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 *Bharathi*

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	Peter R. Girguis	USA
Loka Bharathi	India	Xiqiu Han	China-Beijing
Nicole Dubilier	Germany	Louis Legendre	France
Katrina Edwards	USA	Ken Takai	Japan

Associate Members

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

Executive Committee Reporter:

2-2

At the SCOR General Meeting in 2014, it was approved to disband WG 135 when its publications were completed. The first publication appeared since then:

C.R. German, L.L. Legendre, S.G. Sander, N. Niquil, G.W. Luther III, L. Bharati, X. Han, and N. Le Bris. 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.

A second publication is being prepared and should be submitted by the end of 2015. The group would like to be extended until the 2016 SCOR meeting.

2.1.2 WG 137: Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Comparative Analysis of Time Series Observation (2009) *Ramaiah, Sun Song*

Terms of Reference:

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

Co-chairs:

Kedong Yin (China-Beijing) and Hans W. Paerl (USA)

Other Full Members

Susan I. Blackburn	Australia	Todd O'Brien	USA
Jacob Carstensen	Denmark	Clarisse Odebrecht	Brazil
James E. Cloern	USA	N. Ramaiah	India
Paul J. Harrison	China-Beijing	Katja Philippart	Netherlands
Ruixiang Li	China-Beijing	Adriana Zingone	Italy
Abigail McQuatters-Gollop	UK		

Associate Members

Robert Le Borgne	N. Caledonia	Snejana P Moncheva	Bulgaria
Perry Elgin	USA	Xosé Anxelu G. Morán	Spain
Alan Jassby	USA	Grant Picher	South Africa
Jorma Kuparinen	Finland	Theodore J. Smayda	USA
Juha-Markku Leppänen	Finland	Wiltshire, Karen	Germany
Thomas Malone	USA	Sinjae Yoo	South Korea

2-4

Executive Committee Reporter: Sun Song

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

Co-Chairs: Kedong Yin and Hans Paerl

Report

September 3, 2015

I. Summary of Activities

1. Meeting Summary

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

2. Meeting Places and Dates

Meeting	Place	Dates	Financial support	Remarks
1st	Hangzhou, China	October 17-20, 2010	SOA, China	Independent meeting
2nd	Sorrento, Italy	September 27-30, 2011	Stazione Zoologica, Italy	Independent meeting
3rd	Hiroshima, Japan	October 12-14, 2012	PICES, partial	A joint SCOR/PICES Workshop W7, PICES Annual Meeting 2012
4th	San Diego, USA	November 2-4, 2013	None	A joint SCOR/CERF Workshop, and a CERF Session SCI-62

				CERF 2013 Biennial Conference
5th	Zhuhai, Guangdong China	November 3-7, 2014	Sun Yat-sen University, Guangzhou China	Independent

II. Achievement in Terms of References

We have accomplished what we outlined in the Terms of References (Appendix 1).

1. We have collected many data sets of phytoplankton in the coastal oceans around the world.
2. We have facilitated migration of individual data sets to a website: www.wg137.net. Now, WG137 datasets have also become part of IGMETS (www.IGMETS.net), an IOC program.
3. We also achieved Terms of Reference No. 3-5, demonstrated by the recently published WG137 Special Issue in the *Estuarine, Coastal and Shelf Science* (see below).

III. Outcome and Scientific Products

1. WG137 has made substantial achievements, not only in its compiling datasets, but also in promoting phytoplankton as an essential part of the ocean ecosystems, emphasizing the values and importance of phytoplankton monitoring programs.

   a) In the PICES Annual Meeting 2012 in Hiroshima, Japan in 2012, Hans Paerl represented WG137 and gave a plenary speech: "Global Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Utilizing long-term data to distinguish human from climatic drivers of ecological change."

   b) In the PICES Annual Meeting 2012 in Hiroshima, Japan, Bill Li of the Bedford Institute of Oceanography, Canada, on behalf of the joint effort between ICES WG on Phytoplankton and Microbial Ecology and WG137, gave a plenary presentation: "An ecological status report for phytoplankton and microbial plankton in the North Atlantic and adjacent seas."

   c) In the CERF 2013 Biennial Conference, WG137 organized a joint SCOR/CERF Workshop, and the CERF Session SCI-62. The session attracted 22 abstracts and ran for a full day, with the room filled during the session.

2. The datasets on phytoplankton compiled by WG137 are very valuable. Recently, IOC has formed an "International Group for Marine Ecological Time Series (IGMETS)", to which WG137 has made a great contribution.

3. IOC has an interest in forming an International Group on Phytoplankton: Climate Change and

Global Trends of Phytoplankton in the Oceans, which will continue WG137 subjects related activities using the datasets compiled by WG137.

4. WG137 produced a special issue in *Estuarine, Coastal and Shelf Science*, including the following papers:

Estuarine, Coastal and Shelf Science
Volume 162, Pages 1-160 (5 September 2015)
Special Issue: Global Patterns of Phytoplankton Dynamics in Coastal Ecosystems
Edited by Riina Klais, James E. Cloern and Paul J. Harrison

- Hans W. Paerl, Kedong Yin, Todd D. O'Brien. 2015. SCOR Working Group 137: "Global Patterns of Phytoplankton Dynamics in Coastal Ecosystems": An introduction to the special issue of *Estuarine, Coastal and Shelf Science* 162:1-3.
- Riina Klais, James E. Cloern, Paul J. Harrison. 2015. Resolving variability of phytoplankton species composition and blooms in coastal ecosystems. *Estuarine, Coastal and Shelf Science* 162:4-6
- Nathan S. Hall, Anthony C. Whipple, Hans W. Paerl. 2015. Vertical spatio-temporal patterns of phytoplankton due to migration behaviors in two shallow, microtidal estuaries: Influence on phytoplankton function and structure. *Estuarine, Coastal and Shelf Science* 162:7-21
- Charles L. Gallegos, Patrick J. Neale. 2015. Long-term variations in primary production in a eutrophic sub-estuary: Contribution of short-term events. *Estuarine, Coastal and Shelf Science* 162:22-34
- Clarisse Odebrecht, Paulo C. Abreu, Jacob Carstensen. 2015. Retention time generates short-term phytoplankton blooms in a shallow microtidal subtropical estuary. *Estuarine, Coastal and Shelf Science* 162:35-44
- R.J. Gowen, Y. Collos, P. Tett, C. Scherer, B. Bec, E. Abadie, M. Allen, T. O'Brien.2015. Response of diatom and dinoflagellate lifeforms to reduced phosphorus loading: A case study in the Thau lagoon, France. *Estuarine, Coastal and Shelf Science* 162:45-52
- L.W. Harding Jr., J.E. Adolf, M.E. Mallonee, W.D. Miller, C.L. Gallegos, E.S. Perry, J.M. Johnson, K.G. Sellner, H.W. Paerl. 2015. Climate effects on phytoplankton floral composition in Chesapeake Bay. *Estuarine, Coastal and Shelf Science* 162:53-68
- Anna Godhe, Chethan Narayanaswamy, Riina Klais, K.S. Venkatesha Moorthy, Rengaswamy Ramesh, Ashwin Rai, H.R. Venkataswamy Reddy. 2015. Long-term patterns of net phytoplankton and hydrography in coastal SE Arabian Sea: What can be inferred from genus level data? *Estuarine, Coastal and Shelf Science* 162:69-75
- Lumi Haraguchi, Jacob Carstensen, Paulo Cesar Abreu, Clarisse Odebrecht. 2015. Long-term changes of the phytoplankton community and biomass in the subtropical shallow Patos Lagoon Estuary, Brazil. *Estuarine, Coastal and Shelf Science* 162:76-87
- Abigail McQuatters-Gollop, Martin Edwards, Pierre Helaouët, David G. Johns, Nicholas J.P. Owens, Dionysios E. Raitsos, Declan Schroeder, Jennifer Skinner, Rowena F. Stern. 2015. The Continuous Plankton Recorder survey: How can long-term phytoplankton datasets contribute to the assessment of Good Environmental Status? *Estuarine, Coastal and Shelf Science* 162:88-97

- Jacob Carstensen, Riina Klais, James E. Cloern. 2015. Phytoplankton blooms in estuarine and coastal waters: Seasonal patterns and key species. *Estuarine, Coastal and Shelf Science* 162:98-109
- Kalle Olli, Hans W. Paerl, Riina Klais. 2015. Diversity of coastal phytoplankton assemblages – Cross ecosystem comparison. *Estuarine, Coastal and Shelf Science* 162:110-118
- Peter A. Thompson, Todd D. O'Brien, Hans W. Paerl, Benjamin L. Peierls, Paul J. Harrison, Malcolm Robb. 2015. Precipitation as a driver of phytoplankton ecology in coastal waters: A climatic perspective. *Estuarine, Coastal and Shelf Science* 162:119-129
- Paul J. Harrison, Adriana Zingone, Michael J. Mickelson, Sirpa Lehtinen, Nagappa Ramaiah, Alexandra C. Kraberg, Jun Sun, Abigail McQuatters-Gollop, Hans Henrik Jakobsen. 2015. Cell volumes of marine phytoplankton from globally distributed coastal data sets. *Estuarine, Coastal and Shelf Science* 162:130-142
- Hans Henrik Jakobsen, Jacob Carstensen, Paul J. Harrison, Adriana Zingone. 2015. Estimating time series phytoplankton carbon biomass: Inter-lab comparison of species identification and comparison of volume-to-carbon scaling ratios. *Estuarine, Coastal and Shelf Science* 162:143-150
- Adriana Zingone, Paul J. Harrison, Alexandra Kraberg, Sirpa Lehtinen, Abigail McQuatters-Gollop, Todd O'Brien, Jun Sun, Hans H. Jakobsen. 2015. Increasing the quality, comparability and accessibility of phytoplankton species composition time-series data. *Estuarine, Coastal and Shelf Science* 162:151-160

In addition to the contributions in the Special Issue, individual and combined members of WG 137 have, over the past 4 years, published numerous peer-reviewed manuscripts (based on WG-137 compiled data sets) in aquatic, ecological, biogeochemical as well as high-profile journals, including *Science*, *PLOS One*, *Transactions of the Royal Society*, *Reviews of Geophysics*, *Limnology and Oceanography*.

2.1.3 SCOR/IGBP WG 138 on Modern Planktic Foraminifera and Ocean Changes
(2010) ***Naidu, 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)

<u>Other Full Members</u>

Jelle Bijma	Germany	Divakar Naidu	India
Jonathan Erez	Israel	Daniela Schmidt	UK
Elena Ivanova	Russia	Howard Spero	USA
Margarita Marchant	Chile	Richard Zeebe	USA

<u>Associate Members</u>

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

Executive Committee Reporter: Corina Brussaard

From: Michal Kucera [mailto:mkucera@marum.de]
Sent: Friday, September 04, 2015 10:09 PM
To: Ed Urban <ed.urban@scor-int.org>
Subject: SCOR WG138 Catalina workshop

Dear Ed,

The final workshop of our WG138 is just over and I feel I have to share some of the highlights with you right away. The meeting attracted 50 participants, including a large group of students from a couple of undergrads to finishing PhDs. We combined lectures, talks and lab training and the resulting total immersion into foram science was a truly remarkable experience. When we were asked by SCOR to incorporate such summer school into our mandate, I was not sure if we would make it, but the result proved you right - there was a huge need for this event and we now have an enthused group of young researchers on the way home, with a network and experience of a lifetime (not to speak of snorkeling with sharks and similar minor side-highlights).

Since you were collecting such information last time, I am pleased to let you know that this time we also reached the community from developing countries. Among the participants were Elena Ivanova from Russia, Margarita Marchan from Chile and Divakar Naidu from India.

The second reason I write is to provide a link to the abstract volume, which turned out really nice and we used it a bit to serve as a material record from the meeting (printed courtesy of Beta analytics), containing information about the WG and some of our achievements:

http://www.eforams.org/img_auth.php/e/ed/SCORWG138_Catalina_2nd_circular.pdf

Third, in the spirit of our keen interest in new media, we arranged for all talks to be videoed. They will be professionally synchronised with the presentations and uploaded via UC Davis (at no cost...). We will seek permissions from all speakers to make these public. If this is of interest to SCOR, let me know and I will provide you with more details and the link. Half of the talks were lecture-style (for the students) so this will certainly be a very interesting resource.

We are now working on the final report, which we hope to finish before Goa.

All the best
Michal

2.1.4 SCOR WG 139 on Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean *Naqvi* (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	Ivanka Pizeta	Croatia
Ronald Benner	USA	Alessandro Tagliabue	France
Martha Gledhill	UK	Rujun Yang	China-Beijing
Katsumi Hirose	Japan		

Associate Members

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

Executive Committee Reporter: Wajih Naqvi

2-12

SCOR Working Group 139:

Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean

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.**

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

> S.G. Sander, K.N. Buck, and M.C. Lohan. 26 June 2012. Improving understanding of organic metal- binding ligands in the ocean. *Eos*, 93(26): 244.
>
> K.N. Buck, M.C. Lohan, and S.G. Sander. July 2012. Metal-binding organic ligands. IUPAC *Chemistry International*, 34(4): 23. http://www.iupac.org/publications/ci/2012/3404/pp4_wg139.html

2. **To summarize published results on all aspects of metal-binding ligands in the oceans (*e.g.*, distributions, chemical structure, sources, sinks, stability constants), and to contribute to the organic ligand database for use in biogeochemical models and for those working in the field (including results from ongoing GEOTRACES, SOLAS and CLIVAR efforts). The summary will be included in a review paper published after year 2, as well as in the database on the proposed website.**

Databases for metal-binding ligand measurements are being compiled by several members of the working group. Four key bioactive trace elements were chosen: Co, Cu, Fe and Zn. The four champions who agreed to collate the data were: Mak Saito for Co, Jim Moffett for Cu, Micha Rijkenberg for Fe and Maeve Lohan for Zn. The iron-binding ligand database is the furthest developed and an additional database for the raw titration data used to calculate iron-binding ligands has recently been initiated. This compilation of unprocessed titration data will be especially useful for the development and testing of new interpretation methods, which members of this working group have shown is exceedingly important. The review paper is underway and will be completed once the databases are established.

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 has 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.**

Several successful intercalibration activities have been pursued as part of this working group. A large intercalibration of the interpretation techniques routinely used for determining ligand concentrations and conditional stability constants from titration data was conducted with 15 participants using a simulated dataset. The results of this intercalibration identified some limitations of interpretation tools and highlighted the importance of interpreting multiple window titration data as a whole instead of individually. These results were published in *Marine Chemistry* as part of a special issue (http://www.sciencedirect.com/science/journal/03044203/173) produced by this working group (Pizeta et al. 2015). This intercalibration also served to expose the wider electrochemistry community to powerful new interpretation tools developed by participants in this working group, which are now freely available to download from our working group website (http://neon.otago.ac.nz/research/scor/achievements.html). Three different interpretation tools are freely available:

1. ProMCC developed by Dario Omanović, Cédric Garnier and Ivanka Pižeta (https://sites.google.com/site/mccprosece/),
2. KINETEQL developed by Bob Hundson (https://sites.google.com/site/kineteql/home/about-kineteql), and
3. an R script developed by Micha Rijkenberg and Loes Gerringa (http://www.researchgate.net/publication/275016798_R_script_for_analysis_of_organic_metal_complexa tion_characteristics_version_15042015).

With a growing consensus on ideal interpretation tools for determining ligand characteristics from titration data, the next step is to conduct an intercalibration for generating the titration data itself. A large volume of filtered seawater has been collected for this purpose from the Gulf of Mexico, and will be distributed to interested analysts for measurement in spring 2016. A similar exercise is planned with water collected from the Southern Ocean. Both of these cruises were funded by the U.S. National Science Foundation.

A discussion on the merits of an analytical intercalibration of commercially available model ligands and ligand mixtures was debated, but this effort is still in the early planning stages.

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

Trace metal-binding ligands play a fundamental role in trace metal residence times and bioavailability and it is therefore essential to represent this organic complexation correctly in biogeochemical models. At present, iron is represented in climate models using three different approaches: (1) Threshold Models that use a threshold ligand concentration, (2) Explicit Models that use a vast range of parameters, and (3) Equilibrium Models that use either a simple case whereby single ligand class concentrations and conditional stability constants are used or a more complex case using two ligand classes, their formation and disassociation constants and photolability. The working group discussed several aspects of incorporating ligands into models, including how analysts can provide ligand concentrations, their sources and sinks and complexation kinetics such as the variability in conditional stability constants of iron, how to distinguish between different iron-binding ligand classes, and if trace metals compete for the same class of ligands. It was decided that a speciation database for bioactive trace elements would be a helpful starting point (see point 2). A paper published by Volker and Tagliabue (2015) in the *Marine Chemistry* special issue examined how organic iron-binding ligands could be represented in a biogeochemical ocean model (http://www.sciencedirect.com/science/article/pii/S0304420314002229).

Furthermore, a new SCOR WG 145 'MARCHEMSPEC – Modelling Chemical Speciation in Seawater to Meet 21stCentury Needs' has been established, which 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. To represent the users of chemical models in this WG, SCOR WG 139 co-chair Sander has also been appointed vice-chair in the new WG 145.

5. **To debate the nature of sampling strategies and experimental approaches employed in laboratory and field efforts from different communities in workshops and meeting discussions to foster cross-fertilization of ideas across groups, capitalize on joint expertise between specialties and ultimately enhance our understanding of the links between the provenance, fate, distribution, and chemistry and biological functions of these organic metal-binding ligands in the oceans.**

This working group has met annually from 2012-2014 in February, coinciding with the February ocean sciences/aquatic sciences meetings hosted by AGU and ASLO. Notes from each of these meetings are posted on our website (http://neon.otago.ac.nz/research/scor/meetings.html). To incorporate updates from the broader community, the co-chairs of this Working Group have also chaired a special session related to the working group at each of the ASLO conferences in 2012, 2013 and 2014. In all three cases, sufficient submissions allowed for both oral and poster sessions at the conferences. At all three sessions presentations were given from trace metal biogeochemists, organic geochemists and biogeochemical modellers, indicating the success of this working group in bringing together new research approaches for determining trace metal speciation. In addition, an open Town Hall Meeting, held during the 2014 Ocean Sciences meeting, was attended by 47 people and served to highlight accomplishments of the working group to date and engaged broader community participation in the ongoing working group activities. This town hall meeting also advertised the symposium and sought feedback in how this symposium would be run. This led to the addition of a training workshop prior to the symposium.

6. **To recommend future approaches to ligand biogeochemistry in a designated symposium, including ongoing GEOTRACES field efforts (i.e., regional surveys and process studies), integration of CLE-ACSV and organic geochemistry techniques, and the need for rapid incorporation of this research in biogeochemical models. Such future recommendations will also be included in the aforementioned downloadable manual. It will also include a series of recommended downloadable digital products on multiple platforms for interpreting ACSV data.**

In April 2015, the final year of this working group, a highly successful two-day symposium was held in Sibenik, Croatia. This symposium was open to the broader scientific community and was used as a platform to recommend future approaches to ligand measurements and highlight results from intercalibration and field activities. A total of 51 people attended the symposium, including 24 students and postdocs, who were each allotted time to present their research results in the field of ligand biogeochemistry. Twenty of the 51 symposium attendees also participated in a training workshop held the day before the symposium. This workshop was held at the Martinska Marine Station in Sibenik, and consisted of hands-on training in analysing samples for metal-binding ligands and in using the state-of-the- art interpretation techniques developed (in part) through the activities of the working group. A best practices manual reflecting the recommendations gained through this working group is underway. Drafts of the manual will be made available to the community on our website and advertised on our email list to elicit feedback. We anticipate that the manual will continue to be updated over time as this community continues making advancements.

7. **To establish a webpage for this SCOR working group, to promote a forum for discussion of ideas and results in form of a blog, soliciting input from the trace metal biogeochemistry, organic geochemistry and modelling communities and provide a platform to propose special sessions on trace metal-binding ligands at international meetings such as Ocean Sciences, AGU and/or EGU.**

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

8. To produce conclusions resulting from the outcome of the above objectives in the form of a Website, a journal special issue or book, and a report to SCOR.

A website for this SCOR WG has been created and is currently being maintained at the University of Otago (http://neon.otago.ac.nz/research/scor/). A special issue resulting from this WG's activities was published in July 2015 in *Marine Chemistry*, and included 28 research articles plus an editorial (http://www.sciencedirect.com/science/journal/03044203/173). Due to the success of the *Marine Chemistry* special issue and discussions at the final symposium, another special issue was initiated. This second special issue is currently underway in *Frontiers Marine Biogeochemistry* and the deadline for submissions to this issue is in December 2015. A total of 24 authors have confirmed their intention to contribute to this special issue.

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

Terms of Reference:

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

Co-chairs:
Jacqueline Stefels (Netherlands) and Nadja Steiner (Canada)

Other Full Members

Gerhard Dieckmann	Germany
Elena Golubeva	Russia
Delphine Lannuzel	Australia
Sang Heon Lee	Korea
Lynn Russell	USA
Paul Shepson	USA
Jean-Louis Tison	Belgium
Martin Vancoppenolle	Belgium

Associate Members

Kevin Arrigo	USA
Jeff Bowman	USA
Clara Deal	USA
Bruno DeLille	Belgium
Scott Elliot	USA
Michael Fischer	Germany
Agneta Fransson	Norway
Francois Fripiat	Belgium
Claire Hughes	UK
Delphine Lannuzzel	Australia
Maurice Levasseur	Canada
Brice Loose	USA
Paty Matrai	USA
Christine Michel	Canada
Lisa Miller	Canada
Jun Nishioka	Japan
Daiki Nomura	Norway
Benjamin Saenz	USA
Veronique Schoemann	Netherlands
Lise-Lotte Soerensen	Denmark
Letizia Tedesco	Finland
David Thomas	UK
Maria van Leeuwe	Netherlands
Roland von Glasow	UK
Chris Zappa	USA
JiaYun Zhou	Belgium

Executive Committee Reporter: Sergey Shapovalov

2-18

SCOR WG 140
Biogeochemical Exchange Processes at the
Sea-Ice Interfaces (BEPSII)
- Annual Report 2015 -

The yearly meeting of WG140 took place after the Gordon Research Conference on Polar Marine Sciences in Lucca, Tuscany, Italy on 20 March 20 2015. 26 members of the BEPSII network, representing 12 countries, attended the meeting. The group consisted of 50:50 established versus early-career scientists and 50:50 female and male participants. A full report of the meeting is presented in **Annex I**.

Participants of the BEPSII meeting in Lucca, Italy, 20 March 2015

Overview of activities

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

1. Methodological review;
2. Provide recommendations for intercomparisons and intercalibration projects; and
3. Guide of Best Practices.

The activities of TG1 to meet these goals were the following:

1.1 A review on sea-ice methodologies has been published in *Elementa: Science of the Anthropocene*. Reference: Miller et al. (2015) Methods for biogeochemical studies of sea ice: The state of the art, caveats, and recommendations. (**Annex II**) This paper is the first of a Special Issue in *Elementa* on sea-ice biogeochemistry that was initiated by BEPSII (see below).

1.2 While it is not the aim of BEPSII to organize such a campaign within the current project period, it is the aim to stimulate discussion, design sampling strategies for method intercalibration and intercomparison projects of various parameters, and seek opportunities to organize these projects on a reasonable time scale. Finding the resources to organize such a project is difficult; it is expensive (remote places; logistically difficult to get to) and concerns a multi-disciplinary and multi-national group of scientists. Several field stations are under discussion and will be further looked into. Currently, the best options seem to be Saroma-Ko, Japan; Cambridge Bay, Canada; and Tvarminne, Finland.

1.3 One of the goals of the intercalibration campaign will be to obtain better insights into current methodologies, in order to go beyond the currently published methods review. Most urgently, intercomparisons are needed for primary production measurements in ice, melting procedures and their impact on biochemical components and gas flux measurements from ice. In the meantime, method testing and improvement by individual members is being stimulated and is a continuing effort (**Annex IV**)

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

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

The activities of TG2 to meet these goals were:

2.1 The collection of chlorophyll-*a* data from the Arctic is taking shape under Canadian/German lead. The respective paper will be submitted to *Geophysical Research Letters*, in which also the first chlorophyll-collation paper by Meiners et al. was published. The Antarctic database will be further extended with data from land-fast ice. Other parameters have been worked on over the past year and new ones were proposed during the March meeting. These include the inorganic carbon system, macronutrients, dissolved and particulate organic carbon, iron and algal biodiversity. Since the amount of data for these quantities is much less than for chlorophyll-a, the data inventories will be combined with mechanistic reviews under task 2 of TG3 (see below).

2.2 The ASPeCt log-sheet – an Excel file with a standardized protocol for ice-core metadata is published on the BEPSII website. Scientists will be encouraged to consistently use the template, which will greatly help future data access and interpretation. Furthermore, a MatLab toolbox to easily extract and analyse log-sheets is currently being developed.

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

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

The activities of TG3 to meet these goals were:

3.1 A paper on "What sea-ice biogeochemical modellers need from observationalists" has been submitted to *Elementa* as part of the BEPSII special issue.

3.2 The open-access journal *Elementa – Science of the Anthropocene* was chosen to publish a special feature on sea-ice biogeochemistry: https://home.elementascience.org/special-features/biogeochemical-exchange-processes-at-sea-ice-interfaces-bepsii/. The editor-in-chief of the Ocean Sciences section, Jody Deming, attended the Lucca meeting in March. The BEPSII Special Feature will contain a collection of synthesis papers reviewing particular biogeochemical processes in sea ice and respective model applications, but also research papers are accepted. Currently, 22 contributions are planned (**Annex III**) of which 1 is published and 6 additional have been submitted.

3.3 A 1-D model intercomparison of a seasonal cycle of ice algae is currently slowed down due to parental leave by the lead author, but will be picked up in November. There are 10 groups contributing. The goal is to evaluate outcomes on biomass and primary production over a seasonal cycle, both in the Arctic and the Antarctic.

3.4 Global and regional model intercomparisons are still mostly focusing on pelagic production and acidification. However, regional modeling of sea ice algae is currently expanding. An intercomparison is likely beyond the time frame of the current WG140.

Status of fulfilling terms of reference

The Terms of Reference of BEPSII are as follows:

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

ToR1 is covered by the activities of TG1 and part of TG2. It has been fulfilled with the publication of the review paper on methodologies in *Elementa* (activity 1.1). Also activities 1.2, 1.3 and 2.2 contribute to this ToR. Given the substantial difficulty to work on and with sea ice, both from an organizational and financial perspective, progress in method standardization is slow and the ambition to finalize this goal within the timeframe of WG140 is not realistic. A continued effort for testing and intercalibrating sea-ice methods is needed. As the BEPSII community is still young and constantly growing, there is a strong wish to continue this collaboration and to develop international projects to fulfill these goals.

ToR2 is well underway with activities 2.1 and 3.2. The *Elementa* Special Feature will be a major end product of BEPSII.

ToR3 is currently being implemented in the 1-D exercise described under activity 3.3. A fully integrated sea-ice biogeochemistry module in global climate models cannot be expected within the life span of WG140. However, up-scaling of individual parameters, such as the inorganic carbon cycle, is currently underway. Based on results from activity 3.2, 3.3 and 3.4, we expect to make recommendations indicating which processes and variables might need to be considered in global climate models.

ToR4 is the most ambitious goal of WG140 and can only be achieved in collaboration with the modeling community at large. Analysis on the role of sea ice biogeochemistry in climate simulations is expected to be performed as a regional downscaling effort (regional models with sea-ice biogeochemistry will be forced with output from global CMIP5 models). This is one of the last activities to be undertaken and will extend past the current BEPSII period in close collaboration with FAMOS (Forum for Arctic Modeling and Observational Synthesis). Significant progress has been made with respect to the implementation and application of sea ice algae models on regional scales. Publicly accessible sea-ice algae codes are now available as part of the Biogeochemical Flux Model (BFM, http://www.bfm-comminity.eu) and the Los Alamos CICE model and will be made available as part of the General Ocean Turbulence Model-*Framework for Aquatic Biogeochemical Models* (GOTM-FABM). All models are developed and maintained by BEPSII Full and Associate members.

