speed of objects (windage); therefore, although it cannot characterize small objects, it may collect information about variables relevant to explain ocean processes. Plastics and biological material respond in the same way to fluorosensors, making separation very difficult, but these sensors offer opportunities to address interactions with marine life. LIDAR penetrates the ocean surface and the reflected signal could potentially give vertical distribution of plastics, but the signal also reflects off air bubbles, which are used to study vertical mixing. SST and ocean color can track small features in time and identify sharp fronts, but requires proper validation and ground truthing. Direct measurements of drifting objects are important (which use satellite systems for position tracking) as well as of the surface ocean current. Although these measurements won't estimate plastic directly, they are important variables to improve models.

ESA funded two projects related to remote sensing of marine debris on the shoreline and in the open ocean. The OPTIMALI project contacted FLOTSAM partners to share a questionnaire about remote sensing to organize an ESA workshop in Noordwijk on 30 November 2017. WG153 was represented by *Erik Van Sebille* and *Stefano Aliani*. *Victor Martinez-Vicente*, OTIMALI coordinator and member of FLOTSAM, got 50% replies to his questionnaire and is drafting a manuscript to be submitted for publication.

TOR4 - Improve awareness of the scientific understanding of marine debris, based on better observations and modelling results.

The FLOTSAM website has been published and updated.

Participants of WG 153 chaired sessions at the Ocean Science Meeting 2018 in Portland, OR (USA), and 6IMDC in San Diego, CA (USA).

Presentations about WG153 were delivered in many institutions; among them at ESA in Rome and broadcasted to all interested ESA facilities in EU, School of Scientific Journalism at University of Milan, East China Normal University (Shanghai).
The group has communicated with media at RAI Italian TV, BBC, etc., and some interviews have been given to newspapers.

Contacts have been made, or are going to be taken soon, to collaborate with GESAMP, UNEP and IUGG/IAPSO.

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

The next FLOTSAM annual workshop is planned in Utrecht (NL) in spring 2019. The topics and the agenda of this workshop will be drafted after web discussion using web conference systems and Slack web services. Webinar discussions may be plenary with all interested partners involved and with focused subgroups.

WG153 will be also present at:

- Protection of the Arctic Marine Environment (PAME) Working Group - June 2018, Iceland
- International Arctic Science Committee (IASC) - June 2018, Davos

- MICRO – Nov. 2018, Lanzarote
- EGU – April 2019, Vienna
- IUGG – July 2019, Montreal
- OceanObs'19 – Sept. 2019, Honolulu

Publications in preparation are:

- OceanObs'19. Our abstract has been selected for a white paper on floating marine debris observations. OceanOb'19 organizers identified four other abstracts potentially complementing ours and recommended combining efforts into a white paper on Marine Litter. *Nikolai Maximenko*, who is leading all abstracts, is contacting the teams and, once all agree, will start preparing the structure and assignments of sections of the full-size paper to be submitted to *Frontiers in Marine Science* by September 30, 2018.
- Presentation of WG in *Oceanography* or *Eos*. A presentation of the WG and some results of the kickoff meeting will be presented in *Eos* or *Oceanography* magazine. Manuscript is under preparation.
- A WG member will lead a session at the IUGG/IAPSO meeting in Montreal next year, focussing on the role of ocean processes in the transport and fate of floating plastic litter in the ocean and shelf-seas: theory, modelling and observations.
- A number of papers about outcomes of the WG153 workshop are expected to be submitted to A Virtual Special Issue in *Marine Pollution Bulletin*, dedicated to 6IMDC. Special Issue content will be published in regular issues of *Marine Pollution Bulletin* as they are accepted. Accepted submissions will also be compiled in a Virtual Special Issue, easily accessible and navigable on ScienceDirect.
- A multi-authored paper lead by *Victor Martinez Vicente* is going to be submitted to *Frontiers Marine Science* as a Perspective Paper. The provisional title is "Towards global remote sensing of marine debris: scientific questions, current capabilities and research needs."

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 difficulties encountered or foreseen to achieve TORs as scheduled.

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.

2.1.17 WG 154: Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS) *Miloslavich* (2017)

Co-chairs: Emmanuel Boss (USA) and Anya Waite (Germany)

Other Full Members: Silvia Acinas (Spain), Ilana Berman-Frank (Israel), Marcela Cornejo (Chile), Katja Fennel (Canada), Heidi Sosik (USA), Sandy Thomalla (South Africa), Julia Uitz (France), and Hidekatsu Yamazaki (Japan)

Associate Members: Sonia Batten (Canada and PICES), Jørgen Berge (Norway), Herve Claustre (France), Gérald Grégori (France), Johannes Karstensen (Germany), Frank Muller-Karger (USA), Anthony Richardson (Australia), Bernadette Sloyan (Australia), and Rik Wanninkhof (USA)

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:

- 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.
- Provide the necessary details associated with every technology/measurement proposed (e.g., power, cost, and human effort).
- Document potential applications, including science case studies and lists of publications, and document measurement protocols. Develop adequate protocols when these are not available.
- 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.
- 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.
- Increase awareness of the availability of biological oceanographic datasets internationally and identify barriers to their access and use, particularly in developing nations.

Executive Committee Reporter: Patricia Miloslavich

Template for Annual SCOR Working Group Reports to SCOR

1. Name of group

SCOR Working Group 154
Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)

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

This is our first SCOR report. We had a one-day initial meeting in conjunction with the Ocean Sciences meeting on Saturday Feb. 10 in Portland, Oregon, USA. We published a community news piece in *L&O Bulletin* asking the community for input and uploading it on ResearchGate, where it had been read 150 times as of 6/13/2018. We had many exchanges in preparation for our first meeting and much material has been assembled. We have begun construction of a Website where this material and future material will be presented.

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

Boss, E., A. Waite, F. Muller-Karger, H. Yamazaki, R. Wannikof, J. Uitz, S. Thomalla, H. Sosik, B. Sloyan, A. Richardson, P. Miloslavich, J. Karstensen, G. Gregori, K. Fennel, H. Claustre, M. Cornejo, I. Berman-Frank, S. Batten, S. Acinas, 2018. Beyond Chlorophyll Fluorescence: The Time is Right to Expand Biological Measurements in Ocean Observing Programs. Community news, *Limnology and Oceanography Bulletin*, https://doi.org/10.1002/lob.10243

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

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 -- *in progress*

Provide the necessary details associated with every technology/measurement proposed (e.g., power, cost, and human effort). -- *in progress*

Document potential applications, including science case studies and lists of publications, and document measurement protocols. Develop adequate protocols when these are not available. – *not started*

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 parameters measured. – *not started*

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. – *not started*

Increase awareness of the availability of biological oceanographic datasets internationally and identify barriers to their access and use, particularly in developing nations. – *not started*

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

Finalize group's Website.

In Nov. 2018, the subgroup leads will meet at the Laboratoire D'Oceanographie de Villefranche to finalize a draft section for the GO-SHIP 'Manual', a document summarizing existing technology that could be incorporated to GO-SHIP cruises to measure plankton-relevant parameters, the relevant best-practice documents, associated costs and effort.
We will also work on organizing the 2nd in-person meeting of our group, possibly in conjunction with Ocean Obs'19.

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 difficulties at this time.

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.

BEYOND CHLOROPHYLL FLUORESCENCE

The Time is Right to Expand Biological Measurements in Ocean Observing Programs

Emmanuel Boss, Anya Waite, Frank Muller-Karger, Hidekatsu Yamazaki, Rik Wanninkhof, Julia Uitz, Sandy Thomalla, Heidi Sosik, Bernadette Sloyan, Anthony Richardson, Patricia Miloslavich, Johannes Karstensen, Gérald Grégori, Katja Fennel, Herve Claustre, Marcela Cornejo, Ilana Berman-Frank, Sonia Batten, and Silvia Acinas

An example of a flow-through system that could be incorporated on GO-SHIP cruises as one component to study plankton. It includes an automated microscope to capture the community of chlorophyll containing particles (McLane's IFCB), a spectro-fluorometer and fast-repetition-rate-fluorometer (WETLabs's ALFA) to study phytoplankton physiology, a particle sizer (Sequoia Scientific's LISST-100X) and a series of bio-optical instruments (WETLabs' AC-S, ECO-BB3, and CDOM fluorometer) to study the signature of upper-ocean plankton on the ocean color signals measured from space as well as constrain photosynthesis. Ocean water to this system is pumped with a diaphragm pump to minimize the impact on particles and is passed through a thermos-salinograph (SeaBird's TSG) to provide environmental information. This system has been installed around a sink of the R/V *Atlantis* as part of the NASA-funded NAAMES project (Photo credit: Lee Karp-Boss).

A new Scientific Committee for Ocean Research (SCOR, http://www.scor-int.org/) working group has been formed, entitled SCOR WG-154 "Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS, http://www.scor-int.org/SCOR_WGs_WG154.htm.)." The working group (P-OBS WG) is reviewing biological sensing technologies and measurements that are ready for integration into existing regional and global ocean observing programs. Multidisciplinary sets of measurements, whose choice is guided by research and societal benefit goals, will transform our understanding of ocean biology and its impacts on Earth systems.

The working group is currently considering measurements from two globally co-ordinated ocean observing networks: The Global Ocean Shipped-Based Hydrographic Investigations Program (GO-SHIP), http://www.go-ship.org/ and OceanSITES, http://www.oceansites.org/. GO-SHIP co-ordinates trans-basin ship surveys that are repeated at least once every 10 yr per transect. OceanSITES co-ordinates full ocean depth time series observations from moorings and repeat ship visits. Both programs are represented in the P-OBS WG, along with the Continuous Plankton Recorder (CPR) program, https://www.sahfos.ac.uk/ (the longest plankton observing system in the world), and the BGC-Argo-Biogeochemical Argo program (BGC-Argo program). BGC-Argo is implementing a global network of profiling floats equipped with bio-optical and biogeochemical sensors. Other P-OBS WG members cover areas such as remote sensing, in situ plankton measurement by imaging, genomics approaches, and biogeochemical modeling.

The P-OBS WG will help the community document the many recent advances in ocean sampling. For example, a global focus on genomic sampling of the oceans began with Venter's Global Ocean Sampling Expedition, which targeted surface waters of the North-West Atlantic and Eastern Tropical Pacific (2004–2006). It was followed by the *Tara* Oceans Expedition (2009–2013), which standardized sampling protocols and genomic analysis. Together with the *Malaspina* expedition (2010–2011), these programs dramatically expanded the geographical extent of genetic sampling of the ocean. They sampled temperate coastal and open oceans, the polar oceans, and both surface and deep waters, including mesopelagic and bathypelagic depths. Ocean time-series of genomic data have been expanding rapidly (e.g., Bermuda Atlantic Time Series, http://bats.bios.edu/; Integrated Marine Observing System, http://imos.org.au/; Hawaii Ocean Time series, http://hahana.soest.hawaii.edu/hot/; Carbon Retention In A Colored Ocean, http://imars.marine.usf.edu/cariaco; FRAM, https://www.awi.de/en/expedition/observatories/ocean-fram.html; and Marine Biodiversity Observation Network, https://ioos.noaa.gov/project/bio-data/). These and other programs have accelerated the availability of genetic data for the oceans. Standardizing, managing, and interpreting these genomic data is an emerging challenge for biologists and oceanographers.

Like genomics, in situ plankton imaging holds great promise. Yet, this approach brings major data demands and a requirement for community consensus. Commercial imaging systems have matured to the point where they are deployed regularly on profiling rosettes, on moorings, and in flow-through systems. These measurements allow high-resolution mapping of organisms and particles which are transforming our understanding of their distribution in the ocean. Pigment data and particulate organic carbon samples are also measured routinely and are being collected in conjunction with validation of ocean color remote sensing and calibration of sensors on autonomous platforms, such as the floats of the BGC-Argo program (many of these floats are deployed from GO-SHIP cruises).

Bio-acoustics and bio-optical sensors are mature technologies used on both moorings and research vessels. While the collection of such data are now standard, the quality control and interpretation of these data still require significant expertise and no global standards exist. By co-ordinating within these global sampling programs, relevant expertise can be shared to compile Best Practices for plankton observations.

Finally, flow-cytometric analysis of marine water samples is a very powerful tool to detect, discriminate, and quantify auto- and heterotrophic bacteria, eukaryotic micro-organisms, and viruses. It has expanded to include robust commercial ocean-going instruments, including some that can be deployed in situ (with remote control from the lab as-needed), including on moorings and in flow-through systems. Some flow cytometers can sort cells based on optical properties related to their size, granularity, structure (nucleic acid, proteins, lipid content) and physiological characteristics, allowing for further quantification of sub populations of particles. Imaging cells is also possible with some flow cytometers—these pictures can provide morphological characterization of the particles (cells) and enhance identification capabilities, especially for microplankton. Conversion of flow cytometry data to biovolume provides a direct pathway to quantify group-specific biomass.

The advances detailed above motivated the formation of P-OBS WG. Its main charge is to identify best practices (technologies and sampling protocols) allowing the incorporation of plankton-related measurements into global ocean observing platforms (initially GO-SHIP and subsequent expansion into the mooring array of OceanSITES).

Among the challenges that P-OBS WG has identified is the lack of standardization and protocols to perform automated quality control, data formatting, and immediate delivery of validated observations to open-use databases (e.g., OBIS). A major challenge is to prepare such global databases for a quantum jump in data volume once these protocols and data pipelines can be streamlined to deliver data.

Together, we hope to facilitate biological sampling of the oceans and promote more robust, systematic, and routine analyses. These data will establish a baseline from interoperable and comparable datasets, and facilitate the identification of spatial gradients and temporal trends in biodiversity and other key biological parameters. The data are needed to help in the calibration of autonomous platforms, contribute to the validation of remote-sensing algorithms, and constrain biogeochemical and ecosystem models of the ocean. Finally, these data are required to understand and quantify the benefits that the ocean provides to society, and how these benefits are being impacted by global change.

The P-OBS WG seeks help in identifying practical and ready-to-use plankton observation methods that use acoustics, including use of the established Acoustic Doppler Current Profiler on the GO-SHIP and OceanSITES platforms, and other programs. More generally, we invite the oceanographic community to provide information to ensure our findings represent existing and ready-to-use methodologies for plankton observations that could be readily integrated into global sampling programs. Information can be provided to any member of our WG.

ACKNOWLEDGMENT

The idea to establish the P-OBS SCOR working group was conceived following discussions at the Global Ocean Observing System (GOOS) workshop on implementation of Multi-Disciplinary Sustained Ocean Observations (IMSOO, http://www.goosocean.org/index.php?option=com_oe&task=viewEventRecord&eventID=1825), funded by NSF, NASA, and NOAA.

Emmanuel Boss, University of Maine, Orono, ME

Anya Waite, Alfred Wegener Institute Helmholtz Centre, Bremerhaven, Germany

Frank Muller-Karger, University of South Florida, St. Petersburg, FL

Hidekatsu Yamazaki, Tokyo University of Marine Science and Technology, Tokyo, Japan

Rik Wanninkhof, National Oceanic and Atmospheric Administration, AOML, Miami, FL

Julia Uitz, Laboratoire d'Océanographie de Villefranche, Villefranche sur Mer, France

Sandy Thomalla, Southern Ocean Carbon and Climate Observatory, CSIR, Cape Town, South Africa

Heidi Sosik, Woods Hole Oceanographic Institution, Woods Hole, MA

Bernadette Sloyan, CSIRO, Oceans and Atmosphere, Hobart, TAS, Australia

Anthony Richardson, CSIRO Oceans and Atmosphere Flagship, Brisbane, QLD, Australia

Patricia Miloslavich, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS, Australia

Johannes Karstensen, GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany

Gérald Grégori, Aix-Marseille University, CNRS/INSU, Université de Toulon, IRD, Mediterranean Institute of Oceanography (MIO), Marseille, France

Katja Fennel, Dalhousie University, Halifax, NS, Canada

Herve Claustre, Laboratoire d'Océanographie de Villefranche, Villefranche sur Mer, France

Marcela Cornejo, Escuela de Ciencias del Mar, Pontificia Universidad Católica de Valparaíso and Instituto Milenio de Oceanografía, Valparaíso, Chile

Ilana Berman-Frank, University of Haifa, Haifa, Israel

Sonia Batten, SAPHOS, Nanaimo, BC, Canada

Silvia Acinas, Institute of Marine Sciences (ICM)-CSIC, Barcelona, Spain

2.1.18 WG 155: Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change *Halpern* (2017)

Co-chairs: Ruben Escribano (Chile) and Ivonne Montes (Peru)

Other Full Members: Francisco Chavez (USA), Enrique Curchitser (USA), Boris Dewitte (France), Sara Fawcett (South Africa), Salvador Lluch-Cota (Mexico), Baye Cheikh Mbaye (Senegal), Andreas Oschlies (Germany), and Parv Suntharalingam (UK)

Associate Members: Edward Allison (USA), Javier Aristegui (Spain), Xavier Capet (France), Ming Feng (Australia), Iris Kriest (Germany), Eric Machu (France), Ryan Rykaczewski (PICES, USA), Lynne Shannon (South Africa), Damodar Shenoy (India), and Beatriz Yanicelli (Chile)

Terms of Reference

Executive Committee Reporter: David Halpern

1. Name of group

WG 155 Eastern Boundary Upwelling Systems (EBUS): Diversity, Coupled Dynamics and Sensitivity to Climate Change

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

Since January 2018, WG 155 EBUS has been developed:

1. Presentation of SCOR WG at the 2018 Ocean Observations Research Coordination Network (OceanObs RCN) on February 11 in Portland, USA: Francisco Chavez.
2. First Online meeting (February 13).
3. Email discussions to prepare an abstract to the call for community white papers for Ocean Obs'19 (February 23-March 5).
4. Email discussions to pre-review the terms of reference (March).
5. Organizing the first in-person meeting that will be held in conjunction of the PICES 4th International symposium ECCWO (June 3).
6. Presentation of the SCOR WG at the IMBeR SSC Meeting on April 15-17 in Hobart, Australia: Ruben Escribano.

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

Not yet published.

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

No significant advances have been achieved yet. Our major efforts have been in review/refinement (preliminarily) the terms of references; these are

1. **Synthesize existing knowledge, that is, summarize and review current trends and drivers of oceanography and ecological properties in order to identify the key feedback processes, establish similarities, differences and the knowledge gaps**
2. **Develop an assessment tool for EBUS by making a web-based platform to graphically query published data, model outputs as well as protocols for measuring key properties and indicators in EBUS.**
3. **Develop a scientific review of numerical model results to establish the strengths and weaknesses of regional coupled models presented as a high impact factor 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), Monterey Bay

(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 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 natural 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.

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

1. To write a multidisciplinary synthesis peer-reviewed publication
2. To write the summer school proposal and apply for funds
3. To discuss and plan a second in-person meeting
4. To conduct bi-monthly online meetings
5. To contribute with CLIVAR RF EBUS (Trieste 2019) to teaching some lectures through the participation of members who are in Europe and do not require travel funding

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

Not difficulties yet.

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

Due to the short time and because planning and defining a host institution requires discussion, we have decided to move the summer school from 2019 to 2020. We are aware that CLIVAR EBUS RF is planning a summer course for 2019, but our SCOR WG needs more time to organize this activity and to search for sponsorship and funding. This issue will be further discussed during the first in-person meeting in June 2018.

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.

2.2 Working Group Proposals

2.2.1 Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity *Smythe-Wright*

1. Summary

Marine primary productivity controls ocean food webs and biogeochemical cycles, exerting a strong influence on CO_2 uptake from the atmosphere and global climate. Unprecedented anthropogenic pressure has created an urgent need to understand environmental controls on primary productivity. This, in turn, relies on consistent and coherent measurements across a range of spatial and temporal scales. Productivity estimates from conventional ^{14}C-uptake experiments require discrete bottle sampling (and suffer potential experimental artefacts), while those from mixed layer dissolved gas measurements (O2, CO2 etc.) do not directly measure gross photosynthesis, and lack the temporal resolution needed to validate daily remote-sensing observations. Active chlorophyll a (Chla) fluorescence-based measurements can overcome these challenges. First introduced several decades ago, techniques such as Fast Repetition Rate fluorometry have significantly advanced our understanding of environmental controls on phytoplankton physiology and productivity. However, rapidly growing capacity to engineer and deploy sea-going fluorometers now poses a major time-sensitive challenge: Conceptual, operational and computational approaches to extract and interpret fluorescence parameters are rapidly diverging. While an increasing number of (often custom-built) sensors, protocols and processing algorithms is being produced, no standard best practices have been formally adopted by the research community. Rapidly growing data sets may thus become increasingly difficult (perhaps impossible) to reconcile, thereby limiting our capacity to integrate observations over large-scales. This SCOR working group will address this challenge by producing international standards for best-practices in the acquisition and interpretation of active Chl fluorescence data, while also creating a framework for a global synthesis of existing and future data.

2. Scientific Background & Rationale

2.1. Importance of high-resolution primary productivity measurements

Marine primary productivity sets the carrying capacity of oceanic ecosystems and exerts a profound influence on the cycling of nutrients and carbon in the biosphere. Global climate change has created a pressing need to understand the environmental controls on marine productivity, its variability over space and time, and its potential responses to altered upper ocean conditions (Behrenfeld et al. 2006, Moore et al. 2018). Addressing these questions requires consistent and coherent measurements of oceanic primary productivity across a range of scales.

Historically, most measurements of marine primary productivity have come from ship-board ^{14}C incubation methods (e.g. Halsey & Jones 2015). Over the past half century, the oceanographic community has built a large global repository of ^{14}C uptake data (http://www.science.oregonstate.edu/ocean.productivity), and used these to inform our understanding of spatial and temporal trends in marine productivity (Behrenfeld & Falkowski 1997). The ^{14}C method, while highly sensitive and simple in principle, has limitations. Most notably, the technique requires the collection of discrete samples, which limits the spatial resolution of measurements, whilst introducing potential experimental artefacts ('bottle effects') via sample containment.

Over the past two decades, there has been an increasing focus on the use of autonomous sensors to quantify marine primary productivity. Satellite-based algorithms are becoming increasingly used to infer productivity from remotely sensed variables (typically, chlorophyll, carbon, light and sea surface temperature) (e.g. Behrenfeld & Falkowski 1997, Behrenfeld et al. 2015). This approach has the advantage of providing synoptic spatial coverage of the surface ocean, but it requires field-based measurement for parameterization of physiological models and algorithm validation (e.g. Lin et al. 2016). More recently, a number of groups have begun using automated chemical sensors to measure mixed layer dissolved gases (e.g. O_2, N_2, Ar, and CO_2) as tracers of net community productivity. These measurements capture bulk productivity on the time-scale of days to weeks, but do not directly measure gross photosynthetic production or physiological responses, nor do they provide appropriate validation for daily remote-sensing observations.

2.2. Rapid expansion of active chlorophyll fluorometers to assess primary productivity

Active chlorophyll fluorometers were introduced to oceanography in the late 1980s. Seminal papers detailed methods to quantify photosynthetic electron transfer rates (ETR), by resolving the induction of chlorophyll a (Chla) fluorescence following rapid modulation of an excitation light source (Kolber & Falkowski 1993, Kolber et al. 1998). As a component of the photosynthetic process, ETR is inherently coupled to the rate of light-dependent water splitting, oxygen evolution and ATP and NADPH production, and, as such, provides an estimate of gross primary productivity. Early studies demonstrated that ETRs derived from active Chla fluorescence measurements correlated well with parallel ^{14}C-uptake rates (Kolber & Falkowski 1993) and gross oxygen evolution rates (Suggett et al. 2003). Others demonstrated important applications of Chla fluorescence data to understand the physiological status of phytoplankton in situ, including cellular responses to iron limitation (e.g. Kolber et al. 1994).

Motivated by these pioneering studies, and facilitated by technological developments, there was a surge of interest in the application of active fluorometry for oceanic productivity and photo- physiological studies. The first commercially available Fast Repetition Rate Fluorometer (FRRf; and derivative FIRe fluorometers, Gorbunov & Falkowski 2005) instruments were released in the early 2000s (Chelsea Technologies Group Ltd., Satlantic Inc.). Most efforts aimed at further reconciling ETRs with ^{14}C-uptake (Corno et al. 2006, Suggett et al. 2006, Moore et al. 2006), and growing data sets repeatedly demonstrated strong covariance between parallel ETRs and ^{14}C-uptake measurements throughout the world's oceans. However, the results of this work demonstrated that the relationship between these measurements varied depending upon the prevailing phytoplankton taxa and/or environmental conditions (see Suggett et al. 2009, Lawrenz et al. 2013). Within a decade, FRRfs (and FIRe fluorometers) became standard instrumentation on many large-scale oceanographic programs (e.g. Atlantic Meridional Transect; Suggett et al. 2006, Hawaii Ocean Time-Series; Corno et al. 2006), and biogeochemical studies of ocean productivity (e.g. Behrenfeld et al. 2006).

While the application of FRRfs and related active Chla induction instrumentation continues to grow, routine derivation of primary productivity from these measurements still faces significant challenges. Operational and technological constraints, as well as complexities associated with the algorithms used to derive ETRs from raw fluorescence data have hampered efforts to derive robust productivity estimates. A major EU program (PROTOOL) brought together a group of experts in an attempt to develop new and more robust ETR algorithms (Oxborough et al. 2012), whilst also incorporating multi-spectral measurements to better resolve the influences of diverse light harvesting across phytoplankton groups (see Silsbe et al. 2015). These critical developments catalysed renewed interest in the use of FRRf as an oceanographic measurement tool (e.g. Schuback et al. 2017, Zhu et al. 2017). This renewed interest, alongside new technological advances in light sources and detectors (PicoF and mini-FIRe, Lin et al. 2016; Hoadley & Warner 2017), point the way towards global-scale oceanographic deployment of active Chla induction fluorometers, using a new generation of systems on a range of platforms, including ships, gliders, mooring and floats.

Our capacity to quantify the spatial and temporal variability in oceanic primary productivity has thus never been greater. However, ***our rapidly growing capacity to engineer and deploy active Chla induction fluorometers now poses a major time-sensitive challenge***: Conceptual, operational and computational approaches used to extract and interpret fluorescence parameters are rapidly diverging. No standard best practices have yet been formally adopted as a large number of (increasingly custom-built) sensors, protocols and processing algorithms are deployed worldwide. As a result, rapidly growing data sets may become increasingly difficult (if not impossible) to reconcile, thereby limiting our ability to build global data compilations and examine large-scale responses of marine productivity to environmental forcing.

2.3. Need and Timeliness for a SCOR working group

A meeting of world experts in active Chla induction fluorometry was recently held in Sydney (AQUAFLUO II: *Chlorophyll fluorescence in the aquatic sciences*, December 2017). Discussions identified a time-critical need for more robust practices to overcome uncertainties and inconsistencies associated with instrument operation, deployment and data fitting and interpretation. As more groups custom-build Chla induction fluorometers, there remains no objective set of international standards for hardware configurations (e.g. excitation-emission wavelengths) or data analysis protocols, and no conventions to validate and inter-calibrate data from these sensors. **Such inter-comparability is critical if we seek to build a global repository of active fluorescence data**. Practices should be based upon minimal, robust assumptions, with clear information on how taxonomic and environmental factors may affect the choice of operating conditions. Establishing guiding principles and models that will allow comparability across research groups is paramount.

Previous working groups have inter-compared active fluorescence data from different commercially available instruments (e.g., AQUAFLUO 2007; GAP-2008, Suggett et al. 2009;

PROTOOL, Silsbe et al. 2015). **These efforts, however, did not include an explicit focus on standardized data collection and analysis, nor did they produce recommendations, best-practice guides and software tools to help non-experts employ this method. Moreover, the rapid development of new cheaper and miniaturised instrumentation, along with a number of conceptual advances in our understanding of chlorophyll fluorescence, has created a need to revisit inter-comparisons of operability and data output.** Progress must be driven the broader community's need to establish and embed standardized operation, data retrieval and reporting/archiving. To this end, our proposed working group will assemble a diverse set of scientists to move the research community forward in the application of active Chla induction fluorometry to understand global-scale patterns in marine productivity.

Terms of Reference.

Our proposed working group will work to achieve the following specific objectives.

- **i.** To inter-compare active Chla induction measurements across instruments and approaches, identifying key aspects of instrument configuration, deployment and parameter acquisition that may introduce variability in retrieved data.
- **ii.** To develop, implement and document internationally-agreed best practice for data acquisition, standardised output formats and archiving approaches.
- **iii.** To develop, implement and document internationally-agreed best practice for processing raw fluorescence data to retrieve photosynthetic parameters and primary productivity estimates, taking into account taxonomic and environment factors driving diversity in chlorophyll fluorescence signals in the oceans. From this work we will develop freely available software and documentation to allow non-specialist users to process fluorescence data according to these best practices.
- **iv.** To produce a new synthesis of parallel ^{14}C and active Chla induction measurements that can be used to examine the relationship between these two productivity metrics under a range of field conditions. We will also consider other metrics of Net Primary Production alongside ^{14}C.
- **v.** To develop a global database structure for hosting quality-controlled active Chla induction measurements, creating standards for data and meta-data collection, submission and archiving.
- **vi.** To build a framework through which in situ active Chla induction data can be used to validate and refine relevant remote sensing measurements (e.g. sun-induced fluorescence yields).
- **vii.** To share knowledge and transfer skills in instrumentation, best practice, quality control and data stewardship with the rapidly expanding user community in developing nations.

3. Working Plan and Time-line

We will meet our objectives via two dedicated in-person meetings, and additional satellite meetings and video conferences focused on implementing and/or delivering our various objectives, and managing the overall project.

Year 1: Kick-off meeting; laboratory inter-comparison study

Objectives i-ii. We will conduct a SCOR-funded laboratory inter-calibration of the state-of-the-art instrumentation, covering the broadest range of commercial and custom hardware and software (FRRf, FRRf-type single pulse, FRRf-flash, LIFT; as well as mini-FIRe and PicoF). This exercise will examine inter-comparability among existing configurations, studying the effects of various sources of variability (hardware and software) on parameter retrieval. We will conduct this exercise at a relatively central location amongst the WG members (likely Vancouver) using a range of marine phytoplankton cultures (with different pigment complements, cell size, taxonomic group) grown under various experimental conditions, including light and nutrient availability.

We will develop a standard set of protocols, including hardware configurations, parameter selection, algorithm assumptions, data formatting, sample collection/treatment. All participants will contribute in their various expertise to a user guide and best-practices report. This work will also likely lead to a significant peer-reviewed publication.

We will also begin to consider how challenges in ship-board deployment may potentially limit capability to meet best practice. This will be addressed, in part, through a parallel set of experiments focusing on known variables (e.g. dark exposure time) that create potential for uncertainty in field-based measurements. Thorough field tests addressing specific at sea deployment challenges be addressed in year 2.

Year 2: Field evaluations of best-practice

An annual meeting will be conducted in year 2 to evaluate project progress. As Working Group members will likely be required to fund their participation, this will be timed to coincide with a large international meeting such as ASLO. Full video conferencing facilities will be made available to maximize participation among all members.

The focus for this second year is:

Objectives i-ii and iv. Working Group members will critically assess application of 'best practice' (developed from the initial laboratory cross-instrument screening) to their own at-sea deployments. Where WG members are able to exploit existing funded opportunities for oceanographic fieldwork, 'best practice' will be evaluated relative to other possible field-deployable configurations. The goal of this is to (a) examine precision and accuracy achievable through a universally applied 'best practice' under any given scenario (e.g. ultra-oligotrophic waters) and specific instrumentation or mode of deployment (e.g. profiling versus underway). Exercises will also include a standardized comparison of FRRf-based estimates of productivity against parallel NPP (^{14}C measurements) as an independent productivity benchmark. This work will be conducted independently by WG members, following standard protocols established by the group in year 1, including the collection of ancillary data that can be used to interpret results.

These field-based evaluations will enable us to examine how ‘best practice’ developed from the laboratory can scale to field applications, and to recommend modified approaches for the collection of robust and inter-comparable field studies. The work will also lead to a new synthesis of parallel ^{14}C-FRRf measurements that can be used to analyse the relationship between these two productivity metrics (and potentially others) when obtained using standardized methodologies. All participants will contribute their expertise to compile these results into a report best-practices guide (objectives ii-iii), and a significant peer reviewed article.

Year 3: Begin ‘legacy phase’ through software and database development

Objectives iii-v. A SCOR funded annual meeting in year three will focus on developing the software and database ‘legacy’ phase. Based on the documents from objectives (i-iv) detailing the optimised workflows for processing and parameterising raw fluorescence data, we will initially conceptualise and then produce an open source software platform for broad scale and cross-instrument data processing. We envisage that this will take the form of a “CO2-sys” type product, enabling user selectable algorithms, and ensuring that ‘first order’ data sets (e.g. raw induction curves) are archived in order to enable re-processing of data at a future date. In this way, users will be able to select different specific parameterisation routines, with the flexibility needed to include data from across different approaches in deployment and configuration. The long-term motivation for this work will be the production of a global database (likely hosted by NASA), designed to archive both raw data and derived parameters. We envisage a data entity similar to (or as part of) NASA’s SeaBASS archive (https://seabass.gsfc.nasa.gov) built on defined standardised parameters (and units etc.), paralleling one already in existence for carbon-uptake data (http://www.science.oregonstate.edu/ocean.productivity/field.data.fl.readme.php). Significantly, we have developed this proposal with specific input from Chris Proctor and Susanne Craig at NASA. They are not listed as WG members, but they have both expressed strong interest in this work, and are expected to participate in relevant meetings, with support from NASA.

Year 4: Remote sensing integration and public release

Objective v-vi: As part of our final meeting, we will formalise all documentation and (beta-version) software for public release as part of an international and community wide meeting. For example, dedicated workshops and events at ASLO or Ocean Optics (and/or a specialist meeting, e.g.AQUAFLUO III). We will seek independent funding (e.g. NASA) to support both broad attendance from amongst the WG but also to support outreach and visibility. Importantly, this meeting will enable us to disseminate (‘launch’) all material to the broadest user base, thereby transforming capacity and creating the maximum visibility. Releases will also be accompanied by press releases and launches through the Working Groups’ institutions and regional networks. Working closely with NASA, we will look to host standard protocol documentation and tools through the IOCCG website as well as data archival portals.

A secondary component of this final meeting will be a one-day session for WG members to build a framework enabling non-specialist users to exploit growing databases with remotely retrieved (e.g. satellite) bio-optical data. We will produce a document detailing steps needed (and data sets required) to validate and potentially refine remotely sensed fluorescence data products, with initial proof of concept data collected earlier in this working group (Year 2).

4. Deliverables

Addressing our objectives will result in the following deliverables:

i. Open access documents fully detailing (a) Standard Operating Procedures (and "Best Practices") that can be applied commonly across (and/or account for differences amongst) instrument type, instrument configuration, and deployment platform; and (b) framework to apply chlorophyll fluorescence data sets to validate and potentially refine remotely sensed fluorescence data products.
ii. Open source "CO_2-sys" type data analysis tool for fluorescence induction curve processing.
iii. New data set of NPP (^{14}C) – active Chla induction inter-comparisons across a variety of oceanographic regimes, conducted with standardized methodology
iv. Web-based global data archival portal (and associated information repository) for data extraction according to user defined temporal-spatial criteria
v. Peer reviewed papers that report instrument inter-comparison exercises from both the laboratory and field.

5. Capacity Building

Fundamentally, our Working Group approach and deliverables provide broad-scale (global) capacity building towards all current users of existing active Chla induction instrumentation. However, by providing a series of standardised operating procedures and open source tools to both collect, parameterise and archive data, we aim to expand the global user group for active fluorescence data, enabling non-specialized users to deploy a highly sophisticated method. The open source nature of the software and archiving tools, as well as the community-wide release through global networks ensure that the outputs have the furthest possible reach. Importantly, our group includes Working Group Members from Developing Countries (e.g. Brazil, South Africa) as well as early career stages to embed potential capacity building from the outset of the project.

Depending on co-funding that can be sourced for the year 4 launch, we see this meeting as an opportunity to include a training event of the new products ('CO_2sys'-type data processing tool and web-based archive) to the broader (and prospective future) user communities.

6. Composition of Working Group

Our Working Group will be comprised of 10 Full and 10 Associate Members that bring collective expertise from biophysics, photosynthesis, bio-optics (including remote sensing), oceanography, data archiving, and instrument and software development. Full Members are primarily responsible for the delivery of our objectives, with the Associate Members providing important input on key specific areas. Our Full members represent 8 different nations, including 1 emerging/developing nation (South Africa) and 2 early career researchers (Thomalla, Schuback). Similarly, our contributing members represent 7 different nations with further representatives from developing nations (Brazil) and early career researchers (Silsbe, Varkey). Finally, we also include a list of additional experts (7.3. Others), with particularly specialised skill sets and who have expressed interest in participating in one or more of the dedicated workshops. We fully recognize some gender imbalance in the overall WG composition, but note that half of our Associate Members are female. The oceanographic active Chl fluorescence field was initially male-dominated from its inception, and we are committed to addressing this gender imbalance moving forward.

6.1. Full Members

Name	Gender	Place of work	Expertise relevant to proposal
David Suggett (Co-chair)	M	Australia	Active chlorophyll fluorescence; phytoplankton physiology
Philippe Tortell (Co-chair)	M	Canada	Sea-going autonomous primary productivity
Zbignew Kolber	M	USA	FRRf instrument development (LIFT); phytoplankton physiology; data analysis and computation
Sandy Thomalla	F	South Africa	Deployment platforms; remotely sensed fluorescence; data analysis, visualisation and archiving
Kevin Oxborough	M	UK	FRRf instrument development (FRRf); phytoplankton physiology; data analysis and computation
Maxim Gorbunov	M	USA	FRRf instrument development (Pico-F); phytoplankton physiology; data analysis and computation
Nina Schuback	F	Switzerland	Active chlorophyll fluorescence; phytoplankton physiology
Tetsuichi Fujiki	M	Japan	FRRf instrument development (FRRf-flash); phytoplankton physiology; data analysis and computation
Jacco Kromkamp	M	Netherlands	Active chlorophyll fluorescence; Primary productivity; phytoplankton physiology; deployment platforms
Mark Moore	M	UK	Active chlorophyll fluorescence; phytoplankton physiology; data parameterisation and analysis

6.2. Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
Greg Silsbe	M	USA	Active chlorophyll fluorescence; data analysis and computation; data analysis, visualisation and archiving; Remote sensing
Kim Halsey	F	USA	Primary productivity; phytoplankton physiology, ^{14}C applications
Ondrej Prasil	M	Czech Republic	Primary productivity; phytoplankton physiology
Doug Campbell	M	Canada	Active chlorophyll fluorescence; Primary productivity; phytoplankton physiology
Aurea Ciotti	F	Brazil	Primary productivity; Sea-going autonomous primary productivity
Yannick Huot	M	Canada	Active chlorophyll fluorescence; remote sensing and bio-optics; data handling
Anna Hickman	F	UK	Bio-optics and fluorescence; remote sensing; modelling
Stefan Simis	M	UK	Active chlorophyll fluorescence; remote sensing and bio-optics; data handling; open source fluorometer hardware
Ilana Berman-Frank	F	Israel	Primary productivity; phytoplankton physiology
Deepa Varkey	F	Australia	Photosynthesis, Chl Fluorescence and data analytics (functional genomics)

6.3. Others:

Additional experts with specialised skill-sets will participate in one or more of the dedicated workshops. All of these individuals have confirmed their interest in our work.

Susanne Craig	F	USA (NASA)	Active chlorophyll fluorescence, Remote sensing Data archiving
Chris Proctor	M	USA (NASA)	Active chlorophyll fluorescence, Remote sensing Data archiving

Paul Falkowski	M	USA	Active chlorophyll fluorescence; Primary productivity; phytoplankton physiology;
Kenneth Hoadley	M	USA, Australia	Active chlorophyll fluorescence; open- source fluorometer development; phytoplankton physiology;

7. Working Group contributions

Tetsuichi FUJIKI brings unique *in situ* FRRf instrumentation for inter-comparison and parameter retrieval (objectives i-iii). Access to field-based deployments in the Pacific (including autonomous platforms, and miniaturised sensors for gliders and floats) provides essential contributions to objectives ii-v.

Maxim GORBUNOV brings key expertise in hardware and software development (including data analysis and algorithm development) of various instrument approaches (FRRf, FIRe, PicoF), and applications of these instruments to different ocean systems (polar, temperate and tropical), thus contributing to objectives i-v.

Jacco KROMKAMP has key expertise developing autonomous productivity measurements (including ships of opportunity) and fluorometer inter-comparisons, contributing significantly to objectives i-v. He will also contribute to database development and data archival through parallel efforts from previous (e.g. leading PROTOOL) and current EU projects examining coastal primary productivity (objective vi).

Zbigniew KOLBER will contribute to identifying fluorescence properties indicative of photo-physiological performance, and assessing the utility of these properties as a proxy for primary production (objectives i-ii, iv)**.** His background in developing new FRR fluorescence instruments (FRRf, LIFT) and data processing algorithms, will be critical to the project.

Mark MOORE will contribute to objectives i-iv, and help us in capacity building (objective vii), based on his previous work with groups in India. In addition to attending to both laboratory and field-based evaluation exercises, Moore will contribute equipment and data from a NERC UK funded autonomous active chlorophyll fluorometer development project (‘STAFES-APP’) to all activities.

Kevin OXBOROUGH has expertise developing single turnover active chlorophyll fluorometer systems for installation on marine autonomous systems. He will focus on objectives i-iii and v, with some involvement in objectives iv, vi and/or vii. His background in developing new fluorescence algorithms from terrestrial and aquatic organisms, as well as new software and hardware, will be critical.

Nina SCHUBACK will contribute significantly to instrument inter-comparisons and reconciliation of electron transfer rates with NPP (objectives i-ii, iv), in particular through her specialist focus and field opportunities in polar systems. Her computational and data handling skills will also contribute to objectives v, vii.

David SUGGETT will be responsible for joint-management and coordination of the overall project and thus contribute to the delivery of all activities. His specific expertise and unique instrumentation pool (e.g. FRRs, LIFT, multi-speQ) is essential to laboratory inter-comparisons and their associated output (i-iv, vi) and in the synthesis of larger data sets for objectives v-vi.

Sandy THOMALLA will contribute to *in situ* application of instrumentation to guide best practice, and in particular through autonomous deployments (objectives ii, iv). Her expertise in development and validation of ocean colour algorithms will contribute to handling and archiving of large data sets, and validation of sun-induced fluorescence observations from satellites (objectives v, vi).

Philippe TORTELL will be responsible for joint-management and coordination of the overall project and thus contribute to the delivery of all activities. His expertise in development and deployment of sea-going autonomous productivity measurements will contribute to all objectives. He will likely organize and host the first full WG meeting and associated inter-comparison work.

8. Relationship to other international programs and SCOR Working groups.

Some of the very first SCOR working groups, more than 50 years ago, focused on understanding large-scale patterns in oceanic productivity; WG3 "*Measurements of the Productivity of the Sea and of the Standing Crops of Phytoplankton and Zooplankton (renamed Biological Production of the Sea)*", WG20 "*Radiocarbon Estimation of Primary Production (approved in 1965; joint with ICES and UNESCO)*", and WG 4 "*Estimation of Primary Production under Special Conditions*". Since that time, new technologies for ocean observations have radically transformed our ability to quantify marine productivity over a range of scales. Yet, no single SCOR Working Group has been dedicated to standardising and ensuring best practice of rapidly expanding autonomous productivity measurements.

As stated in section 2.3, previous working groups have attempted to inter-compare active fluorescence data from different commercially available instruments (e.g., AQUAFLUO 2007; GAP- 2008, Suggett et al. 2009; PROTOOL, Silsbe et al. 2015). These past efforts highlight major global demand and incentive to reconcile data from across an ever evolving and growing instrument base. However, they did not include an explicit focus on the need for standardized data collection and analysis, nor did they produce best-practices guides and software tools for wide distribution to non-experts. Our WG proposes to further advance the field by producing a singular set of openly available recourses needed to generate large inter-comparable data sets of active fluorescence (FRRf and FRRf-like) measurements. Such efforts mirror programs that broadly exist for global bio-optical data sets and ^{14}C uptake data (e.g. Prof. Mike Behrenfeld, Oregon State University; http://www.science.oregonstate.edu/ocean.productivity/field.data.fl.readme.php).

Our objective to better reconcile field-based fluorescence data with remotely sensed fluorescence parallels efforts initiated by researchers working in terrestrial systems (e.g. SpecNet, http://specnet.info/index.php). Several of our objectives (e.g. v-vi) will directly leverage with the EU-funded Horizon 2020 project MONOCLE (www.monocle-h2020.eu; coordinated by Stefan Simis–Associate member of this proposed WG), which is already developing state-of-the-art networking for in situ sensors, links with satellite observations, data visualisation and analysis tools (e.g. anomaly detection), which can be applied to instrumentation once best-practice is established.

By introducing quality control and best practice procedures into rapidly growing capability to measure key ocean biogeochemical metrics, we parallel SCOR WG 142 "*Quality Control Procedures for Oxygen and Other Biogeochemical Sensors …*", WG143 "*Dissolved N_2O and CH_4 measurements…*" and WG148 "*International Quality Controlled Ocean Database…*". As a founding member of WG143 (which is now coming to an end), Tortell has significant experience with the implementation of a successful SCOR program. Similarly, our focus on developing inter- comparable data sets to support a global database compliments other Working Groups, such as WG147 "*Towards comparability of global oceanic nutrient data (COMPONUT)*" and WG149 "*Changing Ocean Biological Systems (COBS): …*". Finally, by providing a means to standardise and archive active fluorometry data, we will support broader implementation of the growing instrument base of active fluorometers into existing global sampling programs. This theme underpins other Working Groups, e.g. WG154 "*Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)*".

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

Tetsuichi FUJIKI

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2.2.2 The Surface Ocean CO_2 Mapping intercomparison initiative: Phase 2 (SOCOMv2)

Smythe-Wright

1. Summary

In recent years, a large number of surface ocean partial pressure of carbon dioxide (pCO_2) studies emerged, taking advantage of novel statistical and machine-learning methods together with the increasing number of available observations in continuously growing databases. These studies led to the discovery that the oceanic sink for carbon dioxide (CO_2) from the atmosphere is much more variable than previously recognised, challenging on the one hand our mechanistic understanding of the oceanic carbon cycle and on the other hand our ability to project the future evolution of the oceanic carbon sink. These methods, however, rely on extensive interpolation of the available observations and it is unclear how reliable these estimates are in data-sparse regions or seasons. The Surface Ocean pCO_2 Mapping intercomparison initiative (SOCOM), a voluntary project established in 2013 during the 9th International Carbon Dioxide Conference (ICDC9) in Beijing, China, gathered more than a dozen diverse methods developed by various groups. Its phase 2 (SOCOMv2) now sets out to quantify the uncertainty in air-sea CO_2 flux estimates, integrate novel data and coastal ocean estimates and help design future observing networks. The results of this project will form a valuable asset to the global carbon community and help to improve data-anchored state estimates spanning decades. This group will thereby provide an essential resource in response to broad demand from within the modeling community, including with efforts focused on projections of ocean carbon uptake, as well as a critical component of efforts towards limiting temperature perturbation by 2100 to 2°C.

2. Scientific Background and Rationale

2.1 Increase in data availability – increasing number CO_2 flux estimates

Over the past decade, the number of publicly available surface ocean CO_2 observations has increased rapidly from 6 million in the first release of the Surface Ocean CO_2 Atlas (SOCAT) database (Pfeil et al 2013, Bakker et al 2014, Bakker et al 2016) in 2011 to 22 million data in 2017. This rich abundance of information has enabled scientists around the world to create a variety of new observation-based estimates of the ocean carbon sink, taking advantage of novel data-interpolation techniques based on statistics and machine-learning to fill observational gaps.

While previous data-based estimates were limited to climatologies, the increase in available observations, both in space and time, has opened new research avenues, such as studies of the variability in the air-sea exchange of CO_2 on interannual to decadal time scales (Landschützer et al 2015, Rödenbeck et al 2015, Ritter et al 2017). These studies suggest much stronger variability on interannual to decadal timescales than earlier model estimates (Rödenbeck et al 2015, Landschützer et al 2016, Gregor et al 2018), calling into question the mechanistic understanding gained from ocean models and challenging our ability to predict the future ocean carbon sink on decadal timescales.

New measurements will be made public through SOCAT in annual releases and in addition, carbon estimates based on observations from autonomous floats are complementing the shipboard data. Hence, improved observation-based studies of the ocean carbon sink will emerge. This development, however, is uncoordinated and lacking in institutional or funding support needed for a careful weighing of priorities moving forward.

2.2 Why is this an important development?

Global assessments suggest that, in recent decades, the ocean has annually taken up about 25% of the CO_2 emitted by human activities (Le Quéré et al 2018). This assessment is based on ocean forward models with a variety of observational approaches for estimating mean ocean CO_2 uptake in the 1990s and cumulative uptake over the full industrial period. Thus, the year-to-year variability, as well as the integrated CO_2 uptake that has occurred since the 1990s is constrained by ocean forward models – the same models with a pronounced bias in variability relative to recent observationally-based estimates.

In light of the Paris climate agreement, it is essential to better understand the mechanisms behind the variability in oceanic CO_2 uptake and to improve ocean models and their near-term projection of the ocean CO_2 uptake in order to test whether we are on the right track towards the 2°C (or 1.5°C) target (Peters et al 2017). The novel observation-based ocean sink estimates can help to achieve these goals, yet without a coordinated effort this opportunity might be lost.

2.3 Why is there a need for an intercomparison project?

Despite the strong increase in available surface ocean pCO_2 observations, shipboard measurements and mooring data are still heterogeneously distributed and thus CO_2 flux estimates based on these data must rely heavily on data interpolation. The resulting estimates are therefore limited by this as well as other sources of uncertainty. However, it is still common practice that a single observation-based estimate, made available via institute websites or various databases, is selected for model comparison ignoring all possible uncertainties and shortcomings of the observation-based data product itself.

This approach is less the result of bad practice than the result of uninformed decision making due to the lack easily interpretable uncertainty estimates. Given the increasing number of data-based estimates available from various sources, the situation has become confusing and resembles a "buffet" of estimates. Furthermore, there is a lack of well-defined, widely agreed-upon criteria for assessing the uncertainty of individual mapping methods. We therefore propose to coordinate with the data providers, SOCAT and Biogeochemical Argo communities, to foster the continuation of observation-based estimates and assess their uncertainty.

The ensemble of estimates offers a variety of possibilities, such as the evaluation of its uncertainty based on the ensemble spread. This can perhaps be understood as the surface ocean observation-based analogue to model intercomparison projects such as C4MIP and atmospheric inversion intercomparison projects such as TransCom. There is a wide range of beneficiaries for such an exercise, e.g. the large modelling groups around the globe that need to evaluate

Earth System Model simulations and improve decadal CO_2 prediction systems as well as future projections.

There is further a lack of coordinated studies using the observation-based CO_2 flux ensemble on a number of spatial scales, from regional to global, concluding with the combination of open ocean mapping efforts with novel coastal ocean mapping efforts (Laruelle et al. 2017, Gruber 2015). Besides SOCAT, there is the potential to complement the ensemble with other measurements, such as measurements from the Global Ocean Data Analysis Project version 2 (GLODAPv2, Olsen et al 2016), and measurements made by vertically profiling floats (Williams et al 2017). This will enable us to study the variability of data-sparse regions such as the Southern Ocean, i.e. the ocean basin responsible for the uptake of the majority of human-emitted CO_2, but also previously largely unexplored basins, e.g. the Arctic Ocean (Yasunaka et al 2018).

Finally, the observation-based air-sea CO_2 flux ensemble and all documentation as well as publications will be publicly available to allow the wider community to advance their own experiments and studies.

2.4 Why is this best organized under the SCOR umbrella?

Many institutes around the globe, have benefitted from the availability of the increasing amount of ocean CO_2 measurements, and have developed their own observation-based air-sea CO_2 flux products (see e.g. Rödenbeck et al 2015). Traditional funding sources have helped these groups to develop new techniques and publish the results. This is, however, where the traditional support stops. No traditional funding source is prepared to fund the global community to take the necessary next step, namely global coordination that benefits other communities, global carbon cycle assessment studies, near-term predictions, future projections, and ultimately society itself. Therefore, today we turn to SCOR to ask exactly for that help.

At the 9th International Carbon Dioxide Conference (ICDC9) in Beijing, China, the idea of a pilot intercomparison project was born and SOCOM was initiated. By 2015, a total of 14 groups had contributed their estimates to this bottom-up air-sea flux assessment project and since then 2 studies emerged (Rödenbeck et al 2015, Ritter et al 2017), highlighting common features and differences between these estimates. Other studies, focusing on specific regions such as the Southern Ocean, used part of the ensemble (Landschützer et al 2015). The value of the emerging observational CO_2 flux constraints has since then continuously been highlighted (e.g. Gruber 2015, Mikaloff-Fletcher 2015, 2017, Ilyina 2017). However, a clear understanding of the robust features and the uncertainties is still lacking, indicating the need to pursue further analysis.

While the first phase of SOCOM has added valuable initial insights, the coordinated design of experiments planned in phase two will benefit the wider scientific community and will inform climate science policy. This can only be established from a generalized approach, i.e. when integrating the project in Earth System Modelling and global carbon budget analysis efforts. We therefore propose the establishment of a SCOR working group that combines the expertise of both the measurement community as well as the modelling community, together with SOCOM scientists, to tailor studies that provide (a) realistic uncertainty estimates alongside the flux estimates, (b) provide the baseline to improve global carbon budget analyses, decadal CO_2 predictions and future carbon cycle projections and (c) feed back to the measurement community where we lack valuable measurements.

3. Terms of Reference

There will be several objectives to the SCOR group. Firstly, we propose to develop a best data-based uncertainty estimate. Secondly, will propose to the carbon and climate modelling communities a set of recommendations for improved process-representation needed to improve simulations of carbon cycle variations. Thirdly, we use both the observational and modelling framework and test the current limits of the data-based CO_2 estimates.