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

1. The major activity in the coming year will be the continued submission of papers to the *Elementa* Special Feature (**Annex III**). Since both mechanistic review papers and modeling applications will be published in this Feature, it is regarded as the main product of WG140.
2. The planned 1-D model intercomparison will take place in the coming year. The instructions for model runs are being finalized and datasets to run the models for both the Arctic and Antarctic are currently collated. Timeline: Runs in December; discussion at next BEPSII meeting in March 2016. Paper writing afterwards. (L. Tedesco, M Vancoppenolle et al.).
3. Large-scale data collections are still on-going: Arctic ice biomass (Ilka Peeken, C. Michel et al.), Antarctic fast ice biomass (K. Meiners et al.), inorganic carbon (B. Delille et al.), inorganic macro-nutrients (F. Fripiat et al.), iron (D. Lannuzel and V. Schoemann), dissolved and particulate organic carbon (A. Roukaert, F. Fripiat et al.), algal biodiversity (M. van Leeuwe, J. Rintala et al.).
4. The SCOR WG140 platform has been extremely helpful in setting up this new network of observationalists and modelers on sea ice biogeochemistry. There is a strong need *and* wish to continue this successful network, explore new ways to collaborate and further develop our understanding of the sea-ice system. In order to discuss options and opinions to continue BEPSII, a discussion session is being held during the SOLAS Open Science Conference in September, in Kiel, Germany (leads: Lisa Miller and Martin Vancoppenolle). The format of a working group or forum under the mutual umbrellas of SOLAS and CLiC will be investigated. CliC is a co-sponsor of the discussion session.

5. The last BEPSII meeting under the umbrella of SCOR-WG140 is planned for March 2016 in Paris, France. This time a dedicated meeting with science presentations and (parallel) discussion sessions to plan the future is planned.

   Special requests for extra funding for outreach and/or capacity building activities

   The costs for publication of a Special Feature in *Elementa* is expected to be around €1000 per article. A contribution from SCOR will be more than welcome.

   Challenges or opportunities the group will experience in the coming year

   The major task for the coming year will be the finalization of all papers within the *Elementa* Special Feature.

   The other challenge will be to explore new avenues for continued support of the activities and collaborations started within WG140. For both the planning and organization of intercalibration field campaigns and the upscaling of model intercomparisons a BEPSII 2.0 is needed. There is much support from the community for the continuation of this new and highly successful collaboration between modelers and experimentalists. The network is a very good mix between junior and senior scientists from all over the world. The group now consists of approximately 85 scientists from 16 countries. Avenues for continuing the network are through the current SOLAS and CLiC programs, but this will not provide funding for actual field campaigns. Other institutions, like the EU funding schemes, need to be explored, but this is likely a longer-term effort.

ANNEX I

Minutes SCOR-WG 140 (BEPSII) Meeting
Lucca, Italy Friday March 20, 2015

Present: Steve Ackley (USA), Jeff Bowman (USA), Bruno Delille (B), Agneta Fransson (NO), Francois Fripiat (B), Klaus Meiners (AUS), Lisa Miller (CAN), Sebastian Moreau (B), Janne-Markus Rintala (FIN), Lynn Russell (USA), Jacqueline Stefels (NL), Nadja Steiner (CAN), Letizia Tedesco (FIN), Jean-Louis Tison (B), Martin Vancoppenolle (FR), Maria van Leeuwe (NL).

New to the group: Melissa Chierici (NO), Jody Deming (USA), Hakase Hayashida (CAN), Nicolas-Xavier Geilfus (DEN), Jennifer Jackson (CAN), Ollie Legge (UK), Eva Leu (NO), Eric Mortenson (CAN), Christiane Uhlig (GER), Pat Wongpan (NZ).

Welcome & Goal

Aim of the meeting was to recap where we are and to discuss what is still missing, what are the next steps, and what is our future.

1. Update on crosslinks (related projects)

OASIS (mail info McNeill): not too much on-going; there is currently no official structure. OASIS members have taken the initiative to prepare a Future Earth call for proposals: lead is Faye McNeill. Their pre-proposal was grouped by FE with two other Arctic-related proposals (one of which was social science related to governance, the other very solution-oriented coastal geography). FE gave the three groups a little bit of money and an assignment to come up with a proposal for how Future Earth should engage in a broad sense with ongoing Arctic-related activities. The new proposal is called ArcticSTAR, and focuses on Arctic research founded in Future Earth principles of transdisciplinarity and stakeholder engagement. It seems likely that FE will approve this; however, FE does not really have the funding at this time to make the value of such a designation go beyond the abstract power of the FE stamp of approval. Among the goals of ArcticSTAR is the one to build a "community of practice" (i.e., research coordination network) and bring researchers from multiple disciplines together in workshops, hold summer schools to promote working across disciplines, etc. including social scientists and stakeholders. McNeill: “The tough thing is we are kind of back at the drawing board in terms of finding funding for those activities - becoming an official FE initiative, if and when it happens, will be a "hunting license" for us to go to other agencies to raise funds for the workshops and other activities. Maybe down the road we would be in a position to serve as a parent organization for other groups the way that IGAC is, but we would not be able to do much in terms of passing along funding to them for at least a few years I think.”

PICES (Lisa Miller): would be supportive of an intercalibration in Japan, but is not able to provide money for it.

ASPeCT (Steve Ackley): Has recently been accepted as a SCAR expert group, but they still need to write the terms of reference. There is a wish to include more ecology in the ASPeCT aims. The ASPeCT icecore database, and its extension towards more biological and chemical parameters, is an important connection with BEPSII. Also the ship-based observation database contains a wealth of information on sea-ice coverage.

2. Summary presentations of task groups

TG1 (Lisa Miller/Lynn Russell)
Progress on Terms of reference for TG1:
Methods review: Published, January 2015 in *Elementa*.

Intercalibration experiments:
Many ideas are still gestating, but no concrete progress has been achieved. The issue is primarily one of resources; the community is talking, generating ideas, and willing to work together, but 'seed' funding to get it all rolling is proving elusive.

Summary of report from Daiki:
For the intercalibration experiment, so far (after IGS Hobart), Daiki and Jun sought funds for the experiment, but there is no appropriate fund (appropriate meaning that travel money is provided for joining scientists and for shipping equipment between abroad and Japan, etc.). Maybe we ask too much. If joining scientists can find the money for coming over and shipping equipment to Saroma themselves, it can be arranged. Accommodation prices etc. will be cheap in Saroma, so, money for lodging will not be an important issue.

The design of a gas flux intercalibration experiment is still under discussion. The idea is to compare tower and chamber measurements, as was recently tried out during a campaign with people from the Norwegian Polar Institute, measuring CO_2 and CH_4 in both set-ups.

Additional sites have been proposed:
Cambridge Bay:
Contact/lead: Brent Else (belse@ucalgary.ca).
Central Canadian Arctic Archipelago

Pros: Confidence in sea-ice formation
Location of new Canadian High Arctic Research Station (CHARS)
Easy access by commercial transportation, with several passenger flights daily and cargo flights several times each week.
Ample housing (houses for rent, hotel rooms)

Cons: Research station is not yet built (expected to be 'functional' in 2017)
For now, the only 'lab' is a trailer with a sink that could maybe be borrowed
Level of logistical support (skidoos, etc.) still uncertain

Station Nord:
Contact/lead: Nix Geilfus (geilfus@bios.au.dk)
Northeast Greenland

Pros: Lots of ice, both land-fast and pack
Ample lab facilities and lodging (about $300/day w/board)

Cons: Travel is expensive (approx. $3000 round trip from Longyearbyen)

Jeff Bowman: Ideas for the genomics portion of the intercalibration experiment. From his own data analysis on bacterial genomes (16sRNA), Jeff started to recognize specific metabolic pathways. This opens the possibility to distinguish between bacterial functional types. Hence, emphasis needed on:

- Ecosystem functions
- Diversity of the sea ice microbial community
- Metabolic processes not yet picked up in either biogeochemical or molecular studies

Francois Fripiat will pursue on his previous outline of a field-campaign and will write a first draft of a proposal (for the next BESPII meeting). This proposal will be dedicated to an intercalibration of methods in sea ice biogeochemistry (e.g., primary production, gas content and exchanges, …) and the elaboration of a best sampling scheme (parameters, resolution, …) for modeling purposes. This proposal can form the basis of an application for a new SCOR working group.

Updated list of potential intercalibration sites/facilities:
Prices in approximate 2013 US dollar equivalents.

Site	Transport (roundtrip)	Lab/Other Facilities (most charge fees)
Alert	3000 from Trenton	Various (labs, trucks, no wireless)
Ny Alesund (Svalbard)	1700 from Tromso	Various
Longyearbyen	800 from Tromso	Various
Station Nord (Villum)	3000 from Longyearbyen	Various (labs, boats, 5 snowmobiles)
Cambridge Bay	Several flights/day	Labs being built; trailers w/sinks for rent
Saroma-ko Lagoon	40 from Memanbetsu	Various (labs, jetskis, hot springs)
SERF @ Manitoba	100 from Winnipeg	Ice pool (artificial SW) for $100/PI/d
IOS @ Victoria	200 from Vancouver	Clean rooms, etc.
Tvarminne	100 from Helsinki	Various (labs, tanks, boats, saunas)
McMurdo	NSF-only/infrequent	Various
Barrow	800 from Seattle	Various (labs, transport, guards)
CRREL @ Hanover, NH	200 from Boston	Wave tank

Manual of best practice:
First we need an intercalibration to be able to go beyond the currently published methods review. The idea is to do this through a growing document and/or videos on the website.
Jody: *Elementa* has a new feature: "practice bridge" which supports videos of practices, which might be useful.

TG2 (Klaus Meiners/Martin Vancoppenolle)
Progress on data compilations and analyses:

1. Collation of DIC and TA started and is in progress (lead Delille et al.) The CO_2 dataset consists currently of 172 stations. The main issue is to discuss the TA:DIC anomaly as the result of degassing. There are still many datasets that need to be added. For the collation of data, the ASPeCT-BIO format and algorithms of Meiners et al. are used.
2. Antarctic database (ASPeCt-Bio) is currently being further analysed to identify drivers of integrated biomass and vertical Chla distribution in particular ice thickness, the influence of snow, snow-ice thickness ratios, on-shelf versus off-shelf location. Potential paper on relationship between ice thickness (snow thickness) versus integrated Chla planned (lead: Vancoppenolle)
3. Collation of Arctic pack ice chlorophyll-a data has progressed. Ilka Peeken (AWI) has collated European data and has sent these to Christine Michel, who is compiling Canadian data and will be leading the write-up.
4. Collation of Arctic and Antarctic iron data has progressed well, paper planned (lead Lannuzel). Data from approximately 100 ice cores are available; which is the total from both Poles + Baltic. Preliminary conclusions: in remote areas, Fe is coming from the water; in the Baltic from the atmosphere. Melting sea ice is seeding surface waters with Fe.
5. Collation of Antarctic macro-nutrient data is progressing well; only a few datasets are still missing (lead: Francois Fripiat). FF will start to interpret the data in summer 2015 (comparison between datasets, ice types and properties, methodological biases, …). Intriguing is the very high concentrations of PO_4 observed.
6. Collation of POC/DOC planned (lead: Fripiat with PhD student Arnout Roukaert). AR is a Ph.D. student working on primary production and N-uptake in sea ice at the Vrije Universiteit Brussel.
7. We have also started collation of Antarctic fast-ice chlorophyll-a data (lead: Meiners. Follow the ideas/layout of Leu et al. paper on ice algal phenology in Pan Arctic fast ice *(Progress in Oceanography*, in press)

Additional points to consider:
Jackson: There might be loads of data from industry available, although mostly physical data. If there is an interest for it, she can look into it.
Info from Rysgaard: A new Danish datacenter, the Isaaffik Arctic Gateway, will be launched soon: http://www.isaaffik.org. For the moment it is only metadata, but it should ultimately also include biogeochemical sea-ice data.

TG3 (Nadja Steiner/Clara Deal)

Task 1: Publication: What sea-ice biogeochemical modelers need from observationalists, will be submitted right after this meeting as part of the *Elementa* special feature for BEPSII.

Task 2: Review papers on major bgc processes in Special feature of *Elementa* (Editor-in-Chief: Jody Deming, present at the meeting)

A collection of synthesis papers reviewing particular biogeochemical processes in sea ice and respective model applications is in full swing. A minimum of 4 papers submitted to *Elementa* is needed by the end of May; after this we can extend the deadline until whatever date we need. Not only reviews can be submitted, but also research papers. All information on planned papers should be sent to Nadja. A list of papers in preparation is below. We expect around 20 papers to be published in the special feature:

0. Miller et al Methods paper – published.... See Annex III for other planned papers

Other issues discussed:

- A previously anticipated review on halogens is not needed. A new review just came out.
- Jen Jackson will investigate the option to link with work of Elena on mixed layer parameterisations.
- Jodie Deming: Can contributions directly submitted to *Elementa* be part of the BEPSII issue? In principle they can, if complimentary to the other papers, but the request should go through the BEPSII coordinators who can then decide.
- *Elementa* offers the option to do a video introduction of the group & BEPSII goals.
- Nice pictures of fieldwork to brighten-up the BEPSII Feature can be send to Nadja.

Task 3: Intercomparison of 1D models

1-D model inter comparison of ice algae seasonal cycle is currently slowed down due to maternity leave by lead author, however will be picked up in November.
Data sets are not chosen yet, but it is anticipated to have one for each Pole: Resolute Bay for the Arctic? and Terre d'Adelie (1997) for the Antarctic. 10 models are involved. Timeline: Runs in December; discussion at next BEPSII meeting. Paper afterwards.

Other potential model analyses were discussed separately in connection with Task 2.

Task 4 - Application in regional models with links to global and regional climate modeling:
Global and regional model intercomparisons are still mostly focusing on pelagic production and acidification. However, regional modelling of sea ice algae is currently expanding. An intercomparison is likely beyond the time frame of the current BEPSII.

3. BEPSII's future

Next year will be the last opportunity to meet under the SCOR umbrella. And although we are well on our way to fulfill the ToRs, we have the feeling that this community just started and that many of the topics BEPSII has touched upon can benefit from an additional in-depth and interdisciplinary approach. Given the fact that the community consists of many young scientists, there is scope for a strong continuation. Therefore, it is time to develop new ideas and strategies to continue on.

The obvious topic for a BEPSII 2.0 initiative could be to organise a sea-ice intercalibration campaign, for which we are already discussing its potential layout under the current Task Group 1. The funding of the field campaign itself will need to come from science foundations, but support for the network (including modelers) will benefit from additional sources.

Potential umbrella's for a BEPSII 2.0:

- the AntERA program of SCAR (contact Julian Gutt), but this will be mainly Antarctic science. Jacq will join their meeting in Sept. 2015 and will probe this avenue.
- the ArcticSTAR initiative as described under agenda item 1.
- Another SCOR proposal: This is an option but will need to be very specific, with distinctively different terms of reference from WG 140 (BEPSII 1.0). This would have some chance of success, although would probably be hindered a bit if reviewed as a continuation of WG 140.
- A Task Group under SOLAS. There is a good spirit about continuation of SOLAS; sea ice is an explicit part in the new science plan. We will ask for endorsement. To start with, a discussion session at the SOLAS OSC in Kiel has been proposed, Sept. 7-11; abstract deadline: 27 May. There we can probe the interest from SOLAS and discuss new avenues (action Lisa).
- Associated with being a SOLAS TG, BEPSII could form a bridge between SOLAS and CLIC. ASPeCT is also connected to CLIC. CLIC has no biogeochemistry yet, but would like to. Good source for meeting support. Is bipolar. Approach Jenny Baesemann, who is coordinator of CLIC (JS: Not any more! She is now executive director of SCAR) (action Lisa).
- Become a project under the umbrella of IASC?? (ask Marit??)
- Applying for a COST action? (only European, but international collaboration is encouraged): 2x/yr, continuous submission. JS sends around guidelines to EU partners.

For all these organizations it will be important to have (new) Terms of References. Brainstorming of such new ToR resulted in the following list of ongoing and new deliverables:

1. Develop and conduct intercalibration campaigns.
2. Guide of best Practice
3. Develop guidelines and encourage technology innovations for sea-ice biogeochemical monitoring and observing systems
4. Review papers on major biochemical processes (special issue)
5. Inventory of available data
6. Recommendations for database improvements and quality control
7. Intercomparison of sea-ice biogeochemical models on multiple scales

8. Analysing the role of sea ice biogeochemistry in climate simulations.

4. Any Other Business

- *2016 meeting*: Instead of a fringe meeting we need this final meeting to be a dedicated BEPSII meeting of 3 days.
  Suggested dates: March 14-18 or mid April 2016
  Where: Groningen/Amsterdam? Paris? Lamont? Liege?
  Needed: Large room + 2 break-out rooms for approximately 40p.
- *Outreach* (webpage, Facebook): website on google is easy to upload & manage (https://sites.google.com/site/bepsiiwg140/home). Jayun will maintain the site. Facebook: Francois will send an email to everybody to update the Facebook page (together with Jiayun): with a special emphasis on educational contents.
  Please visit the sites and give input!

- Julian Gutt has invited us to provide a *"Scientific Highlight"* for the SCAR-AntERA website. (action Jacq)
- SCOR reimbursement form: Nadja sent around.
- SCOR report (due end of August).
- Bruno for Roland von G.: RvG has a new project funded by the ERC: it will involve sea ice-snow interaction experiments in new chambers, focusing on CO_2, CH4, DMS, NO_x, OC and halogens. The experiments should lead to improved modeling of the atmosphere and aerosols. Collaboration is welcome.

17:00 End of meeting

ANNEX II

Methods for biogeochemical studies of sea ice: The state of the art, caveats, and recommendations

Lisa A. Miller, Francois Fripiat, Brent G.T. Else, Jeff S. Bowman, Kristina A. Brown, R. Eric Collins, Marcela Ewert, Agneta Fransson, Michel Gosselin, Delphine Lannuzel, Klaus M. Meiners, Christine Michel, Jun Nishioka, Daiki Nomura, Stathys Papadimitriou, Lynn M. Russell, Lise Lotte Sørensen, David N. Thomas, Jean-Louis Tison, Maria A. van Leeuwe, Martin Vancoppenolle, Eric W. Wolff, and Jiayun Zhou

The relationship between sea ice bacterial community structure and biogeochemistry: A synthesis of current knowledge and known unknowns

Jeff S. Bowman

pdf can be found on the Elementa website:
https://home.elementascience.org/special-features/biogeochemical-exchange-processes-at-sea-ice-interfaces-bepsii/.

ANNEX III

List of Elementa papers

1. Miller et al Methods paper – already published....

Submitted:

2. Title: What sea-ice biogeochemical modellers need from observationalists
Authors: N. Steiner, C. Deal, D. Lannuzel et al.....

3. Title: Closing the O2 (and CO2) budget under a growing ice sheet
Authors: Moreau, S., Kaartokallio H., Zhou J., Kotovitch M., H. Kuosa, Goosse H., Dieckmann G. S., Thomas D., Tison J.-L., Delille. B

4. Title : Measurements of air-ice CO2 fluxes over artificial sea ice emphasize the role of bubbles in gas transport
Authors : Marie Kotovitch1,2, Sébastien Moreau3, Jiayun Zhou1,2, Jean-Louis Tison2, Gerhard Dieckmann4, David Thomas5, and Bruno Delille1

5. Title: The structure and activity of sea ice bacterial communities: Biogeochemical implications and known unknowns
Author: Jeff Bowman

6. C:N ratios in Arctic sea ice
Authors: A. Niemi et al.

7. A bio-optical model for photosynthesis in sea ice.
Authors: Müller, S., Uusikivi, J., Vähätalo, A., Majaneva, M., Majaneva, S., Autio, R., Rintala, J.-M.

To Be Submitted:

8. Title: Thermally-forced cycling of DMS, DMSP, and DMSO in Antarctic spring sea ice
Authors: Brabant, F., Carnat, G., Dumont, I., Becquevort, S., Vancoppenolle, M., Ackley, S.F., Fritsen, C., Delille, B., and Tison, J.-L.
Anticipated submission: Fall 2015

9. Title: Seasonal and vertical variability of DMS and DMSP in Arctic first-year sea ice
Authors: Carnat, G., Tison, J.-L., Gilson, G., Delille, B., Brabant, F., Levasseur, M., Geilfus, N.-X., and Papakyriakou, T.
Anticipated submission: Fall 2015

10. Title: First long-term large-scale estimates of primary production in Baltic sea ice
Authors: Tedesco, L., Miettunen, E., An, B.Y., Haapala, J., Kaartokallio, H. and H. Kuosa

11. Title: Coupling between inorganic carbon and biological parameters in melting AA sea-ice
Authors: Fransson, Chierici, Torstensson, Wulff
Anticipated submission: December 2015

12. Title: Iron in sea ice: a review
Authors: D. Lannuzel, M. Vancoppenolle, P. van der Merwe, V. Schoemann, M. Grotti, J. Nishioka and K.M. Meiners
Anticipated submission: Fall 2015

13. Title:Temporal changes in biogeochemical properties of Antarctic sea-ice during spring in the western Weddell Sea with emphasis on DMS(P).
Authors: Jacqueline Stefels, Matthias Steffens, David Thomas, John Dacey, Stathys Papadimitriou, Gerhard Dieckmann, ...
Anticipated submission: January-February 2016

14. The role of the sea-ice carbon pump for the marine carbon budget.
Authors: Grimm, R., Notz, D. Rysgaard, S., Glud, R.N.
Anticipated submission: September 2015

15. The role of sea ice DIC and TA boundary conditions on the sea ice carbon pump in a global blue-white-green ocean modeling system
Authors: Moreau S., Vancoppenolle M., Goosse H., et al.
Anticipated submission: September 2015

16. Modelling DMS in sea ice
Authors: H. Hayashida, E. Mortenson, N. Steiner, A. Monahan
Anticipated submission: November 2015

17. Modelling the carbon cycle in sea ice areas
Authors: E. Mortenson, H. Hayashida, N. Steiner, A. Monahan
Anticipated submission: November 2015

18. Title: Antarctic sea ice nutrients compilation
Authors: Francois Fripiat et al.
Anticipated submission: January-February 2016.

19. 1D sea ice algae model intercomparison
Authors: Letizia Tedesco et al.
Anticipated submission: March 2016

20. Sea ice - pelagic coupling
Authors: Letizia Tedesco et al.
Anticipated submission: February-March 2016

21. Title: Algal species composition in sea ice: functional groups for modelers.

Authors: van Leeuwe, M.A., Rintala, J.M., Assmy, P., and J. Stefels
Anticipated submission: February-March 2016

22. Title: Incorporation of iron and organic matter into young Antarctic sea ice and during its initial growth stages.
Authors: Julie Janssens, Klaus M. Meiners, Jean-Louis Tison, Gerhard Dieckmann, Bruno Delille and Delphine Lannuzel

ANNEX IV

List of papers contributing to BEPSII

Publications in prep:

Arctic sea ice chlorophyll review
Authors: C. Michel, A. Niemi, M. Gosselin ...
To be submitted to GRL.

The Future of the Subsurface Chlorophyll-a Maximum in the Canada Basin - A Model Intercomparison N. S. Steiner, W. Williams,T. Sou, C. Deal, J. M. Jackson, M. Jin, E. Popova, A, Yool
To be submitted to JGR Oceans, FAMOS special issue.

Published contributions:

Rintala, Janne-Markus, Jonna Piiparinen, Jaanika Blomster, Markus Majaneva, Susann Müller, Jari Uusikivi, Riitta Autio (2014) Fast direct melting of brackish sea-ice samples results in biologically more accurate results than slow buffered melting. *Polar Biology*. DOI 10.1007/s00300-014-1563-1

Tedesco L, Vichi M (2014) Sea Ice Biogeochemistry: A Guide for Modellers. *PLoS ONE* 9(2): e89217. doi:10.1371/journal.pone.0089217

2.1.6 WG 141 on Sea-Surface Microlayers (2012) *Burkill*

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)

<u>Other Full Members</u>

Anja Engel	Germany	Mohd T. Latif	Malaysia
Sanja Frka	Croatia	Caroline Leck	Sweden
Sonia Giasenella	Brazil	Gui-Peng Yang	China-Beijing
Bill Landing	USA	Christopher Zappa	USA

<u>Associate Members</u>

David Carlson	UK	Anna Lindroos	Finland
Alina Ebling	USA	Kenneth Mopper	USA
Werner Ekau	Germany	Alexander Soloviev	USA
Blaženka Gašparović	Croatia	Robert Upstill-Goddard	UK
Karstan Laß	Germany	Svein Vagle	Canada
Miguel Leal	USA		

Executive Committee Reporter: Peter Burkill

SCOR Sea Surface Microlayer Working Group Annual Report – 2015

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

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

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

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

- Organization of the SCOR SML workshop in Qingdao in October 2014

WG members (Cunliffe, Engel, Landing, Lass, Stolle, Talib, Wurl, Yang, Zappa) organized and participated in the SCOR SML workshop at the Ocean University of China in Qingdao in October 2014. The workshop ran from Monday 13th October to Friday 17th October. Nearly 50 students from Qingdao University attended the workshop (Fig. 1).

Fig. 1: Participants of the SML workshop and Prof. Huajun LI, vice-president of Ocean University of China (fifth person from left).

The agenda was as follows; Monday, WG members arrive and prepare; Tuesday, series of lectures delivered by the WG members, followed by a poster session for researchers and students attending the workshop from Qingdao University; Wednesday, practical demonstrations, including SML sampling and sample analysis; Thursday/Friday, WG members met and started writing the opinion/position paper that will be published in a peer-reviewed journal (TOR 2). All WG members were grateful for the hospitality and local organization by Prof. Yang and his colleagues.

- *Preparation for special session on the air-water interface for Ocean Sciences Meeting 2016*

WG members (Cunliffe, Engel, Wurl) together with James Bird (Boston University, Boston, MA, United States) have been preparing the special session ***Linking the Ocean with the Atmosphere - Exploring the Importance of the Ocean-Atmosphere Interface and Near Surface Waters in Global Scale Processes*** for the upcoming Ocean Sciences Meeting 2016 in New Orleans. 23 abstracts have been submitted to the session, and the preparation of oral and poster sessions is currently ongoing. Running the special session is part of terms of reference (TOR 3) of the working group. The WG will have its final meeting during the Ocean Sciences Meeting to review achievements and future activities and collaborations among WG members.

- *Preparation of an opinion/position paper in a peer-reviewed journal*

WG members started discussion and outline of the proposed opinion/position paper. During an additional SML workshop (not funded by SCOR), held by the Helmholtz Centre for Ocean Research Kiel in July 2015, a similar paper was initiated. After discussion between some WG members, the organizer of the Kiel workshop and SCOR, an agreement of a joint paper has been made. The manuscript should be ready for submission, but the main organization and responsibility lies now with Anja Engel (also SCOR WG member) and her colleagues at the Helmholtz Centre for Ocean Research Kiel.

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

Four WG members (Cunliffe, Landing, Wurl, Zappa) have been preparing a proposal to the Schmidt Ocean Institute (SOI) for a collaborative research cruise on SOI's RV Falkor in 2016. The proposal has been accepted by SOI, and the cruise is scheduled for 9th October to 12th November 2016 for a transect from Darwin (Australia) to Guam.

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

Overall, the preparation of the proposal involved members, and, if funded, to new proposed cruise is two-fold: (i) increase the understanding of the microlayer interaction using new technology, and (ii) increase the awareness of the importance of the SML within the general ocean science community, which is part of terms of reference (TOR) 3 of the working group.

Status of fulfilling terms of reference (TOR)

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

- The guide has been published, and, therefore TOR 1 fulfilled.

2) **Create a consensus definitio**n 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.

- We scheduled two days during the workshop in October 2014 and discussed a first outline of the member. Some contributions have been submitted by WG members. As discussed above, the organization of a SML workshop in Kiel and initiation of a similar paper could not be foreseen by the chairs. We anticipate that TOR 2 will be completed as part of a joint paper and submitted for peer review by spring 2016. Anja Engel from the Helmholtz Centre for Ocean Research Kiel is now in charge of the publication.

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.

- We initiated a session on the microlayer during the Ocean Sciences Meeting 2016. 23 abstracts have been submitted. TOR 3 will be completed by February 2016.

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.

- Calls for paper will not open until after the SML special session at a major meeting. TOR 4 will be completed by the end of 2016.

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

- As outlined in our previous annual report, we are interested to request extra funds for the WG to develop an outreach programme associated with the cruise and to maximise the potential of the cruise e.g. increase PhD student and Post-Doctoral Researcher involvement. We (Cunliffe, Landing, Wurl and Zappa) would be happy hearing from SCOR about potential possibilities.