Objective 1: Gather the up-to-date publicly available and best estimates of the global ocean carbon sink based on surface ocean CO_2 observations, in collaboration with data providers. Use the ensemble of data-based pCO_2 estimates and quantify the oceanic uptake of carbon dioxide and its uncertainty based upon the ensemble spread.

Objective 2: Provide best observation-based constraints of the marine CO_2 uptake, including known processes driving its variability, for global carbon budget analysis, **ocean model validation and carbon cycle projections, including a well-founded representation of the uncertainty derived from the ensemble**. This objective aims to (a) provide a baseline for model validation studies, (b) foster research regarding the source of the variability mismatch between observations and models and (c) provide guidance on the integration of observation-based estimates into global carbon budget analyses.

Objective 3: Combine open ocean air-sea CO_2 flux estimates with high-resolution coastal ocean estimates and to help design future sampling strategies. The working group will integrate new data streams (shipboard and float-based) as well as unique coastal ocean estimates, and further perform optimal observing system simulations using state-of-the- art ocean biogeochemical models.

4. Working Plan

Month 1 until month 6: In order to deliver the 3 objectives, a set of basic rules will be established. Participating data-mapping methods will need to be (a) publicly available and (b) well documented. Once these criteria are met, the set of data-based estimates will be collected and the scientists responsible for the method will be invited to contribute to the further analysis. Since we already have a good overview from the SOCOM pilot project, we do not expect this step to take longer than 6 months. As the project continues, however, we will be open to additional contributions as they emerge.

During the data gathering phase, we propose to host the first coordination meeting, bringing together representatives from the measurement, modelling, and global carbon budget analysis communities as well as the data providers. We propose to organize this meeting alongside the SOLAS open science conference in Sapporo, Japan from 21-25 April 2019. The aim of this meeting is to design the following main analyses:

- The first analysis will prioritise the ensemble-based air-sea CO_2 flux variability and uncertainty estimate. A sustainable goal arising from this analysis will be the development and publication of an uncertainty metric based upon the spread across the ensemble. This metric will serve as standard for future studies of similar scope.
- A second analysis will focus on the limitations posed by the observing network. Global model output will be selected to perform optimal observing system simulations to investigate the robustness of current estimates based on the observation platforms (ship, mooring, float, etc.) and the frequency and resolution of measurements used by the various methods. The analysis will define key regions of high CO_2 sampling priority.
- A third analysis will expand the open ocean estimates with newly emerging high- resolution coastal ocean pCO_2 estimates. The integration of estimates will provide a more complete picture of the ocean carbon cycle. Furthermore, it will focus on the coastal-to-open-ocean aquatic continuum and identify regions where we lack essential observations.

Lead scientists will be identified to coordinate each analysis. In addition, all other meeting participants and also scientists from various communities will be encouraged to actively contribute to the analysis. The existing resources, such as the SOCOM website, will be updated. The website will include all necessary information regarding participating methods and working groups and links to all publicly available data.

Following the first coordination workshop in Sapporo, key conferences will be selected that the majority of participants are planning to travel and side events as well as workshops will be organised during these meetings. Proposed upcoming conferences for the remaining annual meetings and workshops organised by the working group are the Ocean Sciences Conference in February 2020 in San Diego, California, USA and the 11th International Carbon Dioxide Conference (ICDC11), which will take place in late 2021. Combining the meetings with conferences will on the one hand provide the opportunity to immediately communicate results to the wider community, and on the other hand reduce the global travelling efforts and further help to reduce the environmental impact of the proposed SCOR working group. Furthermore, combining the working group meetings with bigger conferences will allow us to organise one hands-on training event for Early Career Scientists on data-mapping and uncertainty evaluation.

Month 6 until month 18: Suitable data-based estimates for each analysis will be selected based on analysis length, spatial extent and other criteria. For each study, a protocol will be created and published on the project website. Preliminary analysis will be performed in each task group and discussed at the second working group meeting, proposed during the Ocean Sciences meeting in 2020 in San Diego, California. Furthermore, we plan to interact with other projects, such as the Global Carbon Project, and the planned continuation of the Regional

Carbon Cycle Assessment Project (RECCAP II) effort, which is currently in preparation, as well as modelling groups for an exchange of data and knowledge.

Month 18 until month 30: Analyses will be performed. Results will be gathered and study protocols will be updated with the analysis methods used. During this period, additional coordination teleconferences will be held.

Month 30 until Month 42: The analyses will be revised according to the feedback received at the 2nd annual meeting and the study protocols will be finalized. Studies will be completed and manuscripts will be drafted including the results of each analysis. The chairs and working group members will organize a special issue in the open-access journal *Biogeosciences* where the manuscripts describing each analysis will be submitted.

A side-event will be organized at the 11th International Carbon Dioxide Conference meeting in late 2021 for the third working group meeting, where the final results including the uncertainty estimates will be presented. We further plan to organize a hands-on workshop for Early Career Scientists in large data handling and estimating uncertainties from observation-based CO_2 flux estimates. Additionally, to advance the long-term planning of oceanic CO_2 research, we propose to provide a statement for the ocean observing community that identifies regions in both space and time where additional measurements will have the largest impact on reducing uncertainties in CO_2 flux estimates. During the side-event, outreach activities as well as press releases will be discussed and drafted. Furthermore, possible follow-up side-events during one major international conference (European Geoscientific Union (EGU) general assembly in April 2022, the American Geoscientific Union (AGU) annual meeting in December 2021, or the Ocean Sciences meeting in February 2022) will be discussed and organised to best communicate the results to the science community. Furthermore, necessary follow-up studies will be discussed and continuation of the project beyond the life of the SCOR working group – should it be desired – will be planned.

Month 42 until month 48: Outreach activities will take place, to communicate our work and results to the non-specialist public, highlighting its significance. Results will be presented at international conferences and final published papers will be highlighted on the project website.

5. Deliverables

Month 6: Project website with all required information regarding the open-access data products, including their documentation, will be updated. A detailed outline plus study protocol of each task group will be made public.

Month 18: Updates made to the methods will be made public on the project website

Month 30: Final study protocols will be published

Month 30-42: A special issue in *Biogeosciences* will be launched and a training event for Early Career Scientists on data-mapping, uncertainty estimation and model evaluation will be held.

Month 42: Publications (resulting from the proposed analysis) will be submitted to the special issue. The uncertainty metric and ensemble uncertainty estimate will be made public and the results will be provided to the Global Carbon Project and the modelling groups. Furthermore, a statement will be provided to the ocean observation communities (SOCAT, BGC Argo), highlighting where SOCOMv2 would benefit most from future measurements.

Month 42-48: Press releases will be created and a side event at one of the major international ocean conference will be planned to present the results.

6. Capacity Building

The project will collect a unique ensemble of observation-based datasets of air-sea CO_2 fluxes and will make it easily accessible. This will help to better understand and quantify the uncertainty of the observation-based products and provide valuable information on where new field campaigns are required to further reduce the methods' uncertainty. A particular focus will be set on regions, where we currently face strong data limitation. While autonomous floats now measure valuable information on the carbonate system, particularly in the Southern Ocean, this working group is the only proposed effort to coordinate the integration of both shipboard and float estimates using state-of-the-art CO_2 mapping strategies.

Additionally, the project will develop a standard uncertainty metric applicable to future observation-based intercomparison projects, also for applications beyond ocean CO_2 research. All research items – from the data-products to the study protocols to the final publications – will be open access to increase visibility and reproducibility. For the first time, the working group will thoroughly assess the uncertainty of data-based surface pCO_2 estimates - and consequently the exchange of CO_2 with the atmosphere. This advance will not only shed new light on the existing knowledge gaps, but also provide a pathway for closing it.

This uncertainty information is further a critical asset for global carbon budget analyses, ocean model evaluation and decadal biogeochemical projections and will help to monitor future carbon inventories in the future. The latter is a necessary requirement for determining if we are on target to meet the 2°C (1.5°C) goal for a maximum temperature increase over the 2100 baseline.

Furthermore, the working group will coordinate the integration between open ocean and coastal ocean CO_2 mapping efforts to provide a more complete picture of the global ocean carbon cycle.

During the proposed annual meeting events, which will take place alongside major conferences to reduce the travel efforts of the members, the working group will additionally organize a training workshop for Early Career Scientists. During these training workshop, Early Career Scientists will learn how to find and use the observation-based CO_2 estimates and how the methods used within SOCOMv2 can be applied to their own scientific research.

7. Working Group Composition

7.1 Full Members (chairs are highlighted in bold letters)

Name	Gender	Place of Work	Expertise
1 Peter Landschützer	**M**	**Max Planck Institute for Meteorology, Hamburg, Germany**	**Chair, Surface Ocean CO_2 mapping member and data contributor**
2 Christian Rödenbeck	**M**	**Max Planck Institute for Biogechemistry, Jena, Germany**	**Chair, Surface Ocean CO_2 mapping lead- scientist and data contributor**
3 Dorothee C. E. Bakker	F	UEA, Norwich, United Kingdom	Lead-scientist in the Surface Ocean CO_2 Atlas data synthesis effort
4 Are Olsen	M	University of Bergen, Bergen, Norway	Lead-scientist in the Surface Ocean CO_2 Atlas and GLODAPv2 data synthesis effort
5 Luke Gregor	M	CSIR and UCT, Cape Town, South Africa	Surface Ocean CO_2 mapping member and data contributor, Southern Ocean expert
6 Galen A. McKinley	F	LDEO and Columbia University, New York, USA	Data-based and model based estimates of CO_2 flux variability and its mechanisms
7 Alison R. Gray	F	University of Washington, Seattle, USA	Expert in BGC float data, scientist in the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project
8 Goulven G. Laruelle	M	Sorbonne Universities, Paris, France	Expert in observation-based coastal ocean CO_2 mapping and the coastal ocean carbon cycle
9 Keith B. Rodgers	M	IBS Center for Climate Physics (ICCP), Busan, South Korea*	Expert in Ocean Modelling and Surface Ocean CO_2 mapping member

10 Vinu Valsala	M	Indian Institute of Tropical Meteorology, Pune, India	Surface Ocean CO_2 mapping member, Expert in ocean modelling and data assimilation

*Will be affiliated in Busan at the start of the SCOR working group. Currently, the member is affiliated with Princeton University in the United States of America.

7.2 Associate Member

Name	Gender	Place of Work	Expertise
1 Marion Gehlen	F	LSCE, Paris, France	CO_2 mapping and marine carbon cycle
2 Geun-Ha Park	F	East Sea Research Institute, Korea Institute of Ocean Science and Technology, Uljin, Korea	CO_2 mapping and marine carbon cycle
3 Yosuke Iida	M	JMA, Tokyo, Japan	CO_2 mapping
4 Ute Schuster	F	University of Exeter, UK	CO_2 observations, marine carbon cycle and CO_2 mapping
5 Steve Jones	M	University of Bergen, Norway	CO_2 mapping and marine carbon cycle
6 Shin-ichiro Nakaoka	M	NIES, Tsukuba, Japan	CO_2 observations, CO_2 mapping and marine carbon cycle
7 Tatiana Ilyina	F	Max Planck Institute for Meteorology	Ocean modelling CO_2 projections and decadal CO_2 predictions
8 Corinne Le Quéré	F	University of East Anglia, Norwich, United Kingdom	Global Carbon Project, Ocean Modelling, Southern Ocean
9 Nicolas Gruber	M	ETH, Zürich, Switzerland	Observation based CO_2 estimates from surface and interior, Ocean Modelling
10 Nicole Lovenduski	F	University of Boulder, Colorado, USA	Ocean Modelling, CO_2 projections

8. Working Group Contributions

The working group will:

- Combine and compare novel data interpolation and machine learning techniques used to map the surface ocean pCO_2 content spatially and temporally
- Provide an open and transparent platform where the data products, reference publications and study protocols can be accessed
- Set out new metrics and standards for observation-based pCO_2 data as well as data-model intercomparison studies
- Combine open ocean with coastal ocean estimates and provide a more complete estimate of the marine CO_2 uptake
- Identify key ocean areas where data collection is a high priority and future field campaigns should set their focus
- Provide a baseline for model validation, e.g. within the CMIP6 effort
- Contribute towards a data-driven global carbon budget
- Provide a realistic "ground truth" for the projection of the oceanic uptake of CO_2 in order to monitor the 2°C climate target
- Advance future observation-based research activities, such as ocean acidification studies
- Reduce the working group's carbon footprint by planning working group meetings in combination with conferences
- Combine these meetings with Early Career Scientist training events to pass on the SOCOMv2 knowledge and advance the careers of the next generation of scientists
- Publish the results in open-access journals and provide press releases to make the results available to a wider audience

9. Expertise

Christian Rödenbeck established and led the SOCOM effort and is an expert in ocean pCO_2 mapping and the air-sea exchange of CO_2.

Peter Landschützer is an expert in ocean pCO_2 mapping using machine learning algorithms and is an expert in the analysis of the decadal variability of the global ocean uptake of CO_2.

Dorothee C. E. Bakker is expert in the collection and synthesis of CO_2 observations and she is carrying a lead role in the SOCAT effort.

Are Olsen is an expert in the collection and synthesis of both surface and interior CO_2 data and carries leading roles in the SOCAT and GLODAPv2 efforts.

Luke Gregor is an expert in ocean pCO_2 mapping based on novel statistical techniques. He is further an expert in the Southern Ocean.

Galen A. McKinley is an expert in assessment of the mechanisms of variability and long-term change of CO_2 fluxes using pCO_2 observations and models. She is a member of the Global Carbon Project Scientific Steering Committee.

Alison R. Gray is an expert in the collection and analysis of Biogeochemical-Argo float data, particularly float-derived pCO_2 data. She is a member of the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project and an expert in the Southern Ocean.

Goulven G. Laruelle is expert in coastal ocean biogeochemistry and in mapping the exchange of CO_2 in coastal regions based on observations and models.

Keith B. Rodgers is an expert in the analysis of the ocean carbon cycle based on models and observations.

Vinu Valsala is an expert in modelling and assimilating the global ocean carbon cycle.

10. Relationship to other International Programs

SOCOMv2 will interact with many international projects, analysis and synthesis efforts. In particular, the working group sets out to provide air-se CO_2 flux estimates including uncertainty for the global carbon budget analysis of the **Global Carbon Project**. The Global Carbon Project provides annual updates of the global sources and sinks of carbon and the results of the working group will help to provide an observation-based estimate of the global oceanic uptake of CO_2 and its variability in time.

SOCOMv2 also sets out to provide observation-based estimates of the ocean uptake of CO_2 for phase 2 of the **Regional Carbon Cycle Assessment Project (RECCAP II)** and actively contribute to the analysis of the state-of-the-art knowledge.
Furthermore, SOCOMv2 will closely collaborate with the existing surface ocean CO_2 data collection efforts, in particular the **Surface Ocean CO_2 Atlas (SOCAT)** and the **Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM)** projects.

SOCOMv2 will collaborate with the **International Ocean Carbon Coordination Project (IOCCP)**, in particular relaying information on critical gaps in the existing pCO_2 network, to ensure that appropriate actions can be taken to improve this.

Finally, SOCOMv2 will work closely with global modelling groups to help improve future carbon cycle projections and decadal CO_2 predictions by adding the observation-based uncertainty, but also by providing an observation-based reference for model intercomparison projects such as **C4MIP**.

11. Key References

The selected key references on the on hand highlight the past achivements of the observation-based CO_2 estimates, and on the other hand highlight emerging research questions that the SOCOMv2 ensemble has the potential to resolve.

Both the Rödenbeck et al 2015 and Ritter et al 2017 publications highlight a stronger marine carbon sink variability on decadal timescales, yet strong differences exist between the various estimates:

1. Ritter, R., Landschützer, P., Gruber, N., Fay, A. R., Iida, Y., Jones, S., Nakaoka, S., Park, G.-H., Peylin, P., Rödenbeck, C., Rodgers, K. B., Shutler, J. D. and Zeng, J.: Observation-based trends of the Southern Ocean carbon sink. Geophysical Research Letters, 44, doi:10.1002/2017GL074837, 2017
2. Rödenbeck, C., Bakker, D. C. E., Gruber, N., Iida, Y., Jacobson, A. R., Jones, S., Landschützer, P., Metzl, N., Nakaoka, S., Olsen, A., Park, G.-H., Peylin, P., Rodgers, K. B., Sasse, T. P., Schuster, U., Shutler, J. D., Valsala, V., Wanninkhof, R., and Zeng, J.: Data-based estimates of the ocean carbon sink variability – The Surface Ocean pCO2 Mapping intercomparison (SOCOM), Biogeosciences, 12, 7251- 7278, doi:10.5194/bg-12-7251-2015, 2015

Several recent journals articles have highlighted scientific challenges, all in fields SOCOM methods have already left their impact:

3. Gruber, N.: Ocean biogeochemistry: Carbon at the coastal interface. Nature 517, 148– 149, 2015
4. Ilyina, T.: Hidden trends in the ocean carbon sink. Nature, 530, 426-427, 2017
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6. Mikaloff-Fletcher S.E.: An increasing carbon sink? Science, 349, 6253, 1165, 2015
7. Mikaloff-Fletcher S.E.: Climate Science: Ocean Circulation drove increase in CO_2 uptake, Nature, 542, 169-170, 2017
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9. Hauck, J.: Unsteady seasons in the sea, Nature Climate Change, 8, 2, 97-98, 2018

Appendix Full Member Key Publications:

Peter Landschützer:

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2.2.3 Ocean Governance and Policy Analysis for Ocean Deoxygenation (WG-OGOD)

Shapovalov

Summary / Abstract:
The oxygen level in the ocean and coastal water is decreasing which is responsible for changing the coastal and marine ecosystems almost in all parts of the globe. This working group on Ocean Governance and Policy Analysis for Ocean Deoxygenation (WG-OGOD) aims to create a regional network in different part of the globe consists of interdisciplinary stakeholders working on issues related to Ocean deoxygenation and its impacts on coastal, ocean and marine ecology and economy to undertake the series of activities includes preparation of status paper, Research papers and Manuals ,Regional Workshops and training courses on different issues related to Ocean Governance and Policy Analysis for Ocean Deoxygenation and its impacts on coastal, ocean and marine resource, marine and coastal policies, integrated coastal and marine resources management, impacts of urbanization on ocean deoxygenation, role of different stakeholders and institutional framework in ocean governance, ocean pollution and climate change, case studies on ocean and coastal governance influencing the ocean deoxygenation. This working group will also seek larger cooperation through organizing regional, national and international meetings, training courses on ocean governance, to participate in the Decade of Ocean Science, SCOR and SOLAS activities etc. to highlight the importance of ocean deoxygenation and it is interrelatedness with urbanization, climate change, ecological changes, coastal human interactions, policies and governance required for monitoring ocean oxygen changes.

2. Scientific Background and Rationale:

As per the United Nations estimates, the world population reached 7.3 billion as of mid-2015, implying that world has added approximately one billion people in the span of the last 12 years. The total population on earth is predicted to increase by more than one billion people within the next 15 years, reaching 8.5 billion in 2030, and to increase further to 9.7 billion in 2050 &11.2 billion by 2100. Looking at the ever increasing urbanization, in 2016, an estimated 54.5 % of the world's populations inhabited in urban region. By 2030, urban areas are projected to shelter 60% of people worldwide. On the basis of these figures and other global trends, it would appear that Africa and Asia will have the highest share of world's urban growth in next 25 years, resulting consideration rise of several metropolitan cities and towns along coastal region of Asia- Pacific and Africa .South America is gaining attention in the global climate change scenario due to its natural resources and its geographical location on globe. Therefore the task of transformation of rapid coastal urbanization in to rising number of coastal cities and towns through ecological, environmental and economic sustainability and building resilient societies in changing climate creating challenges for ocean governance and ocean policy formation for sustainability of urban coastal ecosystem will be vital.

The analysis of the Dead Zones (oxygen-starved zones) was conducted by a team of scientists from the Global Oxygen Network (GO$_2$NE), created in 2016 by the Intergovernmental Oceanographic Commission of the United Nations (UNESCO-IOC). Researchers determined that open-ocean "oxygen-minimum" zones have expanded since 1950 by an area roughly equivalent to the size of the European Union. The volume of ocean water completely devoid of oxygen has more than quadrupled in that time, the study found. The number of hypoxic, or oxygen depleted, zones along coasts has increased up to 10 times, from less than 50 to 500. This is caused by the rapid uncontrolled urbanization along coast and increased ocean-human interactions. The scientists recommend salvaging oxygen-starved areas by tackling climate change and nutrient pollution, focusing on protecting particularly vulnerable sea life with no-catch or no-fishing zones, and increasing and improving surveillance of areas where oxygen is plummeting.

The size of oxygen-starved ocean "dead zones," where plants and animals struggle to survive, has increased fourfold around the world, according to a new scientific analysis.

The growth of the zones is yet another consequence of global warming- including increasing ocean temperatures -triggered by greenhouse gases and, closer to the coasts, contamination by agriculture "Rising nutrient loads coupled with climate change -each resulting from human activities -are changing ocean biogeochemistry and increasing oxygen consumption," says the study published in the journal of Science(http://science.sciencemag.org/). Ultimately, such changes are "unsustainable and may result in ecosystem collapses, which ultimately will cause societal and economic harm." Therefore interdisciplinary and multidisciplinary studies coupling with impacts of urbanization and increased ocean human interactions on coastal, Marine and Ocean systems are required for systematic assessments, policy formulation and implementation for ocean governance at local, regional and global scale.

3. Terms of Reference:

The term of reference of the working group will lead to interdisciplinary and multidisciplinary studies and research work involving various aspects of Ocean Deoxygenation in local, regional and global context.

(1) To Assess, Examine and Document the current status and issues related to Dead zones (Dead spot), Oxygen minimum zones in the world ocean due to urbanization, pollution and climate change .
(2) To document and develop the global network of stakeholders for research on Ocean Deoxygenation, Ocean Governance and Policy Analysis.
(3) To publish the research papers, manual and reports to mitigate the impacts of ocean deoxygenation for sustaining coastal and marine economy and ecology for the use of local stakeholders, governments and educational institutes.
(4) To develop and implement the web based tools for information related to Ocean Deoxygenation.
(5) To improve awareness of scientific understanding and local capacity building on Ocean Deoxygenation, oxygen minimum zones or dead zones, its causes, effects and impacts on coastal, ocean and marine system to form the sustainable solutions.

4.Working plan:

The work plan is divided in different activities in the specified time schedule. As regards to the TOR 1, the current status of the Ocean Deoxygenation in different part of the globe will be assessed in first 18 months. For this a regional subgroups will be formed to identify the local issued on global scale. The documentation will be completed intermittently within 3 years after researching the current status, issues in local level etc. With respect to TOR 2, the series of meetings will be planned in Asia-Pacific, Europe, Africa, America and South America within first 2 years of the WG depending on the financial resources to assess the current status of the Ocean Deoxygenation and stakeholders involved in the process to form the global network. This network will be developed in association with the local research institutions, Universities and Governments to bring the sustainability after end of the working group. Some of the institutions have already shown interest to provide the infrastructural facility for such networks. Series of research publications, reports, manuals will be published in association with the local stakeholders during the 2nd and 3rd year of the WG period region wise as well as global level. Depending on the financial resources and local support series of meeting, either webinar or in person will be undertaken to strengthen the research and development activities related to TOR 1 and 3 periodically in consultation with SCOR secretariat. The TOR 4 activity, the web based tools for information and communication will be started after completion of the first year of WG after collecting sufficient data on Ocean Deoxygenation, Ocean Governance, policies, urbanization status along coastal cities and towns etc. The web based tools will be completed at the end of 3rd year for the use of the global stakeholders. The work plan for TOR 5 is supportive to all the TORs as the meetings, seminar, conferences , workshop and training programs will be planned throughout the 3 years as most of the members of the WG are members of Regional and global associations on Ocean, coastal and marine science, urban networks, Future Earth Networks, UNESCO-IOC- WMO Ocean experts etc. In addition to the regular meetings of the WG, it will be our focus to participate in the global meetings on Ocean and marine science, Urbanization, climate changes organized by the UNEP, WMO, SCOR, WCRP, SOLAS, IUGG, UNESCO-IOC, IPCC, IPBES and CBD, AGU, EGU etc .Some of the meetings are already planned which will be coupled with the WG, if this proposal is selected. We have received the commitment from the Organizations in India to provide matching funding for organizing one Annual meetings of WG, two training programs of one week duration and three workshops in India. This will help to bring the synergies on local, regional and global issues on Ocean Deoxygenation. Also we are in process of dialogue with the international institutions to provide institutional support or funding support for achievements of the TORs. The University of Naples 'Federico II'. Naples, Italy has agrees to host the Regional Chair of Europe for the activities of this WG. Similarly we are in process of selecting the organizations to host the Regional Chair of Africa and South America to have a joint activities and assessments on regional basis with in the time frame with increased participation from all the stakeholders. This will also help to raise the awareness on the Ocean dead spots and minimum oxygen zones along the coastline of coastal countries and particularly coastal cities and towns.

5. Deliverables:

The deliverables are planned through various modes, printed reports, web based tools, research publication, Documentaries and research reports of the WG. First the current status report will be delivered in first phase of 18 month to seek the larger cooperation from stakeholders in Ocean Deoxygenation and ocean governance for completion of the TOR 2 to 5 in second phase. The WG desires to publish at least one research paper in the international journal on regional scale and at the final stage at the Global scale. The database and maps of the Oxygen minimum zones, dead zones will be publish yearly and finally will be made available on the web based tool. The WG will be represented by the WG members and associated members in different global and regional meeting to review the work depending on the funding availability. Also some short term fellowships, summer schools and training programs are planned in association with the local institutes. In addition to the financial resources from SCOR and other participating institutions, the WG aims to obtain the additional funding support for early career scientist and researchers from various funding institutes, universities and government institutes. The WG will publish the final report of all activity along with the data, analysis and results and recommendations. We planned one training session in India in first year for which the Partner institute has agreed to provide matching grants .In second year training sessions are planned in Africa and America for which we will be able to generate the resources. The third training course will be planned in Europe in third year. Some of the training sessions will be planned during the WG annual meetings to optimize the financial resources.

6. Capacity Building:

This WG will help to strengthen the efforts of mitigating impacts of Ocean Deoxygenation in Coastal urban region of the world. The WG will bridge the gap in ocean governance and ocean policy development through participation of global stakeholders to form the sustainable solutions to Ocean Deoxygenation along the coastal urban centers. The WG will contribute in providing training the local stakeholders around the globe to enhance the skills and knowledge on urbanization and its impacts on ocean and marine system, Ocean Deoxygenation, ocean human interactions and ocean minimum zones and dead zones. The web based tools will be helpful in capacity building to aid in identification of ocean minimum zones and dead zones, caused, effects and solutions. The WG will help to stimulate new research activities with interdisciplinary and multidisciplinary approach in ocean minimum zones and dead zones, Ocean Deoxygenation coupling the human interactions and governance and policies required for ocean sustainability. It is proposed that the participating member's institutes/ organizations will be associated with the WG by providing the infrastructure facilities for other members of the WG. This will also help in institutional capacity building of the members of WG as well as associate members and associate institutions who are willing to contribute to the WG activities. We have already received confirmation from Italy, India, Sweden and Sri Lanka regarding institutional participation and support from Universities, Government and Intuitions. We are planning to couple the activities with the WMO, UNESCO-IOC, Future Earth, FAO for strengthening the training activities for enhancing the skills and knowledge for the stakeholders from North –South part of the Globe. It is also proposed a long term joint training and research programs through memorandum of associations (MoU) with the institutions of the Full and Associated members after completion of the WG period to bring the sustainability and providing leadership on this forefront areas. This will help in capacity building of the SCOR partner institutions as well as the Institutions of the Full members and Associate members of this WG. It is expected that more organizations from different part of the globe may be willing to associate with the long term training and research activities of this WG for strengthening their local program on Ocean Deoxygenation and Oxygen minimum zone, Dead spots in marine and coastal zone. The Full members from University of Naples, Italy are already providing scientific and technical knowledge and services to local coastal towns to overcome these problems. It is expected that more local governments from the coastal cities and towns in Asia-

Pacific, Europe, America and Africa may likely to approach the WG for assessment of the dead zones in coastal region to form the costal and ocean governance and policy formulation.

7. Working Group composition (as table).

(A)Full Members .

Name	Gender	Place of work	Expertise relevant to proposal
1.Kalpana Chaudhari (Chair)	F	Institute for Sustainable Development and Research, ISDR, India. (Mumbai,India)	Coastal cities , Urban Environmental management, Ocean Governance, Coastal pollution , Ocean Information and communication
2. Murray Rudd (Co- Chair)	M	World Maritime University (WMU), Malmö, Sweden.	Ocean Governance, Institutional analysis, marine policy science policy interface, ocean policy
3.Pasquale De Toro	M	Interdepartmental Research Centre in Urban Planning 'Alberto Calza Bini' (CIRURB), The University of Naples 'Federico II'. Naples, Italy	Environment and climate change, Coastal cities, Landscape and conservation , Urban coastal zone management.
4. Annette Breckwoldt	F	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven, Germany.	Coastal Change, Fisheries Management and Ecology, marine resource management

5.Chandra Prakash	M	ICAR-Central Institute of Fishery Education, Mumbai, India	Ocean Deoxygenation, Marine pollution, Urban Coastal zone management
6.Mario Rosario Losasso	M	The University of Naples 'Federico II'. Naples,Italy	Urban Planning, Coastal infrastructure and planning, coastal cities.
7.H.M.Palitha Kithsiri	M	National Aquatic Resources Research and Development Agency (NARA),Crow Island, Colombo 15, Sri Lanka.	Ocean Deoxygenation, Marine Pollution, Marine Fisheries and Aquaculture, Ocean Governance
8.Ruby Asmah	F	CSIR-Water Research Institute, Accra-North, Ghana	Ecological Marine Management, Sustainable aquaculture development, environmental and socio-economic impact assessments; integrated coastal zone management; assessment, monitoring and management of pollution in inland and coastal waters, ecotoxicological assessments, and applications and use of Geographical information systems in environmental management.

9. Alice Newton	F	Centre for Marine and Environmental Research,(CIMA), University of Algarve, Faro, Portugal	Environmental Impacts and Economics, Marine and Environmental Sciences, oceanography, Land ocean interactions in the coastal zone, Bioeconomy Strategy
10. Iosu Paradinas	M	University of Valencia, San Sebastian, Basque Country, Spain	Marine Spatial Planning, Fisheries and Aquaculture, Biostatistics, Ecological and Environmental modeling, Marine Biology

(B)Associate Member (no more than 10) :

Name	Gender	Place of work	Expertise relevant to proposal
1.Kithulampitiya Koralege Tharaka Nuwansi	F	ICAR Research Fellow, Galle, Sri Lanka	Fisheries biology rejuvenation technology and economics, coastal zone management, Nutrient Recycling, Marine Fisheries and Aquaculture.
2. Jerry Miller	M	Science for Decisions, Washington DC, USA	Costal Pollution, Marine Policy Management, international Census of Marine Life programs, Ocean Science and Policy, Oceanography.

3. Alex Godoy-Faundez	M	Universidad del Desarrollo, Santiago, Chile.	Strategic Resource Management, Environment and Climate Change, water recovery and recycling, engineering, societal and political frameworks.
4. Samiya Selim	F	University of Liberal Arts Bangladesh, Dhaka, Bangladesh.	coastal management and conservation, marine ecosystem services, Sustainable Development.
5. Christina Cheong	F	UN-Women, Port Moresby, Papua New Guinea.	Coastal Urbanization, Small and Island countries, Urban planning in Coastal region ,Coastal cities management.
6. Anjana Sing	F	Tribhuvan University, Kathmandu, Nepal	Biological Science, Microbiology, Ecology, Waste Water treatment .
7. Mr.Saikat Shome	M	Haldia Institute of Technology,India	Environmental Management, Coastal Zone Management, Water Pollution and treatment.
8.tbd			
9.tbd			
10.tbd			

8. Working Group contributions:

1) Kalpana Chaudhari (Chair) is member of Future Earth – Ocean KAN Development Team having experience of Urbanization in Coastal region, climate change, Ocean Governance Information and Communication for Coastal Ocean and Marine system. She is interested in Assessment of Coastal Urbanization in Asia-Pacific and to coordinate with other participating institutes.

2) Murray Rudd (Co-Chair) is working with World Maritime University, Sweden and has expertise with the international ocean laws and governance. He will be responsible for organizing the training session on Ocean governance and issues related to Marine science

.He will be responsible for assessments of Coastal cities in Europe and identifying the Minimum Oxygen Zone in Coastal Europe.

3) Pasquale De Toro is working as Professor in Urban Planning in Italy and has expertise in Coastal urban management, impacts of urbanization on coastal zones. He will be responsible to organize the training session on urbanization and coastal pollutions.

4) Annette Breckwoldt is working at center for Polar and Marine research, Germany. She will be responsible for organizing training and research program on Coastal Change, Fisheries Management and Ecology, marine resource management.

5) Chandra Prakash is expert in marine pollution, coastal urbanization and sewage treatment in Coastal urban region. He will be responsible for work related to ocean deoxygenation and related training programs. He will be responsible for synchronizing the work related to Ocean Deoxygenation in Asia-Pacific, Europe, Africa, America and South America.

6) Mario Rosario Losasso is expert in Urban Planning, Coastal infrastructure and planning, coastal cities. He will be responsible for assessing the impacts of Urban effluents on Ocean and Marine water. He will also organize a training session on Municipal sewage discharge in coastal cities and Towns.

7) H.M.Palitha Kithsiri is working with Sri Lankan Government in Fishery Center. He will be responsible for the work related to Ocean Deoxygenation, Marine Pollution, Marine Fisheries and Aquaculture, Ocean Governance in Small and island countries.

8) Ruby Asmah is working with Government Research institute in Ghana. She will be responsible for work related to the status report on Coastal cities in Africa and impacts of Ocean Deoxygenation on African Coast.

9) Alice Newton has a long standing experience on Ocean governance, policy, Ocean human interaction. She is member of Scientific steering committees related to Ocean and programs. She will be responsible for organizing the training session in relevant areas as well as to organize the training works related to European, African and South American Coast.

10) Iosu Paradinas is Working in Fishery assessment and Marine spatial planning for fisheries and aquaculture. He is interested in Costal ecology, Biostatistics, Ecological and Environmental modeling, Marine Biology of European and Mediterranean coast.

9. Relationship to other international programs and SCOR Working groups:

The activities of this working group are in consistence and mutually beneficial to the other SCOR working Groups as well as other international programs. There is strong correlation with the other International programs of ICSU, SCOR, WCRP, WMO, UNESCO-IOC, SOLAS, IMBeR, UNFCC, IPCC and United Nations Decade on Ocean.

(1) SCOR WG 132; Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems is useful for data collection on Marine Pollution and its impacts on coast. The data and research work of this WG will be mutually beneficial for both the Working group for simulation analysis.
(2) GEOTRACES: The work of this WG is closely related to GEOTRACE as the data on biogeochemical cycle and marine environment will be required for analysis. The WG activities related to training session on Ocean Deoxygenation can be collaborated with GEOTRACES.
(3) SOLAS: We anticipate that the coordination with SOLAS China and SOLAS, Germany will be beneficial for organizing the research and status reports on Deal Zones in Ocean in various part of the World in association with SOLAS IPO. The SOLAS related project on Global Ocean Oxygen Network (GO_2NE) is highly relevant for collaboration and long term association.
(4) IMBeR: The activities are beneficial to IMBeR. This WG already consists of the experts from IMBeR for synergies. Also we are planning to organize one training session during IMBeR open Science Conference in 2019. More scientist and researchers can be collaborated in future to utilize the IMBeR's world wide framework.
(5) UNESCO-IOC: We are in contact with the WMO–JCOMM to provide us the training facilities for the early career scientist and researchers from coastal countries. There is a possibility to organize the training session in association with WMO partner organization.
(6) Future Earth: Ocean KAN and Urban KAN: As the WG members are also connected with the Future Earth Ocean Knowledge Action Network , there is every possibility that this WG will coordinate with the Ocean KAN Development Team members world wide to get the real time data for assessment .Also few meeting can be organize jointly with the regional Future Earth offices. This WG is expecting the Future Earth–Urban-KAN can be associated for the impacts of urbanization on coastal and marine ecology and economy as the Coastal cities are gaining importance in view of implantation of Sustainable Development Agenda 2030. The Long term association in joint activities with Future Earth is expected with this WG in cross cutting issues on coastal and marine science with interdisciplinary and multidisciplinary subjects.

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Appendix .I :

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

Kalpana Chaudhari

(1) Dr. Kalpana Chaudhari, Dr.Suresh yavalkar," Changes in marine ecosystem: evaluating the impacts of climate change and developing adaptation strategies using application of e-governance and ICTs for protection and sustainable exploitation of coastal and marine resources " Scoping Workshop on the Development of an Integrative Ocean Research Network,Jointly hosted by: Future Earth, Future Ocean – Kiel Marine Science, Kiel, Germany and ICSU, IOC, SCOR and WCRP, 4-5 December 2016, Cruise Terminal Ostseekai, Kiel, Germany.

(2) Mrs. Kalpana Chaudhari, Dr.Upena D Dalal , Mr.Rakesh Jha, "Application of Wireless Technology For Electronic Governance in Rural Region Using Information And Communication Technologies", " International Journal of Wireless Communication and Simulation (IJWCS), Volume 2, number 1-2 (2010) pp.113- 126

(3) Mrs. Kalpana Chaudhari, Dr.Mr. P.T. Karule, "How to Improve Role of Information and Communication Technology for Health Care in Maharashtra State", International Journal of Advanced Research in Science, Engineering and Technology (IJARSET), Vol. 1, Issue 3, ISSN: 2350-0328 (2014) 115-125

(4) Mrs. Kalpana Chaudhari' Dr.Upena D Dalal , Mr.Rakesh Jha "Application of WiMAX Technology for Electronic Governance in Rural Areas" The Journal of Computing (TJC) ISSN:0976-6928 in Vol.2 Issue2-Feb,2011,PP.1-10

(5) Dr. Kalpana Chaudhari , Dr.P.J.Philip,"Application of Information and Communication Technologies for Transboundary Water Governance and Diplomacy in Indo-Pacific and Beyond, IAHS Scientific Assembly, 10-14 July 2017, Port Elizabeth, South Africa.

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Pasquale De Toro

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2.2.4 Carbonate system intercomparison forum (CSIF) *Burkill*

Summary

Recent literature has highlighted several ongoing challenges regarding the consistency of seawater CO_2 measurements with estimates from alternate input pairs. These gaps in our knowledge of the ocean carbonate system are probably related to carbonate constant uncertainties, frequently-unknown concentrations of organic bases in seawater, and unrecognized measurement uncertainties. CO_2 measurement intercomparability is also challenged by the large and growing variety of instruments and approaches used for measurements and the lack of a robust assessment of some methods. While measurement strategies diversify and evolve, the need remains for consistent records of key measurements over time to assess marine CO_2 cycling and its impacts: e.g. dissolved inorganic carbon (DIC) records for anthropogenic carbon storage, partial pressure of CO_2 (pCO_2) records for air-sea flux estimates, pH records for ocean acidification (OA) monitoring, and seawater alkalinity (A_T) records for assessing the impacts of OA on carbonate mineral cycling. It is therefore more critical than ever that scientists develop a strategy for identifying and addressing carbonate system intercomparability uncertainties, thus enabling existing and future data to be reconciled into internally-consistent data products with associated uncertainties. We therefore propose a forum between experts in carbonate system parameter measurements, data documentation, and interconversion to debate the nature of the problems, advocate for needed research to resolve these problems, and provide guidance for data product assembly and documentation. The forum will have the additional goal of bringing new and developing analytical marine chemistry labs into ongoing intercomparison and standardization efforts, and lowering barriers for such groups to participate.

<u>Scientific background and rationale</u>

In principle, any of the commonly-measured seawater carbonate parameter measurements (pH, pCO_2, DIC, A_T, and, as of recently, carbonate ion) can be calculated from any two of the others along with carbonate constants (as functions of S, T, and pressure) and knowledge of the chemical properties of all other acid-base systems in the seawater. Moreover, great progress has been made toward standardization of measurement practices through the distribution of Best Practices literature (Dickson et al. 2007; Riebesell et al. 2011) and Certified Reference Materials (Dickson et al. 2003) for key measurements. However, recent literature has highlighted that disagreements remain between direct measurements of carbonate parameters and calculations of these parameters from other measurements (e.g. Kulinski et al., 2014; Chen et al., 2015; Patsavas et al. 2016; Carter et al. 2017; Woosley et al., 2017). These disagreements are comparable in magnitude to, or larger than, the likely decadal changes from climate forcing. Furthermore, there are biases between calculations obtained from different sets of commonly-used carbonate chemistry constants (Woosley et al., 2017). Disagreements between measured and calculated carbonate parameter values and the diversity of measurement types are hampering efforts to combine data sets into unified data products (e.g. Olsen et al. 2016), to interpret existing data products and infer climate signals (e.g. Carter et al., 2017), and to fully utilize measurements from new sensors and measurement platforms to make inferences about the full carbonate system in seawater (e.g. Williams et al., 2017).

Seawater pH can provide an example of this problem and why it is urgent that it be addressed. One of the main symptoms of OA is the ocean pH decrease, however, direct detection of OA based on ocean pH measurements was not feasible prior to the development of the highly-precise spectrophotometric methods (Clayton and Byrne, 1993; see the review of Dickson, 2015). The lack of a certified pH seawater reference material is an additional ongoing challenge for pH measurements. Also, seawater pH has been measured with a variety of methods--and reported on a small collection of pH scales and at a range of temperatures and pressures--over the last several decades. The pH measurement approaches used include potentiometric measurements, sensor measurements, and spectrophotometric measurements made with several different dyes and different batches of dyes, all with differing concentrations of impurities that affect the measured pH (Yao et al., 2008; Liu et al., 2011). The recent emergence of purified m-Cresol dyes and dye coefficients raised the possibility that pH measurements would be brought in line with other carbonate system measurements (Liu et al. 2011). However, pH calculated from other measured parameters such as DIC and A_T) has been observed to still have a pH-dependent offset from spectrophotometrically measured pH, even when purified dyes are used (Patsavas et al., 2015; Williams et al., 2017; Carter et al., 2017). This problem is not thought to come from analytical or instrumental uncertainty in the pH spectrophotometric method (DeGrandpre et al., 2014) but rather from gaps in the knowledge of the information used to calculate carbonate system properties from one another (e.g. various measurements and their calibrations, *K* constants, and the concentrations of borate and other minor seawater acid-base pairs). As a result of these issues and the infrequency with which seawater pH was measured, discrete water column pH measurements were completely absent in the first effort synthesizing a globally consistent CO_2 data product, GLODAPv1 (Key et al., 2004). Instead, the mismatch between calculated and measured pH was made apparent with the introduction and quality assessment of water column pH data in regional data products such as CARINA (Velo et al., 2010) and the most recent version of GLODAPv2 (Olsen et al., 2016). Moreover, over these same recent years, the number of seawater pH measurements available has increased by orders of magnitude following the development of inexpensive, low-power, pressure-tolerant, occasionally reagent-free pH sensors (see: Wendy Schmidt Ocean Health XPRIZE), and their implementation on biogeochemical profiling floats and other sensor platforms. A float observing strategy is under consideration for implementation as a global array, and related strategies are being developed for other moored and autonomous platforms. Any limitations to the interchangeability of pH with other carbonate parameters will directly limit the utility of sensor measurements for observing air-sea carbon fluxes (from pCO$_2$ calculations) and carbon storage (from DIC calculations). Essentially random measurement errors and offsets are mitigated by the large number of profiling floats that would compose such a global array, but consistent errors from carbonate parameter calculations would result in significant biases.

These are problems with solutions. The ideal solution to the problems for intercomparability of future measurements would be to identify the remaining factors limiting carbonate measurement comparability and address them through carefully planned and agreed upon research among independent research laboratories. Even should such efforts prove unsuccessful at resolving all the issues, an improved understanding of the biases inherent in various approaches for constraining the carbonate system should allow information from these approaches to be appropriately interpreted. In some cases, the biases may even be able to be countered with carefully considered adjustments. This Working Group proposal aims to workshop these solutions. It would assemble a team of experts to identify the remaining unknown aspects (including measurement uncertainties) of the carbonate system in seawater; the terms in the equations for carbonate parameter interconversion where these uncertainties have the greatest influence; and the research efforts most likely to reduce these uncertainties. Further, the experts would provide guidance on how best to proceed with data assembly and documentation. Finally, the working group will include members of emerging carbonate chemistry groups, and consider how best to encourage widespread adoption of the proposed improvements by both established and emerging laboratories internationally.

Terms of reference

The working group will pursue the following goals through discussion, debate, and writing peer-reviewed articles:

1. Identify and quantify the remaining unknowns for describing seawater CO_2 chemistry (e.g. uncertainties in measurements, CO_2 system calculations and constants, and organic base concentrations);
   a. estimate the magnitudes of these uncertainties, and thereby determine how important each unknown is to address;
   b. outline and advocate for research that could fill the most important gaps in our understanding;
2. review measurement reporting practices (e.g. reporting of pH scales, reference temperatures, uncertainty, and measurement methods);
   a. debate whether standardized reporting practices would be appropriate, and develop and advocate standardized reporting practices if so;
3. review the current state of reference materials for seawater CO_2 system measurements, and identify which seawater CO_2 parameters need more viable or available reference materials;
   a. make recommendations for making such materials more viable or available;
   b. make recommendations for how to best use reference materials to characterize measurement uncertainties;
4. review the barriers preventing groups from making seawater CO_2 measurements with low uncertainties (e.g. availability of calibrated titrant or purified spectrophotometric dyes);
   a. make recommendations for lowering those barriers;
5. identify barriers preventing research groups from participating in international standardization and intercomparison efforts;
   a. make recommendations aimed at lowering those barriers and increasing participation.

The metric for the success of these efforts will be publication of 1-2 peer-reviewed white papers on the Working Group's findings, and citation of such papers in research proposals and papers.

<u>Working plan</u>

The CSIF team will make progress on its terms of reference primarily at 2 to 3 day-long meetings associated with major international ocean science themed research conferences. Between each of these meetings, spaced by ~1 year, the Working Group will collaborate remotely to build upon and publish their findings from these meetings. The schedule for these meetings will be determined based upon the availability of full members to attend, but the meetings will begin in either Europe or the United States. The second meeting will then be on the other continent. The third meeting, if one is necessary to conclude business and if funding allows, will be held in association with a conference in Asia or Australia. Examples of potential two-meeting schedules include:

Meeting 1: EGU2019 Vienna, Austria, 7-12 April
Meeting 2: Ocean Sciences 2020, San Diego, CA, USA, 16-20 Feb
-Possibly AGU 2021 instead of OS2020
Or…
Meeting 1: OceanObs2019, Honolulu, Hawaii, USA, 16-20 September, 2019
Meeting 2: EGU2020 Vienna, Austria, 3-8 May, 2020.

Year 0-3:
Prior to the first meeting and throughout the duration of the Working Group, CSIF would aim to increase the Working Group's visibility by hosting sessions and town halls at major international research conferences. This will serve both to increase awareness of relevant research, and to generate enthusiasm and involvement from the community, with special consideration given to involving emerging CO_2 laboratories.

Year 1:
The first meeting would begin with a review of the evidence for carbonate system intercomparability problems, as well as a summary of the various uncertainties that have been proposed to account for these problems, and a round-table discussion of what research is thought to be most likely to clarify these issues (ToR 1,1a,1b). The meeting would then commence preliminary discussions on how best to assemble consistent data products from diverse measurements (ToR 2,2a), given what was discussed earlier. The final part of the meeting would involve planning the work involved in writing a review paper designed to articulate the Working Group's current understanding of the likely uncertainties involved in computing CO_2 parameters from other measurements (see Deliverables - part b) together with specific recommendations where practical. It is intended that this paper be written and submitted with the 12 months immediately after the meeting. Collaboration will be maintained remotely through E-mail correspondence and, if deemed appropriate by CSIF members, free online collaboration software such as Slack. Once specific values have been agreed on for the various likely uncertainties, it will be practical to start (as a group) on the work required to produce the second proposed manuscript.

Year 2:
The second meeting would occur 1 to 2 years after the first, and will be held alongside another major international oceanographic meeting. The format of this meeting is expected to be similar to the first, beginning with a refresher on the major issues and including an update on research and new results that have come to light in the intervening year and the work done by Working Group members towards the papers proposed in the "Deliverables". The team would then break into two groups. The focus of the first group would again be considering what additional research is likely needed to address the remaining uncertainties (ToR 1,1a,1b). The focus of the second group would be on ideas for new efforts aimed at establishing carbonate measurement and data reporting best-practices, as well as identifying issues that may have prevented more complete adoption of past and ongoing best-practices guidelines (ToR 3,3a,3b,4,4a,5,5a). The working group would then meet in plenary to discuss authorship of documents summarizing the findings of the group's 2nd meeting. The first of these would aim to finalize the second manuscript proposed in the deliverables, and started in the first intersession. The second would be a white paper proposing explicit best-practice guidelines for CO_2 measurement and reporting, that also aims to address necessary quality control issue such as ensuring accessibility to appropriate reference materials.

Year 3:
The third CSIF meeting would occur provided there is travel funding and would focus on ensuring that the proposed publications were completed and submitted. This meeting would have a dual focus on wrapping up these efforts and on planning for future intercomparison efforts.

Deliverables

The expected deliverables from the activities of the proposed Working Group are:

(a) Reports to SCOR on the details of the meetings that were held.
(b) A series of papers (probably submitted to Frontiers in Marine Science under their topic "Best Practices in Ocean Observing"). These will comprise:

An initial methodological paper that primarily focuses on assessing the likely uncertainties of the manifold factors contributing to the overall uncertainty of computed results for the CO_2 system for a particular sample of seawater. Once these have been assessed and documented, it will be possible to use them in conjunction with publicly available computational software that propagates such uncertainties so as to estimate uncertainties in calculated values (Orr et al., in prep.)

A second review paper that re-assesses a number of published "over-determined" data sets to assess the degree to which the careful assessment of uncertainties does indeed provide an explanation for previously noted discrepancies, and to identify if additional contributions to uncertainty still remain to be found. Ideally, as more and more data are examined carefully, it may become practical to identify potential biases in one or more of the parameters, to suggest potential adjustments, and to modify the estimated uncertainty appropriately.

A third white-paper that makes explicit recommendations for CO_2 system measurement and reporting best practices that build upon the community experience to date, and that aim to address those issues that are believed to have compromised wholesale adoption of previous "best practice" guides.

Capacity building

The Working Group (CSIF) will be engaged in capacity building for many distinct aspects of seawater CO_2 chemistry science. CSIF will aim to improve capacities related to:

1. Uncertainty estimation: In order to be meaningfully interpreted, CO_2 measurements require accurate and well-estimated uncertainties. The first-order CSIF goal of estimating the uncertainties for several key gaps in our understanding of seawater CO_2 chemistry will have direct impacts on our interpretation of measured and calculated seawater CO_2 chemistry values. An improved understanding of how comparable measurements are to the true seawater chemistry and to one another will broadly improve the capacity of the oceanographic community to make correct inferences based on seawater CO_2 measurements.
2. Reference material diversity, availability, affordability, and viability: Reference materials for DIC and A_T measurements have had large positive impacts on the quality of the carbonate chemistry measurements since their introduction in the early 90s. CSIF will examine whether this impact can be extended by encouraging development of additional reference materials for other seawater carbonate measurements, or with a wider range of carbonate chemistry states than are current readily available, and that are more inexpensively available (perhaps more efficiently distributed) to laboratories globally.
3. Measurement material availability: The availability of purified or calibrated measurement materials (e.g. dyes and titrants) is one identified barrier preventing some research groups from making seawater chemistry measurements of the highest quality. CSIF will explore ways to lower this barrier and thereby potentially improve measurement capacities worldwide.
4. Data product development: CSIF plans to debate the metadata requirements for data products that combine measurements made using a range of approaches. The goal for this debate is to create guidelines that will assist members of the community working to compile such data products, and thus resolve challenging questions that are limiting data product development capacities.
5. Intercomparison exercises: These exercises are one of the key audits for the success of efforts to improve laboratory-to-laboratory CO_2 measurement comparability globally. They also provide some of the only independent feedback for how comparable measurements from an individual laboratory are with the measurements of the global community. CSIF will work to bring more laboratories into these exercises, and thereby increase both the impact of the exercises and their value as an assessment for laboratories that already participate.

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<u>Working group composition</u>

All full and associate members of this working group have extensive expertise with seawater carbonate chemistry measurements. Here we note additional relevant expertise that would likely prove useful for the Working Group.