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

- We are not anticipating any major challenges for the WG in the coming year.
- Our (Cunliffe, Landing, Wurl and Zappa) proposal for a multidisciplinary cruise on microlayer research with the Schmidt Ocean Institute was successful, and will be a major driving force for collaborative research between the WG members.

WG 142 on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders (2012) ***Prakash, 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
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
Osvaldo Ulloa	Chile

Executive Committee Reporter: Peter Burkill

SCOR WG 142 Annual Report 2014/2015

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

1. Activities During Reporting Period

1.1 2nd Working Group Meeting

About 12 months after the 1st meeting, SCOR WG 142 held its 2nd meeting, on 16-17 March 2015 at the Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) in Plouzané, near Brest/France. The schedule of the meeting (see attached minutes) was organized around the 5th Euro-Argo User Workshop and immediately prior to the 16th Argo Steering Team. This assured better attention of the WG meeting, saved tremendously on the SCOR travel budget, and allowed WG member to attend the other meetings.

The WG meeting served two main purposes: (i) to inform the group about new developments in the state of the art and quality control (QC) aspects of major biogeochemical sensors for floats and gliders (chl *a* and bio-optical parameters, nitrate, pH, pCO_2); and (ii) to discuss an official recommendation of SCOR WG 142 regarding in-air measurements as a regular in-situ calibration routine for oxygen optodes. Due to the brevity of the WG meeting, the latter had been prompted by providing each group member ahead of the meeting with short summary papers by Bittig/Körtzinger, Bushinsky/Emerson, and Johnson on relevant new field evidence. This allowed the group to directly jump into an informed discussion of this main topic.

The major outcome of the meeting was a clear agreement among group members to prepare and publish a recommendation to the Argo community to implement an in-air measurement routine during float surfacings as an independent and reliable method to in-situ calibrate/correct oxygen optodes data from floats. Based on the evidence provided (Körtzinger, 2005; Bittig & Körtzinger, 2015; Johnson et al., subm.) such a QC routine would remove any calibration biases, as well as drift issues, to an overall accuracy of approximately 1%. This would be a tremendous improvement over the current situation, but it may also have implications for sensor manufacturers as the current Sea-Bird oxygen optode SBE-63 is not set up to perform in-air measurements. We plan to inform the wider Argo and marine biogeochemistry community about this recommendation through an *Eos* article.

1.2 Round-Robin-Experiment with Aanderaa Oxygen Optode

The Round-Robin Experiment was initiated in April 2012 by the calibration of six Aanderaa optodes (3830, 4330, 4330F) at GEOMAR. These optodes were then sent around consecutively to five other labs before they were returned for re-calibration to GEOMAR (GEOMAR → CMAR → MPI Bremen → IFREMER→ →AADI →JAMSTEC → GEOMAR). The results show a clear temporal drift as well as some inter-laboratory differences. A detailed analysis of this beautiful data set is underway (Bittig et al., manuscript in prep.) and will provide further qualitative and quantitative insight in the character of the known long-term optode drift.

1.3 Improved Understanding of Oxygen Optode Characteristics

A significant body of published work (e.g., Bittig et al., 2014; 2015a; 2015b; Bushinsky and Emerson, 2013; D'Asaro and McNeill, 2013; McNeill and D'Asaro, 2014; Johnson et al., 2015; Takeshita et al., 2014) addressing all major characteristics of oxygen optodes (temperature sensitivity, pressure sensitivity, response time, long-term stability, laboratory calibration, in-situ calibration, in-air calibration etc.) is or will soon be available. This will allow SCOR WG 142 to fully define best operation and QC practices for optode-based oxygen measurements on floats and gliders as the major group deliverable.

1.4 Implementation of Oxygen QC Procedures in Standard Argo Routines

A dedicated session on Oxygen QC Procedures was organized by members of the SCOR WG 142 at the Argo Data Management meeting held in Ottawa in November 2014 to review existing and future real-time and delayed-mode QC procedures. Real-time QC tests for oxygen data, defined and validated by the Argo Data Management Team in 2012 (Wong et al., 2014), are now implemented in most Argo Data Assembly Centers (Table 1):

AOML	BODC	CORIOLIS	CSIO	CSIRO	INCOIS	JMA	KMA	KORDI	MEDS	NMDIS
done	Done	Done	?	done	done	no	End of 2014	no floats	No (no more active floats)	No floats

Table 1: Status of implementation of Real Time QC tests on O2 data as of November 2014.

The manual describing the management of oxygen data has been updated (Thierry et al., 2014) to take into account the evolution in oxygen sensors and calibration equations. This manual will continue to be updated when needed. A new format for Argo data was defined and implemented. It splits into different files the core parameters (P, T, S), which can be found in the so-called c-file and biogeochemical data that can be found in the so-called b-file (see http://www.argodatamgt.org/Documentation).

1.5 State of Knowledge with Respect to Other Biogeochemical Sensors

Chemical sensors for nitrate (Johnson et al., 2013) and pH (Johnson, K.S., in prep.) are now available and in use on increasing numbers of floats. In the United States, the SOCCOM (Southern Ocean Carbon and Climate Observations and Modeling) program has begun deployment of 20 to 40 profiling floats per year in the Southern Ocean with nitrate, pH, oxygen and bio-optical sensors. In France, regional programs in the Mediterranean (D'Ortenzio et al., 2014), North Atlantic, and Southern Ocean are underway, with dozens of nitrate and oxygen sensors deployed. Integration of the data with the Argo system is underway.

With respect to bio-optical measurements (chl a, b_{bp} and radiometry) the QC procedures for real-time data are progressively implemented as part of the Argo data stream. From first in situ comparisons between HPLC chl a measurements and float chl a (Wetlabs fluorometers), it appears that (1) the standard calibration of fluorometers might be off by a factor of ~2 (overestimation) and (2) regional variations in this calibration are observed, likely related to phytoplankton community composition. This potential variability will be addressed in the coming months. Additionally, procedures for delayed-mode data delivery are developed for all bio-optical variables.

2. Proposal for 3rd Working Group Meeting

We propose to hold the 3rd WG meeting in conjunction with the 2016 Ocean Sciences Meeting New Orleans (21-26 Feb. 2016). A major focus of this meeting will be the implementation of the proposed oxygen QC procedures in standard Argo routines. Also the state of the art of other biogeochemical sensors will be critically reviewed and possibilities of best practices and QC recommendations will be discussed. Another discussion item is the final product to be delivered by SCOR WG 142 at the end of it life, which is expected after four years, i.e. in spring 2017.

Relevant Publications from Working Group Members (2013-2015)

Bittig, H.C., B. Fiedler, R. Scholz, G. Krahmann, and **A. Körtzinger** (2014). Time response of oxygen optodes on profiling platforms: Dependence on flow speed and temperature and recommendations for field applications. *Limnol. Oceanogr.: Methods* **12**, 617-636, doi: 10.4319/lom.2014.12.617.

Bittig, H.C. and **A. Körtzinger** (2015a). Tackling oxygen optode drift: Near-surface and in-air oxygen optode measurements on a float provide an accurate in-situ reference. *J. Atm. Ocean. Techn.* **32**, 1536-1543, doi: 10.1175/JTECH-D-14-00162.1.

Bittig, H.C. and **A. Körtzinger** (2015b). Pressure response of Aanderaa and Sea-Bird oxygen optodes. *J. Atm. Ocean. Techn.*, re-submitted.

Bushinsky, S.M., and **S. Emerson** (2013), A method for in-situ calibration of Aanderaa oxygen sensors on surface moorings. *Mar. Chem.* **155**, 22–28, doi:10.1016/j.marchem.2013.05.001.

D'Ortenzio, F. H. Lavigne, F. Besson, **H. Claustre**, L. Coppola, N. Garcia, A. Laës-Huon, S. Le Reste, D. Malardé, C. Migon, P. Morin, L. Mortier, A. Poteau, L. Prieur, P-Raimbault, and P. Testor (2014). Observing mixed layer depth, nitrate and chlorophyll concentrations in the northwestern Mediterranean: A combined satellite and NO_3 profiling floats experiment. *Geophys. Res. Lett.* **41**, 6443-6451, doi: 10.1002/2014GL061020.

Fiedler, B., P. Fietzek, N. Vieira, P. Silva, H.C. Bittig, and **A. Körtzinger** (2013). In situ CO_2 and O_2 measurements on a profiling float. *J. Atm. Ocean. Techn.* **30**, 112-126, doi: 10.1175/JTECH-D-12- 00043.1.

Johnson, K.S., L.J. Coletti, H.W. Jannasch, C.M. Sakamoto, D.D. Swift, and **S.C. Riser** (2013).Long-Term Nitrate Measurements in the Ocean Using the in situ Ultraviolet Spectrophotometer: Sensor Integration into the APEX Profiling Float. *J. Atm. Ocean. Techn.* **30**, 1854-1866, doi: 10.1175/JTECH-D-12-00221.1

Johnson, K.S., J.N. Plant, **S.C. Riser**, and **D. Gilbert** (2015). Air oxygen calibration of oxygen optodes on a profiling float array. *J. Atm. Ocean. Technol*., subm.

Ohde, T., B. Fiedler, and **A. Körtzinger** (2015). Spatio-temporal distribution and transport of particulate matter in the eastern tropical North Atlantic observed by Argo floats. *Deep-Sea Res. I* **102**, 26-42, doi: 10.1016/j.dsr.2015.04.007.

Takeshita, Y., T.R. Martz, **K.S. Johnson**, J.N. Plant, **D. Gilbert**, **S.C. Riser**, C. Neill, and **B. Tilbrook** (2013), A climatology-based quality control procedure for profiling float oxygen data. *J. Geophys. Res.* **118**, 5640-5650, doi: 10.1002/jgrc.20399.

Takeshita, Y., T.R. Martz, **K.S. Johnson**, and A.G. Dickson (2014). Characterization of an Ion Sensitive Field Effect Transistor and Chloride Ion Selective Electrodes for pH Measurements in Seawater. *Anal. Chem.* **86**, 11189–11195, doi: 10.1021/ac502631z.

Group photo from the 2nd meeting of SCOR WG 142 in Brest/France
(from left: Hiroshi Ushida, Satya Prakash, Henry Bittig, Ken Johnson, Arne Körtzinger, Antoine Poteau, Virginie Thierry, Catherine Schmechtig, Orens de Fommervault, Denis Gilbert, Hervé Claustre

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2.1.8 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 *Bange, 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
Guiling Zhang	China-Beijing

Associate Members

John Bullister	USA
Jan Kaiser	UK
Annette Kock	Germany
Sunyoung Park	Korea
Andy Rees	UK
Alyson Santoro	USA

Executive Committee Reporter: John Turner

2015 Annual Report for SCOR WG #143 "Dissolved N_2O and CH_4 measurements: Working towards a global network of ocean time series measurements of N_2O and CH_4", 1 January 2014 – 31 December 2017

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

1. N_2O and CH_4 standards. At the February 2014 meeting in Honolulu, it was evident that the production of precise, common N_2O and CH_4 standards was vital for the comparison of dissolved concentrations across the global oceans. Production of the gas standards became a top priority and by May 2014, we had raised $30,000 (from NSF via C-MORE, InGOS, and SCOR). By September 2014, we had the contractual agreement established between NOAA PMEL and UH for the production of the standards. John Bullister has coordinated the production of these standards and we are incredibly grateful for his leadership on this matter. All standards have been produced and will be shipped to the SCOR WG member labs by end of 2015, at the latest. The delay in production is due to complications with the purchase and delivery of empty gas cylinders from Air Liquide. Once the lab groups have received the standards, we will conduct a calibration comparison, and then conduct a second comparison of seawater samples. This second sample intercomparison will also include some elevated CH_4 samples, due to the low concentrations in the open ocean.

2. SCOR Working Group meeting on 4 September 2015. We had two SCOR WG#143 meetings scheduled in our proposal, the Honolulu meeting in Feb 2014 and a follow-up meeting in Kiel, Germany in September 2015, in conjunction with the SOLAS conference (7-11 Sept. 2015). The 2nd annual meeting was held on Friday, 4 September, at GEOMAR in Kiel. Please find attached the meeting agenda and participant list. Major discussion points were:

- 2nd Intercomparison exercise: It was agreed that additional samples should be taken from Boknis Eck (BE, as coastal reference site: surface/1m, and deep layer/25m). It was suggested that sampling at BE should be coordinated with the sampling from ALOHA.
- Intercomparison cruise, 12-20 Oct. 2016: It was decided that we should go for it and have an intercomparison exercise for both discrete and underway measurements. A total of 12 berths are available: There will be a max. of 8-10 berths available for WG members and we reserved 2-4 berths for CTD and nutrient/O_2 measurements during the cruise. Gregor Rehder (IOW) will submit the application (ship time is already allocated, but it needs an official application). In order to proceed with the cruise preparation a questionnaire will be distributed to the members of WG mailing list in order to collect information about who would like to participate. It turned out already that some WG members cannot participate, but will send sample vials or instruments (-> Cliff Law, NIWA). There is a Chinese group from U Xiamen which is now operating an underway system for N_2O/CH_4. This group may be invited to join.
- Dave Capelle (U. British Columbia) is using self-made N_2O/CH_4 water standards (=

equilibrating N_2O/CH_4-free water with ambient air). He suggested that for the 2nd Intercomparison, the participating labs should try to prepare and use this kind of water standards as well in order to have a further independent method check. Dave is going to send further information on the standard preparation, which will be distributed to the WG members.

- It was suggested that, prior to the 2nd intercomparison, a method/best practice recommendation/guideline should be distributed. With this we want to make sure that all participating labs are using the same equations, doing the same corrections, apply the same form of calibration curves etc.
- In order to proceed with the framework for the N_2O/CH_4 measurement network it was suggested to set up a list with known time-series measurements (incl. VOS lines) to get a first overview.
- It was suggested to provide (i.e. write) a 'toolbox' for dissolved N_2O/CH_4 concentration computations that can be used as standard routine in Matlab (or other software packages).
- It was suggested to produce a video showing best practice for N_2O/CH_4 sampling.

Additional to the points listed above, there are two new requests to join the upcoming 2nd intercomparison, from Bess Ward (U. Princeton) and Macarena Burgos Martin (U. Cadiz, Spain). This should be not be a problem.

SCOR WG#143 Annual Meeting at GEOMAR, Kiel, 04 Sept. 2015: Andy Rees, Cliff Law, Mingshuang Sun, Jan Kaiser, Annette Kock, Gregor Rehder, Laura Farías, Pacific Ocean, David Capelle, Damian Arévalo Martínez, Mercedes de la Paz, Xiao Ma.

3. SCOR WG#143 in the literature. SCOR WG#143 has been mentioned twice in the literature to our knowledge: In February 2015 Hermann Bange and Annette Kock had a front-page article in Volume 3, no. 3 issue of *Eos* on the MEMENTO database. More recently, David Capelle and Philippe Tortell had a publication in *L&O: Methods* where they include some of the sample intercomparison data.

- Capelle, D.W., Dacey, J.W. and Tortell, P.D., 2015. An automated, high through-put method for accurate and precise measurements of dissolved nitrous-oxide and methane concentrations in natural waters. *Limnology and Oceanography: Methods*, 13(7): 345-355.
- Kock, A. and Bange, H.W., 2015. Counting the ocean's greenhouse gas emissions. *Eos - Earth & Space Science News*, 96(3): 10-13.

4. SCOR WG#143 at conferences. An overview poster about the activities of the WG have been presented at the SOLAS Open Science Conference (Kiel, 7-11 September 2015) and at the InGOS International Conference (Utrecht/The Netherlands, 22-24 September 2015).

SCOR WG #143

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

Annual Meeting, Kiel, 04 Sept 2015
(venue: GEOMAR, Düsternbrooker Weg 20, 24105 Kiel , Germany)
Hermann W. Bange (hbange@geomar.de) & Sam T. Wilson (stwilson@hawaii.edu)

AGENDA

9:00-9:45	Welcome and Summary of WG activities: Hermann Bange & Sam Wilson (*via GoToMeeting*)
9:45-10:30	Short Reports from WG members (D Capelle/U British Columbia, X Ma/GEOMAR, A Kock/GEOMAR- MEMENTO)
10:30-11:00	Coffee Break
11:00-12:00	Review of the status of Terms of Reference:

1) Conduct an intercalibration exercise between the time series programs
2) Establish the appropriate standards to be used by the scientific community
3) Recommend the analytical reporting procedures to be used for N_2O and CH_4
4) Establish framework for an N_2O/CH_4 ocean time series network

12:30-14:00 *Lunch*
14:00-14:30 N. Ramaiah (NIO, India): Introduction to SCOR WG#144 “Microbial community responses to ocean deoxygenation”
14:30-15:00 Toste Tanhua (GEOMAR, IOCCP): “Essential Ocean Variables, thinking along the Framework of Ocean Observations”
15:00-15:30 Jamie Shutler (U Exeter, UK): Introduction to ISSI WG “Satellite Earth observation for atmosphere-ocean gas exchange“ *(via GoToMeeting)*
15:30-16:00 *Coffee Break*
16:00 WG Discussion ‘The way forward’

- 2nd intercomparison exercise
- A common best practice for the processing/calculation/reporting of underway data: G. Rehder
- Intercomparison cruise, Oct 2016: G. Rehder

18:00 Joint Dinner

List of Participants

1	**D Arévalo-**	**GEOMAR**	**darevalo@geomar.de**
2	**H Bange**	**GEOMAR**	**hbange@geomar.de**
3	**D Capelle**	**U British**	**dcapelle@eos.ubc.ca**
4	**M de la Paz**	**U Cadiz**	**mercedes.delapaz@iim.csic.e**
5	**L Farias**	**U Concepcion**	**lfarias@profc.udec.cl**
6	**N Ramaiah**	**NIO**	**ramaiah@nio.org**
7	**J Kaiser**	**UEA**	**j.kaiser@uea.ac.uk**
8	**A Kock**	**GEOMAR**	**akock@geomar.de**
9	**C Law**	**NIWA**	**c.law@niwa.co.nz**
10	**X Ma**	**GEOMAR**	**mxiao@geomar.de**
11	**A Rees**	**PML**	**apre@pml.ac.uk**
12	**G Rehder**	**IOW**	**gregor.rehder@io-**
13	*J Shutler**	*U Exeter*	*j.d.shutler@exeter.ac.uk*
14	**M Sun**	**GEOMAR**	**misun@geomar.de**
15	**T Tanhua**	**GEOMAR**	**ttanhua@geomar.de**
16	*S Wilson**	*U Hawaii*	*stwilson@hawaii.edu*

*via GoToMeeting

2.1.9 WG 144 on Microbial Community Responses to Ocean Deoxygenation *Ramaiah* (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)

<u>Other Full Members</u>

Sean Crowe	Canada	Elsabe Julies	Namibia
Virginia Edgcomb	USA	Phyllis Lam	UK
Veronique Garcon	France	Nagappa Ramaiah	India
Steven Hallam	Canada	Osvaldo Ulloa	Chile
Klaus Juergens	Germany		

<u>Associate Members</u>

Mark Altabet	USA		
Annie Bourbonnais	Canada	John Kaye	USA
Karen Casciotti	USA	SWA Naqvi	India
Francis Chan	USA	Nancy Rabalais	USA
David Conley	Sweden	Mak Saito	USA
Robinson (Wally) Fulweiler	USA	Frank Stewart	USA
Jung-Ho Hyun	Korea	Matt Sullivan	USA
David Karl	USA	Jody Wright	Canada

Executive Committee Reporter: Mark Costello

SCOR Warnemünde Workshop (Aug 30-Sept 3, 2015)

Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany

Workshop as part of the activities of the **SCOR Working Group 144: "Microbial Community Responses to Ocean Deoxygenation"**

More detailed information on the core objectives of this SCOR working group are found here: http://scor-int.org/Working_Groups/WG144.htm

Workshop Objective:

Cross-scale comparison of microbial community structure and function in O_2-deficient marine waters is occluded by a lack of standards for integrating physico-chemical measurements, process rates and multi-molecular (DNA, RNA and protein) analyses. This impedes scientific synthesis using datasets collected by different research teams in a variety of oxygen-deficient marine waters. The Saanich Inlet workshop in 2014 started the process of establishing a minimal core of technologies, techniques and standard operating procedures (SOPs) to enable compatible process rate and multi-molecular data collection. These recommended techniques and SOPs should facilitate future cross-scale comparisons and time-series efforts that more accurately reflect *in situ* microbial community structure and functions, an important consideration for future numerical model development incorporating multi-molecular data.

Whereas the workshop in 2014 included practical exercises in sampling and analyses in Saanich Inlet, the 2015 workshop in Warnemünde aims to summarize existing knowledge and to elaborate recommendations for best practices for assessing microbial communities and biogeochemical processes in oxygen minimum zones (OMZs). For this purpose, additional experts from surrounding institutes in Northern Germany and Denmark were invited to join the SCOR meeting.

Confirmed Attendees:

SCOR members

Jennifer Brum (for Matthew Sullivan), University of Arizona, Ecology and Evolutionary Biology Department, Tucson, AZ, USA. E-mail: jbrum@email.arizona.edu
Sean Crowe, University of British Columbia, Depts. of Microbiology & Immunology, and Earth, Ocean, & Atmospheric Sci., Vancouver, BC, Canada. E-mail: sacrowe1@gmail.com
Virginia Edgcomb, Woods Hole Oceanographic Institution, Geology and Geophysics Department, Woods Hole, MA, USA. E-mail: vedgcomb@whoi.edu
Steven Hallam, University of British Columbia, Department of Microbiology & Immunology, Vancouver, BC, Canada. E-Mail: shallam@mail.ubc.ca
Klaus Jürgens, Leibniz Institute for Baltic Sea Research (IOW), Department of Biological Oceanography, Rostock-Warnemünde, Germany. E-mail: klaus.juergens@io-warnemuende.de
Phyllis Lam, National Oceanography Centre Southampton, Ocean and Earth Science and University of Southampton, Southampton, UK. E-mail: P.Lam@soton.ac.uk

Nagappa Ramaiah, CSIR-National Institute of Oceanography, Biological Oceanography Division, Dona Paula, Goa, India. E-mail: ramaiah@nio.org
Bess Ward, Department of Geosciences, Princeton University, NJ, USA. E-mail: bbw@princeton.edu

Invited guests
Hermann Bange, GEOMAR Helmholtz-Zentrum für Ozeanforschung, Marine Biogeochemie, Kiel, Germany. E-mail:
Carlo Berg, SciLifeLab Stockholm, Dept. of Ecology, Environment and Plant Sciences, Stockholm, Sweden. E-mail: carlo.berg@scilifelab.se
Gaute Lavik, Max Planck Institute for Marine Microbiology, Bremen, Germany. E-mail: glavik@mpi-bremen.de
Carolin Löscher, Kiel University, Department of Microbiology, Kiel, Germany. E-mail: cloescher@ifam.uni-kiel.de
Andreas Oschlies, GEOMAR Helmholtz-Zentrum für Ozeanforschung, Marine Biogeochemie, Kiel, Germany. E-mail: aoschlies@geomar.de
Niels Peter Revsbech, Aarhus University, Department of Bioscience, Aarhus, Denmark. E-mail: revsbech@bios.au.dk
Bo Thamdrup, University of Southern Denmark, Department of Biology, Odense, Denmark. E-mail: bot@biology.sdu.dk
Heide Schulz-Vogt, Leibniz Institute for Baltic Sea Research (IOW), Department of Biological Oceanography, Rostock-Warnemünde, Germany. E-mail: heide.schulz-vogt@io-warnemuende.de

Logistics Support:
Solveig Kühl, Leibniz Institute for Baltic Sea Research (IOW), Department of Biological Oceanography, Rostock-Warnemünde, Germany. E-mail: solveig.kuehl@io-warnemuende.de

General Schedule:
Aug. 30: Arrival in Warnemünde
Aug. 31: Review of 2014 Saanich workshop; SCOR group general issues, future meetings and tasks; discussing plan for white paper
Sept. 1 Presentations and discussion Sept 2nd: Presentations and discussion Sept 3rd: Working groups, writing
Sept. 4: Departure from Warnemünde

Venues

Workshop location

Leibniz Institute for Baltic Sea Research Warnemünde (IOW) Seestraße 15, D-18119 Rostock-Warnemünde, Germany

SCOR Workshop Warnemünde (Aug 30 – Sept 3, 2015)

Leibniz Institute for Baltic Sea Research Warnemünde (IOW) Seestraße 15, D-18119 Rostock-Warnemünde, Germany

Monday, Aug 31 (IOW, room 227)

9:00 a.m.	Welcome and Workshop Overview (Klaus Jürgens)
9:30 a.m.	Review of Saanich Inlet Workshop 2014 (**Steven Hallam, Sean Crowe**)
11:00 a.m.	Goals and future activities of SCOR group (all)
12:30 a.m.	**Lunch at IOW**
1:30 p.m.	Introduction to white paper "Recommendations for best practices for investigations in oxygen-deficient marine systems"; discussion of concept and structure
3:30 p.m.	Presentation: Rates of sulfur oxidation in OMZs (**Sean Crowe**)
4:00 p.m.	Discussion white paper
After 7:00 p.m.	Meeting at Restaurant/Pub "Casablanca" (near Hotel Alter Strom)

Tuesday, Sept 1

9:00 a.m.	Wrap up of last days discussions; concept white paper; program overview
9:30 a.m.	**Topic section 1: Adequate Sampling of OMZs**
9:30 a.m.	Impact of spatial and temporal variability in redoxcline structures for microbial communities and biogeochemical processes (**Klaus Jürgens**)
10:00 a.m.	High resolution measurements in the water column with a combination of pump CTD, autoanalyzer and flow through microelectrodes" (**Heide Schulz-Vogt**)
10:30 a.m.	High resolution oxygen measurement in situ and in laboratory incubations (**Niels Peter Revsbech**)
11: 00 a.m.	The case for in situ sample processing and preservation for studies of microbial activities central to our understanding of OMZs (**Virginia Edgcomb**)

11:30 a.m.	Sample collection time is a relevant parameter for unraveling microbiomes of OMZ waters (**Carolin Löscher**)
12:00 a.m.	General discussion section 1
12:30 p.m.	**Lunch at IOW**
1:30 p.m.	Modeling OMZ biogeochemistry (**Andreas Oschlies**)
2:00 p.m.	Topic section 2: Assessing microbial communities in OMZs
2:30 p.m.	Sampling and analysis of viruses in marine oxygen minimum zones (**Jennifer Brum**)
3:00 p.m.	Co-occurrence of microaerobic and anaerobic activity in OMZs (**Gaute Lavik**)
3:30 p.m.	Assessing biogeochemical functions of microorganisms in OMZs (**Phyllis Lam**)
4:00 p.m.	Microbial processes and communities in Arabian Sea oxygen deficient regions (**Nagappa Ramaiah**)
4:30 p.m.	General discussion section 2
7:00 p.m.	**Diner –** Teepot Restaurant

Wednesday, Sept 2

9:00 a.m.	Wrap up of last days discussions; concept white paper; program overview
9.30 a.m.	Topic section 3: Biogeochemical process rates
9:30 a.m.	Nitrogen transformations using ^{15}N tracer incubation experiments (**Bess Ward**)
10.00 a.m.	Experimental assessment of nitrogen transformation rates - water sampling, incubations, and data interpretation (**Bo Thamdrup**)
10.30 a.m.	Trace gases in oxygen minimum zones (**Hermann Bange**)
11.00 a.m.	General discussion section 3
12:00 a.m.	Lunch at IOW

1:00 p.m.	**Topic section 4: Genomic tools**
1:00 p.m.	"Multi-Omics" methods and downstream analyses in OMZ research (**Steven Hallam**)
1:30 p.m.	The OMZ water-column microcosm: A view from single-cell genomics (Osvaldo Ulloa)
2:00 p.m.	General discussion section 4, overall discussion white paper and how to proceed; determining working groups for writing up different section topics
4:00 p.m.	**Excursion**: Departure from IOW to Minster of Bad Doberan
5:00 p.m.	Guided tour Minster of Bad Doberan

<u>Thursday, Sept 3</u>

9:00 a.m.	Wrap up of last days discussions; planning of the day
9:30 a.m.	Elaborate topic sections 1-4 for white paper in small groups
12:30 a.m.	**Lunch at IOW**
1:30 p.m.	Elaborate topic sections 1-4 for white paper in small groups
3:00 a.m.	Coffee Break and General Discussion
3:30 p.m.	Finalize writing on topic sections 1-4 in small groups
5:00 p.m.	Final Discussion and Outlook
7:00	**Farewell diner** at Neptun Hotel

<u>Friday, Sept. 4</u>

Departure from Warnemünde

2.1.10 WG 145 on Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC) (2014) *Urban*

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)

Full Members

Heather Benway	USA
Arthur Chen	China-Taipei
Andrew Dickson	USA
Vanessa Hatje	Brazil
Maite Maldonado	Canada
Alessandro Tagliabue	UK
Rodrigo Torres	Chile

Associate Members

Eric Achterberg	Germany
Yuri Artioli	UK
Martha Gledhill	Germany
Giles Marion	USA
Peter May	Australia
Frank Millero	USA
Ivanka Pizeta	Croatia
Darren Rowland	Australia
Stan van den Berg	UK
Wolfgang Voigt	Germany
Christoph Völker	Germany
Mona Wells	China-Beijing

Executive Committee Reporter:

The first meeting of WG145 was held in Šibenik, Croatia, on 12-13 April 2015, immediately following the closing symposium of WG139. The achievements of that meeting, and planned further work, are described in Appendices 1 to 3, which were written directly after the meeting as an internal WG report.

The progress towards the Terms of Reference can be summarised as follows:

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.**

A draft scope of the waters and components to be included was developed at the first meeting. WG members have contributed text on each of these waters and components, and this is now being edited for publication as set out in the Meeting Report. A poster describing the WG and the draft scope has been prepared, and will be shown at the SOLAS Open Scientific Meeting in Kiel, Germany (7-11 September).

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.**

At the first meeting, it was decided to bring forward the public presentation of the WG and its work, in order to inform the community at an early stage in order to maximise acceptance of the results, and to obtain feedback. The WG applied for a Special Session at the 2016 Ocean Sciences meeting in New Orleans, which was combined with a proposal from the WG139 community at the request of the Programme Committee. An application has been made for a Town Hall meeting at Ocean Sciences 2016 to present the draft scope: the outcome will be known later in the autumn. Communication with interested researchers is being developed through a mailing list, and at a website hosted by the University of Otago (http://neon.otago.ac.nz/research/scor145/).

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.**

WG members have submitted 10 reviews of existing speciation calculation programmes using a common questionnaire format focusing on the user interface. This material will be used to develop a first draft of desirable features in a “best practice” model, which will be discussed and refined at the second meeting.

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.

The question of external funding was addressed at the first meeting, where individual WG members were tasked with investigating potential funding sources. This is a continuing process, which will be reviewed at the second meeting.

A second meeting is planned to be held in New Orleans in February 2016 in conjunction with the Ocean Sciences Meeting.

Appendix 1. Report from Meeting #1, 12-13 April 2015, Šibenik, Croatia

1. Scope of the planned speciation model

The first task for this WG is to define the scope of the planned speciation model, in terms both of environmental conditions and chemical components. A draft was generated on the afternoon of 12 April, and reviewed on 13 April. It was agreed that each item in the planned scope would be accompanied by a short justification explaining which global questions can be addressed with the help of this particular speciation modelling. These texts will form an important component of the various activities aimed at maximising the visibility of the WG (see § 3 below), and will also be important in justifying new work to fill gaps in the availability of the necessary thermodynamic information. The Tables give the allocation of responsibilities. These texts should be accompanied by key references, and submitted via the WG Dropbox by 31 May at the latest.

	Table 1: Conditions	
Priority		**Writer**
1	Oceans	-
1	Temperature -2 to 40°C	-
1	Pressure up to 1100 atm	-
1	Estuaries, including groundwater discharges and river end members)	**Arthur Chen**
2	Polar brines, temperatures below 2°C	**Eric Achterberg**
2	Pore waters	**Vanessa Hatje**
2	Sulphidic conditions	**Maite Maldonado**
2	Temperature up to 100°C for diffuse hydrothermal discharges	**Sylvia Sander**

3	Inorganic contaminant inputs	**Eric Achterberg**
3	Temperature up to 300°C for mixing of hot hydrothermal discharges	**Sylvia Sander**
4	Salt lakes and brines	**Simon Clegg**

	Table 2. Major and minor components	
Priority		**Writer**
1	Major ions of seawater, carbonate species	-
1	Weak acids and bases: bisulphate, borate, fluoride, phosphate, ammonia	**David Turner**
2	Silicic acid	**David Turner**

	Table 3. Trace metals (* = redox active)	
Priority		**Writer**
1	Fe*, Cu*, Zn, Cd	**David Turner**
2	Mn*, Co, Ni,	**David Turner**
2	Pb, Hg (and MeHg)	**Mona Wells**
3	Cr*, As*, Ag, Al, Ln(*)	**Mona Wells**

	Table 4. Buffers and indicators (laboratory conditions only)	**Writer**
Priority		
1	pH buffers: tris, aminopyridine	**David Turner**
1	CLE-CSV buffers: EPPS, HEPES	**Stan van den Berg**
1	Indicators: m-cresol purple, thymol blue, bromocresol green	**David Turner**

	Table 5. Complexants* (laboratory conditions only)	
Priority		**Writer**
1	CLE-CSV competing ligands: SA, NN, APDC, DHN	**Stan van den Berg**
1	”Standard” ligands: EDTA, DTPA, DFB	**Sylvia Sander**
1	S ligands: glutathione, cysteine, thiourea	**Sylvia Sander**
2	Cyclam, cyclen	**Maite Maldonado**

3	”Standard” ligands: NTA, DFE, more siderophores	**Maite Maldonado**
3	CLE-CSV competing ligands: DMG, TAC	**Sylvia Sander**

* Humic materials have also been discussed as Complexants. These will not be included in the Pitzer model, but coded separately e.g. according to the WHAM or NICA-Donnan formulations.

2. Planning the review of available thermodynamic data

This was a subgroup meeting held on the afternoon of 13 April. The participants were Simon Clegg, Darren Rowland, David Turner and Mona Wells. It was agreed that the first priority would be the major, minor and trace components of seawater. The following order of actions was agreed:

- **Simon Clegg** will document the data sources used by the Miami and Clegg & Whitfield models.
- **David Turner** will document the data sources used by the Miami model for trace elements.
- This documentation will be passed to **Darren Rowland**, who will check whether the JESS database contains later information on the interactions documented.
- The results will form the basis of a review of data availability for the relevant elements in seawater. This review will be presented at the planned 2016 Town Hall meeting, and submitted for publication during early 2016. Potential journals identified were *ES&T* and *Environment International.*
- The data review for buffers, indicators and ligands will be carried out and published separately to the review of the elements.

3. Activities to maximise the WG visibility in the marine science and chemical communities

Based on experience from previous SCOR WGs, Arthur Chen and Sylvia Sander emphasised the need to act on this point as soon as possible so as to ensure the that final product is well known and thus has a good chance of being accepted and used by the marine science community. Using the speciation model scope as the basis of this initial dissemination will allow interested scientists to comment on this scope, and thus ensure a broad acceptance.

- An article presenting the WG and scope in *Eos* (**David Turner** to make contact and coordinate writing)
- An article presenting the WG and scope in *Chemistry International* (**David Turner** to make contact and coordinate writing)
- An article presenting the WG and scope in *Elements* (**Sylvia Sander** to make contact and coordinate writing)

- An article presenting the WG and scope in *Frontiers in Marine Biogeochemistry*, in the WG139 special issue (Editor **Eric Achterberg**; **David Turner** to coordinate writing)
- A WG website, to be hosted at Otago University, following a similar structure to the WG139 website (responsibility: **Sylvia Sander**)
- A Special Session on speciation modelling at Ocean Sciences 2016 (application deadline 29 April, responsibility: **David Turner** and **Sylvia Sander**)
- A Town Hall meeting at Ocean Sciences 2016 (applications open in July, responsibility: **David Turner** and **Sylvia Sander**)
- Establishment of a mailing list of interested scientists. **Sylvia Sander** will ask scientists on the WG139 mailing list if they also wish to be on the WG145 mailing list.

The articles listed above should be submitted, and preferably published, before the end of 2015.

4. External funding opportunities

Additional funding for both senior scientist and postdoc time would be valuable in developing the optimal Pitzer database for marine applications. Additional funding will be essential for developing the user-friendly Web-based calculation programme described in the terms of reference. Based on the WG discussion, **Simon Clegg** will circulate a list of potential funding opportunities, identifying the individual WG member tasked with investigating each opportunity in further detail.

5. Additional expertise

The need for additional expertise, complementing the WG membership was discussed. A shortlist of names was identified. The WG Chair and Vice-chairs will sound out these individuals' interest in attending the 2016 meeting as guests.

6. Review of existing speciation modelling programmes

A task for the WG is to develop specifications for a Web-based speciation modelling tool. As a first step, the WG will review the user interfaces of existing programmes in order to identify capabilities that are well appreciated by users. 15(?) potentially interesting programmes were identified. It was agreed that these would first be reviewed by WG members experienced in their use, in order to identify a smaller number of programmes to be reviewed in more detail at the next meeting. **Simon Clegg** will circulate the list of programmes with a nominated reviewer for each programme, and a questionnaire to be completed by the reviewers.

7. Plan for the next meeting

The next meeting will be held in conjunction with the 2016 Ocean Sciences Meeting in New Orleans, USA. The provisional date is 21 February, the day before the Ocean Sciences Meeting opens. The following agenda items will be covered:

- Adjustments to the modelling scope, following comments received

- Status of the data availability review
- External funding opportunities
- Workshop on the user interface of existing modelling programmes
-

8. Thanks to the local host

The WG expressed their sincere appreciation to Ivanka Pižeta for her tireless and efficient support.

Appendix 2. Meeting programme

12 April

9:00	Introduction: background to the WG and project plan	David Turner
9:30	WG members present themselves (1-2 minutes each)	
9:45	Project scope: Summary of questionnaire replies and draft project scope	Sylvia Sander
10:30	Coffee	
11:00	Talk: overview of chemical speciation modelling	Simon Clegg
11:45	Talk: modelling natural organic matter chemistry	David Turner
12:30	Lunch	
13:30	Talk: The TEOS standard for seawater	Arthur Chen
14:15	Discussion: scope of the project	
15:00	Coffee	
15:30	Discussion: scope of the project	
17:30	End of Day 1	

13 April

9:00	Scope of the project: discussion of the revised draft
10:30	Coffee
11:00	Discussion: additional contacts and potential external funding (questions 9 and 10 in the questionnaire)
11:45	Assignment of tasks in preparation for Meeting no. 2
12:15	Next meeting: time, place and meeting plan
12:30	Lunch

Afternoon session for speciation modellers only:

13:30	Discussion on the scope of the review paper (Deliverable 1 of the WG)
14:00	Discussion on the work to be done to meet Objectives 1 and 2. This includes collection and review of relevant physico-chemical information for the seawater electrolyte; analyses of current Pitzer parameter databases for data sources and coverage of agreed systems and environmental conditions; uncertainty analysis.
15:00	Coffee
15:30	Discussion continues
16:30	Discussion on potential external funding for the above and later work of the WG.
17:00	Assignment of tasks.
17:30	Meeting ends

Appendix 3. Participants

David Turner, chair
Simon Clegg, vice-chair
Sylvia Sander, vice-chair
Eric Achterberg
Arthur Chen
Vanessa Hatje
Maite Maldonado
Ivanka Pižeta
Darren Rowland
Rodrigo Torres
Stan van den Berg
Christoph Völker (12 April only)
Mona Wells

2.1.11 WG 146 on Radioactivity in the Ocean, 5 decades later (RiO5) ***Naqvi***

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.
7.

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

Other Full Members:

Michio Aoyama	Japan	Pere Masqué	Spain
Claudia Benitez□Nelson	USA	Paul Morris	Monaco
Sabine Charmasson	France	Deborah Oughton	Norway
Roberta Delfanti	Italy	John Smith	Canada

Associate Members:

Andy Johnson	USA	Nuria Casacuberta	Switzerland
Reiner Schlitzer	Germany	Jordi Vives i Batlle	Belgium
Gary Hancock	Australia	Vladimer Maderich	Ukraine
José Godoy	Brazil	Sandor Muslow	Chile

Executive Committee Reporter: Wajih Naqvi

First report of SCOR Working Group #146, September 2015.
Radioactivity in the Ocean, 5 decades later (RiO5)

Group photo taken on July 17, 2015 at WHOI

I. Major Activities:

SCOR WG 146 held three teleconferences on 3 June and 1 July 2015 to discuss WG activities and the plan of the first meeting. The first WG meeting was held on 15-17 July 2015 in Woods Hole Oceanographic Institution. Eight Full Members, and two Associate Members participated throughout the meeting. The meeting went extremely well with very fruitful discussion.

II. Progress

The proposed action items of WG # 146 are well underway and/or being planned. Along the lines of the Terms of Reference, we summarize as below some of the actions being taken and/or being planned:

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 databases via the IAEA's MARiS portal, including data collected, and is working on the compilation of other data sets via the GEOTRACES and HAM databases and individual studies. MARiS is a publicly accessible database in the same spirit embraced by GEOTRACES (http://www.egeotraces.org/) and various time-series programs (HOT (http://hahana.soest.hawaii.edu/hot/hotdogs/interface.html), PAPA (http://oceanobservatories.org/infrastructure/ooi-stationmap/station-papa/), etc.).

ToRs #2 & 3: Summarize and publish review papers in peer-reviewed 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.

During the first WG meeting, we came up with an outline for a paper to be submitted to *Annual Reviews in Marine Science* in March 2016. Other possible review papers are being discussed and developed.

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

We were initially hoping that IAEA would be a major sponsor for such an international symposium, but it turned out that major support from IAEA is not possible. The WG is exploring and considering alternative ways to promote marine radioactivity science and to foster exchanges between academic, industrial and governmental sectors.

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

The WG has been working towards the development of a series of e-lectures on: 1) Radioactivity Basics, 2) Introduction to Radionuclides in Marine Systems, 3) Radionuclides as Tracers of Marine Processes, 4) Impacts and Radioecology. These lectures will be in Benitez-Nelson radiochemistry course in Spring 2016 and further tested in Xiamen Marine Radiochemistry Course in June 2016. Eventually, these lectures will be submitted for publication to eLectures: http://aslo.org/lectures/.

The brochure "How radioactive is our ocean?" (www.OurRadioactiveOcean.org) will be made available at least into Chinese by 2016, perhaps into Portuguese and other languages. We also discussed about improving the survey used to see what students know about radioactivity.

The WG will also take the advantage of having its next WG 2016 meeting in Xiamen to give public lectures on ocean radioactivity topics on World Ocean Day (June 8). Also, the WG will be holding a short training course following the WG meeting in Xiamen on June 9-11, 2016 for Asian students and young scientists. SCOR has been requested to provide travel support for developing country scientists to attend this course.

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

A new data visualization tool is being developed at WHOI via the OurRadioactiveOcean website.

III. Future plan

The second meeting of the WG#146 has been scheduled to be held in Xiamen on 5-7 June 2016. The third WG meeting will be held in Aug. 2017 in France.

2.1.12 WG 147: Towards comparability of global oceanic nutrient data (COMPONUT)

Naik, Naqvi

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	Hema Naik	India
Karin Bjorkman	USA	Raymond Roman	South Africa
Anne Daniel	France	Bernadette Sloyan	Australia
Claire Mahaffey	UK	Toste Tanhua	Germany

Associate Members:

Karel Bakker	Netherlands	TaeKeun Rho	Korea
Minhan Dai	China-Beijing	Sophie Seeyave	UK
Andrew Dickson	USA	Jonathan Sharp	USA
Akiharu Hioki	Japan	Winnie van Vark	Netherlands
Alex Kozyr	USA	Takeshi Yoshimura	Japan
Akihiko Murata	Japan		

Executive Committee Reporter: Wajih Naqvi

First report of SCOR Working Group #147, September 2015. Towards comparability of global oceanic nutrient data (COMPONUT)

SCOR WG 147 held its first meeting on 14-15 April 2015 in Vienna, Austria. The first day was held as a workshop of the 2015 EGU General Assembly, with the second day held outside of the main conference venue. Eight Full Members, 3 Associate Members and 2 observers participated throughout the meeting, and a further two Full Members participated via Skype in the morning session of Day 2. Following useful and active discussions during the meeting, all of the Terms of Reference and proposed actions were discussed at length, and action timelines were agreed to be worked towards in the coming months and years. A number of the actions are well underway, and a summary of the year so far with regard to the Terms of Reference, is highlighted below:

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

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%.

To assess the homogeneity and stability of currently available RMs/CRMs, reported values that were a result of the JAMSTEC-IOCCP 2014/2015 International Nutrient inter-comparison study (58 participating laboratories in 28 countries) are now being analyzed as the results are now all being correlated and prepared for publication. In this inter-comparison study, 4 CRMs jointly certified by KANSO/JAMSTEC, Japan; 3 CRMs certified by NMIJ, Japan; and 4 RMs produced by KIOST, Korea were used. The homogeneity of 7 CRMs at higher nutrient concentration levels has been judged by uncertainty of certificated values at better than 1% (k=1) and those measured by consensus median and standard deviation of reported values were between 1 and

2%. A further set of CRMs from Canada, called MOOS-3, were found to be contaminated, and hence their values compromised, and so were not used in the intercalibration exercise.

ToR #3: To develop standardized data-handling procedures with common data vocabularies and formats, across producers and users, and will include the future linking of national and international data archives. The group will seek to involve international data center representatives to contribute to and lead this task.

We discussed the idea that reported format should contain uncorrected RMNS data for the Reference used. In the future, the updated GO-SHIP manual should specify that reported seawater nutrient values will be the ‘unadjusted’ ones, that is, with no corrections to RMNS applied on initially reported data. Reported values will be in µmol/kg, with conversion from µmol/l performed to be the responsibility of the chief scientist or nutrient PI. Ideally, reported values should be accompanied by a summary of RMNS analysis results. However, this is still in discussion, as there are other views from other data centres. Progress is being made, but dialog will continue with various data centres. A final way forward will be concluded for the GO-SHIP manual in 2016.

ToR #4: To promote the wider global use of RMs 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.

One major criticism of the early work was that the CRMs recommended were profiting one commercial manufacturer. To address this and to promote the wider global use of RMs (ToR 4 of WG#147), JAMSTEC stated that they would seek to provide CRMs to the global community at a more reasonable price than currently available commercially: (expected price per bottle is between ¥6,000 and ¥7,000) (US$50-US$58, £32-£38 or 45-52 Euros). Essentially, JAMSTEC would purchase a number of batches of CRMs for the global community and sell them at no profit. The range of nutrient concentrations will be probably at 5 levels, ranging from Atlantic surface water to North Pacific high levels; the probable levels are as follows:

No.	Level and seawater	Nitrate	Phosphate	Silicate
1	Low in Atlantic	1.0	0.4	~2
2	Middle in Atlantic	~12	~0.5	~12
3	Middle in Pacific	~25	~1.5	~60
4	High in Pacific	>35	>3	>110
5	High in Atlantic	~30	~1.5	~30

NIOZ have this summer provided 400 liter of Low Nutrient Seawater (LNSW) to JAMSTEC to begin preparation of a low-concentration nutrient CRM. This is now in Japan and CRM production will be carried out in October 2015.

To produce the Pacific deep water level CRM, JAMSTEC will collect 1,000 liters of seawater in October 2015, and discussions are underway to obtain Atlantic deep water, from a UK cruise vessel.
These are the first 2 of the new series of CRMs being produced as a result of the WG #147 group. In order to estimate and confirm the requirements of the global community and the full required range of CRMs wanted by the community over the next few years, WG#147 will distribute a questionnaire in September 2015 to the global community, by various mailing lists and websites, attempting to gain a true consensus of the CRMs required.

A further part of this ToR is to provide training in analytical protocols and best practices, and we will aim to provide places for scientists from developing countries to be trained in nutrient analysis, with possible support from POGO, and other financial support initiatives within the WG. This training course is provisionally programmed for November 2017, to be held at NIOZ (The Netherlands) with a number of analyzers available for use, where some scientists from developing countries will be able to work and learn alongside experienced nutrient analysts.

As part of making the global community more aware of the work of the WG, it is important to get the message to the community. There have been two specific talks/presentations made this year. Dr. Claire Mahaffey presented a talk to the UK Marine Management Forum in August about the work of the Group, and Malcolm Woodward presented a talk at the International GAIC 2015 conference in Galway, Ireland, entitled ‘Towards comparability of global nutrient data’. One very important issue affecting the global community is the varying quality of various commercially available silicate standards (sodium hexafluorosilicate). Discussions have begun to investigate the possibility of having one central silicate material used by all labs from one supplier from the same high-quality batch, and so gaining more consistency among laboratories. Investigations and discussions with manufacturers has commenced.

Novel ways were discussed on how to arrange funding for activities of this WG, and it was hoped that through selling small batches of CRMs at reduced rates, the money generated would go to supporting scientists from developing countries to attend the training workshop at NIOZ, for example. Funding sources to enable these developing countries to send scientists also were discussed through support from POGO grants that are available.

ToR #5: To continue regular global inter-comparison studies, following on from the previous exercises in 2003, 2006, 2008 and 2012, with collaboration of IOCCP-SSG and RCGC-JAMSTEC.

The JAMSTEC-IOCCP 2015 International Intercomparison study of CRMs was conducted and completed this year. This I/C study had 58 participating laboratories from 28 countries. In this I/C study 4 CRMs jointly certified by KANSO/JAMSTEC, Japan, 3 CRMs certified by NMIJ, Japan and 4 RMs produced by KIOST, Korea were available to the global community for analysis. JAMSTEC and IOCCP have a plan to conduct the next I/C study of CRMs in 2016/2017.

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).

To update the GO-SHIP nutrient measurement manual, which was originally a product of the IOC-ICES SGONS (Study Group on Nutrient Standards) (Hydes et al., 2010), WG#147 will start to update this GO-SHIP manual later this year. Susan Becker, the Head of the Scripps Nutrient Facility, has agreed to lead this update, with input from all the members.

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

A report of the workshop focused on phosphate analysis that was held at NIOZ in 2012, which was originally a product of the IOC-ICES SGONS, will be officially published in October 2015, with an ISBN number.

Second meeting of the WG#147, 2016.
Various meeting venues for the second workshop for 2016, were discussed in Vienna, and although the 2016 Ocean Sciences Meeting (21-26 February 2016, New Orleans, Louisiana, USA), was an obvious venue, it was decided that it was too early and many people would not be able to attend for various reasons. Other options are being investigated and discussed, and it is hoped to decide the venue in the autumn of this year.

2.2 Working Group Proposals

2.2.1 Towards a Global Comparison of Zooplankton Production: Measurement, Methodologies and Applications (ZooProd) *Sun Song*

Abstract

Knowledge of zooplankton production rates is key to our understanding how physical forcing such as climate change will impact the material and energy flux pathways which characterize the structure and function of marine ecosystems. Unfortunately, our understanding of the processes driving variation in zooplankton production is limited due to difficulties in identifying the most practical and relevant methodologies for measuring the production rates of natural zooplankton populations and communities across a wide range of phyla and trophic levels. A quantitative comparison, reevaluation and inter-comparison of methodologies are urgently needed.

The proposed Working Group (WG) will focus its attention on assessing the applicability of existing methodologies (i.e., traditional and biochemical methodologies) for measuring *in situ* rates of zooplankton production, and for developing new methodologies. The work will be conducted over a period of four years, culminating in a final report that will:

1. Review and summarize assumptions (in peer-reviewed articles), recent progress and limitations of traditional and biochemical methodologies for measuring the production of natural zooplankton populations and communities.
2. Develop recommendations for standardized protocols for both the traditional and biochemical methodologies available for measuring zooplankton production. These standardized protocols will be made available globally to users via a website.
3. Build a global network of the scientists and laboratories measuring zooplankton production rates.
4. Develop a rigorous inter-comparison/calibration methodology for production rates measured with different approaches.
5. Compile published rates of zooplankton production measured with both traditional and biochemical methodologies.
6. Promote international cooperation of zooplankton production researchers through international organizations such as ICES, PICES and IMBER.

Scientific Background

Zooplankton communities occupy a central position in the flow of matter and energy passing from primary producers to animals at higher trophic levels in marine ecosystems (e.g., Lalli and Parsons 1993). Over the past two decades, the need for quantitative evaluations of marine ecosystem function has been emphasized as necessary toward improving our understanding of how marine ecosystems respond to global climate change (e.g., Walther et al. 2002; Edwards and Richardson 2004; Boyce et al. 2010). Zooplankton production represents a quantitative proxy for the functional response of marine ecosystems since it corresponds to the zooplankton biomass accrued through consumption of lower food web levels.

Zooplankton production has long been estimated using a variety of methods which either: 1) follow the development of zooplankton populations or communities over the course of several weeks or months (e.g., Hirche et al. 2001; Ohman and Hirche 2001); or 2) employ *ex situ* fixed-period incubations (e.g., Burkill and Kendall 1982, Kimmerer and McKinnon 1987; Berggreen et al. 1988; Peterson et al. 1991). Incubation-based techniques with simultaneous sampling of natural communities are the most widely used methods in the field. In 2000, Runge and Roff (2000) reviewed the field application of these traditional methods in a chapter of the ICES Zooplankton Methodology Manual (Harris et al. 2000). However, shortly after its publication, some studies documented limitations of the incubation-based methods, which required revision of the application and interpretation of these approaches and their derived production estimates (Hirst and McKinnon 2001; Hirst et al. 2005; Kimmerer et al. 2007). Meanwhile, advances in biochemical tools for measuring zooplankton growth and production, which were not covered by Runge and Roff (2000), were also developed (Wagner et al. 2001; Sastri and Roff 2000; Oosterhuis et al. 2000; Yebra and Hernández-León, 2004) and have been applied to a wide range of organisms and habitats (e.g., Yebra et al. 2004, 2009; Sastri et al. 2012).

Over the past half century, phytoplankton production rates have been measured using radio-isotope (Steeman-Nielsen 1952) and stable isotope-based approaches (Hama et al. 1983). In the early 1980's, similar measurement approaches were also developed for bacterial production rates (Fuhrman and Azam 1982). A major consequence of the long-term use of routinely applicable *in situ* methods for phytoplankton and bacterial productivities is that we can now generate their spatio-temporal patterns at relatively high resolution using satellite imagery. SCOR has sponsored several working groups covering related topics such as standardization for zooplankton sampling (WG3 and WG13), biomass measurements (WG23), and global comparisons of zooplankton time series (WG125). Despite support by SCOR and the availability of many measurement methods zooplankton production, the routine and universal application of these methodologies is limited because they can only be used under specified conditions and are not necessarily comparable. Moreover, the existing production estimates include some uncertainty because zooplankton communities span a wide range of phyla and trophic levels.

In October 2012, a workshop was convened to discuss the issues surrounding the most commonly applied zooplankton production measurement methodologies. The motivation for this workshop was the recognition that there is still little knowledge of, or confidence in, the existing zooplankton production methodologies relative to those used for estimating primary and bacterial productivity. The two major conclusions which emerged from the workshop are as follows:

1) We need to summarize assumptions, limitations and recent progress of existing methodologies which purport to measure zooplankton production.
2) We need methods which are routinely applicable to natural zooplankton populations and communities across a wide range of phyla and trophic levels.

In order to resolve these significant issues, an international WG on zooplankton production methodologies was proposed during the workshop.

Rationale

It is particularly timely to focus on zooplankton production because assumptions and limitations underlying the most commonly applied methods have now been reconsidered and other approaches have also been developed since the publication of the *ICES Zooplankton Methodology Manual* in 2000. A major consequence of these recent developments has been a general confusion about how these methods should be applied for natural zooplankton populations and communities, and how the various estimates can be compared. The latest IPCC report (IPCC 2013) has reaffirmed that global warming exerts widespread impacts on natural systems; a quantitative evaluation of secondary productivity is therefore both timely and critical for understanding how marine ecosystems adapt to continued global climate change. However, there is still little information on zooplankton production as a proxy for the integrated biological response of lower trophic levels in marine food webs. Indeed, the generation of global maps of primary productivity is now routine, but the ability to make similar spatial comparisons is lacking for zooplankton productivity. At this stage, a comprehensive review of zooplankton production methodologies (in the context of recent advances) would allow us to:

1) Elaborate on recommendations for the standardized application of traditional and biochemical zooplankton production measurement methodologies for worldwide users
2) Develop protocols for inter-comparison/calibration between different approaches
3) Compile existing zooplankton production estimates.