Name	Gender	Place of work	Expertise
Andrew Dickson (co- chair)	M	Univ. California San Diego (UCSD), USA	Physical chemist and modeler: CO_2 system in seawater, uncertainties of CO_2 system measurements, reference materials for seawater CO_2 measurements
Marta Álvarez (co-chair)	F	Instituto Español de Oceanografía (IEO), Spain	Seawater CO_2 internal consistency, time- series, anthropogenic carbon. North Atlantic, Mediterranean Sea. CO_2 facility
Robert Byrne	M	Univ. South Florida, USA	Marine CO_2 system chemistry and ocean acidification and development of in situ methods and instrumentation
Kim Currie	F	National Institute of Water and Atmospheric Research, NIWA, New Zealand	Surface ocean IOCCP co-chair, IP for ocean acidification multi disciplinary observatories in NZ coast and open ocean
Sue Hartman	F	National Oceanography Center (NOC), UK	Open ocean and coastal UK observatories, ferry-box continuous biogeochemical data, CO_2 facility
José Martín Hernandez- Ayon	M	Univ. Autónoma de Baja California, México	Member of the Mexican Carbon project, specialist in coastal carbon cycle and anthropogenic stressors
Siv Lauvset	F	Bjerknes Center for Climate Research, Norway	GLODAPv2, SOCAT CO_2 quality control, global pH distributions and ocean acidification mechanisms

Claire Lo Monaco	F	Laboratoire d'Océanographie et du Climat (LOCEAN), France	GLODAPv2, air-sea CO_2 exchange, decadal changes, Indian Ocean and CO_2 French facility
Akihiko Murata	M	Japan Agency for Marine- Earth Science and Technology (JAMSTEC), Japan	Japanese GO-SHIP cruises, decadal changes in biogeochemical variables, focus on pH and anthropogenic carbon
Weidong Zhai	M	Institute of Marine Science and Technology, Shandong Univ., China	Marine carbon cycle in the coastal ocean: air- sea CO2 exchange, terrestrial inputs, stressors, ocean acidification

Associate Members

Name	**Gender**	**Place of work**	**Expertise**
Brendan Carter	M	University of Washington/National Oceanic and Atmospheric Administration, (UW/NOAA) USA	Estimating decadal anthropogenic carbon changes, developing algorithms for CO_2 parameter estimation
Socrates Loucaides	M	NOC, UK	Head of analytical Science team in the ocean technology group at NOC. Spectrophotometric assays and electrochemical techniques. Sensor development and optimization for carbonate chemistry methods
Triona McGrath	F	National University of Ireland (NUI), Ireland	Responsible for NUI ocean acidification program, expertise in discrete biogeochemical measurements
Yui Takeshita	M	Monterey Bay Aquarium Research Institute (MBARI), USA	Involved in developing and applying autonomous sensing technology to observe marine biogeochemical cycles in situ, SOCCOM program
Melissa Chierici	F	Institute of Marine Research (IMR), Tromsø, Norway	Expert in CO_2 variability in the Arctic Ocean, responsible for monitoring programs in Norway

Louisa Giannoudi	F	Hellenic Center for Marine Research (HCMR), Greece	Expertise in biosensors and responsible for discrete CO_2 measurements in the Greek near waters
Karol Kuliński	M	Institute of Oceanology of the Polish Academy of Sciences (IO PAN), Poland	Biogeochemistry in the Baltic Sea, ocean acidification and organic matter contribution to alkalinity
Henry Bittig	M	Laboratoire d'Océanographie de Villefranche (LOV), France	Expert in Biogeochemical Argo measurements, neural networks for biogeochemistry
Carolina Cantoni	F	Consiglio Nazionale delle Ricerche, Istituto de Scienze Marine (CNR-ISMAR), Italy	Time series in the Adriatic Sea and Western Mediterranean Sea
James Orr	M	Laboratoire des Sciencesdu Climat et l'Environnement (LSCE/CEA), France	Expertise in Global Carbon Chemical Modelling and intercomparability, global carbon cycle, CO_2 software calculations

Working Group contributions

Andrew Dickson
Expert in laboratory measurement of CO_2 parameters and modelling of chemical speciation; and also in the development of standard materials, calculation methods and documentation for the marine CO_2 system.

Marta Álvarez
Chemical oceanographer, expertise in CO_2 discrete data, CO_2 internal consistency and decadal biogeochemical changes. IEO IP for biogeochemistry in coastal North Atlantic. MEDSHIP program.

Robert H. Byrne
Expertise in marine and riverine CO_2 system chemistry and internal consistency, and in developing in-situ methods for measurements of carbon system parameters

Kim Currie
Responsible for the New Zealand Ocean Acidification Observing Network, studying long term changes in subantarctic waters (Munida transect) and New Zeeland coastal waters.

Sue Hartman
Chemical oceanographer, expertise in ferry-box sensor data processing and calibration. Responsible for biogeochemistry in PAP time series and UK ocean acidification cruises, UKOA CO_2 facility.

José Martín Hernández-Ayón
Chemical Oceanographer with experience in quality data for coastal regions and the potential contribution of organic bases to the alkalinity of seawater samples.

Siv K. Lauvset
Expert in quality control of seawater CO_2 measurements from surface CO_2 to water column and sensors. Active in Global Ocean Data Analysis Project (GLODAP), SOCAT (Surface Ocean CO_2 Atlas) and ICOS (Integrated Carbon Observation System).

Claire Lo Monaco
Expertise in quality control for surface and water column CO_2 data (GLODAP and SOCAT), decadal changes in biogeochemistry and carbon cycle in the Indian Oc. IP for CO_2 French facility.

Akihiko Murata
Chemical oceanographer, expertise in producing high-quality data for carbonate system and the related properties through repeat hydrography (GO-SHIP) cruises.

Weidong Zhai
Expertise in surface and water column CO_2 and carbonate measurements and studies. Representative for ocean carbon cycle investigations in China.

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2.2.5 Toward a new global view of marine zooplankton biodiversity based on DNA metabarcoding and reference DNA sequence databases (MetaZooGene) *Miloslavich*

Abstract

Marine zooplankton biodiversity remains a significant unknown throughout the global ocean. Molecular approaches, including DNA barcoding (use of short DNA sequences for species recognition and discrimination) and metabarcoding (large-scale taxonomic identification of complex samples via analysis of one or few orthologous DNA barcode regions), are expected to significantly revise global estimates of zooplankton diversity. Primary obstacles to broader use of metabarcoding for fundamental research on the biodiversity, biogeography, and trophic dynamics of marine zooplankton include lack of best practices for barcoding and metabarcoding analysis, and lack of taxonomically-comprehensive global-scale DNA sequence reference databases (libraries of DNA sequences determined for identified specimens) for the selected barcode gene regions. The MetaZooGene SCOR Working Group will develop a global vision for the continuing development of integrative molecular – morphological taxonomic analysis of marine zooplankton biodiversity through international communication, cooperation, and collaboration. Terms of Reference include: 1) create an open-access web portal for DNA barcodes for marine zooplankton; 2) design an optimal DNA barcoding pipeline for marine zooplankton; and 3) develop best practices for DNA metabarcoding of marine zooplankton biodiversity. Deliverables include a project website, web portal, and database; dissemination of best practices for DNA barcoding and metabarcoding of marine zooplankton; and publications and review papers in open access peer-reviewed journals. Workshops to build capacity for the MetaZooGene mission will be designed for early career scientists and those from developing countries, and will be held in association with international conferences.

Scientific Background and Rationale

Marine zooplankton are key players in pelagic food webs, central links in ecosystem function, and useful indicators as rapid responders to environmental variation and climate change (Beaugrand et al., 2010). Characterization of biodiversity of the marine zooplankton assemblage is complicated by many factors, including the systematic complexity of the assemblage; presence of cryptic, rare, and novel species; and high local-to-global ratios of species diversity (Snelgrove et al., 2016). Molecular approaches, including DNA barcoding (use of short DNA sequences for species recognition and discrimination) and metabarcoding (large-scale taxonomic identification of complex samples via analysis of one or few orthologous DNA barcode regions), are providing important new insights into the 'hidden diversity' of marine zooplankton (Bucklin et al., 2011, 2016; Lindeque et al. 2013). A compelling question driving development of new genetic and genomic tools for characterization of zooplankton biodiversity is that the number of species occurring in the pelagic realm remains unknown (Mora et al., 2013; Chust et al., 2017). Metabarcoding is expected to increase estimates marine zooplankton biodiversity dramatically, although recent studies differ in these estimations by at least several orders of magnitude (e.g., Brown et al., 2015; de Vargas et al., 2015; Sommer et al., 2017).

The MetaZooGene SCOR Working Group will seek to develop a global vision for the continuing development of integrative molecular – morphological taxonomic analysis of marine zooplankton biodiversity through international communication, cooperation, and collaboration.

The overarching goal will be to promote and facilitate development and use of best-practices for molecular, statistical and bioinformatics approaches for DNA barcoding and metabarcoding, and thereby to accelerate progress in characterizing local-to-global scale patterns of biodiversity and biogeographic distributions of marine zooplankton, and contribute to better understanding of the functioning of pelagic ecosystems.

Metabarcoding relies on high-throughput DNA sequencing (HTS) technologies, which yield millions of DNA sequences in parallel and allow large-scale analysis of environmental samples. A number of different gene regions are used for metabarcoding, including several hypervariable regions of nuclear small- (18S) and large-subunit (28S) rRNA (Lindeque et al., 2013; De Vargas et al., 2015; Hirai et al., 2015). Metabarcoding studies have also used mitochondrial cytochrome oxidase I (LeRay and Knowlton, 2016), which can detect species-level diversity, but may yield inconsistent results. In addition to fundamental research on pelagic biodiversity and ecosystem functioning, promising applications of metabarcoding of marine zooplankton include rapid detection of impacts of climate change, monitoring and assessment of ecosystem health, characterization of food webs, and detection of introduced and non- indigenous species (Aylagas et al., 2014; Bucklin et al. 2016; Deagle et al., 2017; Goodwin et al., 2017).

A primary obstacle to the widespread use of metabarcoding for fundamental research on the biodiversity, biogeography, and trophic dynamics of marine zooplankton is the lack of taxonomically-comprehensive global-scale DNA sequence reference databases (libraries of DNA sequences determined for specimens identified to species by morphological taxonomic characters) for the selected barcode gene regions.

Reference DNA databases have been shown to markedly improve the accuracy and taxonomic resolution of metabarcoding data for zooplankton diversity (Hirai et al, 2015; Machida et al., 2017; Yang et al., 2017). Among the challenges remaining for reliable and routine application of metabarcoding for analysis of zooplankton diversity are evaluation and inter-comparison of results using different barcode gene regions; development of best practices to ensure accurate identification, discrimination, and detection of taxa; and continued development of taxonomically comprehensive reference databases for all barcode gene regions.

Metabarcoding is revolutionizing the analysis of marine biodiversity and is expected to significantly revise global estimates of zooplankton diversity. Yet the remarkable promise of DNA barcoding and metabarcoding will only be realized with global-scale conversation, cooperation, and collaboration among scientists devoted to the integration of morphological and molecular taxonomic approaches. The proposed MetaZoogene WG members share a dedication to this shared goal, and will work together to promote and facilitate the broad application of DNA barcoding and metabarcoding for analysis of zooplankton diversity, to allow more rapid detection and description of the impacts of climate change, and provide a new foundation for future research, monitoring and management of the pelagic realm.

Terms of Reference

1) *Create an open-access web portal for DNA barcodes for marine zooplankton*

An online open-access database will be designed and populated with species and specimen metadata, photographs, and deep links to sequence data deposited in major repositories. All molecular data, metadata, and protocol information will be publicly available via one or more of the existing open-access repositories. The portal will facilitate and expedite searches for data for marine zooplankton species, which are difficult to discriminate and retrieve via usual keyword searches of online repositories.

2) *Design an optimal DNA barcoding pipeline for marine zooplankton*

MetaZooGene WG members will develop and recommend best practices for DNA barcoding, including evaluation of all steps necessary for the bug-to-sequence pipeline. The WG will coordinate and accelerate the augmentation of taxonomically-comprehensive DNA barcode datasets for the global ocean by setting priorities and identifying gaps.

3) *Develop best practices for DNA metabarcoding of marine zooplankton biodiversity*

The MetaZooGene WG will evaluate and compare the many diverse molecular, analytical, and bioinformatics approaches now used for metabarcoding. A globally-integrated metabarcoding dataset will be developed to allow comparison of results from local, regional, and global scale efforts by all participating investigators. This shared resource and the ensuing discussions and deliberations will provide the basis for high-level synthetic and review papers that recommend and promote best practices for metabarcoding of marine zooplankton biodiversity.

Working Plan

The MetaZooGene web portal and database (ToR #1) will be designed and populated with data and information (including unique identifiers) for samples, specimens and vouchers. The database will include deep links via accession numbers or other unique identifiers for DNA sequence data available on established public open access repositories. Only repositories that assure fully open and public access to all data by any user – without password control, registration, or other impediments to open access – will be included in the MetaZooGene database and web portal.

The MetaZooGene WG members will develop and recommend a sequence and set of procedures for barcoding pipelines (ToR #2), designed to guide related efforts in laboratories or facilities throughout the world. Description of best practices for DNA barcoding will include morphological identification of species by taxonomic experts, photographs of specimens, archives of specimen and DNA vouchers, DNA sequencing primers and protocols for all agreed-upon barcode gene regions, inclusion of all specimen data and metadata in open access websites and portals, and submission of all DNA sequence data to existing open access data repositories. Information and advice will be sought from several WG members who are currently engaged in bug-to-database multi-gene semi-automated DNA barcoding pipelines at their home universities and institutes.

MetaZooGene WG members will develop recommendations for best practices for metabarcoding of marine zooplankton biodiversity (ToR #3), based on examination, review, comparison and evaluation of key issues, including selection of marker gene regions, design of

PCR primers and sequencing protocols, comparisons of analytical and bioinformatics parameters and approaches, and benefits of taxonomically comprehensive global-scale reference DNA sequence databases. Particular attention will be given to ongoing programs that have implemented metabarcoding for routine local-to-regional monitoring and assessment of zooplankton biodiversity.

The MetaZooGene WG will meet three times over the 4 years in association with international scientific conferences (see *Timeline*). Four MetaZooGene workshops will be organized (one each year) to provide in-depth training for graduate students and early-career scientists, especially from developing countries (see *Capacity Building*).

Timeline

Year 1 (January 1 – December 31, 2019)

- Create MetaZooGene database and web portal; populate the database with all available specimen data and metadata (including unique identifiers), and deep links to DNA sequences in existing open-access repositories.
- Develop and describe best practices for multi-gene DNA barcoding "pipelines" from bug-to- database, including sample collection, preservation and archiving; specimen identification and vouchering; DNA extraction, PCR and sequencing primers and protocols; submission of data and metadata to open-access repositories.
- Convene first MetaZooGene Working Group meeting following the ICES 2019 Annual Science Conference; September 9-12, 2019; Gothenburg, Sweden.
- Organize a MetaZooGene Workshop to review and compare present approaches and best practices for multi-gene DNA barcoding pipelines from bug-to-database. The workshop will be held following the International Council for the Exploration of the Sea (ICES) 2019 Annual Science Conference; September 9-12, 2019; Gothenburg, Sweden.

Year 2 (January 1 – December 31, 2020)

- Conduct comparative examination of metabarcoding approaches and protocols for analysis of marine zooplankton biodiversity.
- Convene the second MetaZooGene Working Group meeting following AGU/ASLO/TOS Ocean Sciences Meeting; February 16-21, 2020; San Diego, California, USA.
- Organize a workshop to evaluate and compare use of DNA sequence databases for different barcode gene regions for analysis of zooplankton diversity based on DNA barcoding and metabarcoding. The workshop will be held following the AGU/ASLO/TOS Ocean Sciences Meeting; February 16-21, 2020; San Diego, California, USA
- Publish comprehensive review paper in open access peer-reviewed journal summarizing and assessing the current view of marine zooplankton biodiversity based on metabarcoding.

Year 3 (January 1 – December 31, 2021)

- Organize an intensive hands-on 'DNA-to-data' training workshop in DNA barcoding and metabarcoding targeted for graduate students and early-career scientists. The workshop will be held at Academia Sinica (Taipei, Taiwan) and hosted by WG member Ryuji Machida.
- Publish comprehensive review paper in open access peer-reviewed journal summarizing current status of multi-gene reference DNA sequence database, with demonstration of the usefulness of reference databases for improved identification of taxa from metabarcoding analysis of zooplankton diversity.
- Fully populate the MetaZooGene database, with specimen data and metadata for described species of marine holozooplankton, including DNA sequences for multiple barcode gene regions and multiple specimens throughout each species' geographic range.

Year 4 (January 1 – December 31, 2022)

- Convene the third MetaZooGene Working Group meeting following the AGU/ASLO/TOS Ocean Sciences Meeting; February 27-March 4, 2020; Honolulu, Hawaii, USA
- Organize a workshop to educate and encourage use of best practices, including use of taxonomically-comprehensive global-scale reference DNA sequence databases, for metabarcoding analysis of marine zooplankton biodiversity. The workshop will be scheduled to follow the AGU/ASLO/TOS Ocean Sciences Meeting; February 27-March 4, 2020; Honolulu, Hawaii, USA
- Publish and distribute a comprehensive recommendation for best practices for metabarcoding of marine zooplankton biodiversity, including use of taxonomically comprehensive global-scale reference DNA sequence databases.

Deliverables

Project website, web portal, and database: The MetaZooGene WG will have a dedicated website and web portal for display and distribution of project updates and results, as well as a login section for exchange of information among WG Full and Associate members. Database design, development and maintenance will be the responsibility of WG member Todd O'Brian, with costs provided by the NOAA National Marine Fisheries Service. All data and metadata associated with the MetaZooGene WG efforts will be publicly available and open access, without password control or required registration.

Best practices for DNA barcoding and metabarcoding: The MetaZooGene WG members will produce recommendations for best practices for both DNA barcoding pipelines and metabarcoding analysis of marine zooplankton diversity.

Publications in peer-reviewed journals: MetaZooGene WG members will publish and acknowledge WG contributions for papers in peer-reviewed open access journals on topics relevant and related to the WG mission. The anticipated goal is a total of 25 publications over the active years of WG effort.

Review papers: Three comprehensive review papers will be co-authored by WG members and published in peer-reviewed open access journals. The reviews will provide summary evaluation and analysis consistent with the MetaZoogene primary goals, including: 1) overview of available DNA sequence reference DNA databases for marine zooplankton; 2) evaluation of best practices for “bug-to-sequence” pipelines for production of DNA sequences for barcode marker genes; and 3) evaluation and recommendation of best practices for metabarcoding analysis of marine zooplankton biodiversity.

Capacity Building

Four workshops are planned to address the key themes central to the MetaZooGene mission. Workshops will be designed for early career scientists and those from developing countries, and will be held in association with international oceanographic conferences. Announcements and invitations will seek to recruit participation by the target groups. The workshops are:

- Best practices for multi-gene DNA barcoding pipelines from bug-to-database. Will be held following ICES 2019 Annual Science Conference; September 9-12, 2019; Gothenburg, Sweden
- Use of DNA reference sequence databases for analysis of zooplankton diversity based on DNA barcoding and metabarcoding. Will be held following the AGU/ASLO/TOS Ocean Sciences Meeting; February 16-21, 2020; San Diego, California, USA.
- Hands-on ‘DNA-to-data’ training workshop in DNA barcoding and metabarcoding. Will be held during Fall, 2021 at Academia Sinica (Taipei, Taiwan) and hosted by WG member Ryuji Machida.
- Best practices for metabarcoding analysis of marine zooplankton biodiversity. Will be held following the AGU/ASLO/TOS Ocean Sciences Meeting; February 27-March 4, 2020; Honolulu, Hawaii, USA

The MetaZooGene workshop participants will have top priority for invitations for collaborative research visits to WG members’ laboratories. A mailing list will be maintained and used for frequent announcements and updates on the activities of the WG. The workshop participants will be used for invitations to special sessions at international conferences and symposia on relevant research topics. The goal will be to ensure significant and continued influence and impact on this group of early career scientists.

Working Group composition

	Full Members	Gender	Place of work (Country)	Expertise relevant to proposal	Geographic Region(s)
1	Bucklin, Ann (Chair)	F	University of Connecticut (United States)	DNA barcoding; Metabarcoding	North Atlantic Ocean
2	Kosobokova, Ksenia (Vice-Chair)	F	Russian Academy of Sciences (Russia)	Zooplankton taxonomy; DNA barcoding	Arctic Ocean
3	Peijnenburg, Katja (Vice-Chair)	F	University of Amsterday (Netherlands)	DNA barcoding; Metabarcoding	North / South Atlantic Ocean
4	Blanco-Bercial, Leocadio	M	Bermuda Inst. Ocean Science (Bermuda)	Zooplankton taxonomy; DNA barcoding; Metabarcoding	N Atlantic Ocean, NE Pacific Ocean
5	Cepeda, Georgina	F	Instituto Nacional de Investigación y Desarrollo Pesquero (Argentina)	Zooplankton taxonomy, DNA barcoding; Metabarcoding	South West Atlantic Ocean
6	Falkenhaug, Tone	F	Institute of Marine Research (Norway)	Zooplankton taxonomy; DNA barcoding	North Sea, Norwegian Fjords, NE Atlantic Ocean
7	Huggett, Jenny	F	Dept of Environmental Affairs (South Africa)	Zooplankton ecology, parataxonomy	SE Atlantic, SW Indian, Southern Ocean
8	Li, Chaolun	M	Institute of Oceanology (China)	Zooplankton taxonomy; DNA barcoding	NW Pacific Ocean; coastal areas of China
9	Machida, Ryuji	M	Academia Sinica (Taiwan)	DNA barcoding; Metabarcoding; Reference Databases	W Pacific Ocean
10	O'Brien, Todd	M	NOAA National Marine Fisheries Service (United States)	Web site design; Data base management	Global Ocean (database management)

	Associate Members	Gender	Place of work (Country)	Expertise relevant to proposal	Geographic Region(s)
1	Escribano, Ruben	M	Universidad de Concepción (Chile)	Zooplankton ecology; taxonomy	S Pacific Ocean
2	Goetze, Erica	F	University of Hawaii (United States)	DNA barcoding; Metabarcoding	N Pacfic Ocean
3	Hirai, Junya	M	University of Tokyo (Japan)	DNA barcoding; Metabarcoding	Western N Pacific Ocean
4	Hosia, Aino	F	University of Bergen (Norway)	Zooplankton taxonomy (gelatinous); DNA barcoding	North Sea, Arctic, NE Atlantic Ocean
5	Laakmann, Silke	F	Helmholtz Institute for Functional Marine Biodiversity (Germany)	Zooplankton integrative taxonomy	North Sea
6	Lindeque, Pennie	F	Plymouth Marine Lab (United Kingdom)	DNA barcoding; Metabarcoding	North Atlantic
7	Mazzochi, Maria Grazia	F	Stazione Zoologica Anton Dohrn (Italy)	Zooplankton ecology; integrative taxonomy (copepods)	Mediterranean Sea, Atlantic Ocean, Southern Ocean
8	Noblezada, Mary Mar	F	Univ. of Phillipines (Phillipines)	Zooplankton taxonomy; DNA barcoding	Phillipine Sea, tropical W Pacific Ocean
9	Rodriguez-Ezpeleta, Naiara	F	AZTI Tecnalia (Spain)	Metabarcoding	Mediterranean Sea, NE Atlantic Ocean
10	Weydmann, Agata	F	University of Gdansk (Poland)	DNA barcoding; Metabarcoding	Arctic, N Atlantic Ocean

Working Group contributions

Ann Bucklin (Chair) has international leadership experience as lead scientist for a Census of Marine Life project, Census of Marine Zooplankton, and as a national delegate and working group chair for the International Council for Exploration of the Sea (ICES). Her research uses diverse molecular genetic/genomic/transcriptomic approaches; she is author of review papers on DNA barcoding and metabarcoding and population genomics of marine zooplankton.

Katja Peijnenburg (Vice-Chair) uses multidisciplinary approaches to resolving global-scale species boundaries and diversity patterns of different groups of marine zooplankton; she is experienced with semi-automated DNA barcoding pipelines, including archives of voucher specimens and DNA. As a WG Vice-Chair, she will lead and contribute to discussions about best practices for metabarcoding, including comparisons among genes and gene regions and identification of taxa using reference databases.

Ksenia Kosobokova (Vice-Chair) is a recognized expert on taxonomy, biodiversity, and ecology of Arctic marine zooplankton, including the full spectrum from jellyfish to crustaceans, with established collaborations for DNA barcoding and metabarcoding studies. As a WG Vice-Chair, she will ensure coordination among morphological and molecular approaches necessary to achieve WG goals, and lead WG efforts to evaluate and guide development of taxonomically-comprehensive reference databases.

Leocadio Blanco-Bercial has expertise and extensive experience in DNA barcoding and metabarcoding of marine zooplankton, with interests in phylogenetic analysis and taxonomic relationships of various groups, including copepods and gastropods. He has participated in several international programs, and has a particular interest in integrating morphological and molecular analysis of marine zooplankton.

Georgina Cepeda is an expert copepod morphological taxonomist, with experience in developing DNA barcoding protocols and metabarcoding methods. She is committed to the MetaZooGene goal of building global consensus for best practices for these methods and approaches.

Tone Falkenhaug has expertise in zooplankton ecology and taxonomy, especially copepods, gelatinous zooplankton, pelagic decapods, and euphausiids. She has led a comprehensive and ambitious DNA barcoding effort focused on planktonic copepods and cladocerans in Norwegian waters.

Jenny Huggett is a zooplankton ecologist and parataxonomist, who has participated in sampling initiatives in the Benguela upwelling regions and Southern Ocean, and is currently most active in the SW Indian Ocean. Among her current projects is the DNA barcoding of meroplankton.

Chaolun Li conducts broad-ranging research in marine zooplankton ecology. He established the first zooplankton DNA barcode database in China, and is now engaged in the application of environmental DNA (eDNA) analysis of zooplankton diversity.

Ryujia Machida has expertise and research interests in mechanisms of diversity maintenance in pelagic zooplankton. He has pioneered the development of molecular approaches and protocols, including DNA barcoding, genomic sequencing, and reference DNA sequence datasets for marine zooplankton.

Todd O'Brien has developed and led international database efforts, serving as plankton lead for the World Ocean Database. He is a member of two SCOR WGs, Global Comparisons of Zooplankton Time Series (WG125.net) and Global Patterns of Phytoplankton Dynamics in Coastal Ecosystems (WG137.net); two ICES WGs, Working Group on Zooplankton Ecology (WGZE.net) and Working Group on Phytoplankton & Microbial Ecology (WGPME.net); and the IMBER Data Management Committee.

Relationship to other international programs and SCOR Working Groups

There is no other equivalent effort focused on this or any closely-related goals in molecular approaches to zooplankton biodiversity among current SCOR Working Groups. Marine zooplankton have been largely overlooked in previous and ongoing efforts focused on building genomic and transcriptomic resources for marine organisms (GIGA, 2014). As an example, there are few – or perhaps none – model species for genome sequencing efforts (Bucklin et al., 2018).

This effort follows two very successful inter-related multi-year programs, the Census of Marine Life (CoML) and Marine Barcode of Life (MarBoL), which laid useful foundations for the proposed MetaZooGene WG effort. In particular, the Census of Marine Zooplankton (CMarZ, see http://www.cmarz.org/) was funded by the Alfred P. Sloan Foundation during 2004-2010, with the ambitious goal of producing a global assessment of marine zooplankton biodiversity, including accurate and complete information on species diversity, biomass, biogeographical distribution and genetic diversity.

The name of the proposed WG stems from an international effort led by Ann Bucklin called ZooGene (see http://www.zoogene.org/), which had the goal of a DNA sequence database for calanoid copepods and euphausiids, and was funded by the US National Science Foundation during 2000-2004.

The topic of DNA barcoding and metabarcoding is central to the mission and goals of the ICES Working Group on Integrative Morphological and Molecular Analysis (WGIMT, see http://wgimt.net/ and http://www.ices.dk/community/groups/Pages/WGIMT.aspx). In contrast to SCOR WG, the focus of ICES WGs is necessarily regional, with a priority on the North Atlantic Ocean.

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

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2.2.6 The Caribbean Upwelling Research Network (CURNet) ***Halpern***

Summary/Abstract

The Caribbean Upwelling system (CUS) is likely the least known coastal upwelling system in the world. Its biological and fishing productivity is lower than the Eastern Boundary Upwelling Systems (EBUS). Total EBUS catch small pelagic in ~ 12 million tons, while the total small pelagic acoustic biomass in CUS has been estimated ~ 1.5 million tons. Despite that, some studies suggest this system could support most of the productivity observed in the Caribbean basin, besides its variability could have an important effect in the climate of the northern South America. The CUS shares some characteristics with its EBUS counterparts, but there is still a lack of information related to its functioning, long-term variability, the origin and nature of its upwelling waters and its real productive potential. Academic, governmental and research institutions in the Caribbean countries currently have limited capacity to develop research initiatives that fill up these information gaps. The Caribbean Upwelling Research Network (CURNet) is proposed as a collaborative strategy to focus research efforts in the CUS, promoting the exchange with recognized research groups from 3 EBUS; the Chile-Peru, California and the Canary systems. The CURNet initiative seeks stimulated the academic exchange, increase the number of indexed publications, and strength the observational and modeling capabilities of the system. The CURNet products could have an important impact on the technological and socioeconomic development of most of the coastal communities of the region, most of which are economically depressed and exploit artisanally the fishery resources as sustenance and source of protein.

1. Scientific Background and Rationale

The southern Caribbean coast off Colombia, Venezuela and Trinidad (61-74 °W and 10- 13 °N) experience an intense coastal upwelling mainly during January to May (Andrade and Barton, 2005; Rueda-Roa and Muller-Karger, 2013). This Caribbean Upwelling System (CUS) generates a significant increase in the phytoplankton productivity (Muller- Karger *et al*., 1989), stimulates the growth and determines the ecological structure of coral reefs, grasslands and macroalgae communities (Diaz-Pulido and Garzon-Ferreira, 2002; Eidens *et al*., 2014), supports ~ 95% of the small pelagic biomass (Rueda-Roa and Muller-Karger, 2013), and affects the hurricanes frequency in the Caribbean (Jury, 2017). The CUS is forced by the trade winds, which flow east-west and get intense in the center of the Caribbean basin, forming the Caribbean Low Level Wind Jet (CLLJ; Wang, 2007). The CLLJ determine more intense upwelling favorable winds in the Western sector of the CUS (74-70ºW), which force an intense seasonal upwelling with high offshore transport of upwelled waters (Andrade and Barton 2005). The Eastern Sector (65-61ºW), outside the CLLJ influence, has less intense winds but upwelling- favorables throughout the year, which produce a lower offshore transport but a deeper pumping than in Western sector (Rueda-Roa and Muller-Karger, 2013). These two sectors also shown differences in biological and fishing productivity. The Eastern sector have the highest chlorophyll concentrations and the major pelagic biomass (~ 78%). This major productivity has been related to a longer retention times and less turbulence, which can favor a major local use of upwelling nutrients by phytoplankton and major recruitment of clupeids (Rueda-Roa and Muller-Karger, 2013). The Western sector shows the formation of extense upwelling filaments which interact with mesoscale eddies transported by the Caribbean Current (Andrade and Barton, 2005). This filament-eddy interaction seems export nutrients and planktonic biomass towards Caribbean open waters and islands, generating impacts still unknown on the biological productivity of the entire basin. The biological production of both CUS sectors is significantly lower than that observed in the major EBUS (Chavez and Messie, 2009). Despite that, some preliminary observations suggest that CUS is probably the largest source of nutrients for the biological productivity of the Caribbean Sea. Even the nutrient enrichment of the upper ocean layer originated in the CUS could have productivity implications in the Gulf of Mexico, which is dynamically connected with the Caribbean through the Caribbean Current, the Yucatan Current and the Loop Current. Preliminary observations in the upper layer (first 400 m) of the Gulf of Mexico (Camacho-Ibar pers. Pers.) indicate a nutrient enrichment with respect to the northwest Atlantic (the origin of Gulf waters), which apparently occurs during the transit of surface waters through the Caribbean and its modification in the CUS.

As the CUS is a tropical upwelling system forced zonally by the trade winds on the southern edge of the Caribbean basin, is not in the strict sense an EBUS. However, some typical EBUS characteristics are similar to those observed in the CUS. Most of CUS variability depends on the variability of the CLLJ (Ordoñez *et al*., In prep.), which have similar structure of the coastal low level wind jets of the main EBUS. The CUS presents 2 well-defined sectors or biomes (Rueda-Roa and Muller-Karger, 2013) and, in general, the EBUS presents between 3 and 4 (Chávez and Messie, 2009). Intense mesoscale eddies are generated in the coastal transitional zones of EBUS (Chaigneau *et al*., 2009), structures that travel hundreds of kilometers (Hormazabal *et al*., 2013, Combes *et al*., 2017), interacting in their path with seamounts and oceanic islands, and producing significant chlorophyll increases associated with the generation of submeso- scale eddies (Andrade *et al*., 2014). Altimetry data have allowed to observe how CUS frontal zones interact with mesoscale long-lived eddies from the Caribbean current (Murcia *et al*., In prep.), structures that are intensified in the CUS and travel toward the west of the Caribbean (Jouanno *et al*., 2012), likely transporting properties to Caribbean island (eg San Andrés archipelago) and the Gulf of Mexico. Some evidences indicate the presence of a subsurface countercurrent in the CUS (Andrade *et al*., 2003) that possibly transports waters and nutrients that are eventually pumped by the upwelling (Correa-Ramirez *et al*., In prep), in a similar way the subsurface countercurrents do in the EBUS (Chávez and Messie, 2009). The EBUS presents an interannual to decadal variability associated to low frequency variability of the Pacific and the Atlantic (Di Lorenzo *et al*., 2008), which is transmitted to these systems through atmospheric and oceanic remote connections (eg, Kelvin waves / Rossby) (Thomas *et al*., 2009). In CUS strong low frequency variability has been observed, whose origin and transmission form to the system is not yet clear (Ordoñez *et al*., In prep), considering that the Caribbean does not have a direct connection with the Pacific and Atlantic oceans. It has been observed a long term trend of upwelling intensification in the CUS (Santos *et al*., 2016) which has also observed in the other EBUS (Bakun, 1990) and has been related to early effects of the global warming due to anthropogenic greenhouse gases (Garreaud and Falvey, 2009).

Despite these similarities, there are many aspects still unknown in the CUS in comparison to its EBUS counterparts, which make CUS the least known coastal upwelling system in the world. Still unknown aspects such as: what is the potential of productive of CUS? What are the main limitations of the biological productivity? Which are the mixing processes in the upwelling waters? What is the role of the mesoscale eddies in the connectivity of the CUS with the rest of the Caribbean? How is the contribution of the CUS to the physical and biological variability of the Caribbean? Which is the origin of the nutrients from the upwelling waters? What is the relationship of the CUS with the oxygen minimum zone and the anoxic events that generate important fishing losses in the region? What is the structure and energy transfer in the tropical food chain of the CUS? What is the long-term variability of the system? How could the CUS respond to future scenarios of atmospheric / ocean warming associated with climate change? This low level of knowledge in the system is reflected in a low number of indexed publications (~ 15), most of which have been cited in the present background. The CARIACO project (Carbon Retention in a Colored Ocean), is possibly the initiative that has developed a greater amount of studies on the biogeochemistry of the Cariaco basin and the CO2 exchange between the atmosphere and the ocean, in the CUS eastern sector. In addition to the CARIACO series, there are no other initiatives promoting a regional analysis, due in part to technical and budget limitations of the academic and research centers in the region.

Most of the Caribbean coastal communities in Colombia and Venezuela have low economic conditions, as a result of political instability, the marginalization of governmental development programs, the historical processes of violence and forced displacement. Much of the current economic livelihood and source of protein dependent on artisanal fisheries associated with CUS. Despite, has been observed a decrease trend of fishing resources (García *et al.*, 2007) whose causes are still unknown, but could be associated with aspects of the CUS variability. The socio-economic importance of the CUS, supports the need to advance in collaborative strategies that allow to concentrate efforts to rapidly increase the current level of knowledge about the CUS, facilitating the exchange / transfer of experiences and technology with other research groups of recognized trajectory in upwelling systems, as proposed in the CURNet initiative.

2. Terms of Reference

ToR 1. Promote research efforts **in the tropical coastal upwelling system** off the Southern Caribbean coast. Facilitate the academic exchange between the institutions conforming CURNet. Increase the number of these works and indexed manuscripts in identified scientific topics of the System.

ToR 2. Advance in the **development of** appropriates **numerical models of the Caribbean Upwelling System**. Conform a working line to build and validate coupled physical-biological models required to understand the dynamic functioning of the system and its long term trends in the future climate change scenarios. Provide information useful to economic and operational activities.

ToR 3. Strengthen the technological exchange to increase the observation capabilities and the social appropriation of relevant information of the system. Improve the built capacity of local instrumental laboratories, promoting the design of low-cost oceanographic instruments to monitor the Caribbean Upwelling variability. Contribute to the development of operational - oceanographic web applications to serve information to artisanal fisheries and economic activities in the region.

3. Working plan

In **year 1**, CURNet will focus on organizing the WG and designing the strategy to reach the proposed terms of reference (ToR). A first meeting of the WG will be held at the main headquarters of INVEMAR (Santa Marta), where it is expected: Act. (Activity) _1 Identify the main research topics required to increase the knowledge of the upwelling system (ToR 1); Act._2 Identify the requirements in terms of training and technology transfer needed to achieve the proposed development and research topics (ToR 1, 2 and 3); Act._3 Prepare a review manuscript that synthesizes current advances in the knowledge of the CUS (Deliverable 1). Part of the strategies for the development of these activities includes the promotion of academic exchanges, topic courses and lectures in the following years. For this purpose, it is expected to identify alternative sources of funding for research internships and student mobility.

During Years 2 and 3 (2020-2021), the efforts of the WG will be focused on the design / implementation / assimilation of physical / biological coupled models (Act._4), that reproduce the Caribbean upwelling system (ToR 2). This activity is expected to be developed through the creation of a work line in numerical modeling, in order to analyze the internal dynamics of the upwelling system and its long-term trend. As a result of this activity, a validated regional model for the Caribbean Sea (Deliverable 2) will be obtained.

Additionally, during the year 2 (2020), the second meeting of the WG will be held at the main headquarters of INVEMAR (Santa Marta). In the 3 days following the meeting, the First cycle of Short Courses in Advanced Topics of Upwelling Systems will be held (Act._5), on some of the key topics that will be identified in Act._1 and Act._2, oriented to the scientific and academic community. Most of these courses which will be dictated by the full members, based on their expertise. This is a strategy of social appropriation of knowledge about the environmental and economic importance of upwelling systems. With this activity it is expected to train a greater number of young researchers and motivate them to develop their undergraduate and postgraduate researches on relevant issues of the upwelling system. This academic activity will be carried out biannually. It is expected that this activity will be recognized as an important periodic event for the regional scientific community, which will leverage resources for its realization in future years, with the option that it can be carried out in other countries of the region.

In the years 3 (2021) and 4 (2022) will be addressed the technological exchange activities related to both, the oceanographic instrumentation and Web platform development, according to the ToR 3. The products obtained in previous years will be reviewed to the identify of information gaps and propose improving alternatives for the observation systems of the CUS, thus creating a research line to propose low-cost devices to monitor the main environmental variables associated with the CUS (Deliverable 3). During these years, efforts will also be directed to design and implement Web modules that complement the already existing Observatory of the tropical seas of the Americas – ObserMar on issues related to biological productivity and variability of the water column in the upwelling system (deliverable 4).

Finally, in year 4 (2022) the third meeting of the WG will be held at the main headquarters of INVEMAR (Santa Marta). This meeting will end with a Socialization Seminar (Act ._7), open to general public, where the WG products will be presented. In the days after the meeting, the full members of the WG will dictate the Second Cycle of Short Courses in Advanced Topics of Upwelling Systems (Act._8).

4. Deliverables

1. (Year 1-2) **A review manuscript** in an indexed journal, with peer review by referees and in Open Access mode, in which the current state of knowledge of the Southern Caribbean Upwelling System will be synthesized. This manuscript will also compare the known characteristics of this system with those of the Eastern Boundary Upwelling Systems of Pacific (Peru-Chile, California) and the Atlantic (Benguela, Canary Islands), in order to identify common dynamic patterns and point out lack of information where it is necessary a greater research effort
2. (Year 2-3) **A regional model for the Caribbean Sea**, which reproduces the main dynamic characteristics of the upwelling system. The model will be validated by comparison with the main historical data bases available. The model will provide information for research and operational purposes.
3. (Year 3-4) **Design of a low-cost oceanographic measurement device** to strengthen the observation / monitoring capacity in the Caribbean Upwelling System.
4. (Year 3-4) Implementation of **two (2) new modules in the ObserMar oceanographic web platform** (obsermar.invemar.org.co): Variability in Depth and the Biological Productivity module.

5. Capacity Building

Establish a research network of the Caribbean Upwelling System (CUS) will allow us to understand this important system of ocean-atmosphere coupling in the Caribbean, and to elucidate its influence on biological, geochemical and climatic aspects, among others. To develop long-term capacity in this area, it is expected that the strengths of each member of the research group will be used, and offered as a tutoring opportunity to further develop understanding of the subject.

Knowledge transfer will be facilitated through workshops and different advanced level courses for undergraduate and postgraduate students to consolidate a new community of ocean scientists. the INVEMAR as a center of the Ocean Teacher Global Academy (OTGA) of

UNESCO, could take advantage of this capacity to obtain additional funds to establish a course on the topics of this proposal in terms of capacity building, Victor Camacho-Ibar has a fully operational laboratory for inorganic nutrient analyses which has recently participated in an international intercalibration exercise led by the SCOR-WG #147. The generation of high quality nutrient data which are comparable among laboratories is not trivial, thus the UABC group can collaborate in capacity building via training, workshop organization and intercalibration exercises for nutrient analyses among laboratories participating in the project. He has performed research on the biogeochemical interaction between the California Current upwelling system and adjacent coastal lagoons in Mexico, and is currently leading research on nutrient biogeochemistry in deep waters of the Mexican region of the Gulf of Mexico. Thus, his group can share his experience in the biogeochemical interpretation of nutrient data. In turn, his group will benefit from the experience of other members in mesoscale processes observations and modeling.

Overall, these activities will maximize the building of long lasting global capacity within this important topic.

6. Working Group composition

CURnet has 10 Full and 3 Associate members that bring together state-of-the-art skills in upwelling systems, modelling and the development of monitoring systems (device and web platform). The Full Members are responsible for the delivery of our objectives, while the Associate Members. provide important input from the complimentary fields. Our Full members represent 5 different nations. Moreover, we include early career researchers as Full members, which will aid their career development.

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

Name	Gender	Place of work	Expertise relevant to proposal
Emanuele Di Lorenzo (United States of America)	Male	Professor of Ocean & Climate Dynamics Director, Program in Ocean Science & Engineering (OSE) School of Earth & Atmospheric Sciences Georgia Institute of Technology Atlanta, GEO, USA	Ocean and Climate Dynamic, Regional and Coastal Oceanography, Low Frequency Ocean Variability, Ocean & and Inverse Modeling, Coupled Ocean & Atmosphere Variability

Angel Rodriguez Santana (Spain) **Co-Chair**	Male	Professor at Universidad de Las Palmas de Gran Canaria – UPLC Grupo I+D Observación y Modelización de Fenómenos Geofísicos y Marinos (OFYGA) Gran Canaria, Spain	Turbulence, mixing processes, nutrient transfer and frontal zones in upwelling systems.
Constanza Ricaurte Villota (Colombia) **Co-Chair**	Female	Coordinator of Geoscieces program, at the Coastal and Marine Research Institute – INVEMAR Santa Marta, Colombia	Past and present Ocean and Climate Dynamic, Regional and Coastal Oceanography.
Samuel Hormazabal Fritz (Chile) **Co-Chair**	Male	Professor at Pontificia Universidad Católica de Valparaiso - PUCV Valparaiso, Chile	Coastal dynamics, upwelling, coastal trapped waves, Rossby waves, El Niño and the Southern Oscillation, Eastern boundaries currents, mesoscale eddies, physical-biological coupling
Marco Correa Ramirez (Colombia)	Male	Researcher at Coastal and Marine Research Institute - INVEMAR Santa Marta, Colombia	Physical-biological coupling in the ocean, upwelling systems, satellite oceanography and mesoscale processes.
Antonio Juan González Ramos (Spain)	Male	Investigador en Robótica y Oceanografía Computacional Instituto Universitario de Sistemas Inteligentes y Aplicaciones Numéricas en Ingeniería - UPLC Gran Canaria, ESP	Operational oceanography, marine robotics and observational systems of the ocean.

Joaqim Bento (Chile)	Male	Assistant Professor at Marine Science School, Pontificia Universidad Católica de Valparaiso - PUCV Valparaiso, Chile	Operational oceanography
Victor Camacho Ibar (Mexico)	Male	Researcher at Instituto de Investigaciones Oceanológicas, UABC Ensenada, México	Nutrient biogeochemistry in upwelling influenced coastal lagoons and in deep waters of the Gulf of Mexico
José Martín Hernández Ayón (Mexico)		Researcher at Instituto de Investigaciones Oceanológicas, UABC Ensenada, México	Chemical Oceanography, coastal and upwelling carbonate system

Associate Member (no more than 10)

Name	**Gender**	**Place of work**	**Expertise relevant to proposal**
Vincent Combes (United States of America)	Male	Research Associate – Physical Oceanography OREGON STATE UNIVERSITY – College of Ocean and Atmospheric Sciences COAS Corvallis, OR USA	Low frequency ocean variability, Coastal upwelling, Eddy dynamics, Cross-shelf transport
Martha Bastidas (Colombia)	Female	Instituto de Investigaciones Marinas y Costeras “Jose Benito Vives de Andreis” Invemar	Remote sensing And dynamic oceanography
Silvio Andres Ordoñez (Colombia)	Male	Instituto de Investigaciones Marinas y Costeras “Jose Benito Vives Invemar De Andreis”	Frequency-Domain Analysis, Statistical approach to system analysis, Programming and development, Satellite Image processing

7. Working Group contributions

Emanuele Di Lorenzo is a modeller of Coupled Ocean & Atmosphere Systems, will be the leader of the development of the regional model of the Caribbean Sea

Angel Rodriguez Santana as expert in mixing processes and frontal zones in upwelling systems, will help to understand these issues in the CUS and will share their knowledge with the group.

Constanza Ricaurte-Villota is the head of the program of Marine and Coastal Geosciences of INVEMAR, and the leader of the new research group of the CUS. She will share her expertise in Past and present Ocean and Climate Dynamic. Also she will coordinate the actions of the group using their great experience in managment of projects and research groups.

Samuel Hormazabal Fritz as expert in coastal dynamics, upwelling, mesoscale eddies and physical-biological coupling, will lead studies in the CUS on these topics.

Marco Correa-Ramirez is an associated researcher at INVEMAR, expert in satellite oceanography and data analysis. He has carried out some studies in the CUS and currently he is leading an agency project on the interconnectivity of this system with the Caribbean basin.

Antonio Juan González Ramos as expert in observational systems of the ocean will lead the development of oceanographic measurement device

Joaqim Bento is an expert in Operational oceanography, who has participated in the development of the POMEO web platform in Chile, and will help the development of the new ObserMar modules.

Victor Camacho-Ibar will share his expertise in nutrient analyses and the biogeochemical interpretation of nutrient data.

Martín Hernandez-Ayon is a Chemical Oceanographer, will lead the subject of the carbonate system in the CUS.

8. Relationship to other international programs and SCOR Working groups

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2.2.7 A Framework for Ocean Observation for the Next Generation - expanding quantifiable methods and Best Practices (FOO-BP) *Burkill*

Summary/Abstract (max. 250 words)

The complexity of ocean observing systems is rapidly increasing as requirements for simultaneous biological, physical, and chemical observations emerge to inform new societal requirements. There are many examples in biogeochemistry and biology with new exciting outcomes, but these may not be comparable quantitatively because of variations in observation methods. Moving toward consistent, quantitative science outcomes is essential to address challenging global issues of changing climate, etc. For this, a major capability needed is access to and the ability to use rigorously tested methods in ocean observing. Such “Best Practices” (BP) have helped promote activity across disciplinary boundaries, as well as supporting training of new observers and analysts. They support reproducibility of science and the transmission of key methods across regions. Fundamentally, the use of BP underpins science at a global scale.

Future use of autonomous, intelligent technologies for observations and linking information to users also drives the need for “standard” BP, such as the development of sensor independent protocols to move directly from sensors and data aggregation devices to appropriate databases/users. The increasing use of big data also drives the need for standard protocols for data preparation and insertion into models. As a SCOR WG, we will develop and test a future facing framework, understanding how BP can be more easily adopted and support multi-disciplinary research, engaging with past SCOR WG chairs in a coordinated effort to validate the framework. We will offer this framework for both present and future SCOR WGs and the broader ocean observing research efforts.

Scientific Background and Rationale (max. 1250 words)

Our vision is to increase efficiency, reproducibility, and global interoperability of the ocean observing value chain by defining a new paradigm, a “Framework”, providing the ocean observing community with a unified, sustained, and readily accessible knowledge base of interdisciplinary best practices (BP), facilitating community consensus through active engagement including a peer reviewed publication of ocean BP. Future use of autonomous, intelligent technologies for observations and linking information to users will further drive the need for “standard” BP as more machine interoperability and artificial intelligence will become part of observation systems in the next decade. The Framework will address current methods and encompass the rapidly changing research capabilities occurring with new generations of sensors, platforms and information flow.

Ocean observing systems/infrastructures must be capable of converting raw data into usable information and knowledge products stored in repositories that are readily accessible to scientists. The methodologies and BP associated with large-scale observing systems engage all aspects of the end- to-end information processes ranging from defining and implementing observation plans to the deposition of high-quality data in repositories and effective distribution to scientists and other users. This needs to cover scientific and societal needs, including citizen science, marine, coastal and fisheries management, marine safety, education, national security. The Framework defined by this SCOR WG addresses the end to end value chain from sensors/instruments to science research access. It will include repository infrastructures, means of community engagement and training methodologies that will expand skills in developed/developing countries, underpinning science at a global scale. It will build upon the base of existing BP from SCOR WGs, large scale networks and experience of individual researchers.

The Framework has three core elements: (1) a sustained, advanced archiving and communication system; (2) a community environment for BP documentation, evolution and adoption; and (3) methods and collaborations for training and professional advancement. This recognizes that to preserve their value, BP need to be reliably archived, accessible, searchable, and comparable across disciplines (e.g. EOVs). Advancing technologies can be adopted in knowledge representation, linked data, natural language processing, and document archiving (https://wwww.oceanbestpractices.net/), where key documents of the global observing communities can be easily accessed. This will have an impact, e.g., on the development of QA/QC methods which have seen significant efforts in diverse projects from SCOR WG142, the European JERICO project, IOOS' QARTOD and others that have not consistently converged. The Framework will provide community mechanisms for dialogues to facilitate defining and publishing BP that can synthesize methods. One aspect of this effort is the recently created Research Topic in Frontiers of Marine Science, which the proposed WG will expand to become a place of commentary and dialog. The third element of the Framework is training - a two way process including feedback that can support evolution and expansion in use of BP. This will be done with the related SCOR capacity committee and major organizations, such as JCOMMOCG, IODE, POGO, to ensure that SCOR (and POGO) programs are providing BP for observations and feedback from their use.

Several factors are driving the opportunity and the timing for creating this proposed WG. The OceanObs'19 organizers have defined BP as a major cross cutting theme in their program vision for the next decade. Also, the Framework for Ocean Observing (FOO) is creating a FOO2.0 with the major technical evolution being the introduction of BP as a global tool for advancing ocean observing. We believe the upcoming UN Decade of Ocean Science will similarly have a component of BP creation and implementation. Also, the movement to global scale observations with a new generation of high productivity sensors is creating a big data environment for ocean observing which needs to be addressed in a consistent manner. The proposed WG is scoped to support all of these efforts through formulation of the Framework and its work with the research community[1].

Past SCOR WGs have produced BP documents, but these are often not archived, published or sustained. For example, the WG142 description has no discussion of sustaining the work. What happens five years from now when the technology has changed, will SCOR need to fund another effort to update DO QC? We propose a WG that will support the capacity to continuously

[1] With these goals, the WG is collaborating with AtlantOS partners and groups of UNESCO/IOC including the global observing networks of the JCOMM OCG, in diverse ocean disciplines to populate a BP repository and to address the utility of the BP process for their communities. The AtlantOS partners and associates currently include the GOOS Regional Alliances, GEOMAR, Ifremer, IO PAS, MARUM, PML, UPMC, WHOI and others. In addition, projects are contributing their experience and documentation including, for example, FixO3, JERICO, GROOM, IOOS, ONC, IMOS and EMSO.

develop and exchange emerging BP. Many current SCOR WGs plan to produce best-practice manuals and will benefit from guidance. We will support this vision by engaging with SCOR WG chairs to test the Framework. We will review all past and present SCOR WG outputs with the support of their chairs and communicate BP outcomes to wider ocean observation communities. We will use these as test cases for assessment (and maturing) of the Framework. The results will be published and community reviewed as an overarching article written by the WG as well as a series of contributed papers in the Frontiers in Marine Science Ocean Best Practices peer-reviewed Research Topic (RT) to disseminate high-quality methodologies over the entire range of ocean observing. We note that the new Research Topic in Frontiers is also a means for academic researchers to gain peer reviewed recognition for career advancement. Thus, one WG outcome will be a 'special issue' of Frontiers. A broader impact will come from the Framework facilitating both the mechanical and cultural movement toward BP documentation.

The WG will focus on global interoperability and long-term usability through use of BP. The underlying principles of this SCOR WG is to provide:

- A long-term Framework for access to observation methods and community building including training in the use of best practices as living documents
- Open access, central sustained Repository for BP with natural language processing for easy cross disciplinary search
- Persistent identifiers (DOI) for easy BP citation and means of discovery through common web tools
- Peer reviewed journal papers with corresponding entry of full BP document in Repository.
- Means for Community Dialogue, through the Journal and the Repository.
- Support of training and implementation of BP, particularly in developing countries

We will build upon IODE's existing capability, both in infrastructure, sustainability and its content of over 200 existing BP. Then expand the infrastructure with new search mechanisms and portable web accessibility based on ontologies[2] that service different ocean research disciplines. We will work with BP creators through a help desk to enter BPs into the repository and link IODE with existing BP repositories ensuring a global and consistent network environment. The creation and support of community tools and service is a core part of the strategy, including training, which needs to be both web and in-person training designed in a flexible format that can be quickly learned and practical.

Given the planned OceanObs19, the FOO evolution and the emphasis on integrated global and regional ocean observing systems, as well as the new evolution into expert machine observations and the necessity for cost effective, accurate, reproducible data and observing methods, there is an urgent need for easily accessible BP which can be queried, reproduced and updated.