Since the WG objectives are global and fundamental to ocean science, it is reasonable that the WG activities are sponsored by an international scientific organization such as SCOR. The WG objectives can also be shared by the global scientific efforts and the science topics of marine ecosystems emphasized by the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES) and the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project. If this WG is sponsored by SCOR and endorsed by PICES, ICES and IMBER, information exchanges and discussion on ocean science would be enhanced among members of these organizations, and would provide the basis for training in both developed and developing countries. For this purpose, the proposed WG has assembled scientific expertise from PICES/ICES and from several developing nations in order to fully represent the worldwide community of zooplankton researchers as well as to foster a global exchange of scientific information and discussion.

Terms of Reference

This WG will:

1. Summarize and review assumptions (in peer-reviewed articles) and recent progress and limitations of traditional and biochemical methodologies for measuring zooplankton production of natural populations and communities.
2. Develop recommendations for standardized protocols for both traditional and biochemical zooplankton production rate measurement methodologies and make these available worldwide for users on a website.

3. Build a global network of scientists and laboratories measuring zooplankton production.
4. Develop protocols for inter-comparison/calibration between different approaches.
5. Compile existing zooplankton production rates estimated by traditional and biochemical approaches.
6. Promote international cooperation between zooplankton production researchers through international organizations such as ICES, PICES and IMBER.

Working plan

Year 1 (2016)

- WG meetings will be held for discussing details of the working plan just before or after the Ocean Science Meeting and the ICES Working Group on Zooplankton Ecology (WGZE) annual meeting.
- The WG will host a workshop at the PICES/ICES 6th Zooplankton Production Symposium (ZPS) to discuss traditional and biochemical methodologies for measuring zooplankton production across a wide range of phyla and trophic levels, including gelatinous groups and other less studied taxa in addition to major crustacean groups. After this workshop, a WG meeting will be held for drafting review articles on traditional and biochemical methodologies for measuring zooplankton production.
- The WG will work on the review articles summarizing the assumptions, advantages and limitations of both traditional and biochemical methodologies for measuring zooplankton production of natural populations or communities.

Year 2 (2017)

- The WG will submit the articles to peer-reviewed journals.
- A WG meeting will be held to discuss standardized procedures and to develop recommendations for the traditional and biochemical zooplankton production measurement methodologies just before or after the Aquatic Sciences Meeting.
- The WG will produce and publish guidelines for standardized procedures with recommendations for worldwide users on the proposed website.
- The WG will build a global network of scientists and laboratories measuring zooplankton production in collaboration with former members of the SCOR WG on Global Zooplankton Time-series (WG125).
- The WG will compile existing zooplankton production rate estimates measured by traditional and biochemical methodologies in order to make comparisons and to quantify driving forces.
- The WG will post the lists of the network partners and the zooplankton production estimates on a website.

Year 3 (2018)

- A WG meeting will be held to discuss suitable protocols for inter-comparison/calibration between different approaches and the WG outreach activities (e.g., summer schools and promotion to international organizations).
- The WG will develop methodological protocols for inter-comparison/calibration of

different approaches for measuring zooplankton production.

- The WG will disseminate the results produced (i.e., guidelines report, list of partners, compilation of production estimates) through workshops and sessions at international conferences such as Aquatic Sciences Meeting, Ocean Sciences Meeting, as well as at ICES WGZE and PICES annual meetings.

Year 4 (2019)

- The WG will promote global cooperation and collaboration on zooplankton production measurements in international programs endorsed by ICES, PICES and IMBER.
- The WG will submit a final report to SCOR.

Deliverables

1. The WG will publish peer-reviewed review articles summarizing the assumptions, recent advances and limitations of both traditional and biochemical methods to estimate production of zooplankton populations and communities.
2. The WG will post a guideline report with recommendations on standardized procedures for both traditional and biochemical methods on a website of an international organization such as PICES and/or ICES.
3. The WG will host summer schools teaching traditional and biochemical methodologies for measuring zooplankton production for students and early-career scientists.

Capacity Building

1. The WG will work to create a global network of collaborating zooplankton production researchers from ICES and PICES nations as well as developing countries.
2. The WG will post a list of the scientists and laboratories (and their contact information) forming the global network on a website.
3. The WG will convene an international and/or regional summer school on zooplankton production measurements for students and early-career scientists.
4. The WG will provide guidelines and assistance on the application of standardized experimental procedures of traditional methodologies and biochemical approaches to estimate zooplankton production for worldwide users on a website.
5. The WG will promote integrating zooplankton production rate measurements into ecological modelling and satellite imaging efforts.

Working Group composition

Full Members (*: Chairs, TM: Traditional method, BM: Biochemical method)

	Name	Gender	Place of	Expertise/ Area	Roles
1	Toru Kobari*	Male	Japan	TM/BM expertise, Western North Pacific	Coordinating to PICES
2	Lidia Yebra*	Female	Spain	BM developer, BM/TM expertise Mediterranean Sea and North Atlantic	Coordinating to ICES
3	Akash Sastri	Male	Canada	BM developer, Freshwaters, Eastern North Pacific and Arctic Seas	Coordinating to PICES
4	Andrew G. Hirst	Male	UK	TM developer, Global oceans	Compiling zooplankton production data
5	Wim J. Kimmerer	Male	USA	TM developer, Coastal regions	Compiling zooplankton
6	Sigrún Jónasdóttir	Female	Denmark	TM/BM expertise, North Atlantic and North Sea	Coordinating to ICES
7	Felipe Gusmão	Male	Brazil	TM/BM expertise, South Atlantic	Networking with developing countries
8	Jenny Huggett	Female	South Africa	TM/BM expertise, Upwelling regions and Indian Ocean	Networking with developing countries
9	Rubao Ji	Male	USA	TM expertise, Production modeler, North Atlantic and Polar Regions	Coordinating to ICES, Incorporating WG products to ecological modelling
10	Takafum i Hirata	Male	Japan	Satellite imagery analysis, Global oceans	Incorporating WG products to satellite imagery

Associate Members (TM: traditional method, BM: biochemical method)

	Name	Gender	Place of	Expertise/ Area	Roles
1	Ruben Escriba	Male	Chile	TM expertise,	Coordinating to IMBER
2	Hyung-Ku	Male	Korea	TM expertise, Continental	Coordinating to PICES
3	Marin a	Female	Argentina	TM expertise,	Networking with developing
4	William T. Peterson	Male	USA	TM expertise, Upwelling regions	Coordinating to PICES
5	Sanae Chiba	Female	Japan	Long-term change, Western North	Coordinating to WG125
6	Elena Gorokhova	Female	Sweden	BM expertise, Freshwaters and coastal regions	Coordinating to ICES
7	May Gómez	Female	Spain	BM expertise, Upwelling regions, North	Coordinating to ICES

Working Group contributions

Toru Kobari

Develop methodology for comparison/calibration between different approaches.
Produce a review paper and standardized manual on traditional methodologies.
Build global network of researchers measuring zooplankton production.
Produce WG report to SCOR committee.

Lidia Yebra

Develop methodology for comparison/calibration of different approaches.
Produce a review paper and standardized manual on biochemical methodologies.
Build global network of researchers measuring zooplankton production.
Produce WG report to SCOR committee.

Akash Sastri

Promote WG activities and results to PICES.
Contribute to review paper and standardized manual on biochemical methodologies.
Build network of researchers measuring zooplankton production in North Pacific and freshwaters.

Andrew G. Hirst

Compile existing zooplankton production estimates by traditional and biochemical methodologies.
Contribute to review paper and standardized manual on traditional methodologies.
Build network of researchers measuring zooplankton production in Southern Ocean.

Wim J. Kimmerer

Contribute to review paper and standardized manual on traditional methodologies.
Develop methods of estimating biomass per animal using image analysis.
Build network of researchers measuring zooplankton production in upwelling regions.

Sigrún Jónasdóttir

Promote WG activities and results to ICES.
Convene international workshops, sessions and/or summer schools.
Build network of researchers measuring zooplankton production in North Atlantic.

Felipe Gusmão

Build network of researchers measuring zooplankton production in South Atlantic.
Convene international and/or regional workshops, sessions and/or summer schools.
Contribute to review paper and standardized manual on biochemical methodologies.

Jenny Huggett

Build network of researchers measuring zooplankton production in South Atlantic and Indian Ocean.
Convene international and/or regional workshops, sessions and/or summer schools.
Contribute to review paper and standardized manual on traditional methodologies.

Rubao Ji

Compile existing zooplankton production models.
Promote incorporation of WG products to ecological modelling.
Build network of researchers modeling zooplankton production.

Takafumi Hirata

Produce global and/or regional map of zooplankton production estimates using satellite imagery.
romote incorporation of WG products to satellite imaging technology.

Relationship to other international programs and SCOR Working groups

1. Contribute to the update of the Zooplankton Methodology Manual (2000) produced by the ICES Working Group on Zooplankton Ecology (WGZE) by publishing review papers.
2. Promote zooplankton production measurements to science plans in international organizations such as PICES, ICES and IMBER.
3. Propose sessions and workshops at international meetings and conferences co-sponsored by ASLO, PICES and ICES.
4. Creation of a global network for zooplankton production researchers based on the products of SCOR WG125.
5. Promote zooplankton production measurements and networking within the 2nd International Indian Ocean Expedition (IIOE-2), an IOC/SCOR/IOGOOS initiative from 2016 to 2020.

Appendix

Key references for each full member (up to 5 papers)

Toru Kobari

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2.2.2 SEAmount Faunal vulnerabilty to impacts of Ocean Acidification and Mining (SEAFOAM) *Burkill*

Summary/Abstract

We propose a new SCOR Working Group (2016 to 2018) that seeks to assess new impacts on seamount ecosystems from ocean acidification (OA) and deep-sea mining for cobalt crusts.

The WG seeks to re-evaluate and augment the science priorities defined in 2012 by the Census of the Marine Life, but taking into account the new threats. The WG would initiate the first conference session focussed on OA impacts and deep-sea ecosystems as part of The Fourth Symposium on Oceans in a High CO2 World, in Hobart, 2016 and plans to work with Dr. Richard A. Feeley with whom Dr. George conducted an international OA Workshop in Florida in 2008) The WG plans to develop a follow-on capacity building workshop in Fiji to address commercial deep-sea mining on seamounts, which will start in the region in 2016. In 2017, the WG will meet for three days at North Carolina State University to generate two open-access publications; 1) the first global assessment of OA on deep-sea fauna, and 2) a blueprint for monitoring mining impacts on seamount ecosystems. In 2018, the WG will meet for 3 days at Oxford University, UK, hosted by Prof. Alex Rogers (SEAFOAM WG) to produce a peer-reviewed publication on conservation objectives for seamounts in the face of multiple human impacts. As a follow-up, WG members will go to Ghent University, Belgium, to work with Prof. Ann Vanreusel (SEAFOAM WG) on 'Capacity Building' in developing nations on deep ocean ecosystem management. The culmination of the WG will be the long-time archiving of information on selected seamounts as "Seamount Data Pool" (SDP) to complement Data Banks on Seamounts at Scripps and University of British Columbia.

Scientific Background and Rationale

Deep-Sea Overview:

It is essential to recognize that there are fundamental links between the deep ocean and the rest of the Earth System. It has been demonstrated that deep-sea ecosystems, their biodiversity and ecosystem functioning, can change quickly and significantly because of direct (e.g. bottom trawling, deep-water oil spills) and indirect (e.g. climate variation) human impacts (Smith et al., 2009). In addition to these known impacts, two new pressures have been recognized in recent years; 1) ocean acidification, including the effects of changing pH on shell-bearing planktonic and benthic organisms, and 2) the rapid development of deep-sea mining with its potential to disturb exceptionally large areas of the seabed. There is an urgent need to consider how deep-sea ecosystems will respond to these new pressures and whether there will be significant feedbacks to other parts of the Earth System. In particular, deep-sea seamounts are considered to be especially vulnerable (Consalvey et al, 2010).

This proposal is timely owing to: (1) the increasing interest of "Oceans in the High Carbon World" and (2) the new licenses (2013 –2015) issued by International Seabed Authority (ISA) for the exploration of cobalt-rich crusts on seamounts. The proposed work is truly global in scale encompassing Exclusive Economic Zones (EEZs), Extended Continental Shelves and the High Seas (Areas Beyond National Jurisdiction). Owing to the cross jurisdictional nature of seamount research, and the need for generic strategies for seamount management, a SCOR WG is probably the only way to approach the growing problem facing seamounts and generate good science to guide management decisions. Seamounts are underwater mountains and occur throughout the world's oceans. There are as many as 100,000 seamounts at least one kilometer in height.

However, of these, less than 200 have been studied in any detail and their biodiversity is still poorly known. Depending on the height of the summit they may have particularly high productivity and may serve as migratory stopovers for whales and other pelagic species.

Seamounts are heterogeneous habitats, often spanning a great depth range (Pitcher et al., 2007; Consalvey et al., 2010; Clark et al., 2010).. Their topography interacts with a wide variety of physical processes including internal waves and tides. As a result seamounts may support highly varied and patchy benthic communities. As for all deep-sea species the seamount fauna generally has long generation times and therefore seamount communities are particularly sensitive to physical impacts, such as bottom trawling and mining. As sampling of seamounts increases, previously held views of seamounts as having a high proportion of endemic species on individual seamounts are challenged (Rowden et al., 2010; Clark et al. 2012). It is now known that many species are shared with other deep-sea habitats, such as continental slopes and banks, although seamounts may have communities with a different structure (Rowden et al., 2010). Historically, seamounts have been poorly sampled owing to their complex topography.

It is only now with the greater availability of Remotely Operated Vehicles (ROVs) and the rapid development of genetic techniques that many issues relating to seamount ecosystems can be resolved. The lack of comprehensive data has led to generalizations about seamounts as a whole. Very often, however, the generalisations apply only to a subset of seamounts, depending also on the biogeographical province and depth band in which they occur (McCain, 2007; Kvile et al., 2013). A concerted effort on studying seamounts is needed, and possible.

Apart from global warming threats on coral reefs in shallow seas through coral bleaching and the increasing spread of deoxygenation by creating hypoxic or anoxic zones in ocean areas off river deltas, ocean acidification (OA) threatens ocean health through effects on plankton (e.g. pteropods) and benthic shell-bearing animals (corals and molluscs) which in some cases are deep-water habitat engineers.. Increasing CO_2 input is expected to decrease ocean pH by 0.3 to 1.5 by 2100, thus lowering the carbon ion concentration of surface waters. This rapid and dramatic scenario of ocean acidification has the potential to have serious effect on calcification of marine organisms. Since industrialization, there has been a substantial increase in CO2 flux into the oceans from atmosphere. It is cautioned that by 2100, if this flux is not reduced by shifting gear to renewable energy, irreversible damage may occur to our ecosystems and may diminish ecological services.

There has been an exponential increase in the number of publications on biological effects of OA and several recent reviews have covered this topic. However, few studies cover the benthic realm. The importance of the combined, and frequently interactive, impacts of multiple stressors (such as temperature, low oxygen and pollutants) is now recognized, as well as the potential for multi-generational adaptation. Experimental research confirms that survival, calcification, growth, development and abundance can all be negatively affected by acidification, but the scale of response can vary greatly for different life stages, between taxonomic groups and according to other environmental conditions, including food availability. Volcanic CO_2 vents can provide useful proxies of future OA conditions allowing studies of species responses and ecosystem interactions across CO_2 gradients. Studies at suitable vents in the Mediterranean Sea and elsewhere show that benthic marine systems respond in consistent ways to locally-increased CO_2. At the shelf-edge, the ongoing shoaling of carbonate-corrosive waters (with high CO_2 and low pH) threatens cold-water corals, in particular *Lophelia pertusa,* in the North East Atlantic Ocean.

In upwelling areas of the Northeast Pacific Ocean, shoaling of the Aragonite Saturation Horizon (ASH) has reduced hard-coral ecosystems dominated by scleractinian corals. The ASH is located much deeper in the other regions of the deep sea. This led, in part, to Tittensor et al. (2010) postulating that OA threat is really confined to continental margins (continental slopes and plateaus) and that mid-ocean seamounts may not be impacted adversely by OA. However, this thesis needs urgent clarification particularly in polar seas and in areas affected by cold water out-flows. A concerted study of seamounts is required in relation to OA threats and other human impacts, such as trawling, mining and OA threats.

Cobalt-rich ferro-manganese crusts are formed by the precipitation of manganese and iron from cold seawater coating the rocky slopes and summits of seamounts in a layer up to 25 cm thick at ocean depths typically between 800 and 2500 m (Baker and Beudoin, 2013). The crusts form very slowly (e.g. only a few mm every one million years). There are about 1,200 seamounts and guyots which may be of commercial interest in the western Pacific Ocean alone, some of which have been licensed in the last 3 years by the UN International Seabed Authority (ISA) for cobalt crust exploration. In addition, the ISA is in the process of agreeing to an extensive exploration license for cobalt crusts on the Rio Grande Rise in the SW Atlantic Ocean.

Mining crusts involves removing the relatively thin layer of ore from the underlying rocky surface. Removing the crust will destroy all the sessile organisms. It is not known how long it will take to recolonize impacted areas, but there is evidence that corals on seamounts at depths where mining may occur may be as old as 2300 years (Carreiro-Silva et al., 2013). Recovery may take a long time. A number of biological issues arise, for instance: 1) How connected are seamounts with other deep-sea habitats such as continental slopes and banks? 2) What population sizes are required in areas of biodiversity conservation to ensure connected and long-lasting reproductive populations? 3) What are the possible cumulative impacts of mining? (Baker and Beaudoin, 2013).

Terms of Reference (ToRs)

1. Ocean acidification impacts of pH change on deep-water coral reefs on continental margin and seamount communities above and below the Aragonite Saturation Horizon (ASH) and Calcite Saturation Horizon (CSH).
2. Influence of physical disturbance and mine tailing releases from deep-sea mining for cobalt crusts on seamounts).
3. Connecting ongoing global deep-sea conservation activities to assess the influences of cumulative human impact on seamount ecosystems and biodiversity of seamount ecosystems.

Work Plan – details of the Terms of Reference

ToR 1. Ocean Acidification

The working group will build upon previous initiatives by organizing a follow-up workshop at the ‘Ocean in a High CO2 World’ conference in Hobart in April 2016, hosted by Dr. Ron Thresher of CSIRO of Australia (WG member and the nominal chair of the international planning committee. The research presented will be used to produce a peer-reviewed publication detailing a 10-years research plan for studying the OA impacts on seamounts in the world oceans (Deliverable #1). This document will be finalized at the second SEAFOAM WG meeting in North Carolina in 2017.

Background for SCOR WG: The Hobart session on deep-sea ecosystems and ocean acidification builds on two previous “Ocean Acidification workshops” led by Dr. Bob George (SEAFOAM Chair), one held at Ft. Lauderdale, Florida during the 11th International Coral Reef Symposium (July 7 –11, 2008) and another held at Wellington, New Zealand during the 4th International Deep-Sea Coral Symposium (Dec. 1-5, 2008). The recommendations from the Florida workshop were submitted through Dr. Shirley Pomponi of the NAS ‘Ocean Studies Board’ to US National Academy of Sciences (NAS) to increase budget allocation for OA research for both NSF sand NOAA through Congressional appropriations.

ToR 2. Mining Impacts

SEAFOAM will seek to stimulate coordinated international research on seamount ecosystems and mining issues, building on the scientific community created through the Census of Marine Life (CoML, 2000-2010) (Consalvey et al. 2010).

A workshop will be organized at North Carolina State University in 2017 to produce: (1) a peer-reviewed publication detailing a 10 year research plan for studying OA impacts on seamounts in the world oceans (Deliverable ToR # 1) and (2) a publication detailing the science behind the first regional environmental management plan for a cluster of seamounts, balancing the needs of resource exploitation with the conservation of regional biodiversity (no species loss). The workshop will focus on the western equatorial Pacific Ocean where a large number of seamounts within a region have been licensed for the exploration of cobalt crusts (Deliverable ToR #2). The workshop will set the proposed management plans within the context of long- term climate change scenarios (e.g. Gehlen et al., 2014).

Capacity building funding will be sought from the ISA (drawn from direct funding of contractors to the ISA, and from the ISA Endowment Fund) for Master’s level students to attend and participate in the workshop, especially those from south west Pacific Ocean island states.

Additional funding for capacity building will be sought from the South Pacific Commission (SPC) which is coordinating deep-sea mining issues within Exclusive Economic Zones in all island states within the region.

ToR 3. Conservation of Seamount Ecosystems

In 2014 the UN Convention on Biological Diversity (CBD), in collaboration with UNEP, updated the impacts of OA in a report on "A Updated Synthesis on the Impacts of Ocean Acidification Impacts on Marine Biodiversity" (Hennige, Roberts and Williamson (2014). Dr. Braulio Dias, Executive Director CBD, gave a succinct summary of this report with recommendations for future OA research and monitoring. In this proposal to SCOR for creating a WG, we have taken the advice from these recommendations. We also realize that thus far we have focused more in the Atlantic and Pacific Oceans and have not included the Indian Ocean. Therefore, we have included an expert from National Institute of Oceanography in Goa, India (Dr. V. K. Banakar). To bring together these many disparate strands a workshop will be organized in Oxford, UK, (2018), building on the results of the two previous workshops, to produce an open access publication on the conservation and management of deep-sea seamounts, including a forward-looking 10-year international research plan (Deliverable ToR#3).

Deliverables:

In addition to the 3 deliverables related to the ToR detailed above, SEAFOAM will prepare a multi-authored comprehensive science paper on potential impact of ocean acidification with emphasis on shell-bearing fauna in the seamounts such as scleractinian coral species. This paper will include the following research questions:

(1) How will ASH and CSH will behave in different geographic regions, upwelling zones on the eastern parts of world oceans vs non-upwelling zones on western parts of the world oceans?
(2) Which deep-sea coral species have inherent genetic adaptability to be resilient in low pH conditions (and what shore-based OA study facilities are called for in order to conduct long-term experiments on chosen deep-sea corals?
(3) What recommendations should be developed to International Seabed Authority for esignation Marine Protected Areas (MPAs) in the seamounts that are targets of seafloor industries in the cobalt mining in the coming decade?

Capacity Building Plan

Much of capacity building and training in marine science, conservation and management is focused on coastal systems. The marine training portal www.marinetraining.eu, as a measure of international opportunities, shows only a very limited number of courses targeting human impacts and deep-water systems. Searching the keywords "ocean acidification" and "deep-sea mining" provides only a negligible number of records. The importance and scale by which OA and mining may impact biodiversity and ecosystem functioning in deep-water have not been reflected in training programs that have been organized to date. This is of concern as developing countries start to utilize offshore resources within their Exclusive Economic Zones (EEZs). The cross boundary causes and consequences of OA, the international framework in which mining operations occur, and the global distribution of seamounts within and beyond EEZs, requires international awareness and action. Therefore, building knowledge and training capacity on OA and deep-sea mining in developed and developing countries, including fast growing nations such as India, and Brazil is a major objective for SEAFOAM.

We aim to inform and educate young scientists on the threats, research needs and management tools for the conservation of biodiversity and resource exploitation on seamounts. We aim to conduct three new capacity building activities related to SEAFOAM.

First, we will contribute expert knowledge to a workshop for developing countries planned for Namibia in 2016 (http://www.indeep-project.org/wg/population-connectivity) by WG 3 of the INDEEP Project. The topic is "Biodiversity and connectivity of deep-sea ecosystems in areas targeted by deep-sea mining" in relation to management and decision making. The plan is to have a 10 day workshop with 18-20 participants.

Second, we will time the third SEAFOAM workshop in Oxford in 2018 to allow a follow up course on seamount ecology and human impacts at Ghent University as part of their international Masters of Oceans and Lakes (www.oceansandlakes.be). This course educates 30 students each year, in a two-year course, complete with project work on a topic of direct importance to the student's country of origin. Students from 30 developing countries have attended at the Master's level todate. Many students have gone on to Ph.D. studies or to environmental management roles in their home country. A special course will be offered with a certificate awarded for attendance.

Third, over the next 4 years new contractors to the International Seabed Authority for exploration of cobalt crusts on seamounts are required to provide at sea training opportunities and fellowships (http://www.isa.org.jm/training). SEAFOAM will work with the students selected to act as role models for future capacity building.

In addition to these initiatives SEAFOAM will search for funding from agencies (e.g. UNESCO) and foundations (e.g. Packard, Sloan, Total) to provide scholarships for people from developing countries to attend targeted workshops. In particular, SEAFOAM will work with the South Pacific Commission (SPC) to provide a training program in Polynesia on seamounts and environmental management to follow on from the WG's meeting in Hobart in 2016.

Funding support, especially in relation to capacity building in developing nations will be sought from private philanthropic foundations concerned about biodiversity loss in the oceans such as the Sloan Foundation and the Packard Foundation.

Relationship to other SCOR WGs and International Programs:

SEAFOAM seeks to interact with the following ongoing efforts that emphasize the need to resolve OA threats to marine ecosystems and biodiversity. Apart from work on seafloormapping and ocean observatories, SCOR has had little focus on benthic ecosystems in the world's oceans in the past. SEAFOAM builds on interests in SCOR on oceans in a high CO2 world and ocean acidification to fill a important gap in SCOR's past and present work.

International programs that will benefit directly from SEAFOAM and which have produced reports calling for research produced by SEAFOAM are:

1. 2014 Recommendations from Convention for Biological Diversity (CBD) Report

2. SCOR WG will interact with Prof. Alex Rogers, Professor of Zoology at Oxford, UK and will use his consultant service on seamount ecosystem research..

3. Dr. Maria Baker of National Oceanography Centre and the University of Southampton UK has consented help as liaison between the SCOR WG and INDEEP and DOSI (Deep-Ocean Stewardship Initiatives) that have made significant progress under the leadership of Prof. Lisa Levin of Scripps Institution of Oceanography and Prof. Elva Escobar of UNAM, Mexico to assemble concerned deep-ocean scientists to address issues such as:

   (A) Deep-Sea Mining (Prof. Craig Smith, University of Hawaii)
   (B) Global Ocean Assessment (Dr. Tony Koslow, Scripps Institution of Oceanography)
   (C) Ocean Conservation (Dr. Jeff Ardron, Commonwealth Secretariat, London)
   (D) Collaborations with Developing Nations (Dr. Christian Neumann)
   (E) High Sea and Sargasso Sea Commission (Dr. Kristina, Gjerde, IUCN)
   (F) Networking (Dr. Maria Baker, NOC, University of Southampton, UK)
   (G) Deep-Sea Fisheries (Dr. Les Watling, University of Hawaii)
   (H) Legal Issues and Mining Tailings (Dr. Eva Ramirez, NIVA, Norway)
   (I) Oil and Gas Explorations and Drilling (Dr. Eric Cordes, Temple University, Philadelphia, USA)).

4. The SCOR WG will also interact with Dr. Tim Shank who will host the 2016 Deep-Sea Coral Symposium. Note: the first International deep-sea coral symposium in USA was coordinated by Prof.. Robert Y. George (GIBS) and Dr. Robert Brock (NOAA) at the University of Miami in 2005). Dr. George co-edited this symposium proceedings with Dr. Stephen Cairns of Smithsonian Institution in two volumes, one entitled: "Conservation and Adaptive Management of Deep-Sea coral and seamount ecosystems."

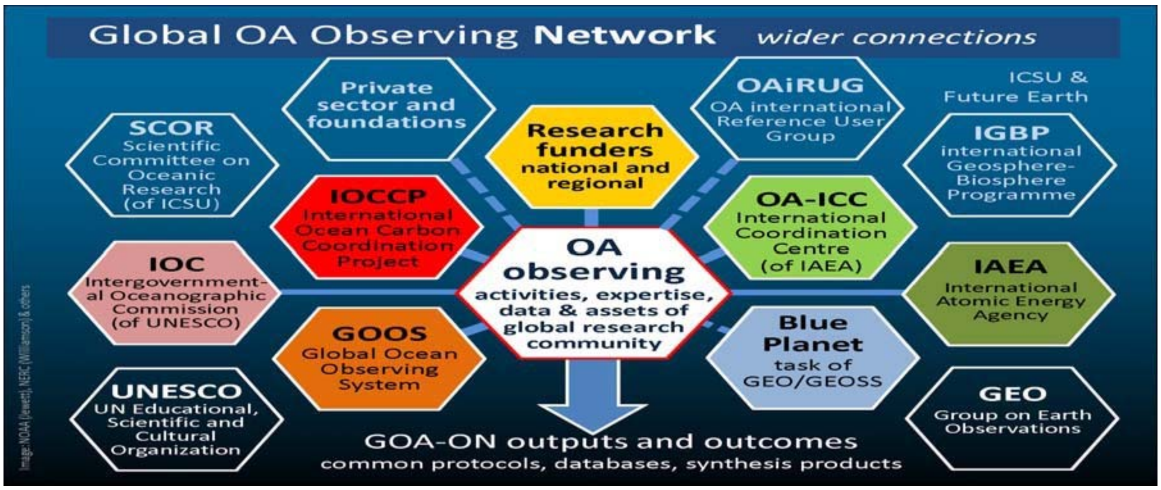
5. The results of the SCOR WG will find ready application in the environmental management of cobalt-rich crusts on seamounts, through the International Seabed Authority, Kingston, Jamaica, which is seeking to expand work on regional Strategic Environmental Assessments (SEA) in relation to deep-sea mining (International Seabed Authority, 2014). SCOR results will be provided through links of the SCOR WG to the ISA Secretariat and ISA Legal and Technical Commission (LTC), an expert group that advises the ISA Council in its decision making (www.isa.org.jm). Dr Billett (SEAFOAM WG) is a member of the current ISA LTC.