Terms of Reference (max. 250 words)

1. Define a future facing Framework supporting multi-disciplinary research through broadly accepted and documented best practices
2. Test and evolve the framework in collaboration with SCOR WGs using best

[2] a set of concepts and categories in a subject area that shows their properties and the relations between them

practices and methodologies from SCOR WGs and EOV formulations
3. Support the Community vision by contributing to the FOO2.0 development in best practices and the OceanObs'19 planning and evolution
4. Create and evaluate a training program in observation methods with a focus on developing countries
5. Support mechanisms and community engagement through a peer reviewed journal research topic in Best Practices in Ocean Observing.
6. Coordinate with IOC organizations and major observation organizations, including JCOMM OCG networks for sustained implementation

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

2019:
Within 2 months of the acceptance of the WG, we will contact the chairs of the initial eight SCOR WG listed in the Appendix, depending on their availability, to be Associate Members. We will work with these chairs to plan a small workshop in early 2019 whereby the core WG will meet to discuss a SCOR BP Framework and the chairs will be invited as part of a larger contingent to give feedback on the repository and how to update the current processes to be more effective (these will be "use cases"). This would be co-funded through the European AtlantOS and INTAROS projects, GOOS, IODE, JCOMM. During this meeting, we would plan the next steps leading up to Ocean Obs19, whereby we would (awaiting confirmation) present a white paper and a workshop on best practices Framework and implementation.

Attendance at this meeting would be co-funded by WG members institutions but may need support for 1 or 2 members through SCOR (developing countries or emerging researchers)

2020:
Approach other SCOR WGs that haven't identified best practices as an output to assess whether this work could be of relevance to them. This would also be done in the context of essential ocean variables and the relevant best practices within the SCOR context. Identifying any key gaps and encourage SCOR WGs or potential new SCOR WGs to address these as part of their capacity development plans.

Work with SCOR, POGO and other training and outreach institutions to define and document a training program for best practices with a focus on developing countries
2020/2021:

We would focus on producing the special issue of Frontiers in Marine Science, focused on SCOR WGs, this would include a workshop with the relevant SCOR WG chairs (past and present). This would involve multiple papers from various ocean observing communities.

We will do a formal release of the Framework with a request for community feedback and then incorporate this feedback into an update and formally documented version.
Introduce the Framework approach to IOC and evaluate the potential for long term sustainability of the Framework. This will include a decadal Vision Paper on observation methodologies and practices.

During the three-year period we would work with SCOR to support all future WGs having a plan for archiving and disseminating their BP, this would be through the WGs capacity development programs.

Between meetings we would have monthly skype calls between the SCOR WG to discuss activities, update and feedback, we would include the large community on a quarterly basis. We would continue to advocate oceanbestpractices.net at relevant conferences and workshops. We would also work with the related SCOR capacity committee to ensure that SCOR (and POGO) programs are providing best practices for observations and also request feedback from them (as laid out below)

<u>Deliverables (state clearly what products the WG will generate</u>.

- A decadal Vision Paper on observation methodologies and practices in response to the evolving and future use of autonomous, intelligent technologies for observations and linking information to users.
- A Framework for future creation and deposition of BP in a sustained repository and community outreach and capacity development of BP within the SCOR context.
- An increase from 200 to 500 in the number of archived, accessible BP on the oceanbestpractices.net repository
- Significantly enhanced search and access capabilities for best practices across disciplines including, for example, the access to measuring oxygen developed under IOCCP, BioArgo and other networks.
- Expansion of content in a peer-reviewed journal on Ocean Observing Best Practices as well as a special issue based on SCOR WGs best practices,
- An element of BP introduced into the POGO Centre of excellence and the FOO 2.0 evolution
- Products to support the training of best practices in different ocean observing methods.

<u>Capacity Building</u>

As discussed, the capacity-building aspect of this WG is a key, overarching part of the ToR. We would work closely with the SCOR Committee on Capacity Building, as well as other activities such as the POGO Centre of excellence and summer schools run by IMBER, SOLAS, GEOTRACES, etc. It may be in some cases ‘best practices’ are not optimal due to costs and so we may need to consider a second level of best practices. Hence, we will also target the GOOS Regional Alliances and other observing programs which have developing countries contributing (such as IIOE2) to understand how different regional observing programs deal with BP, in particular in regions with developing countries. We will work with these communities to ensure training and access to best practices and also to get feedback as to the appropriateness. It is essential that emerging and mid-career scientists and technicians have access to these best practices and give feedback on the functionality of them, this can only be done through utilising them. We will move access to web based tools including iPads and iPhone. This will be complemented by social media support. This way, people have these as tools when they get back from training and can continue using the information and experience of the training as well as giving feedback. The BP repository will be available as a DVD as the most up-to-date version at the end of the training.

Working Group composition

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

Name	Gender	Place of work	Expertise relevant to proposal
1 Juliet Hermes, co-chair	Female	SAEON, South Africa,	Physical ocean observing BP and capacity development
2 Cristian Muñoz-Mas, Co- Chair	Male	SOCIB, Spain	Technical ocean observing and interoperability
3 Ana Lara Lopez	Female	IMOS, Australia	BP in all areas of observing systems, Chief Scientist of IMOS
4 Pier Luigi Buiteigieg	Male	AWI, Germany	Ontologies, data systems, BP Arctic observing
5 Tang Hairong	Female	NCOSM, China	BP in WMO and JCOMM systems
6 Emma Heslop	Female	GOOS, France	BP in international observing systems and GOOS RA
7 Johannes Karstensen	Male	GEOMAR, Germany	BP in mooring observing systems, physical oceanography
8 Jay Pearlman	Male	IEEE, France	BP coordination, ocean information systems and AtlantOS
9 Pauline Simpson	Female	IODE, Cayman Islands	IODE and BP database

10 Maciej Telszewski	Male	IOCCP, Poland	BP of biogeochemical observing systems

Associate Members (no more than 10)

Name	Gender	Place of work	Expertise relevant to proposal
1 Mark Bushnell	Male	IOOS, US	QA/QC
2 Frank Muller-Karger	Male	U. South Florida, US	Biological observing BP
3 Rachel Przeslawski	Female	Australian Geoscience, Australia	Biological observing BP
4 Sophie Seeyave	Female	POGO, UK	International observing systems and capacity development
5 Chairs of the WG listed in the Appendix (to be invited)	various	various	various
6			
7			
8			
9			
10			

<u>Working Group contributions (max. 500 words)</u>

- Juliet Hermes is currently the JCOMM OCG vice chair focussing on standards and BP and has considerable knowledge of the various BP involved in the major global observing systems. Juliet also has good knowledge of observing systems and capacity development within Africa and other Indian Ocean rim countries.
- Cristian Cristian Muñoz-Mas is a senior technician and brings sea going expertise to the working group.Cristian's areas of expertise cover the whole range of the data life cycle, ranging from data acquisition (including field operations, oceanograhic instrumentation, survey and moorings design), processing, analysis, QA/QC, data/metadata integration, visualization and dissemination.

- Ana Lara Lopez specializes in long term ecological research and runs the BP for IMOS, she recently produced an overview of BP utilised throughout the Australian ocean observing system.
- Pier Luigi Buiteigieg focuses on technologies for discovery and access including semantic searches, natural language processes as well as wiki- based options. He also has a focus on Arctic observing systems
- Tang Hairong is the lead for ocean best practices as part of the regional marine instrumentation centre for Asia.
- Emma Heslop is the representative for BP within GOOS and works with all of the global observing systems, as well as connecting with the GOOS regional alliances and hence has good knowledge of and support to BP within developing countries' observing systems. Emma has been instrumental in the design and promotion of the Essential Ocean Variables best practices.
- Johannes Karstensen is the lead for Ocean Sites and is driving the BP for global mooring arrays. Johannes is the editor of the BP Journal Research Topic in Frontiers of Marine Science.
- Jay Pearlman leads the AtlantOS work package on BP and has considerable experience with BP of all ocean observing systems, as well as a good understanding of the database and technologies
- Pauline Simpson is the key person for the database of ocean best practices and to represent IODE within the working group.
- Maciej Telszewski leads the integrating of carbon and biogeochemistry observations into the multidisciplinary global ocean observing system through direct and active interaction GOOS, specifically leading the GOOS Biogeochemistry Panel and with IOC-WMO JCOMM. Maciej has a specific focus on marine biogeochemistry observations, and has been strongly involved in the development of the Essential Ocean Variables specification sheets, designing an approach to setting observing targets and metrics for biogeochemical observations, promoting and designing standards and best practices for observations and data management and finally active promoting of data interoperability standards across domains and disciplines.

<u>Relationship to other international programs and SCOR Working groups</u> ***(max. 500 words)***

Most or all of the current SCOR WGs are based on exciting science and it is an appropriate time to support a WG that supports these efforts, and focuses on solving methodological and conceptual problems that hinder research. We would leverage the support of SCOR to enhance the approach to past and present SCOR working groups' best practices and create sustainability into the future. We would also utilize all of SCOR's outreach activities (POGO, cruises, summer schools, visiting scientists etc) to promote best practices and gain feedback from the community.

The relationship to the other SCOR Working Groups has been highlighted throughout the document and is an integral component of the proposal for this WG. One focus of this SCOR WG is to review all past and present SCOR WG outputs with the support of their chairs and identify descriptions or work which represent BP and take the results to the wider ocean observation communities. The key international programs that this WG relate to have also been discussed throughout document but are, for the most part, represented by the full members and include JCOMM, GOOS, POGO, IOCCP and IODE as well as various regional observing systems.

Key References (max. 500 words)

N/A

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

The relevant publications are mostly in the form of grey literature or institutional reporting, key papers are listed below

- Bakker, E. B. Pfeil, C. S. Landa, S. XU, **M. Telszewski** and others A multi- decade record of high-quality fCO_2 data in version 3 of the Surface Ocean CO_2 Atlas (SOCAT), May 2016, DOI: 10.5194/essd-2016-15; D. C.
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Appendix 1

Initial target SCOR WG groups:
SCOR Working Group 154
Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)
Co-Chairs: Emmanuel Boss (USA) and Anya Waite (Germany)

SCOR Working Group 152
Measuring Essential Climate Variables in Sea Ice (ECV-Ice)
Co-Chairs: Daiki Nomura (Japan), François Fripiat (Belgium), and Brent Else (Canada)

SCOR Working Group 143
Dissolved N2O and CH4 measurements: Working towards a global network of ocean time series measurements of N2O and CH4
Co-chairs: Herman Bange (Germany) and Sam Wilson (USA)

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

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

SCOR/IGBP Working Group 138
Modern Planktic Foraminifera and Ocean Changes
Co-chairs: Gerald Ganssen (The Netherlands) and Michal Kucera (Germany)

SCOR Working Group 147
Towards comparability of global oceanic nutrient data (COMPONUT)
Co- chairs: Michio Aoyama (Japan) and E. Malcolm S. Woodward (UK)

SCOR Working Group 149
Changing Ocean Biological Systems (COBS): How will biota respond to a changing ocean?
Chair: Philip Boyd (Australia)

SCOR Working Group 141 Sea-Surface Microlayers
Co-chairs: Michael Cunliffe (UK) and Oliver Wurl (Germany)

Acronyms:

AWI	Alfred Wegener Institute)
EOVs	Essential Ocean Variables
GEOMAR	Research Centre for Marine Geosciences
GOOS	Global Ocean Observing System
IEEE	Institute of Electrical and Electronics Engineers
IIOE-2	Second International Indian Ocean Expedition
IMBER	Integrated Marine Biosphere Research Project
IMOS	Iraqi Marshlands Observation System
INTAROS	Integrated Artic Observing System

IOCCP International Ocean Carbon Coordination Project
IODE International Oceanographic Data and Information Exchange Academic & Science>> Ocean Science)
IOOS Integrated Ocean Observing System
JCOMM Joint Technical Commission for Oceanography and Marine Meteorology
JCOMM OCG Joint Technical Commission for Oceanography and Marine Meteorology Observations Coordination Group
JERICO Joint European Research Infrastructure for Coastal network for Coastal Observatory
NCOSM National Centre of Ocean Standards and Metrology
POGO Polar Orbiting Geophysical Observatory
QA/QC Quality Assurance/Quality Control
QARTOD Quality Assurance/Quality Control of Real-Time Oceanographic Data
SAEON South African Environmental Observation Network
SCOR WG Scientific Committee on Oceanic Research Working Group
SOCIB The Balearic Islands Coastal Ocean Observing and Forecasting System
SOLAS Safety of Life at Sea

2.2.8 Coordinated Global Research Assessment Of Seagrass Systems (C-GRASS) *Sun*

1. Summary

Seagrasses provide the foundation of submerged coastal grassland ecosystems around the world but are threatened worldwide by human activities, with almost 30% of seagrass global cover lost since the late 19th century. Seagrasses provide multiple ecosystem services, particularly in the developing world. Yet obtaining an accurate understanding of seagrass status, trends, and responses to global change has been challenging due to the fragmented nature of available data. The time is opportune for a new scientific synthesis and coordination of global seagrass research activities toward this goal. We propose a series of SCOR workshops to organize and synthesize existing data in a scientific analysis of seagrass ecosystems under global change and provide a framework for an ongoing observation program of seagrass cover and composition as an Essential Ocean Variable. Our Working Group engages a diverse community of scientists and stakeholders to (1) integrate existing seagrass monitoring and analysis efforts into a unified, global community of practice that incorporates diverse data types and informs diverse end users; (2) establish common protocols and best practices for seagrass data collection, curation, and sharing, collated in a multi-media handbook of accepted protocols and best practices; (3) integrate existing and ongoing seagrass data collection into international, open-access portals, with common frameworks for data vocabulary, metadata, management, and service to stakeholders; and (4) collate and analyze existing data on seagrass occurrence and composition to publish a scientific synthesis of current status, trends, and drivers of change in global seagrass systems as an open-access publication in the peer-reviewed literature.

2. Scientific Background and Rationale

2.1. Global status of seagrass ecosystems

Seagrasses provide the foundation of submerged coastal grassland ecosystems around the world. They are among the most productive natural habitats on land or sea [1], store substantial quantities of carbon, and provide humanity with fishery habitat, coastal protection, erosion control, and other services [2]. Seagrass nutrient cycling services alone have an estimated value of nearly $2 trillion per year [3], and Indonesian seagrass meadows provide fishery nursery areas that contribute an estimated 54% to 99% of daily protein intake for local communities [4]. Seagrasses also serve as early warning indicators of anthropogenic perturbations in the coastal zone due to their sensitivity to changing water quality and fishing activities [5].

These important habitats are threatened worldwide by human activities: the best available data indicates that almost 30% of seagrass global cover has been lost since the late 19th century [6] and 22 of the world's 72 seagrass species (31%) are in decline [2, 7], a trend widely considered a global crisis [8]. Recognizing their importance, the Global Ocean Observing System (GOOS) has proposed seagrass cover and composition as one of seven Essential Ocean Variables (EOVs). The EOVs are defined on the basis of societal importance as reflected in reporting requirements for the international conventions and agreements that shape policy responses to global change [9]. These include the Ramsar Convention on Wetlands, the Convention on Biological Diversity,and the UN Sustainable Development Goals (particularly SDG 14, Conservation and sustainable use of the oceans and marine resources), among others.

Despite the importance of seagrasses to coastal ecosystems, economies, livelihoods, developing coordinated systems for observing their status and trends have been challenging for several reasons. First is the fragmented nature of available in situ data. Numerous local and regional monitoring programs collect data on seagrass cover and ecosystem characteristics, and several regional to global programs exist. The latter include Seagrass-Watch [10, 11], SeagrassNet [12], and the relatively new MarineGEO program led by the Smithsonian Institution. Together, these programs have engaged hundreds of scientists and thousands of citizens in collecting data relevant to assessing seagrass occurrence and composition. But such programs often have different objectives, employ a range of methods, and measure different variables, making inter-comparison and scientific analysis difficult. A second challenge is that field sampling is biased geographically, concentrated in North America and western Europe around major scientific organizations. As a result, existing syntheses of seagrass occurrence necessarily rely heavily on interpolation of expert knowledge and low-resolution point-based occurrence sampling, whereas seagrass extent is more difficult to quantify, and resolution is especially low in the regions where seagrasses are most diverse such as the western Pacific.

2.2. New opportunities in seagrass science and conservation

Several converging trends create a promising opportunity to assemble a more geographically comprehensive and highly resolved understanding of global seagrass status, trends, and drivers of change. These include innovations in remote sensing; engagement of citizen scientists in field data collection; and growing community consensus around the need for standardization of sampling protocols, data management, and sharing. Our proposed working group (WG) aims to integrate and coordinate remote sensing and in situ sampling programs toward a more powerful scientific synthesis of global seagrass distribution and ecosystem characteristics. The WG will build toward this goal by coordinating a global community of seagrass ecosystem researchers and managers toward consensus on standard approaches in collecting and organizing data on seagrass cover and composition, and a new analysis of those data. The WG will have the secondary benefit of providing a scientific foundation to advance seagrass cover and composition as an Essential Ocean Variable.

We propose a series of SCOR workshops to organize and synthesize existing data in a scientific analysis of seagrass ecosystems under global change and provide a framework for an ongoing observation program of seagrass cover, biodiversity, and ecosystem characteristics. Our Working Group engages a diverse community of scientists and stakeholders toward these goals to (1) integrate existing seagrass monitoring and analysis efforts into a unified, global community of practice that incorporates diverse data types (in situ sampling, remote sensing, etc.) and informs diverse end users, including decision makers, resource managers, educators, scientists, and the public; (2) establish common protocols and best practices for seagrass data collection, curation, and sharing, collated in a multi-media handbook of accepted protocols and best practices; (3) integrate existing and ongoing seagrass data collection into open-access portals, with common frameworks for data vocabulary, metadata, management, and service to stakeholders; and (4) collate and analyze existing data on seagrass occurrence and composition to publish a scientific synthesis of current status, trends, and drivers of change in global seagrass systems as an open-access publication in the peer-reviewed literature. The proposed workshops will establish the community to continue the process into the future, and several participating institutions are committed to supporting achievement of the long-term goals.

2.3. Rationale for a SCOR working group

The time is opportune for a new global scientific assessment of the status, trends, and drivers of change in seagrass ecosystems, based on synthesis of the heterogeneous and fragmented existing data on seagrass occurrence and coordination of ongoing research and monitoring. Achieving such a synthesis requires engaging expertise in seagrass physiology, field ecology, remote sensing, database architecture, geospatial science and mapping, and social science. The proposed WG brings together a group spanning this expertise. We will organize and link existing seagrass data and field programs with global databases to improve accessibility and interoperability of seagrass data, and build a foundation for coordinated, global seagrass observations by establishing consensus on a common set of protocols and best practices for field sampling and data management. These activities will foster a new quantitative analysis of the drivers of change in seagrass systems and will have the secondary benefit of testing approaches to implement quantification of seagrass cover and composition as an Essential Ocean Variable.

Candidate protocols and best practices have been developed, vetted, and formalized by Seagrass- Watch, SeagrassNet, the Zostera Experimental Network [13, 14], and other programs, providing a set of demonstrated cases available as a foundation for a global community of practice.

Application of satellite remote sensing [15, 16] and lightweight drone technology [17, 18] demonstrate the ability to obtain high-resolution maps of seagrass distribution and resolve variation in abundance, offering promise in linking regional and global-scale cover mapping with strategically sited *in situ* measurements. It will be important to understand the capabilities of present remote sensing efforts and technologies to conduct regional assessments on the health and cover of seagrass communities. Satellite images collected over the past 30 years provide an important basis for evaluating change. More satellite data are now available than ever before, yet it is not clear how this technology can be leveraged with new unmanned airborne systems and field efforts to evaluate scientific questions on seagrasses. WG Members Frank Muller-Karger and Heidi Dierssen bring experience in these areas to the WG.

Moreover, the accessibility of shallow-water seagrass meadows and their importance to local fisheries and ecosystems makes seagrass systems prime targets for application of citizen science monitoring, as done by Seagrass-Watch and the Seagrass Spotter phone app[3], co-developed by WG Associate Member Richard Unsworth. There is considerable potential to expand and integrate these activities, streamlining efforts and adding value to separate programs. This WG is poised to conduct a comprehensive synthesis of the changing distribution of global seagrass habitat, and the drivers of these trends. This process will also advance implementation of the seagrass EOV envisioned as part of GOOS.

[3] See: https://seagrassspotter.org/

Terms of Reference

The objectives of the SCOR C-GRASS Working Group are:

Objective 1: Organize an interdisciplinary community of practice to synthesize data on status, trends, and drivers of global change in seagrass ecosystems, building on and integrating existing resources.

Objective 2: Produce a handbook of standard protocols and best practices for collecting, curating, and sharing data on seagrass ecosystems among scientists and stakeholder groups, building on existing experience of scientists and end-users in management and conservation, and contributed to the Ocean Data Standards and Best Practices Project of IODE.

Objective 3: Promote development of standardized vocabularies for variables and data schemes specific to seagrass ecosystems, and integration of existing and new data into the Ocean Biodiversity Information System (OBIS) using the EVENT-DATA schema [19].]

Objective 4: Produce a scientific synthesis of status and trends in global seagrasses and the systems they support, via a comprehensive review of peer-reviewed and gray literature on seagrass occurrence, ecosystem characteristics, and benefits to human well-being.

3. Working plan

3.1. Objective 1: Organize an interdisciplinary community of practice

A rigorous analysis of how and why seagrass systems are changing on a global scale requires a coordinated effort, structures to manage ongoing data input and access to maintain inter-comparability, and engagement of a group with diverse geographic origins, disciplinary expertise and knowledge of the needs of policy- and decision-makers. To begin, we will focus on linking the web portals of the Seagrass-Watch, SeagrassNet, the Ocean Data Viewer, and MarineGEO networks, leveraging resources already invested in them and the continuing support of their secretariat institutions. Working Group members, including the UN Environment World Conservation Monitoring Centre (UNEP-WCMC, with leadership from co-chair Weatherdon) will assist in engaging end-users of the information products from the policy community, and in developing a communications strategy. UNEP-WCMC’s existing seagrass layer has been used for environmental sensitivity mapping, marine spatial planning, high-level screening of biodiversity risk [20], and blue carbon assessments, and its application to ecosystem-based adaptation to climate change is in progress.

3.2. Objective 2: Produce a handbook of standard protocols and best practices

A key component of coordinating monitoring across a distributed network is common protocols and best practices. Ensuring that seagrass data are comparable across space and time requires community consensus on the core measurements and protocols for collecting and integrating them. These include in situ survey methods [21], remote-sensing approaches [16], and sampling designs for achieving data that is fit to purpose, with acceptable error variance. The Working Group will collate, analyze, and update existing seagrass-related protocols to produce a multi-media handbook, linked to training videos and other online resources, that includes accepted methods for field data collection, data management, and curation. Protocols will be structured hierarchically, with a small core set of variables that can be integrated with remote sensing data and allow for repeated measures. Major criteria for variables will include fitness for purpose, i.e., the ability to provide information of appropriate resolution, quality, and scale to capture seagrass trends relevant to reporting requirements of nations and decision-makers.

3.3. Objective 3: Promote development of standardized vocabularies and data schemas

Rigorous comparison of data among programs requires a common language. The new EVENT-DATA OBIS schema uses a standard Darwin Core set of terms and accommodates sampling descriptions, environmental data, and biodiversity records. But using it requires developing a standardized set of vocabulary terms for seagrass-related data. The WG will develop and compile this vocabulary in close collaboration with OBIS under leadership of WG Full Member and OBIS co-chair Eduardo Klein.

The WG will promote integration of a substantial body of records of seagrass cover and species composition into OBIS. WG Member Short will make available data from the SeagrassNet program he founded in 2001, which includes data from 33 countries. The Smithsonian-led MarineGEO program (led by co-Chair Emmett Duffy) networks 13 sites and counting worldwide and will contribute seagrass and environmental data from this effort. We will also work with Seagrass-Watch to integrate as much data as possible from its sources.

Data access and ownership are key issues in the emerging networked data ecosystem. We will promote availability of as much seagrass data as possible, as close to open access as possible, while respecting needs of data providers. We will build on the experience of Seagrass-Watch, which provides a model for a tiered system of data sharing that respects the ownership of raw data, while making detailed summaries available via open access portals.

3.4. Objective 4: Produce a scientific synthesis of status and trends in global seagrass systems

A central goal of the Working Group will be to assemble the existing data on global seagrass cover, condition, and trends into an updated scientific assessment, building on previous assessments of global seagrass occurrence [22]. The data will be analyzed with ocean environmental data layers and data on human activities in an analysis of drivers of change in global seagrass occurrence. The results will be published in peer-reviewed paper(s) and integrated into the UNEP-WCMC Ocean+ initiative, which maintains a database of seagrass cover and produces maps and knowledge products that directly inform decision-making (available through Ocean Data Viewer[4]), including the *Global Distribution of Seagrasses*[5], curated on behalf of numerous contributors (including WG member Short). The synthesis will build on WG Member Muller-Karger's methods to map seagrasses using satellites [15]. And recent progress and frontiers in quantification of seagrass ecosystem services [23, 24], and WG Member Unsworth's ongoing global synthesis of seagrass trends.

[4] Available at: http://data.unep-wcmc.org.
[5] Available at: http://data.unep-wcmc.org/datasets/7.

3.5. Timeline

Working Group meetings will be held in association with international conferences and we will work to leverage other funds to cover costs of participants; several participating institutions have offered financial or in-kind support. Possible venues for meetings include OceanObs'19 in Honolulu, USA (2019); the 14th International Seagrass Biology Workshop (2020, venue not yet scheduled); regional symposium of the Blue Carbon Project in the Philippines (date not yet chosen).

Month 1: Working Group meeting 1. Hone goals, assignments of subgroups with leads for each of the four objectives. Begin identification of data sources (Objective 1), discuss and analyze standard protocols and best practices (Objective 2).

Month 1-12: Subgroups work on collation of data and assessment of needs for integrating into common framework (Objectives 1,3) and converge on best practices for handbook (Objective 2).

Month 12: WG meeting 2. Present draft of best practices document (Objective 2) and data schema (Objective 3) for discussion by WG. Review data assembled and outline synthesis paper(s) (Objective 4).

Month 12-24: Integrate sample data sets into OBIS using draft schema (Objectives 1,3). Continue work on best practices (Objective 2) and synthesis paper(s) (Objective 4).

Month 24: WG meeting 3. Complete best practices handbook (Objective 2) and synthesis papers (Objective 4). Report on data integration (Objectives 1, 3), challenges, and plans.

Month 24-36: Subgroups finish work on all four objectives.

Month 36: Meeting of selected WG members, lead authors, and data architects, to synthesize results toward the Objectives, finish products, and develop plans for long-term advancement.

4. Deliverables

(1) Hold a town hall meeting at the Ocean Sciences meeting (and potentially others) to announce the Working Group effort and solicit broad input. Contributes to delivering Objective 1.

(2) Produce a peer-reviewed handbook of standard protocols and best practices for seagrass field measurements and data management, published and contributed to the Ocean Data Standards and Best Practices Project of IODE. Delivers Objective 2.

(3) Integrate existing seagrass data, and ongoing monitoring data, into the Ocean Biodiversity Information System (OBIS) using a common data schema. Contributes to delivering Objectives 1 and 3.

(4) Produce a peer-reviewed scientific synthesis of status, trends, and drivers of change in global seagrasses and the systems they support, based on a comprehensive review of peer-reviewed and

gray literature. Delivers Objective 4.

5. Capacity Building

The community of practice built through this series of working groups will be advanced into the future in several ways. First, we engage seagrass researchers and stakeholders from a diverse range of backgrounds, geographic regions, and disciplines in this common, collaborative effort. Second, we intend to develop courses with support from IODE Ocean Teacher Global Academy (OTGA) of the International Oceanographic Data and Information Exchange (IODE) to spread the protocols, best practices and synthesis tools in seagrass research to a global community. WG Member Eduardo Klein will liaise with the OTGA program to propose an OBIS course tailored for the seagrass community, with potential support from OTGA. Third, the several seagrass observation programs, including Seagrass-Watch, SeagrassNet, the Smithsonian-led MarineGEO program, and the MBON conduct training and outreach activities that will promote the best practices developed by the WG. Finally, development of the handbook and other products will also focus on feeding information into international targets such as the UN Sustainable Development Goals and Aichi Targets, as well as the post-2020 biodiversity agenda, with leadership by UNEP-WCMC.

6. Working Group Composition

Our Working Group brings together ten Full Members (5 female, 5 male), representing 9 countries, and a range of career stages and disciplinary expertise from seagrass biology to biogeochemistry, remote sensing, fisheries, social science, database architecture, and global conservation. Several Full and Associate Members are leaders in existing synthesis and coordination efforts in coastal marine and seagrass science. This diversity will help ensure that interdisciplinary products of the working group are effectively communicated to a wide audience and translated into practical applications.

6.1. Full Members

Name	Gender	Place of Work	Expertise
Emmett Duffy (co-chair)	M	Smithsonian Institution, USA	Marine ecology and biodiversity
Lauren Weatherdon (co-chair)	F	UN Environment World Conservation Monitoring Centre, UK	digital knowledge products, ocean biodiversity and spatial data
Rohani Ambo Rappe	F	Universitas Hasanuddin, Indonesia	Seagrass ecology, ecosystem services, seagrass restoration
Leanne Cullen-Unsworth	F	Cardiff University, Wales	Coupled social-ecological systems, seagrass ecosystem services

Miguel Fortes	M	University of the Philippines	Seagrass & mangrove ecology, blue carbon, policy
Eduardo Klein	M	Universidad Simón Bolívar, Venezuela.	Marine ecology, data management, statistical/numerical methods for analysis of ecological data
Núria Marbà	F	Consejo Superior de Investigaciones Científicas, Spain	Seagrass ecology, global change
Frank Muller-Karger	M	University of South Florida, USA	Biological oceanography, remote sensing, global
Masahiro Nakaoka	M	Hokkaido University, Japan	Coastal ecosystem dynamics, seagrass ecology
Jacqueline Uku	F	Kenya Marine and Fisheries Research Institute	Seagrass physiology, ecology, community development

6.2. Associate Members

Name	Gender	Place of Work	Expertise
Connolly, Rod	M	Griffith University, Australia	Seagrass ecosystem resilience, carbon pathways, fisheries food web
de la Torre Castro, Maricela	F	Stockholm University, Sweden	Social-ecological systems analysis, governance, gender, sustainable resource use, resilience
Dierssen, Heidi	F	University of Connecticut, USA	Remote sensing of seagrass extent, leaf area index, carbon
Fourqurean, James W.	M	Florida International University, USA	Ecosystem ecology, biogeochemistry of seagrass systems
McKenzie, Len	M	James Cook University, Australia	Seagrass status, management and sustainable use, founder Seagrass-Watch

Prathep, Anchana	F	Prince of Songkla University, Thailand	Seaweed and seagrass biodiversity and ecology; coastal climate change
Short, Fred	M	University of New Hampshire, USA	Seagrass ecology and restoration, founder SeagrassNet
Unsworth, Richard	M	Swansea University, Wales	Seagrass ecology, conservation, and ecosystem services, co-founder Project Seagrass

7. Working Group contributions

Emmett Duffy is a biodiversity scientist who founded the Zostera Experimental Network (ZEN) and is the first Director of the Smithsonian's Tennenbaum Marine Observatories Network and MarineGEO program. He is a member of MBON, the GOOS Biology and Ecosystem panel, and led development of the draft specification sheet for the GOOS seagrass EOV.

Rohani Ambo Rappe is a seagrass ecologist, studying ecosystem services and seagrass restoration, with expertise in the seagrass systems of the coral triangle region, the most diverse marine systems in the world.

Leanne Cullen-Unsworth is a coupled social-ecological systems analyst focusing on seagrass ecosystem services, in particular seagrass fisheries and associated food security.

Miguel D. Fortes is a coastal Ecologist, and specialist on Biodiversity, ICZM and Blue Carbon, focusing on seagrasses and mangroves. His works are major additions to seagrass science and policy in the tropics and are having major impacts in applications and in development of coastal resilience in the face of climate change and other environmental uncertainties.

Eduardo Klein is a marine ecologist, with extensive experience in environmental impact assessment, database architecture and standardized vocabularies, and statistical/numerical analysis. He is coordinator of the Caribbean Regional Node for OBIS, OBIS co-chair of the Steering Group, country representative for the UNESCO/IOC Caribbean Marine Atlas, and Resource Person for the Convention on Biological Diversity Marine Program (Ecological and Biological Significant Areas EBSA, and Sustainable Ocean Initiative SOI programs).

Núria Marbà is a seagrass ecologist focusing on assessing sustainability and integrity of coastal ecosystems and ecosystem services as well as the impact of global change.

Frank Muller-Karger is a biological oceanographer with expertise in marine biodiversity, marine policy, public outreach, in situ observing systems, and ocean color in coastal and pelagic systems. He is Co-chair of the Marine Biodiversity Observation Network (MBON).

Masahiro Nakaoka is a marine ecologist studying coastal ecosystem dynamics, including seagrass ecosystem in Eastern and Southeastern Asia and the West Pacific. He is a member of the IUCN SSC Seagrass Specialist Group, the World Seagrass Association, and of the Zostera Experimental Network (ZEN).

Jacqueline Uku is a marine ecologist working on seagrass systems in Kenya and recently engaged in community development projects along the Kenyan Coast. She is current President and member of the Western Indian Ocean Marine Science Association (WIOMSA), providing linkage to the member countries of the Western Indian Ocean.

Lauren Weatherdon leads development of digital knowledge products that contribute to a step-change in global access to, and use of, ocean biodiversity information and spatial data. These products help to support the delivery of global ocean goals and targets, and to support marine spatial planning, conduct environmental impact assessments, produce ecosystem assessments, and enhance ocean literacy; she is also a member of MBON.

8. Relationship to other international programs and SCOR Working groups

The proposed WG has important relevance to several other interdisciplinary global change science efforts, to the science-policy-society interface and communication initiatives, and to other SCOR groups. These other efforts are not specifically focused on seagrasses and would benefit from the research advanced by this SCOR WG on seagrasses. Among these are the following. The OceanObs Research Coordination Network is an NSF-sponsored effort to advance the integration of biological observations into ocean observing systems for societal benefit, co-led by WG member Muller-Karger. The OceanObs'19 Program Committee is processing community proposals for white papers in governance for the Global Ocean Observing System within the Framework for Ocean Observing v. 2.0, and determining user requirements for ocean observing, technology, and scientific approaches to solutions through the OceanObs'19 meeting in Honolulu, Hawaii, September 2019. The Marine Biodiversity Observation Network (MBON) is a thematic program under the Group on Earth Observations Biodiversity Observation Network or GEO BON to strengthen understanding of marine biodiversity and coordinate monitoring of associated changes over time by defining marine Essential Biodiversity Variables or EBVs. The Global Ocean Observing System (GOOS) Bio-Eco Panel seeks to improve the availability of existing core biological variables and identify and prioritize additional cross- cutting biological and ecosystem observation needs by defining Essential Ocean Variables or EOVs for biology and to integrate these with physical and biogeochemical EOV and observing programs. The SCOR Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs Working Group (P-OBS) has the goal of identifying measurements that can expand the number of observations of biological stocks, diversity, and rates or fluxes of planktonic organisms). Several members of the proposed C-GRASS WG are closely involved in each of these efforts and will work to integrate the WG's activities with their goals.

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2.2.9 Co-ordinated approach for Aerosol Trace element Solubility and Bioavailability Research in Oceanography (CoATS-BRO) *Casacuberta Arola*

1. Summary

The availability of iron directly impacts marine ecosystem functioning, and indirectly influences global climate through its role in the carbon cycle. In large areas of the ocean, atmospheric deposition is the dominant source of iron and other elements (which, depending on the element, can be either beneficial or detrimental to the ecosystem). Therefore, it is vital that we fully understand the processes governing the solubility and bioavailability of aerosol-derived metals. In order to advance current understanding in this field, our vision is two-fold: (1) standardize aerosol solubility methods and (2) establish standard protocols for assessing which of these methods accurately reflects the biologically-available fraction to marine biota. The results of this SCOR working group will provide both the foundation and a framework for proposals to address questions of methodology, biological cycles, and modelling of trace element availability. In addition, two papers will be published in open-access journals (a review paper linking the results of the biological-availability of iron experiments to the solubility of aerosol elements; a paper linking previously published and unpublished aerosol TE leach data to the standardized recommended protocols). One of these papers will be adapted for younger audiences (aged 8-15 years). A low-cost and accessible aerosol reference material will be distributed to the community for intercalibration, and a database of the intercalibration results will be made publicly-available. Dedicated sessions will be hosted at major international meetings, which will promote the findings and recommendations of the proposed Working Group and highlight the work of SCOR.

2. Scientific background and rationale for the working group

Atmospheric dry and wet deposition is a major input route of iron (Fe) and other trace elements (TEs) to the sunlit, surface ocean (e.g. Duce et al., 1991). The availability of Fe exerts a fundamental control on biological activity in the ocean, primary productivity and fisheries while indirectly influencing global climate through its role in the carbon cycle (e.g. Martin, 1990; Moore et al., 2013; Mahowald et al., 2014). At the pH of oceanic waters (~ pH 8.2), Fe is relatively insoluble and, despite being maintained in solution in excess of its solubility by Fe-binding ligands, primary productivity is limited by insufficient Fe availability in a significant proportion of the global ocean (Moore et al., 2013). A common assumption of biogeochemical and ecosystem models is that all soluble Fe is biologically available, but there is evidence that casts doubt on this assumption (von der Heyden et al., 2012; Fitzsimmons et al., 2015). The links between the biological availability of Fe and its physico-chemical speciation can be complex and indirect. Yet, Fe solubility, both a constraint and a proxy for bio-availability, is a critical parameter in global models as they evolve to explicitly include Fe biogeochemistry; thus, it is essential to progress this research area by bringing together a multidisciplinary team to review the current state of knowledge and identify priorities for future research.

Simultaneously, there is an urgent need within the marine aerosol community to undertake further intercalibration and standardisation of aerosol solubility experiments. Due to the short residence time of aerosols in the atmosphere (hours to days), there are no aerosol cross-over stations among different cruises, so aerosol intercalibration requires a different approach than those used for water column parameters. An initial aerosol intercalibration exercise was undertaken in 2008 (GEOTRACES aerosol intercalibration; Morton et al., 2013). In this intercalibration a set of replicate aerosol samples consisting of a mixture of marine, lithogenic and anthropogenic components was successfully analysed for many total element and soluble ion concentrations. This exercise resulted in a recommended protocol to follow to ensure total dissolution of aerosol material, but it revealed discrepancies in the measurement of soluble aerosol trace element and isotope (TEI) concentrations, most importantly for Fe, a key parameter in many observational and modelling studies. Therefore, we propose a timely follow-up (a decade has passed since the first aerosol intercalibration; IC) to standardise aerosol TEI solubility measurements to address the discrepancy highlighted by the 2008 IC. This second round of intercalibration will use a 'reference' material, Arizona Test Dust (ATD, Powder Technology Inc.), that has been found to be homogeneous at subsample masses of 10-20 mg (Shelley et al., 2015). A large quantity of this reference material has been purchased and work has already begun to characterize its TEI composition. Our goal is to avoid the cost and time delays needed to produce a true certified or standard reference material, and to use the ATD material to intercalibrate analyses of aerosol TEIs in much the same way that the SAFe and GEOTRACES seawater samples have been used to intercalibrate the analyses of TEIs in seawater (Baker et al., 2016).

In addition to investigations with the ATD material, a large number (e.g. 60) of aerosol samples will be collected simultaneously for distribution to WG participants and other interested parties. Most marine TE aerosol collections are done using high- or low-volume samplers that filter known volumes of air onto suitable filters, and therefore it is necessary to undertake a portion of the IC using the same sampling procedures currently in use by the marine aerosol community. As part of this second IC round, we propose to use the aerosol-laden filters as well as the ATD for the intercomparison of various aerosol solubilization schemes.

2.2. The importance of a standardized aerosol Fe solubility protocol

As aerosol Fe solubility is frequently used as a proxy for the bioavailable fraction in models, it is essential that we fully understand the links between the two and the controls on both. At present, several aerosol leaching protocols are used by different research groups (Morton et al., 2013), which hampers direct inter-lab comparison of aerosol fractional solubility data. This situation presents a challenge for modellers who want to use experimental data to validate and refine their models. Regardless of the leaching scheme used, an inverse trend between atmospheric loading and fractional solubility appears to be reasonably robust throughout the world ocean.

Unfortunately, the value for fractional solubility is a function of the different leaching schemes to some extent (e.g. batch versus flow-through methods and/or differences in pH, ionic strength and contact time between the aerosols and leach medium). Therefore, it is a research priority to introduce some means of standardization into leaching protocols (Baker et al., 2016). An additional research priority that was recently identified was to link aerosol TE fractional solubility to bioavailability (Baker et al., 2016) which can be used to improve the predictive capabilities of the next generation of biogeochemical and ecosystem models. The focus of this WG will be on Fe, but a strength of bringing together this diverse group of Full and Associate members is that data for other TEs will be produced.

2.3. Why a SCOR Working Group?
Much of our current understanding of the ***relationship between the solubility*** of trace nutrients in aerosols ***and the availability*** of those nutrients to marine microbes is ***operationally defined***, but few of these methods have been properly compared (or intercalibrated; Morton et al. 2013) and even fewer accurately related to bioavailability in the field or lab cultures. Our vision is two-fold: (1) standardize solubility methods and (2) establish standard protocols for assessing if any of these methods represent an accurate bioavailable fraction in the marine environment. The results of this SCOR working group will provide both the foundation and a framework for proposals to address questions of methodology, biological cycles, and modelling of trace nutrient availability. A co-ordinated global effort of this type would not be funded through national funding channels. This vision will be realized by bringing together experts in the fields of aerosol TE solubility, aerosol chemical composition, experimental biogeochemists focused on the bioavailability of TEs and modellers (biogeochemical, ecosystem and atmospheric) in order to:

i) Produce an environmentally relevant, consensus aerosol reference material (ATD).
ii) Link the results of aerosol leaching experiments to bioavailability of TEs in the ocean. Specifically, we need to bring together aerosol and bioavailability/uptake researchers to understand which aerosol leach provides the closest approximation to what the bioavailability experiments tell us. It is also important that it is understood and communicated which fraction of Fe is accessed by the various leaching schemes in use by the community.
iii) Use the information from (ii) to agree on a standardized aerosol leaching protocol.
iv) Link historical aerosol leach data with outputs from the recommended standardized protocol

3. Terms of reference (ToR)
ToR1. Establish a database of the composition and fractional solubility of elements in the aerosol reference material, Arizona Test Dust (ATD, nominal size 0-3 µm diameter).
ToR2. Identify gaps in current knowledge of the relationship between the physico-chemical speciation of elements in aerosols, aerosol trace element solubility and bioavailability.
ToR3. Undertake a community aerosol intercalibration exercise to standardize aerosol solubility experiments.
ToR4. Improve parameterization of aerosol trace metal solubility in combined atmosphere-ocean models.

The ToRs will be met by:
- Distributing sub-samples of the aerosol reference material, ATD, to the marine aerosol community. The ATD will be chemically characterized using e.g. mass spectrometry, acid digestion, Synchrotron X-ray fluorescence spectrometry (S-XRF), XANES and scanning electron microscopy (SEM) (**ToR1**).
- A review paper will be the outcome of **ToR2** and will inform the WG on the most environmentally-relevant leaching scheme(s), resulting in identification of standardized leach protocols.
- Collecting replicate sub-samples of authentic aerosols collected on filters and distributing them to the marine aerosol community. The sampling period will coincide with the maximum period of Saharan dust deposition. The equipment necessary for this sample collection is available from Florida State University. The equipment will be shipped to

Miami in advance and forecasts monitored to ensure that the samplers are deployed during a Saharan dust deposition event. These samples will be characterized using the same techniques used to characterize ATD. (**ToR3**).

- **ToR4** will be realized through open and focused dialog with the biogeochemical modellers in the WG.

4. Work plan

Month 1:
First full WG meeting (Aquatic Sciences Meeting, 2019).
Planning meeting to address the following points:

- Which fraction do existing leach methods access?
- Which leach best replicates what the bioavailability experiments tell us?
- Which leach protocol will be used in the intercalibration?
- What do modellers need to know?

Month 2 – 12:
Project website and social media pages online.
Distribution of ATD to interested parties.
ATD must be digested using the recommended protocol (Morton et al., 2013) and data submitted before the end of month 12. This step is an absolute prerequisite for participation in the aerosol sample leach intercalibration.
Collection and physico-chemical characterization of replicate aerosol samples (min. 60) at RSMAS, Miami in July/August 2019.
Submit review paper: Linking the results of TE bioavailability of Fe experiments to the solubility of aerosol TEs.
Session on the bioavailability of TEs from aerosols at an international meeting.

Month 12-18:
Second full WG meeting (Ocean Sciences Meeting/EGU, 2020).
Parallel sub-group meetings to identify gaps in our knowledge.

- 1) Aerosol IC – results from ATD total digestion.
- 2) Bioavailability of TEs

Database of ATD total TEs online (submit to GeoREM).
Adaptation of the review paper for younger readers (aged 8-15).
Distribution of replicate aerosol samples from Miami.

Month 18-24:
Participants to complete leaching experiments by the end of this period and submit data.
Submission of proposals to funding bodies for bioavailability experiments necessary to address gaps in knowledge.

Months 24-36:
Third full WG meeting (Aquatic Sciences Meeting, 2021).
Meeting goal: A strategy for best practice in incorporation of the WG findings into the next generation of biogeochemical models.

Database of aerosol leach intercalibration online.
Submission of review paper linking historical leach data to the standardized leaching approach and physico-chemical composition of aerosols.
Funding for proposals to link historical leach data with the standardized leach data will be sought to address gaps in knowledge.

5. Deliverables

- A review paper will be published in an open-access journal (e.g. *Frontiers in Marine Science*) that summarizes the state of the art in linking the results of TE bioavailability of Fe (and other TEs) experiments to the solubility of aerosol TEs, with a focus on Fe. This paper will consider a number of key questions, e.g. i) is there a direct link between bioavailability and solubility, ii) what is nature of any link(s), iii) what experiments have been done to date (including experimental 'dead-ends'), iv) do existing leach protocols mimic natural processes and v) future directions and recommendations.
- The above review paper will be adapted for younger audiences for publication in *Frontiers for Young Minds*, or similar.
- A low cost and accessible aerosol reference material (ATD) analogous to the SAFe and GEOTRACES seawater TE reference materials.
- Database of an aerosol reference material (ATD) of total and soluble TE concentrations (GeoREM).
- Recommended procedures to follow when leaching aerosol material. This will be published on the GEOTRACES website and added to the GEOTRACES aerosol 'cookbook'.
- Publish a paper linking previously published and unpublished aerosol TE leach data to the standardized recommended protocol so that valuable historical data is not lost. This will be published in a special issue of an open-access journal (e.g. *Frontiers in Marine Science* or *Biogeosciences*) to reach a wide audience.
- Dedicated aerosol TE solubility and TE bioavailability sessions will be hosted at oceanographic research meetings (e.g. AGU Fall Meeting, Ocean/Aquatic Sciences, Goldschmidt).
- WG meetings and Town Halls will be held before, during or immediately after large international meetings (e.g. Ocean/Aquatic Sciences) to maximize opportunities for participation by Associate Members and others.
- A dedicated website and social media accounts (Twitter, Facebook) will be created so that any interested party can follow the progress of the WG and find out how to participate in the IC.

6. Capacity building

Our vision is that this WG will identify significant gaps in the current knowledge which will stimulate new research proposals and collaborations between established and early-career scientists globally.

Proposed membership of the WG is diverse in terms of gender and geographical representation, and it is interdisciplinary, promoting dialogue between chemical oceanographers, modellers and atmospheric scientists from around the world in a focused group. In addition to a number of the participants from the 2008 IC, early-career scientists will be members of this working group, which will aid their career development. There are two proposed Full Members from developing countries, Argentina and South Africa. The working group will seek opportunities to involve early-career scientists in sessions related to the group's topic and will provide mentoring opportunities (Urban and Boscolo, 2013).

The social media (Twitter, Facebook) accounts and the adaptation of the review paper for younger audiences will facilitate access to the work of this WG and the work of SCOR to a wider audience than the scientific community.

This outputs of this WG will be of particular interest to the GEOTRACES, SOLAS and IMBER communities, as these communities have an interest in processes that occur at the ocean-atmosphere boundary. We will seek opportunities for co-sponsorship from the aforementioned organisations (and other sources) as products of this WG will contribute to the realisation of their mission statements. In addition, this WG will complement current SCOR WGs: WG139. Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean, WG141. Sea-Surface Microlayers, WG145. Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC), WG151. Iron Model Intercomparison Project (FeMIP) and GESAMP WG38 (Changing Atmospheric Acidity and the Oceanic Solubility of Nutrients). Some of the Full and Associate members are members of the listed synergistic WGs which will help ensure that the work of this WG is complementary and does not repeat work already done.
The results of this group may be useful to the final cruises and processes studies of GEOTRACES, although most of the field work of GEOTRACES will be completed by the time this group is finished. Nonetheless, research that builds on the work of GEOTRACES will benefit from the work of the proposed working group.

7. Working group composition

This WG will have 10 Full Members and 10 Associate Members which have the expertise to address the terms of reference.

7.1 Full members

Name	Gender	Place of work	Country	Expertise relevant to proposal
Rachel Shelley (co-chair)	F	National High Magnetic Field Lab/Florida State University	USA	TEs in aerosols. GEOTRACES and CLIVAR aerosols. TE biogeochemistry
Simon Ussher (co-chair)	M	University of Plymouth	UK	Aerosol TE solubility and Fe biogeochemical cycling in the ocean
Peter Croot (co-chair)	M	National University of Ireland, Galway	Ireland	Aerosol Fe solubility and determination of metal binding ligands in seawater
Alakendra Roychoudhury	M	Stellenbosch University	South Africa	TE biogeochemistry in the ocean and particle dissolution kinetics

Cassandra Gaston	F	Rosenthiel School of Marine & Atmospheric Science/University of Miami	USA	Atmospheric chemistry. Composition of aerosols. Focus on soluble phosphorus and the single-particle mixing-state of nutrients in individual aerosol particles.
Karine Desboeufs	F	Laboratoire Interuniversitaire de Systemes Atmospheriques, Paris	France	Aerosol TE solubility and composition
Diego Gaiero	M	National University of Cordoba	Argentina	High latitude dust and Fe biogeochemistry in Southern Ocean
Bikkina Srinivas	M	Stockholm University	Sweden	Marine aerosol Fe solubility
Christel Hassler	F	University of Geneva	Switzerland	Bioavailability of Fe
Akinori Ito	M	Japanese Agency for Marine-Earth Science and Technology	Japan	Atmospheric Fe modelling

7.2 Associate members

Peter Morton	M	National High Magnetic Field Lab/Florida State University	USA	TEs in aerosols. GEOTRACES and CLIVAR aerosols. TE biogeochemistry
Andrew Wozniak	M	University of Delaware	USA	Organic composition of aerosols
Alex Baker	M	University of East Anglia	UK	TEs in aerosols. GEOTRACES and CLIVAR aerosols. TE biogeochemistry
Alessandro Tagliabue	M	University of Liverpool	UK	Biogeochemical modeler
Yeala Shaked	F	Hebrew University of Jerusalem	Israel	Biogeochemistry of TEs in the ocean
Dolores Gelado-Cabellero	F	University of Las Palmas de Gran Canaria	Spain	Aerosol TEs
Jaw Cheun Yong	M	GEOMAR - Helmholtz Centre for Ocean Research, Kiel	Germany	Aerosol TEs and solubility
Tung-Yuan Ho	M	Academia Sinica	Taiwan	Marine biogeochemistry

Andrew Bowie	M	University of Tasmania	Australia	Fe biogeochemistry
Barak Herut	M	National Institute of Oceanography	Israel	Aerosol mineral dust; bioaerosols

8. Working group contributions

Rachel Shelley (co-chair)
Contributes expertise in the trace element composition of aerosols and trace element biogeochemistry in the ocean. Early-career scientist.

Simon Ussher (co-chair)
Expertise in trace element biogeochemistry, trace element air-sea interactions. Oversees aerosol collection of inorganic species at Penlee Atmospheric Observatory, UK.

Peter Croot (co-chair)
Marine biogeochemist whose research focuses on understanding the role of biogeochemical processes on the concentration and distribution of trace elements and chemical species in the ocean.

Alakendra Roychodhury
Marine biogeochemist. Expertise in dust and marine particle chemistry and biogeochemical dynamics in aquatic environments with a focus on reaction kinetics and other controls over elemental cycling.

Cassandra Gaston
Expertise in atmosphere-ocean interactions, atmosphere-biosphere interactions, atmospheric chemistry, heterogeneous chemistry, air pollution, climate change. Cassandra Gaston (RSMAS) chemically characterises Saharan dust by single-particle mass spectrometry, which provides vital data on the mixing-state of nutrients found in the aerosols. She also looks at the solubility of particulate phosphorus. Early-career faculty.

Karine Desboeufs
Extensive experience and expertise in determining atmospheric dust chemistry and making trace element deposition measurements.

Diego Gaiero
Expertise in understanding dust activity in southern South America. Diego Gaiero's main research foci are determining dust fluxes from southern South America, improving understanding of present-day and past dust provenance, and evaluating the relevance of iron-rich dust on the biogeochemistry of the Southern Ocean.

Bikkina Srinivas
Expertise in the chemistry of atmospheric aerosols. Fe speciation. Early-career scientist.

Christel Hassler
Expertise in the connection between iron chemistry with iron bioavailability and the role of microbes in the carbon pump.

Akinori Ito
Expertise in Earth System model development and application with a focus on Fe in the atmosphere.

9. References

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Appendix

Key Publications of Full Members of relevance to this Working Group.

Rachel Shelley

1. **Shelley, R.U.**, Landing, W.M., Ussher, S.J., Planquette, H., and Sarthou, G. (accepted). Regional trends in the fractional solubility of Fe and other metals in North Atlantic aerosols (GEOTRACES cruises GA01 and GA03) following a two-stage leach. Submitted to Biogeosciences Discuss. DOI: 10.5194/bg-2017-415.
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<u>Peter Croot</u>

1. Simonella, L.E., Palomeque, M.E., **Croot, P.L**., Stein, A., Kupczewski, M., Rosales, A., Montes, M.L., Colombo, F., García, M.G., Villarosa, G., Gaiero, D.M. 2015. Soluble iron inputs to the Southern Ocean through recent andesitic to rhyolitic volcanic ash eruptions from the Patagonian Andes. Global Biogeochemical Cycles, 29 : 1125-1144. DOI: 10.1002/2015GB005177.
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Cassandra Gaston

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