6. To bring together these many disparate strands a workshop will be organized in Oxford, UK, (2018), building on the results of the two previous workshops to produce an open access publication on the conservation and management of deep-sea seamounts,

including a forward-looking 10-year international research plan

7. Global Ocean Acidification Network (GOAN)

We are also aware of the existing "Global Ocean Acidification Network" , with a vast number of scientists and managers from many nations, actively involved in OA research and monitoring efforts in the world ocean with Dr. Libby Jewett of NOAA as a coordinator of this activity, as illustrated below. The Scientific Committee for Oceanic Research (SCOR) is one of many participants in this ongoing network



8. The Brazilian Ocean Acidification Research Group (BrOA; www.broa.furg.br) was created in December 2012, as an action arising out of the workshop "Studying Ocean Acidification and its Effects on Marine Ecosystems" (Dec. 4-6, 2012, Cananéia, Brazil), which was organized by the International Geosphere-Biosphere Program, University of São Paulo, Brazilian Council of Scientific Research and Development and Brazil's National Institute for Space Research. In March 2015, BrOA identified: (A) National ocean acidification projects and learning how they have integrated field and laboratory experimentations (B) Scientific collaboration between Brazil and other countries in the context of ocean acidification research.

COLLABORATION WITH GOA-ON, NOAA AND OA EXPERTS

Dr. Sam Dupont at the Department of Biological and Environmental Sciences of Gothenburg University and Sven Loven Center for Marine Sciences, Kristineberg, Sweden, has offered to help SEA FOAM and will participate in the first meeting of SEASFOAM WG for SCOR on May 7, 2016 in Hobart, soon after the 4th High Carbon Ocean Symposium. Dr. Dupont is a member of Executive Council of Global Observatory Network for Ocean Acidification (GOA-ON) and he is leader of the Biology WG of GOA-ON). Dr. Dupont is also a member of the International Coordination Center for Ocean Acidification. We will also invite Dr. Sam Dupont (Sweden), Dr. Richard A, Feely (NOAA) Dr. Libby Jewett (NOAA) and also Dr. Jean-Pierre Gattuso

(University of Pierre-et-Marie Curie) who chairs the 'Ocean in the High Carbon World' symposium in Hobart (May 3-6, 2016) to participate in the SEAFOAMWG meeting on May 7, 2016.

SCOR WG SEAFOAM (Seamounts Ocean Acidification and Mining)

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

Name	Gender	Place of work	Expertise relevant to proposal
1 Prof.Robert Y. George (CHAIR)	Male	Raleigh, North Carolina	Deep-Sea Ecology. Ocean Acidification
2 Dr. David Billett (VICE_CHAIR)	Male	Southampton, UK	Deep-Sea Mining and Benthic communities
3 Prof. Billie J. Swalla	Female	Univ. of Washington, Washington State	Ocean Acidification Research Facility
4 Prof. Alex Rogers	Male	Oxford University, UK	Seamounts Ecology
5 Dr. Anna Metaxas	Female	Dalhousie University, Canada	Deep-Sea Ecosystems
6 Dr. Ron Thresher	Male	CSIRO, Hobart, Tasmania, Australia	High Carbon Oceans
7 Prof. Marco Taviani	Male	Marine Geology Institute, Italy	Deep-Sea Geology and deep- sea Corals
8 Dr. Marcelo Kitahara	Male	Sao Paola, Brazil	Deep-Sea Hard Corals
9 Prof. Ann Vanreusel	Female	University of Ghent Belgium	Deep-Sea seeps and nematode biodiversity
10 Dr. V. K. Banakar	Male	NIO, Goa, India	Deep Sea Minerals

Associate Members (no more than 10)

Name	Gender	Place of work	Expertise relevant to proposal
1 Dr. Jason Hall-Spencer	Male	Univ. of Plymouth, UK	Deep-sea conservation and Ocean Acidification
2 Dr. Thomas Hourigan	Male	NOAA, USA	Deep-Sea Corals
3 Prof. Robert S. Carney	Male	LSU, USA	Deep-Sea Ecology
4 Dr. David Eggleston	Male	CMST, North Carolina State University, NC	Marine Ecosystem Services/Conservation
5 Dr. Myriam Sibuet	Female	Institut Oceanographique, Paris, France	Deep-Sea Ecology
6 Dr. Alison Swaddling	Female	Suva, Fiji	Deep-Sea Mining and Ecology
7 Dr. Eva Ramirez	Female	NIVA, Oslo, Norway	Marine Ecology
8 Dr. Ashley Rowden	Male	NIWA, Wellington, New Zealand	Seamount Ecology/Fisheries
9 Dr. Robert H. Byrne	Male	University of South Florida,	High Carbon Ocean/ pHMonitoring
10 Dr. Telmo Morato	Male	University of Azores	Seamount Ecology

Brief CVs of each Full Member

1. Dr. Robert Y. George (GIBS) – Chair

Dr. Robert Y. George was Professor of Biological Oceanography for 30 years (1972-2002) at UNC-Wilmington, North Carolina, USA and he taught a graduate course on deep-sea biology. Dr. George conducted original deep-sea research for 40 years off North Carolina Coast, Puerto Rico Trench, Blake Plateau Coral Ecosystems, Sargasso Sea (Beaufort – Bermuda Transect), Arctic and Antarctic deep-sea. Since 2002, Dr. George has been the President and CEO of the George Institute for Biodiversity and Sustainability, a Non-Profit 501-C-3 organization in North Carolina. Dr. George now serves as NOAA delegate to ICES (International Council for Exploration of Seas) Deep-Sea Working Group, since 2005, and organized with NOAA the 3rd international deep-sea coral symposium at the University of Miami.

2. Dr. David Billett, (NOC, Southampton, Visiting Research Fellow, UK) Vice-Chair/Rapporteur

David Billett is a Visiting Research Fellow at the National Oceanography Centre, Southampton and a deep-sea biologist with over 38 years of experience of mid-ocean ridges, abyssal sediments, seamounts, coral mounds, submarine canyons, continental slopes. Dr Billett has a particular interest in 1) the effects of climate change on deep-sea ecosystems, 2) distinguishing between natural and man-made change, and 3) the environmental management of offshore deep- water fisheries, oil and gas production and mineral mining, working on the expert advice group, the Legal and Technical Commission, for the UN International Seabed Authority.

3. Dr. Billie J. Swalla, Director, Friday Harbor Laboratories, UW

Dr. Swalla is an expert on sessile tunicates with several papers on molecular taxonomy. She is also involved in the operation of 'Ocean Acidification Research Facilty", funded by US National Science Foundation. Dr. Swalla holds summer courses to train graduate students both American and from abroad to offer research skills in the areas of marine biodiversity conservation and ocean acidification impact on shell-bearing invertebrates in the sea.

4. Dr. Anna Metaxas (Dalhousie University, Canada)

Dr. Anna Metaxas is professor at the Department of Oceanography in Dalhousie University, Nova Scotia, Canada. Dr. Metaxas teaches 'Deep Sea Biology' and she also participates in the International Ocean Institute Training Program in Dalhousie University. She is the chair of the INDEEP working group on "Population Connectivity" and is spearheading the capacity-building workshop in Namibia. She is also chair of the INTERRidge working group on "Ecological Connectivity and Resilience. Her research expertise encompasses a wide variety of interests that include octocoral larval ecology, hydrothermal vent system associated with seamounts and deep water gorgonian corals. Dr. Metaxas does field-oriented research on cruises, laboratory research experiments on both larval and adult deepwater corals and prediction models.

5. Dr. Ronald Thresher (CSIRO, Australia)

Dr Ron Thresher is a senior scientist at the Australian Commonwealth Scientific and Industrial Research Organization with a focus on deep-sea oceanography/communities, in particular deep-sea corals, studying long-term oceanic records for the Southern Ocean to complement modern instrumental records, threats posed by climate change and ocean acidification on deep-sea reefs. He has examined options for mitigating the impacts of climate change on seamount communities and investigated the potential application of pH and other environmental proxies in the ecology of deep-sea corals, including links to regional oceanographic features at intermediate depths.
Ron is also the Chair of the international scientific steering committee for the planned 2016 "Oceans in the High CO2 World", to be held in Australia, which directly dovetails with the proposed WG work plan.

6. Prof. Ann Vanreusel (University of Gent) –Coordinator for Capacity Building

Prof Ann Vanreusel is head of the research group Marine Biology of Ghent University (Belgium) with extensive expertise in structural and functional biodiversity research in shallow-water and deep-sea benthic ecosystems. Prof. Vanreusel has focused her research on the ecology of extreme marine environments including the canyons, cold water corals, polar seas and cold seeps. Recently much of her research has focused on CO_2 seeps to understand impact of long term extreme acidification on biota.

7. Dr. Marco Taviani (Italian Marine Institute)
Dr Marco Taviani is Research Director at the Insititute of Marine Sciences (ISMAR)-CNR, Bologna, Italy, with an interest in bio-sedimentology (biogenic carbonate factories, hydrocarbon-imprinted carbonates, deep water coral ecosystems), Cenozoic-Recent marine extreme environments (polar, cold seeps), carbonate geochemistry, paleoclimatology and paleoceanography (Antarctica, Mediterranean, Red Sea, Western Indian Ocean). He has carried out over 40 oceanographic missions (Mediterranean, Red Sea, Atlantic Ocean and Antarctica) often as chief-scientist, onboard Italian, German, French and US research vessels, including ROV operations, manned submersibles, rotary drilling, scientific SCUBA diving for the study of cold-water corals to assess their biodiversity and unravel their paleoclimatic potential.

8. Dr. V. K. Banakar (National Institute of Oceanography, Goa, India)
Dr. Banakar has three decades of research experience in the field of deep-sea mineral exploration and paleoceanography/palaeoclimate working on marine mineral deposits particularly manganese nodules, seamount crusts and hydrothermal sulfides.

9. Dr. Marcelo Kitahara (University of Sao Paulo, Brazil)
Dr Kitahara is a deep-sea coral molecular biologist at the University of Sao Paulo, Brazil, using molecular approaches in addition to morphology (microarchitecture, and macro and microstructure of the skeleton), fossil data, and bioinformatics to study the evolutionary history of scleractinian corals and related groups, such Corallimorpharia. This research is showing how scleractinians have survived climate change and OA events in the past and shedding light on how corals of ecological and economic importance will cope with increasing modern anthropogenic pressures.

10. Dr. Alex Rogers (Oxford University)
Dr. Rogers is an expert on seamount ecosystems with focus on cold-water coral. He employs molecular tools and traditional taxonomy to study seamount ecosystems in spatial and temporal scales. Dr. Rogers has worked with International Seabed Authrities (ISA), IUCN and UN Division of Laws of the Seas. He has guided Ph.D research pf more than 2 dozen doctoral scholars

Five key references for each Full Member

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2. Dr. Alex Rogers (Oxford University)

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10. Dr. Marcelo Kitahara (University of Sao Paulo, Brazil)

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ASSOCIATE MEMBERS

The Associate members play a key roles in two relevant areas (1) Teaching training courses for students from developing nations concerning deep sea biodiversity and resources as well as (2) advising the SCOR-SEAFOAM WG.on areas of their expertise. For example, (A) Dr.Telmo Morato (Azores) will advise on seamount fisheries, (B) Dr.Myriam Subuet (France) will be an asset as Associate Member wit vast experience in deep-sea ecosystem service, (C) Dr. Alison Swaddlng in Fiji will provide guidelines on deep sea mineral explorations, based on her experience in in Fiji. Papa New Guinea and Tonga. (D) Dr. Ashley Rowden (New Zealand) will help SEAFOAM with his knowledge on biodiversity, habitat heterogeneity and seamount fisheries.(E) Dr. Tom Hourigan (NOAA, USA) has authored a comprehensive report on the status of cold water corals of the world in 2008 and is now heading the habitat conservation program focusing on deep-sea corals. Dr. Hourigan, in collaboration with Dr. Peter Etnoyer of NOAA, is currently preparing a summary report on status of the deep-sea coral ecosystems in continental margins and seamounts within US EEZ and this report will be published online in 2016 and will become a valuable resource for the proposed SCOR WG – SEAFOAM.(F) Dr. Bob Byrne of University of South Florida is well-known for his research on climate change on carbon chemistry of the ocean and (G) Dr. Bob Carney was director of NSF Biological oceanography program is renowned scholar on deep-sea zonation and biodiversity.

PROPOSED BUDGET

1. 2016 SCOR WG Delegates for participation High Carbon Ocean conference and workshop in Tasmania

$ 12,000

2. 2017 SCOR WG Annual meeting workshop at NC State University
   (Cost for travel plus hotel/per diem for 9 members of WG, George as host)

$ 15,000

3. 2018 SCOR WG Final Conference at Oxford, UK
   (Travel/hotel cost at flat rate of $ 2,000 for five WG members)

$ 14,000

4. Travel cost for chair and vice-chair (Final Report Preparation)

$ 4,000

TOTAL FUNDS REQUESTED FROM SCOR

$ 45,000

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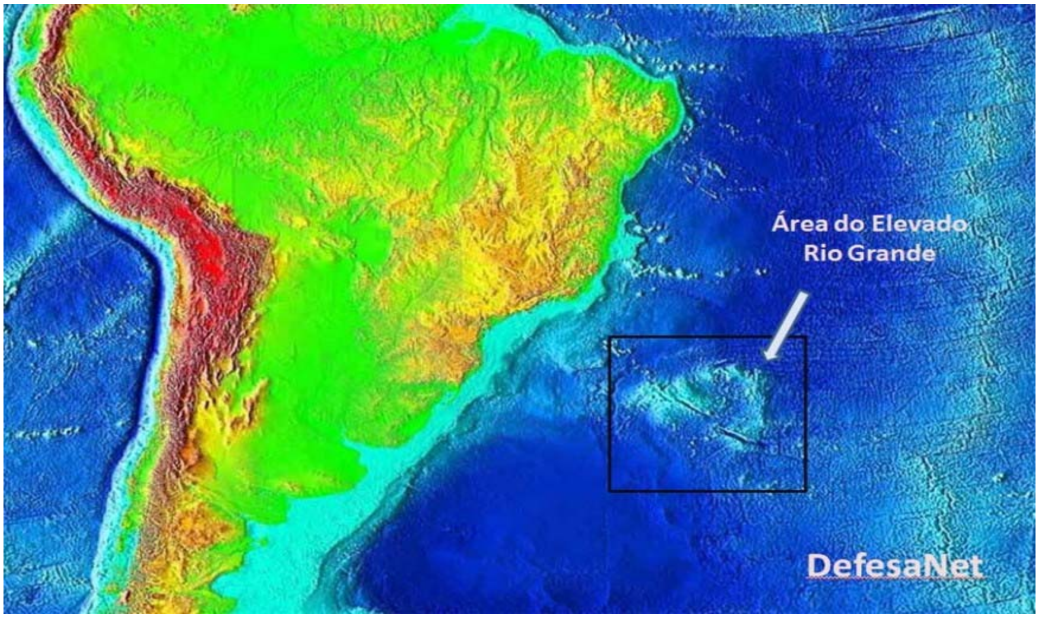
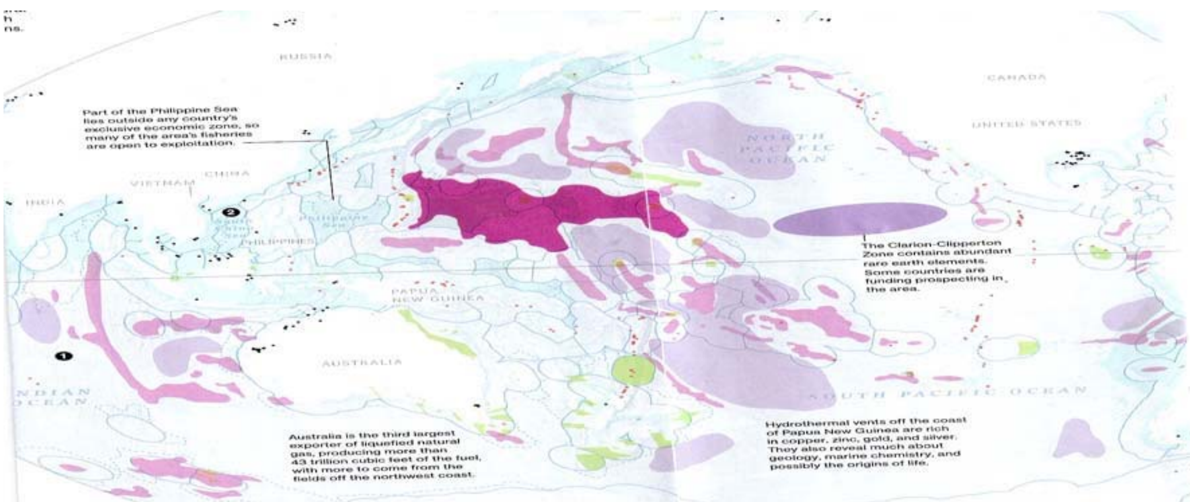
Figure 1. RIO GRANDE RISE: COBALT MINING ZONE



Location of RIOGRANDE RISE

FIGURE 2. MINERAL RESOURCES ON DEEP-SEA FLOOR IN PACIFIC



Mineral deposits in Deep-Sea (Source: National Geographic). Dark Pink-reddish is Cobalt; Violet is Copper and Nickel and Black Dots are Oil and Gas Explorations.

2.2.3 BIOgeochemistry of COral REef systems (BIOCORE) *Brussaard*

Summary/Abstract
Coral reefs are home to more than 25% of all marine species, making them the most diverse marine ecosystem. However, globally coral reefs are threatened by human activities at both large- (ocean warming and acidification) and local-scales (e.g. pollution, overfishing).The impact and extent of these disturbances vary between ocean regions, due to factors such as proximity to land and local human activity. While some anthropogenic activities have been clearly demonstrated to cause decline of dominant reef taxa, it is currently unclear how such changes impact the overall biogeochemistry and function of these ecosystems. This is caused by the fragmented knowledge of impacts, derived from observations from relatively few locations. Because many anthropogenic impacts are fundamentally chemical in nature, understanding the biogeochemical context of coral reefs in a changing world is critical to improve preservation efforts and enhance the health quality of these endangered ecosystems. Therefore, a coordinated international effort is needed to obtain a global understanding of biogeochemical processes in coral reef systems.

The **BIOCORE** working group would take a major step towards understanding the global variability in coral reef system biogeochemistry by 1) creating an accessible internet-enabled data platform, 2) summarizing the latest scientific insights by publishing a series of open access manuscripts, 3) hosting international workshops geared toward identifying gaps in our understanding of coral reef biogeochemistry, and 4) pursue capacity building in the research field for scientist from developing countries. The **BIOCORE** working group would thereby not only advance our understanding of coral reefs, but also provide knowledge of crucial importance for predicting how future changes will impact these unique ecosystems.

<u>Scientific Background and Rationale</u>
Coral reefs are vibrant, living assemblies which are amongst the most impressive and varied ecosystems on the planet. They are primarily found in tropical and semitropical waters (between 30°N and 30° S), where they provide food and income and a variety of services to hundreds of millions of people, mainly from tourism and fisheries (Moberg and Folke 1999), and are home to a myriad of marine species that are dependent on coral reefs to feed, reproduce, and obtain shelter. Globally, coral reefs are threatened by a combination of local (e.g. pollution, overfishing, growing coastal populations) and global stressors (ocean warming, acidification)(e.g. Cyronak et al. 2013), which, across large parts of the ocean have caused the steady decline of dominant coral communities (Burke et al. 2011; Fabricius 2011; Hughes et al. 2010). Corals are ecosystem engineers and thus play a crucial role in physically shaping the ecosystems they live in, mainly by their ability to produce large calcium carbonate structures. In order for corals to calcify and grow, they need stable environmental conditions, temperatures typically around 25□C, and oligotrophic, sunlit, and alkaline waters (Atkinson & Falter 2003; Uthicke et al. 2014). Understanding the interactions of biological, chemical, and geochemical fluxes and processes, that is the biogeochemistry, that control environmental conditions and the response of coral ecosystems to change is therefore crucial. However, much of the research on coral reefs to-date has been biological, with some geological and geochemical work.

We propose to form a SCOR Working Group which would focus on the biogeochemistry of coral reef systems (**BIOCORE**) across global and local scales to determine how coral reef systems have been and are being altered by environmental change. As coral reefs are globally spread over large geographical areas, the work we propose, naturally includes a strong international element, providing a unique framework to link existing information. Human pressures on coral reefs are increasing globally in both developed and developing countries. But the impact and extent of these disturbances varies between regions due to factors such as proximity to land, coral reef community composition, local human activities and the extent to which strategies for coral reef management are followed. The **BIOCORE** working group would provide the first step towards a more complete understanding of global variability in the biogeochemistry of coral reef systems. Many relevant data sets have been collected by independent researchers, agencies and nations, but comparing and synthesising this data from different reef systems, is a huge task, which requires sustained activity of a co-ordinated group of researchers. One example of such an analysis would be to summarize and understand why the daily and seasonal patterns in the partial pressure of carbon dioxide (pCO_2) are different between coral reef systems globally. It can easily be visualized using the NOAA Coral Reef Moorings data (http://www.pmel.noaa.gov/co2/story/Coral+Reef+Moorings), that the amplitude and patterns in the pCO_2 varies between systems, but understanding why this is the case would be one of the questions addressed by the **BIOCORE** working group. Another example of a detailed analysis would be to review and comprehend why the limiting nutrients for primary production varies between systems. While primary productivity in some coral reef systems is suggested to be limited by phosphorus (e.g. Florida Keys) others are limited by nitrogen (e.g. Great Barrier Reef) when assuming a Redfield Nitrogen: Phosphorus ratio of 16:1 (Redfield et al. 1963). This points to the nutrient biogeochemistry of these systems being different. Understanding the causes of these fundamental differences would be another valuable endeavour for the **BIOCORE** working group. As international efforts requiring prolonged activities are rarely funded by national research agencies a SCOR Working group would be an ideal platform to gather experts from key coral reef areas from around the world.

The "**BIOCORE**" working group would be comprised of an international consortium of coral reef researchers. Our major focus would be on increasing knowledge of coral reef biogeochemical processes that can be utilised for scientific, management and public outreach activities. This would be accomplished through; 1) providing a synthesis and review of coral biogeochemical processes by publishing a special issue in an open-access journal, 2) developing a strategic plan to fill in gaps in our knowledge, 3) pursuing capacity building for developing country scientists and 4) improving access to information by creating online databases and use other available communication tools.

Terms of Reference

The working group on "BIOgeochemistry of COral REef systems (**BIOCORE**)" would:

1. **Identify and combine datasets** of key biogeochemical measurements in coral reefs to centralize the information and improve accessibility;
2. Write a **short perspectives paper** after the first meeting, to be submitted to an open-access journal (PeerJ or Frontiers in Marine Science), highlighting the importance and knowledge gaps in coral reef biogeochemistry;

3. Identify gaps in scientific knowledge and **develop priorities and recommendations** for future efforts within coral reef biogeochemistry studies;
4. Organize a **series of invited, peer-reviewed manuscripts** as a special issue in an open-access journal to enhance our understanding of coral reef processes;
5. **Conduct active outreach to coral reef researchers in developing countries** to build capacity through participation in the working group activities;
6. **Engage with the wider scientific and management coral reef community** by inviting them to the regular working group meetings.

These actions would be achieved during the working group meetings (annually for three years), building web-based resources and publishing of scientific manuscripts. This would establish the platform for the coral reef science community to build an international programme on coral reef biogeochemistry similar to existing international oceanic programs such as "GEOTRACES".

Working plan/Timeline

Year 1 In order to provide high international visibility the first working group meeting would piggyback on the 13th International Coral Reef Symposium (ICRS: Hawaii, USA, June 19-24, 2016). The meeting would consist of an organized presentation session and subsequent 2-day workshop after the symposium so that participants from the symposium would be able to attend. Local coral reef authorities (e.g. NOAA-CRED and OAP) would also be invited to attend the workshop in order to provide end-user inputs and perspectives on the working program. This would ensure that the coral reef community is well informed of the working group objectives and targets. Other goals for the first working group meeting would specifically include the following:

- Inform the coral reef community of working group goals and targets;
- Obtain input from the coral reef research community and authorities on priorities and targets for future studies;
- Identify and distribute specific tasks to working group participants and set targets for deliverables, to ensure that all of the terms of reference would be covered during the 3-year period;
- Present the outline of the working group database and facilitate discussion for improvement;
- Launch social media platforms (e.g. Facebook, Twitter) which would be updated during the meeting and over the following 3 years;
- Draft a brief perspectives paper to be submitted to open-access journal highlighting the importance and research needs;
- Coordinate a special issue of an open-access journal (e.g. PeerJ or Frontiers in Marine Science) using papers presented in the special session at ICRS to report the current state of reef biogeochemistry and future research goals.

Year 2 Working group meeting 2. We would apply for a topical session at the aquatic science Meeting 2017 (Hawaii, USA; February 26 – March 3) and furthermore organize a 2-day workshop following the meeting. This would ensure participation and input from the wider oceanographic community. Goals of the meeting would include the following:

Focus progress on database synthesis and get the data webpage operational;

- Publish special issue in open-access research (PeerJ or Frontiers);
- Inform oceanographic community of working group goals and targets and discuss with the ASLO community the major goals and knowledge gaps;
- Develop final list of future challenges and research needs.

Year 3 Working group meeting 3 would be a 4 days meeting hosted by the Australian Institute of Marine Science, Townsville (AIMS) in 2018, with venue and accommodation costs covered as an in-kind contribution from AIMS. Representatives from the Great Barrier Reef Marine park authority would also be invited to this meeting to provide end-user inputs. Goals for the meeting would include the following:

- Finalize data access portal;
- Produce working group outcome document as open-access perspectives article in the journal "Coral Reefs";
- Discuss future plans for continuing working group efforts to build a robust platform for an international programme similar to the "GEOTRACES" program.

Capacity Building

Understanding coral reef biogeochemistry is essential for our understanding and capability to predict how coral reefs will respond to environmental changes and to develop and test strategies for coral reef management. Currently, this knowledge is often restricted to single locations and individual research groups. Many coral reef systems are located in developing nations with growing, but limited, research capacity. **The BIOCORE working group would therefore link key geographical areas and experts to enhance our understanding and develop new capability in coral reef biogeochemistry.** To ensure that these links are created, we would have full participation from Full Members in the meetings to be held in 2016, 2017 and 2018. We would also identify important knowledge gaps which would encourage new research efforts in this area. All working group members would furthermore participate individually and collectively in efforts to increase public and scientific understanding of coral reef biogeochemistry. Specifically we would develop capacity on several levels by:

- Creating a Facebook page and a Twitter account to promote public interaction. Activities of outreach are also anticipated through national and regional user groups and media.
- Including experts from around the globe to increase interactions, knowledge transfer, student exchanges and mentoring. The inclusion of scientists from developing nations provide links to ecosystems and research institutions in their respective regions and this ensure capacity building for developing country scientists through participation in the working group meetings and sessions hosted at international conferences, otherwise difficult to archive.
- Publishing of the working group outcomes in an open-access journal to provide a new resource to help expand the field and provide information to policy makers and managers. To build new capacity and sustain young researcher we would encourage all working group members to involve early career scientist in the writing of these open-

access publications.

- Invite end-user groups to attend and contribute to working group meetings (e.g. Great Barrier Reef Park Authority, NOAA).

Start and End Date

July 2016 to September 2018

Deliverables

If approved, this working group would:

1. Establish a database, hosted at AIMS, to connect available data of reef biogeochemical measurements.
2. Publish a scientific perspectives manuscript in an open-access journal, highlighting the importance and knowledge gaps in coral reef biogeochemistry.
3. Produce a series of publications to be included in a special issue of an open-access journal to enhance our understanding of coral reef processes. The papers would summarize current knowledge and identify gaps in our scientific knowledge and help us prioritise and make recommendations for future efforts within the research area.
4. Build and maintain at AIMS a support network for coral reef researchers in developing countries, including resources for grants, supplies, data repositories, and management guidelines.

Working Group Members

Full members of this Working Group were selected to assemble the appropriate scientific expertise and to span over the different geographical areas where coral reefs exist, including developing countries where a large fraction of the world's coral reefs are found.

Associate Members were chosen to expand the scientific and geographical working area, and they would assist with specific working group deliverables. As costs of attending the 3 working group meetings won't be covered for these members, we have mainly chosen associate members from countries where funding is likely to be available to cover such expenses in order to maximize meeting attendance.

The researchers included represent a broad geographical spread, from Asia, Australia, Europe, Middle East, North and South America. The working group members also span from early to mid-career international researchers to international leading experts in coral reef biogeochemistry.

Full members			
Name	**Gender**	**Place of work**	**Expertise**
Nicholas Bates	M	BIOS, Bermuda	Coral biogeochemistry
Beatriz Casareto	F	Shizuoka University, Japan	Microbial ecology and
Ruy Kenji Kikuchi	M	Universidade Federal da Bahia, Brazil	Coral biogeochemistry
Christian Lønborg*	M	AIMS, Australia	Microbial ecology and biogeochemistry
Craig E. Nelson*	M	CMORE, USA	Microbial ecology and biogeochemistry
Xosé Anxelu G. Morán	M	KAUST, Saudi Arabia	Microbial ecology and biogeochemistry
Aazani Mujahid	F	University Malaysia Sarawak, Malaysia	Physical oceanography
Anond Snidvongs	M	Phuket Marine Biological Center, Thailand	Coral biogeochemistry
Adrienne J. Sutton	F	NOAA, USA	Ocean acidification
Aline Tribollet	F	IRD, France	Coral ecology and biogeochemistry
* = co-chairs			

Associate members			
Name	**Gender**	**Place of work**	**Expertise**
Eric De Carlo	M	University of Hawaii, USA	Coral biogeochemistry and acidification
Henrieta Dulaiova	F	University of Hawaii, USA	Coral geochemistry
Bradley D. Eyre	M	Southern Cross University, Australia	Coral biogeochemistry
Andréa G. Grottoli	F	Ohio State University, USA	Coral and isotope biogeochemistry
Joanie Kleypas	F	CGD/NCAR, USA	Ocean acidification
Nichole Price	F	Bigelow, USA	Ocean acidification
Jing Zhang	M	State Key Laboratory, China	Coral biogeochemistry

Funding

In order to reduce overall costs and ensure sufficient funding is available for all full members to attend all meetings we have 1) arranged that the Australian Institute of Marine Science, Townsville would cover the venue and accommodation costs for the third meeting in 2018 and 2) agreed that full members from developed countries, where possible, would cover parts of the cost of their own travel and accommodation from other sources.

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Uthicke S., Furnas M., Lønborg C. 2014. Coral reefs on the edge? Carbon Chemistry on inshore GBR Reefs. PloS One 9, doi:10.1371/journal.pone.0109092

2.2.4 Changing Ocean Biological Systems (COBS): how will biota respond to a changing ocean?

Miloslavich

Abstract

Climate models all project concurrent alterations to multiple oceanic properties, due to the effects of anthropogenic climate change. These projections are supported by a growing body of ocean observatory evidence demonstrating simultaneous shifts in life-sustaining properties such as temperature, CO_2, O_2, and nutrients. Hence, a major challenge for marine sciences is to determine the cumulative effects of such interactive and widespread alterations of oceanic conditions on organisms, communities and ecosystems. This challenge is multi- faceted, and research must advance in parallel to tackle three major themes: effects of multiple environmental drivers on the performance of individual organisms; community and foodweb responses to complex ocean change; and timescales of biological responses to climate change.

Consequently, we urgently need to develop a new generation of studies based on methodology that will allow us to progress from:

- **Single to multiple environmental drivers**
- **Organismal to community and ecosystem level responses**
- **Transient acclimation physiology to long-term adaptation and evolution.**

This proposed SCOR working group will build strong transdisciplinary linkages to facilitate the design and development of a framework of experiments, observations, and conceptual/mathematical models to evolve each of these themes. This multi-thematic approach will provide a platform for the next generation of scientists to conduct rigorous inter-related research and to further refine this approach as new technologies emerge. The working group will also target how to develop powerful tools to convey the major research findings of this complex topic as directly and simply as possible for decision-makers in the marine realm.

Background and Rationale

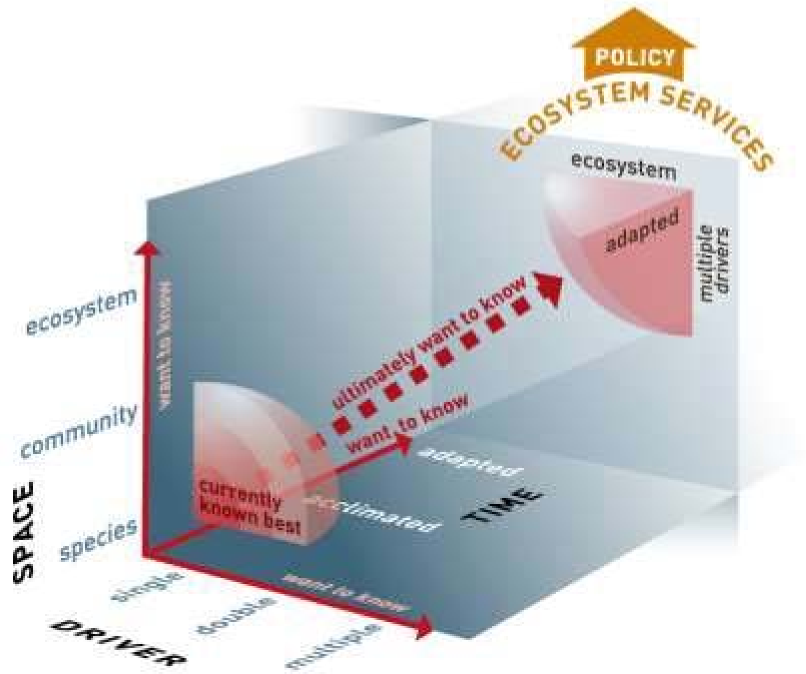

Figure 1 Present state of knowledge on Changing Ocean Biological Systems: most information on the impacts of ocean change presently available is on acclimated single species/strains under the influence of a single driver (lower left corner). Red arrows indicate the direction where we must expand our understanding. Assessment of impacts on ecosystem services, leading up to science-based policy advice, requires information on adapted responses to multiple drivers at the ecosystem level (upper right corner). From Riebesell and Gattuso (2015).

Theme 1: From single to multiple drivers

Experiments manipulating climate-related variables have provided valuable insights into the wide range of biological responses to projected alteration of oceanic conditions, for example ocean acidification (Gattuso and Hansson, 2011; Hutchins et al. 2013) or warming (Boyd et al., 2013). The design and interpretation of these single-driver manipulation experiments, in which a range of altered conditions – such as 550, 750 or 1000 µatm pCO_2 - are compared and contrasted with a control treatment (present day 400 µatm CO_2) – have been relatively straightforward. Since 2010, increased awareness across the marine science community of the complexity of the many concurrent changes to future ocean conditions (Doney, 2010) has resulted in more studies manipulating several environmental drivers concurrently. For example, one third of the 225 papers at the 2012 SCOR-sponsored symposium on "The Ocean in a High-CO_2 World" which reported on the biological response to Ocean Acidification (OA) also manipulated at least one other property (Cooley, 2012). Cooley reported a wide range of permutations of multi-driver perturbation experiments, for example pH and temperature, or CO_2 and nutrient manipulations. Figure 2 provides estimates of the number of studies which looked at multiple drivers (acidification plus at least another one) and how this trend has developed with time.

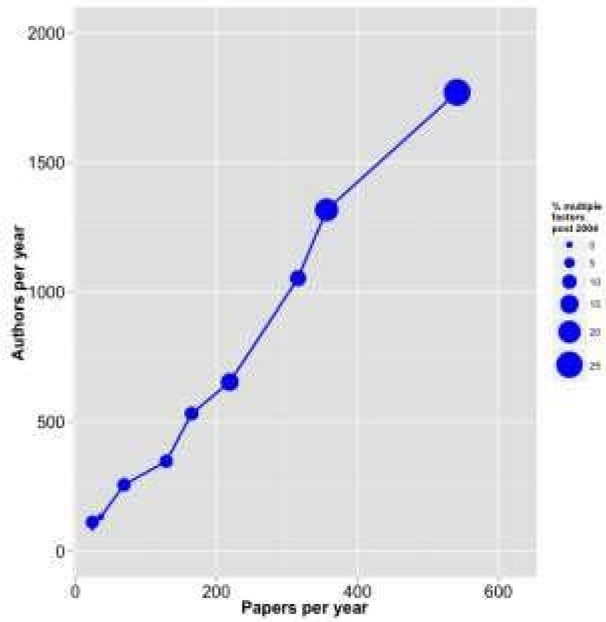

Figure 2 Increase in the number of papers focusing on both ocean acidification and other environmental drivers. Data courtesy of Jean-Pierre Gattuso, from a bibliographic database arranged with the Ocean Acidification International Co-ordination Centre (OA-ICC).

There has been a growing realisation that the experimental outcomes of such multi-driver experiments may not simply be additive and some are therefore highly non-linear, so their interpretation is exponentially more challenging than for single driver experiments (Figure 3).

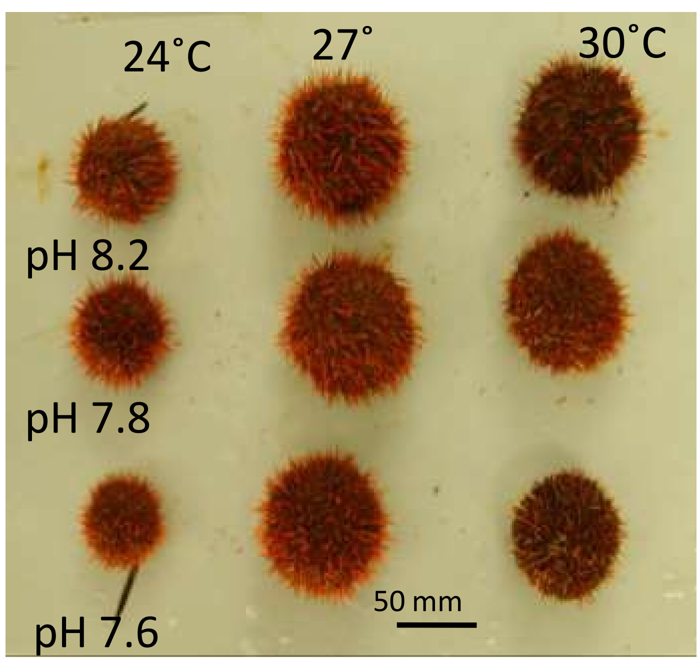

Figure 3 An example of the complex interplay of multiple environmental drivers on marine life. Temperature and pH both had a significant effect on growth of this sea urchin.

Acidification reduced body size and warming mitigated this effect. Image - courtesy of Maria Byrne (University of Sydney, Australia).

Moreover, the results of the warming and acidification manipulation study on the sea urchin presented in Figure 3 highlight several important issues that have both direct scientific and wider policy ramifications. First, the effects of multiple drivers can offset or magnify one another, and so provide a different outcome than could be predicted from the results of a single-driver experiment. Second, the outcome of a multiple-driver experiment depends heavily on the selection and magnitude of the individual drivers being combined. Third, accurate communication and predictions of the collective effects of multiple drivers on marine life to policy makers requires consensus (in experimental trends) across a representative number of multiple-driver experiments.

Hence, to provide more reliable estimates of how marine biota will respond to the cumulative effects of multiple drivers requires that we develop comprehensive approaches/studies that progress from single to multiple environmental drivers.

Theme 2: From organisms to ecosystems

The findings from even sophisticated multiple-driver experiments on organisms, such as phytoplankton, that occupy a single trophic level in a foodweb cannot be used to predict how entire ecosystems will respond to complex ocean change (Boyd et al., 2010; Caron and Hutchins, 2013). The components within a foodweb, such as predators and their prey, may respond in very different ways to the same changing ocean conditions. For example, the physiology of microzooplankton (grazers) is more responsive than that of their prey (phytoplankton) to warming (Rose et al., 2009). Hence, as is evident for the previous theme, there has also been progress in the last five years in transitioning from an organismal to an ecosystem-level view of how marine life responds to global change (Brose et al., 2012).

There has been increased use of mesocosms (large volume, 1000 L or more, enclosures, Figure 4) to examine marine pelagic ecosystems in coastal and most recently oceanic waters, which has provided valuable information on the responses of the organisms that occupy trophic levels across foodwebs (Calbet et al., 2014). These mesocosm studies provide unprecedented detail on how ecological and biogeochemical processes will be altered by ocean change. This approach has also opened the door for implementing experimental evolutionary biology approaches in natural systems (Scheinin et al. 2015). Other ecosystems, such as those in benthic nearshore waters (from the tropics to the polar oceans) have also been examined via mid-term (months) deployments of innovative large volume (1000 L) experimental chambers such as Free Ocean CO_2 Enrichments (FOCE) (Gattuso et al., 2014). Both mesocosms and FOCE enable multiple large-scale multi-disciplinary marine manipulation experiments that detail both ecological and biogeochemical responses to environmental change (Figure 1).

Figure 4 Large volume mesocosms of 20 m depth deployed in the Raunefjord, Norway to investigate the impacts of ocean acidification on pelagic communities (photo: Solvin Zankl, GEOMAR, 2015)

Although these large volume holistic approaches are advancing this theme, they do have limitations, such as the logistical challenges presented in manipulating more than a single driver (Figure 4). This illustrates the need to build strong cross-links with theme 1 which can more readily tackle the effects of multiple drivers. Thus, an approach such as modelling that facilitates integration of organism to community and ecosystem levels responses is urgently needed.

Theme 3: From Acclimation to Adaptation

Virtually all manipulation experiments, whether based on single- or multiple-driver experiments with organisms, communities, or ecosystems, have not considered the potential for adaptation to influence the outcome of the study (Schaum et al., 2014). In order to detect a measurable response to environmental manipulation, such experiments are primarily conducted using climate change projections for the year 2100, and thus represent a quasi- instantaneous alteration of environmental conditions, for example, increasing pCO_2 from present day (400 µatm) to 750 µatm (projected in some climate change IPCC scenarios for year 2100) on a timescale of hours to days. Such an experimental design cannot take into account the abilities of the study organisms to acclimate (days to weeks) or adapt (longer timescales) to alterations of oceanic conditions that occur incrementally over years or decades. Adaptation via micro-evolution for rapidly reproducing organisms such as microbes has been shown to occur on shorter timescales (<1000 generations, years) than previously thought (Lohbeck et al., 2013, Hutchins et al. in press), revealing the ability and indeed the need to consider evolutionary responses in global change experimental design (see Figure 1).

Hence, failure to more accurately mimic the ability of organisms to respond to environmental change in manipulation experiments may give a series of misleading experimental outcomes which could skew predictions of how organisms, communities and/or ecosystems will response to changing oceanic conditions. Thus, this third theme must be interwoven into themes 1 and 2, such that a subset of experiments considers adaptation in their design.

Terms of Reference (TOR)

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) Build an interactive website on 'multiple drivers and marine biota' to ensure the long-term future and inter-connectedness of this international research community, and to provide educational information at a variety of levels.

7) 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.

8) 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.

Working plan

The TOR will each be fulfilled as action items between and/or during WG meetings. We will run each meeting alongside conferences that will be well attended by WG members including Oceans in a High CO_2 World (May 2016), the Ocean Global Change Biology Gordon Research Conference (GRC, July 2016, 2018), and other venues – AGU/EGU meetings to minimise travel costs.

Year 1

The proposed WG will focus on TOR 1/2 to develop the point of departure for this WG (i.e. assessment of the status of emerging research themes), and to build a research community (better alignment and integration of research themes).

Specifically we will use the IPCC AR5 2014 marine chapters as a platform to assemble this Review (TOR 1). To 'kick-start' this WG, the Chair will initiate this Review so that a draft can be circulated to stimulate discussion at our inaugural meeting.

Efforts to initiate better alignment and integration of research efforts will commence early in year 1 by surveying different research communities (outlined in Figure 1) through customized questionnaires such as SurveyMonkey (https://www.surveymonkey.com/) that have been used previously by Boyd/Hutchins. Surveys will enable the WG to identify which meetings different researchers attend (e.g., experimental evolutionary biologists), that will help to assess the suitability of conferences (GRC, EGU, AGU) to bring together many different marine scientists.

At our first WG meeting, the design of customized questionnaires (akin to those used for the IPCC ocean acidification special report, Gattuso et al., 2013) will be discussed so they can be circulated (via the Web) at the end of year 1 to identify experts from other fields (e.g. marine ecotoxicology) to learn from their approaches to multiple drivers (TOR 2/3).

Year 2

We will build on our initial activities, in particular to co-ordinate thematic transdisciplinary sessions (TOR 3) and to develop a Best-Practice Guide (BPG, and/or other tools) for COBS. These discussions will commence at the 2nd WG meeting (end of year 1). We will target transdisciplinary workshops such as GRC/GRS (Gordon Research Symposia for early career researchers) which regularly attract a diverse range of speakers from paleoceanography to ecotoxicology (TOR2).

Based on the experiences of Riebesell/Gattuso in preparing and updating the Ocean Acidification BPG (Riebesell et al., 2010), this WG proposes to proceed in a more innovative and flexible way – via wiki books (http://www.gms-books.de). This approach can involve many contributors, leading to a better product that could be launched initially with a few chapters and expanded later. Furthermore, updates would be relatively straightforward to implement.

The synthesis of these findings will help guide us as to the timeline for developing BGP wiki books that will commence towards the end of year 2.

Year 3

The main goals (in addition to adding further value to earlier TORs that will be fulfilled, partially or wholly in years 1/2) will be to run a 'hands-on' training workshop that targets primarily early career scientists (TOR 5) and to build the interactive website (TOR 6). This will be done in conjunction with the capacity building activity of the Ocean Acidification International Coordination Center which organizes several training courses worldwide annually.

The workshop will train researchers, and in particular early career researchers (ECRs), in the design of complex multiple driver manipulation experiments. It will also familiarize them with BPG, and assist with development of skills needed for analysis of their experimental findings. The WG will bring together a diverse range of skillsets (physiology, -omics, bio- statistics, evolution, food webs, ecosystems, mesocosm 'engineering', chemistry, remote- sensing and modellers) to build a workshop programme. To make the most of the assembled interdisciplinary talents, the WG will seek co-funding from national and foundation science fundingagencies to expand the scope of this workshop and maximise the participation of ECRs. We will align this workshop with a WG meeting to further enhance the interactions between the WG, other experts and the workshop participants. Our ability to raise additional funding will also determine whether we run this workshop once or twice during the WG's four-year tenure.

The interactive website (TOR 6) will ensure the long-term future and inter-connectedness of this international research community, and provide educational information from school- leavers to postgraduate. It will also provide live links to prior TOR's such as 1 (the state-of-the-art review) by updating bibliographies of new research, emerging policy documentation, and be a repository for topical popular articles.

In addition, the website will list international contacts and national programmes that are aligned with this research network, publicise up and coming events, workshops and conferences, and ensure that these activities and the capacity build during the lifetime of the WG continues to thrive beyond this WG.

Year 4 and looking beyond the lifetime of the COBS WG

The final TORs will be fulfilled in year 4, and together with some of the prior TOR's will provide a range of flexible tools and approaches that up-and-coming ECRs (from TOR 5 workshops) as well as established scientists can build upon, ensuring the longevity of this research theme, that will be required for at least a decade (Riebesell and Gattuso, 2015).

We will publish articles (research and popular) in both the scientific media and with scientific journalists to disseminate the issues surrounding multiple drivers and marine ecosystems. Articles will include a thematic section in an open-access journal such as Marine Ecology Progress Series. Popular articles will be contributions to the media, as well as the product of discussions/advocacy with journalists at magazines including Scientific American. The website will integrate these approaches and make further links to a new generation of scientists and environmentalists who increasingly use social media to disseminate their research and scientific opinions.

The website will help to build strong relationships with policy-makers and science communicators to produce a glossary of terms and a practical implementation guide for policy-makers (similar to the IOC/UNESO ocean fertilization guide) to better understand the role of multiple drivers in altering marine ecosystem services. 8 TOR will link to IPCC AR6 (due 2020) individual chapters, and assist with Executive Summaries and other IPCC products.

Deliverables

TORs 1 and 2: Communicate this state-of-the-art as a Synthesis paper to an open-access journal (end of year 1). This Review paper will contribute to IPCC AR6 cycle.

TORs 2 and 3: Co-ordinate thematic transdisciplinary sessions at international conferences to attract and assemble experts from fields such as paleoceanography and marine ecotoxicology. Produce a short popular article on this topic in an open-access journal (end of year 2).

TOR 4: Produce a BPG or equivalent tool(s) for COBS such as wiki books in conjunction with Copernicus/EGU (end of year 4)

TOR 5: Establishment of a new training course for young scientists moving into this field, with the intention of this becoming an annual or semi-annual event for the foreseeable future (years 3, 4, and beyond).

TOR 6: Build and maintain an interactive website focused on new approaches to multiple- driver research themes for document and methods collation, open forum discourse, and communication and outreach activities. Actively seek web co-ordinators and a host institution beyond the life of this WG.

TOR 7: Publish a transdisciplinary thematic series in an open-access journal such as MEPS. Publish a range of articles in both the popular scientific media and with scientific journalists to disseminate the challenges and opportunities surrounding multiple drivers and marine ecosystems.

TOR 8: Policy outreach via the production and dissemination of a clearly written, non- technical guide for marine resource managers and policy managers that includes a glossary of terms and a practical set of recommendations for predictive management of marine multi- driver impacts.

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

Given the need for long-term (i.e., well beyond the lifetime of a 4 year WG) and sustained international research into how biota will respond to a changing ocean, we have in part detailed some of our longer term aspirations in our working plan under the section “Year 4 and looking beyond the lifetime of the COBS WG”.

The combination of training workshops for early career scientists (TOR 5), online publication of a COBS BPG as wiki books (TOR 4), and of succession planning (TOR 6) beyond the lifetime of the proposed COBS WG will ensure the following:

a) A new generation of scientists, from an wide range of countries, with comprehensive skillsets to further evolve the field of COB, and to meet the challenges that lie ahead in better understanding how ocean biota will respond to changing ocean conditions.

b) A series of interactive guidelines (wiki books on a multiple drivers BPG) that can be readily updated and accessed on line by the emerging international community of both established and emerging early career researchers.
c) An interactive website that will continue to act as a repository for new information and emerging initiatives that the international community can focus on.

The wide range of products from this WG from popular articles (TOR 7) to tools for policy analysts (TOR 8) will raise awareness on this issue from schools through to Governments. Such enhanced awareness will provide a platform for further engagement with a new generation of scientists, and the publications from the COBS WG will act as benchmarks that will be updated and improved over the coming decade.

The provision of synthesis products (TOR 1 and 2) will feed into landmark widely-read publications such as IPCC AR6 (due in 2020) and beyond 2020 provide a "point of departure'' for other IPCC cycles. The outreach fostered by this WG will also provide important links into emerging and multi-faceted organisations such as Future Earth.

Working Group composition

Full Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Philip Boyd (chair)	Male	Institute for Marine and Antarctic Studies, Australia	Phytoplankton and multiple drivers
2 David Hutchins	Male	University of S. California, USA	Global change and ocean biogeochemical cycles
3 Jean-Pierre Gattuso	Male	University of Paris, France	Foodweb responses to ocean acidification and warming
4 Ulf Riebesell	Male	IFM-GEOMAR at University of Kiel, Germany	Pelagic foodwebs and mesocosm enclosures
5 Christina McGraw	Female	University of New England, Australia	Chemical engineering and experimental design
6 Sinead Collins	Female	University of Edinburgh, UK	Experimental evolutionary biology
7 Aurea Ciotti	Female	Centro de Biologia Marinha (CEBIMAR), Universidade de São Paulo, Brazil	Detection of phytoplankton functional types from Space
8 Marion Gehlen	Female	CNRS-LSCE-IPSL-CEA, France	Biogeochemical modeler, co-chair e Marine Ecosystem and Prediction Task Team

9 Jorge Navarro	Male	Marine Science Institute, Austral University of Chile, Chile	Climate change and marine bivalves
10 Kunshan Gao	Male	Xiamen University, China	Multiple drivers and their interactive effects on ocean biota

Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Hans-Otto Pörtner	Male	Alfred Wegener Institute, Germany	Animal physiology and multiple drivers, IPCC AR5 Co-ordinating lead author
2 Graham Bell	Male	McGill University, Canada	Evolutionary rescue and climate change
3 Gorann Nilsson	Male	Biosciences, Univ. of Oslo, Norway	Fish dynamics and climate change
4 Marcello Vichi	Male	Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy	Climate change modelling
5 Uta Passow	Female	Univ. California Santa Barbara, USA	Climate change and the oceans biological pump
6 Katharina Fabricius	Female	Australian Institute of Marine Sciences, Australia	Natural laboratories to study multiple drivers (vent systems)
7 John Havenhand	Male	University of Gothenburg, Sweden	Biostatistics and experimental design
8 Haruko Kurihara	Male	University of the Ryukyus, Okinawa, Japan	Impact of ocean change on marine invertebrates
9 Sam Dupont	Male	University of Gothenburg, Sweden	Coastal communities and multiple drivers

Working Group contributions

Together, the full members bring a wide range of expertise that ranges from multiple driver lab and field manipulation studies, evidence of biological responses to a changing ocean (from satellites), environmental sensor design, experimental evolutionary biology, and mathematical modelling.

Philip Boyd (Australia, Chair). Boyd is a Professor in Marine Biogeochemistry whose research focusses on the influence of multiple drivers on pelagic ecosystems. He was a lead author on the Ocean systems chapter of the IPCC AR5 report and will chair the 2016 Gordon Research Conference on Ocean Global Change Biology.

David Hutchins (USA). Prof. Hutchins has expertise in how global change affects marine biology and carbon, nutrient and trace metal biogeochemistry. His most recent work has examined evolutionary responses of phytoplankton to ocean acidification and warming, and he served as chair of the first Ocean Global Change Biology Gordon Conference in 2014.

Jean-Pierre Gattuso (France). Is a field leader in the study of multiple drivers and their effects on coastal marine communities using innovative experimental systems. He led the seminal European Project on OCean Acidification (EPOCA) for four years.

Ulf Riebesell (Germany). Prof. Riebesell's research aims to address physiological, ecological, biogeochemical and, in recent years, evolutionary responses to ocean change. He combines approaches ranging from single species lab experiments to large-scale mesocosm studies on natural plankton communities.

Christina McGraw (Australia). Dr. McGraw is a chemical engineer who is a field-leading innovator in the design of experimental manipulations uystems (ocean acidification under trace metal clean conditions. She is currently working on the design of novel sensors for multiple driver research.

Sinead Collins (UK). Dr. Collins is one of the pioneers of experimental evolutionary global change biology. Her expertise thus crosses disciplinary boundaries from evolutionary biology to marine science.

Aurea Ciotti (Brazil) Dr. Ciotti is a field-leading optical oceanographer who studies the remote sensing of phytoplankton communities in order to better assess how changing ocean conditions are altering community structure. She is a member of the International Ocean- Colour Coordinating Group.

Marion Gehlen (France). Dr. Gehlen is a renowned modeler focusing on global ocean biogeochemical processes in a changing climate. She is currently co-chair (along with Katja Fennel (Canada) of the Marine Ecosystem and Prediction Task Team.

Jorge Navarro (Chile). Professor Navarro is a leading researcher on the impact of ocean changes on commercial bivalves such as mussels. His multi-driver research has targeted larval to adult bivalves to assess which part of the life cycle is most susceptible to changing ocean conditions.
Kunshan Gao (China). Prof. Gao is recognized as the leading authority in China on ocean acidification and primary producers, including both microplankton and macrophytes. His

recent work has focused on understanding the responses of phytoplankton to multi-variate climate change processes.

Relationship to other international programs and SCOR Working groups

The proposed working group will provide much needed linkages across a range of national programmes that are focusing on various aspect of multiple drivers, such as those investigating ocean acidification (BIOACID, Germany, www.bioacid.de/ ; UK Ocean Acidification Research Programme (UKOA) www.oceanacidification.org.uk/), the wider ramifications of aspects of multiple drivers on biogeochemistry (US Ocean Carbon Biogeochemistry, www.us-ocb.org/) or ecology (Japanese NEOPS (The New Ocean Paradigm on its Biogeochemistry, Ecosystem, and Sustainable Use), ocean.fs.a.u- tokyo.ac.jp/index-e.html). Other invaluable relationships will be formed with organisations such as the Ocean Acidification International Coordination Center, whose prior experience in running training workshops will help our proposed WG to excel in achieving our TOR #5.

At the international level, our SCOR working group will also liaise with other initiatives such as the recently established Gordon Research Conference (and Gordon Research Symposium for early career scientists) on Ocean Global Change Biology (for details of the inaugural July 2014 meeting see https://www.grc.org/programs.aspx?id=15855; for the 2016 GRC and GRS see https://www.grc.org/conferences.aspx?id=0000771). Several of the proposed full members of this WG are active participants in organizing the 2016 meeting.

Proposed full members also have strong linkages to other international programmes that have begun to focus some of their efforts on the field of multiple environmental drivers and marine biota. These include SOLAS (Surface Ocean Lower Atmosphere Study) which has identified "Multiple stressors and ocean ecosystems" as one of eight themes as part of their 2015-2025 research plan (http://www.solas-int.org/about/future_solas.html). Boyd has strong links with the SOLAS programme. Multiple drivers has also been the focus of the IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) programme which is holding a workshop on "Marine and human systems - Addressing multiple scales and multiple stressors" In late 2015 (http://www.imber.info/). Both Gattuso and Riebesell have long established links with the IMBER programme.

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

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2.2.5 A Functional Trait Perspective on the Biodiversity of Hydrothermal Vent Communities (FDvent) *Burkill*

Abstract: Species diversity measures based on taxonomy, and more recently on molecular data, dominate our view of global biodiversity patterns. However, consideration of species functional traits, such as size, feeding ecology and habitat use, can provide insights into biodiversity patterns by representing how communities contribute to ecosystem processes. Moreover response traits, characteristics linked to how species respond to environmental change, have been linked to the processes underpinning community recovery following disturbance. We propose identifying functional traits for the global vent species pool to provide the first quantification of spatial and temporal patterns in functional diversity in this unique ecosystem. We will use expert knowledge and a literature review to identify both effect and response functional traits, and retrieve data for diverse macrofaunal and meiofaunal taxa. Our aim, given that trait-based measures provide a means to directly compare communities with species arising from different evolutionary trajectories, is to test whether vent communities from different biogeographic provinces display functional convergence while accounting for the geological and chemical settings. We will further test for change in functional diversity following the formation of new vents and disturbance events. This knowledge is critical for environmental management, given that hydrothermal vents are presently targeted for mineral resource exploitation by 2017. Our proposed working group will build an open-access traits database and offer a novel perspective on global biodiversity and succession patterns in vent communities. We will advance our understanding of the potential for functional diversity metrics to inform effective management and risk assessment guidelines at vents.

Scientific Background and Rationale

Why Functional Diversity? Most studies of biodiversity patterns and assemblage change focus on species. Even so, while some species may be very similar, others may differ markedly in their morphology, behavior, and ecology, and play different roles in a community and, ultimately, ecosystem function. Therefore functional trait approaches offer a means to distinguish differences in how species interact with their environment and other species (Lefcheck et al. 2015). Functional diversity (FD) metrics integrate the total variation in functional traits across all species within a community, providing an important perspective to diversity that complements patterns gained from taxonomic diversity measures (Faith 1996, Stuart-Smith et al. 2013).

Changes in community processes that are linked to functional traits are, in some cases, more important than changes in the species present, such as when understanding the implications of community responses to disturbance is of interest. Community processes may also be more predictable in comparison to traditional taxonomic approaches (Suding et al. 2008), as well as being a more sensitive measure of community change (Coleman et al. 2015). Therefore, using trait-based methods to characterize community dynamics provides a means to examine functioning-related consequences to community processes following both natural and human-related disturbances.

Functional trait ecology and statistical tools are also rapidly evolving to consider changes in community function driven by local diversity (alpha diversity) and variation of community composition through space (beta diversity). Thus a functional trait perspective will allow us to identify those species that play an important role in maintaining local functional diversity, sites that contribute in exceptional ways to beta diversity, and drivers of significant temporal trends at different spatial scales.

Why Hydrothermal Vent Communities? Functional trait methods have largely been developed using plant assemblages (although functional trait approaches are presently being widely applied) where characteristics that define species in terms of their ecological roles and interactions are direct indicators of ecological process and function. For instance, there is a strong link between leaf traits (e.g., size), plant growth and primary production through photosynthesis. In a similar way, symbiont-hosting invertebrates are dependent on access to hydrothermal vent fluids, which deliver reduced compounds such as hydrogen sulfide or methane, used by microorganisms as an energy source for the synthesis of organic molecules. Animals that host bacterial symbionts have specialized morphological traits including enlarged tissues where bacteria are located, and thus there is a direct relationship between the size and shape of chemosynthetic animals and ecosystem processes, such as primary productivity. Hydrothermal vent ecosystems are therefore particularly compelling conceptually for analysing functional diversity patterns in both time and space. However, a functional trait approach has not yet been attempted in these communities.

The timing and geometry of ancient plate boundaries have shaped the distribution of hydrothermal vent communities which group into distinct biogeographic provinces (e.g., Tunnicliffe & Fowler 1996, Bachraty et al. 2009, Moalic et al. 2011). Vent species therefore differ among vent fields and plates and cannot be compared at a global scale using taxonomic differentiation measures. However, trait-based approaches provide a means to compare communities comprised of different species. Although functionally equivalent species may be present in different vent provinces, it remains an open question whether vent communities have a similar functional composition and structure, although their phylogenetic origins differ. By quantifying global patterns in vent functional diversity we will answer this question and further test whether large-scale differences in physical factors (such as depth) relate to functional diversity patterns (Ramirez-Llodra et al. 2007).

Conservation of hydrothermal vent ecosystems is a growing concern as exploitation of massive sulfide deposits is planned for 2017 in Papua New Guinea and exploration licenses have been issued in both state and high seas vent systems. The strong association of vent ecosystems with the target high-grade ores has focused attention on the risks and the lack of management frameworks to assess potential impacts and devise mitigation (Van Dover 2010, Boschen et al. 2013, Collins et al. 2013). As the International Seabed Authority considers management frameworks for high seas extraction (ISA 2015), our proposed SCOR Working Group (WG) will make considerable progress with a focus on ecosystem function using functional diversity measures to complement taxonomic and molecular approaches.

Functional traits have the potential to offer new insights into how we prioritize, assess risk, and develop conservation and management strategies for these unique ecosystems at local, regional and global scales. We will identify functional traits that are expected to respond to habitat disruption, and test for change in these metrics following formation of new vents, replicated at different sites (e.g., Mid-Atlantic Ridge, East Pacific Rise and Juan de Fuca Ridge) where time-series community data have been collected (e.g., Marcus et al. 2009,Mullineaux et al. 2012, Cuvelier et al. 2014). What we propose is, therefore, a direct analogue of the classical ecological experiment with replication, but one that has been conducted at an appropriate scale for improved global management understanding.

The potential for new ecological understanding gained from analysis of functional diversity at vents to inform global conservation and management policy is great, however a rigorous traits database has yet to be collated for the global vent fauna. We will bridge this gap to build an open-access functional trait database that can be updated as new species and areas of hydrothermal activity are discovered, and can also be extended to include additional chemosynthetic systems such as cold seeps and whale falls.

Terms of Reference

We have assembled an international and interdisciplinary team to:

1. Synthesize species lists for each hydrothermal vent ridge and volcanic arc system by updating and error checking previously collated databases (e.g., Chemosynthetic Ecosystem Science, ChEss: http://chess.myspecies.info) so that we have the most up-to-date species database incorporating newly discovered areas of hydrothermal activity (e.g., Rogers et al. 2012).
2. Identify key functional traits including i) effect traits: traits related to how species influence ecosystem processes, and ii) response traits: traits that we would expect to influence the magnitude, direction and how quickly species respond to environmental change or a disturbance event (Díaz et al. 2013). Given that one of the main and unresolved challenges in the field of functional ecology is the selection of traits that relate to ecological processes and ecosystem functioning (Lefcheck et al. 2015), we will formulate a conceptual framework describing our rationale for inclusion of each functional trait.
3. Use expert knowledge and the literature to parameterize a functional traits database for hydrothermal vent fauna.
4. Apply macroecological analyses to map functional diversity in vent systems and test hypotheses regarding the mechanisms underpinning spatio-temporal patterns in functional diversity, using the best numerical methods to analyze trait-based alpha and beta diversity.
5. Identify functional traits that may have relevance for conservation and management objectives given possible exploitation of deep-sea sulfide deposits and provide guidelines for incorporating functional trait approaches into risk assessment procedures.

Working Plan

Our team includes experts in geochemistry, oceanography, biology, ecology, biogeography, statistical ecological and network modeling, and spans highly experienced senior researchers through to early career researchers. We are thus building international capacity to develop a comprehensive functional traits database and ask ecological questions that are fundamental to building ecological and applied theory. We will achieve our terms of reference though three workshops.

The first workshop "*FDvent: A functional traits database for hydrothermal vent fauna*" will be hosted [early 2016] at the National Oceanography Centre, Southampton, UK. Prior to the workshop, WG members will have produced an updated global species list for vents. We will use the first days of the workshop to identify traits for inclusion in the global database, with the aim of contributing to ongoing efforts to collate functional trait data in a standardized and accessible format (to both humans and computers) and integration with trait information from other taxa (e.g., EMODnet: http://www.emodnet-biology.eu/, Encyclopedia of Life, Traitbank: http://eol.org/info/516, FishBase: www.fishbase.org, Polytraits: (Faulwetter et al. 2014), TRY: http://www.try-db.org).

We will focus on a mixture of effect and response traits that shape ecosystem structure and function, as well as mediating how species respond to environmental changes, such as physiological niche, body mass, generation length, trophic level and reproductive strategy. We will also consider whether species are endemic to vents and their relative dispersal abilities – traits likely to influence species responses to disturbance.

In the second and third days of the workshop we will fill in our traits matrix using the taxonomic literature, to be supplemented as required from museum collections, and the collections of the workshop team. Bringing experts together to represent hydrothermal vent fauna from each ridge system and different taxa will lead to efficient collection of these traits from the literature and allow gaps of knowledge to be filled using expert opinion. Moreover, approaches to missing data have been developed that we can apply, such as the use of imputation methods for ranking of communities on the basis of their functional diversity indices (Taugourdeau et al. 2014). We will further use hierarchical Bayesian analysis to infer values based on those of closely related species, which allows (1) quantitative data-driven assessment of the lowest level in the taxonomic hierarchy at which a significant proportion of the variation in species-level values is explained and (2) quantification of uncertainty so that values in derived analyses can be weighted to reflect confidence (e.g., Fazayeli et al. 2014) which can be compared to expert estimates.

As a group we will also explicitly consider the sources of error and bias in cross-ecosystem and cross-taxa estimates of traits that can be incorporated in our modeling frameworks (e.g., greater inaccuracy for some taxa or between sampling methods). Defining these issues will then allow us to present solutions, such as modeling sampling variability independently between regions or using machine learning approaches which are not constrained by probabilistic assumptions about the distribution of the response.

The second workshop will be hosted [early 2017] at the University of Victoria, Canada: "*Global patterns in the functional diversity of hydrothermal vent communities*". We will take the functional traits matrix developed in the first workshop to link functional diversity patterns among biogeographic provinces with physical data (e.g., ridge spreading rate, ocean depth, fluid chemistry) to identify patterns, possible drivers and potential processes underpinning the functional diversity of vent communities at large spatial scales. Functional diversity reflects the value and range of traits that influence ecosystem function and thus is not captured in a single measure. We will therefore use community-weighted mean trait values, as well as functional richness, dispersion and redundancy (Mouchet et al. 2010, Laliberté et al. 2014). We will use a variety of approaches including methods to test for trait-environment relationships, e.g., fourth-corner method (Dray and Legendre 2008), generalized and linear mixed effects modeling, and network theory (Moalic et al. 2011, Lindo 2015). We will also extend recently developed tools in community ecology such as local contributions to beta diversity (LCBD indices) to the study of functional trait ecology (Legendre & Gauthier 2014). Our aim is to provide a creative opportunity for our team to explore and model the data using different methods at a range of spatial scales, as well as to brainstorm ways of conceptualizing the data.

The third workshop entitled "*Using community responses to natural disasters and disturbance to guide conservation of hydrothermal vent communities*" will be hosted [early 2018, location to be announced pending the success of co-funding applications to assist associate members with travel costs]. Prior to the workshop our WG will synthesize time- series data from vents (e.g., Marcus et al. 2009, Mullineaux et al. 2012) and analyze trends in the functional diversity of the community. Our aim will be to identify functional traits that are expected to respond to habitat disruption, and test for sensitivity in these functional traits following formation of new vents or disturbance events, replicated at different locations. The workshop will therefore be a venue for our WG to discuss the application of functional traits to inform impact assessments of large-scale exploitation of sulfides and to explore the use of approaches such as temporal beta diversity indices (P. Legendre) and network modeling (S. Kininmonth). We will thus aim to develop a framework to explore how functional traits can inform the management and conservation guidelines for hydrothermal vents and publish our findings (open-access) in an international journal.

<u>Deliverables</u>

<u>Database</u>

- Deliverable 1: Our WG will release our functional traits database at the end of the project including up-to-date and accuracy checked species lists representing the world's vent systems, to be hosted on the InterRidge website (http://vents-data.interridge.org/), and distributed to the Oceanographic Biodiversity Information System (OBIS) database repository and the World Register of Marine Species (WoRMS, T. Horton, proposed associate member, is on the WoRMS steering committee).

Open-access peer-reviewed publications

- Deliverable 2: Our WG will describe the database, our rationale for inclusion or exclusion of particular traits, and a reproducible example for our methods to estimate missing trait data. We will publish these details and the database in a scientific data journal (e.g., Scientific Data) so that the database will be associated with a DOI.
- Deliverable 3: We will accomplish the first macroecological analyses of functional diversity patterns in hydrothermal vent systems, and target our findings for a high-impact, open- access journal.
- Deliverable 4: We will conduct an analysis of functional time-series following catastrophic events and disturbance at hydrothermal vents, and target our findings for a high-impact, open-access journal.
- Deliverable 5: We will publish management and risk assessment guidelines for hydrothermal vent communities based on functional traits for publication and dissemination to policy makers.

Capacity Building

A downloadable, searchable, and freely accessible functional traits database product (FDvent) that will also be published in a static, open-access format (target journal: Scientific Data) will be an important resource. We will ensure compatibility with other database schemas and metadata (e.g., EMODnet, Encyclopedia of Life, and Traitbank). FDvent will provide a basis upon which we can expand in future proposals to include other chemosynthetic communities, such as hydrocarbon seeps and organic falls (e.g., large mammal carcasses, wood). The FDvent database will also be a resource that will allow these unique ecosystems to be included in global analyses comparing different ecosystems to develop ecological theory.

Building FDvent will further allow us to develop proposals to produce more accessible data that is fit for purpose. For instance, Microsoft Research (http://research.microsoft.com/en-us/labs/Cambridge/) offers funding to make biodiversity and functional trait data available in different formats, tailored to a variety of purposes including education, outreach, policy and science.

We will also actively involve early career researchers (full member: Alejandro Estradas, UNAM, Mexico) and invite PhD students to contribute to the working group meetings and to run analyses with the FDvent traits database (Abbie Chapman, NOCS, UK, presently undertaking a PhD co-supervised by A.E. Bates and V. Tunnicliffe, and Rachel Boschen, NIWA, NZ, presently undertaking a PhD co-supervised by WG full member A.A. Rowden). Involving early career researchers will provide important training opportunities and spearhead functional trait ecology in chemosynthetic systems, as well as engaging early career talent in the SCOR process.

Working Group Composition

Full Members (in alphabetical order after the proposed SCOR WG chairs)

Name	Gender	Place of work	Expertise relevant to proposal
1. Amanda Bates (Co-Chair)	Female	University of Southampton, UK	Functional trait ecology, global biodiversity and conservation, hydrothermal vent gastropod biology
2. Verena Tunnicliffe (Co-Chair)	Female	University of Victoria, Canada	Deep-sea biodiversity and conservation, functional traits, Northeastern and western Pacific vent fauna
3. Alejandro Estradas-Romero	Male	Instituto de Geofísica, UNAM, Mexico	Mexican vent fauna, biological oceanography, diatom biology, chemosynthetic microorganisms
4. Andrey Gebruk	Male	P.P. Shirshov Institute of Oceanology, Russia	Deep sea bottom communities, Mid-Atlantic Ridge vents, trophic ecology of hot vent shrimps, functional traits
5. Ana Hilário	Female	University of Aveiro, Portugal	Reproductive ecology and biogeography of deep-sea ecosystems
6. Baban Ingole	Male	CSIR-National Institute of Oceanography, Dona Paula, Goa, India	Environmental impact assessment, conservation and management, Indian Ridge vent fauna
7. Pierre Legendre	Male	Université de Montréal, Canada	Functional diversity statistics, beta diversity indices, numerical ecology
8. Eva Ramirez-Llodra	Female	NIVS, Norway	Census of Marine Life project ChEss coordinator, reproductive ecology
9. Ashley Rowden	Male	NIWA, New Zealand	Biodiversity and conservation, Kermadec Ridge vent fauna
10. Hirome Watanabe	Female	JAMSTEC, Japan	Biogeography and biodiversity, western Pacific and Indian Ocean hydrothermal vents

Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
1. Stace Beaulieu	Female	WHOI, USA	Biodiversity, biogeography
2. Peter Girguis	Male	Harvard University, USA	Physiology and biochemistry of deep sea microorganisms, relationships between microbes
3. Tammy Horton	Female	NOC, UK	Amphipod taxonomy, functional traits, biogeography
4. Stéphane Hourdez	Male	Station Biologique Roscoff, France	Polychaete taxonomy, biology and ecology
5. Stuart Kininmonth	Male	Stockholm Resilience Centre, Sweden	Bayesian network modeling, global ecology
6. Jozée Sarrazin	Female	IFREMER, France	Biodiversity, impact assessment, Mid- Atlantic and Northeast Pacific Ridge vent fauna
7. Hans Tore Rapp	Male	University of Bergen, Norway	Taxonomy and systematics of marine invertebrates, Arctic Ridge
8. Ann Vanreusel	Female	University of Ghent, Belgium	Meiofauna, biodiversity and functioning

Working Group Contributions

- **Amanda Bates** will co-chair the WG meetings. Amanda did her PhD on the functional traits of gastropod species from the Juan de Fuca Ridge hydrothermal vents. She is a lecturer in macroecology where she works on developing functional trait metrics for conservation applications and global ecology.
- **Verena Tunnicliffe** will co-chair the WG meetings. Verena has been developing understanding of the biogeography of vent systems, community ecology, and species functional traits since their discovery.
- **Alejandro Estradas-Romero** will contribute knowledge of the shallow water vents in the Pacific. He has an interest in the ecology and functioning of microorganisms, phytoplankton ecology and biological oceanography.
- **Andrey Gebruk** will contribute to WG activities as an expert on hydrothermal vent fauna of the Mid-Atlantic Ridge, trophic ecology of hydrothermal vent shrimps and relationships between shallow and deep-water hot vent communities.
- **Ana Hilário** did her PhD on the reproductive ecology of siboglinid tubeworms from hydrothermal vents and cold seeps. Her research is focused in the reproductive ecology and larval dispersal of deep-sea invertebrates, and population connectivity and its implications for biogeography, and spatial planning and management.
- **Baban Ingole** is an expert on Indian Ridge vent fauna, seamount fauna, as well as Environmental Impact Assessment of Deep Sea mineral mining. He further has an interest in the diversity of meio- and macrobenthic species and functional traits for conservation applications.
- **Pierre Legendre** is an expert in numerical ecology, with special emphasis on the

variation of communities through space and time (beta diversity). An important component of his research is the development of quantitative methods to analyze multivariate ecological data. He has published papers on functional diversity indices.

- **Eva Ramirez-Llodra** was the Project Manager of the ChEss- Census of Marine Life project (2002-2010) investigating the biogeography of deep-water chemosynthetic ecosystems. She developed ChEssBase, is co-PI of the international INDEEP network for deep-sea research, and has expertise in biodiversity and reproductive studies of deep-sea ecosystems, including hydrothermal vents.
- **Ashley Rowden** has been developing an understanding of the vent biogeography of the New Zealand region, and its relationship to the vent biogeography of the western Pacific Ocean, through sampling of vent communities on the Kermadec volcanic arc. Ashley is also currently involved in a functional traits-based ecological risk assessment of deep-sea habitats, which includes an assessment of both vent and seep habitats.
- **Hiromi Watanabe** researches biodiversity, biogeography and population connectivity using genetic analyses as well as rearing experiments of embryos and larvae of deep-sea hydrothermal vent faunas in western Pacific and Indian Oceans. She will contribute expertise in reproductive and larval traits of vent species.

Relationship to Other International Programs and SCOR Working Groups

We will build upon the ChEss database (http://chess.myspecies.info) by collating species lists produced since 2010 and error-check the database (proposed full member, E. Ramirez- Llodra designed ChEssBase and co-coordinated ChEss). We will further take advantage of databases that are under development by our WG team (e.g., InterRidge, http://www.interridge.org, by S. Beaulieu).

Our WG will also embrace an open-data philosophy. For instance, WG associate member P. Girguis is presently the chair of DeSSC (Deep Submergence Science Committee, https://www.unols.org/committee/deep-submergence-science-committee-dessc) and he has been working to facilitate international collaborations and “open access” to data and metadata generated during US expeditions. Moreover, Girguis is on the advisory board for the Ocean Genome Legacy (http://www.northeastern.edu/cos/marinescience/ogl/), a non- profit marine research institute and genome bank dedicated to exploring and preserving the threatened biological diversity of the sea. The purpose of OGL’s collection of DNA blueprints (genomes) is to provide secure storage and broad public access to genomic materials, to create a forum for sharing samples, data and ideas, and to serve as a catalyst for research that can help to protect marine ecosystems and improve the human condition. OGL is willing to serve as an open access repository for new samples, and will provide any and all samples for SCOR WG members.
We will contribute understanding on the importance of ecosystem function with respect to deep-sea mining, and thus link to projects such as DOSI, Deep-Ocean Stewardship Initiative (WG members E. Ramirez-Llodra, A.A. Rowden, and V. Tunnicliffe sit on the DOSI advisory board). DOSI seeks to integrate science, technology, policy, law and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems (http://www.indeep-project.org/deep-ocean-stewardship-initiative).

We will further take advantage of any opportunties to develop cross-overs between the SCOR Working group on “Seafloor Ecosystem Functions and their Role in Global Process" through Prof. Ingole, who has been invited to attend the group’s first meeting in Naples, Italy (September 2015).

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2.2.6 Rheology, nano/micro-Fluidics and bioFouling in the Oceans (RheFFO) *Fennel*

Summary

Ocean water is a biofluid, thickened by exopolymeric substances (EPS) produced mainly by algae and bacteria. Locally, particularly at scales <~1 cm, this EPS has been shown to increase viscosity many-fold, and gives elasticity to the water. Some of this EPS occurs as sheaths and glycocalyxes around algae and bacteria, and are thought to be part of their ecological engineering strategy.

In the last ~15 years, superhydrophobicity (SH) has been discovered at hydrophobic, sculptured surfaces. SH is manifest by superhydrophic drag reduction (SDR) in surface layers up to several, µm thick. It also can promote strong repulsion of materials such as dirt and fouling organisms. Commercially available SH self-cleaning materials are now widely available, and are being developed for non-toxic ("green") antifouling coatings for ships, etc.

There is little awareness of these developments amongst the ocean-environment research community, and little understanding of the sciences underlying their development: namely rheology; nano/microfluidics (NMF), and the electrochemical bases of non-toxic antifouling mechanisms.

Swarming of protists and bacteria occurs, where concentration is much increased and synchronised swimming occurs, in which viscosity can be changed many-fold. *RheFFO* WG shall investigate such effects occurring locally in the oceans.

A principal object of this WG is to form a nucleus of scientists all literate in: (i) ocean sciences of pelagic ecology and biogeochemistry; (ii) rheology; (iii) surface science, including NMF and biofouling/antifouling mechanisms. The WG will thus have strong activities in capacity development (CD), from an interdisciplinary team of experts mainly to young scientists.

2. **Scientific Background and Rationale (1237/1250)**

2.1 Rheology

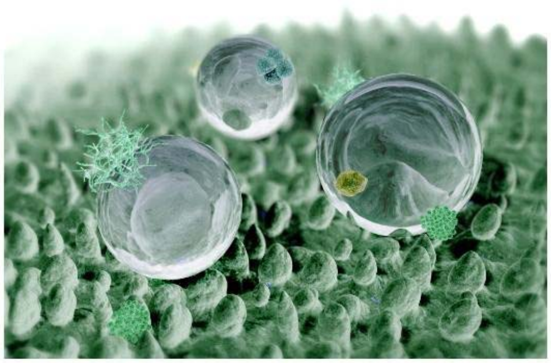
Left: Foam on the beach at Yamba, north of Sydney, Australia, produced from EPS, believed to be primarily secreted by Phaeocystis *sp. (c) Icon Images.*

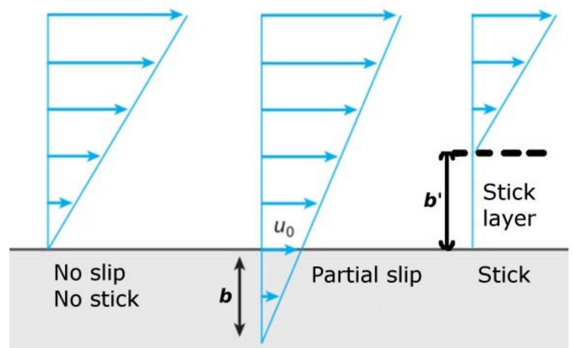
Right: Marine organic mega-aggregate during a mucus event in the northern Adriatic. Its form reflects deformation by a large turbulent eddy. From Stachowitsch et al. (1984, P.S.Z.N.I., Mar. Ecol., 5: 243-264).

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

2.2 Superhydrobicity (SH), antifouling and self-cleaning

Have you ever wondered how many algae keep so clean? Lotus leaves do it by having SH self-cleaning surfaces. Encounter and fouling of surfaces by plankton, including their larvae, take place largely in near-surface layers. Recent developments in "green" (i.e. non-toxic) methods of antifouling on ships (Wang et al., 2014), other marine structures and desalination membranes (Balzano et al., 2014) can be applied to investigate adhesion, recognition, and repulsion by plankton.





Left: Computer-enhanced image of SH leaf surface in air ((c) Julia Lauren Vasic on March 30 2008). Right: A fluid flowing over a surface. Left - standard model; middle SH tends to produce slipping; right - adsorption of ions or mucus tends to produce a "sticky" layer. b is slip length; b' is sticking length; u0 is slip velocity. b can range from nanometres to micrometres, or occasionally millimetres.

2.3 Nano/microfluidics

Recent developments in nano- and microfluidics, including "lab-on-a-chip", have shown that surfaces in fluids exert influence from nanometre to millimetre scale into the fluid. This concerns pico- to micro- plankton, including the sculptured surfaces of diatoms, the microfibrils around pro- and eukaryotes and the micrometre-scale feeding appendages of copepods and other zooplankton (Rothstein, 2010; Wong et al., 2011; Jenkinson, 2014). Most oceanographers are unaware of this.

2.4 Incorporation rheological measurements into models of ocean fluidics

GEOHAB (2011) posed the question, "How can we quantify modifications in turbulence by phytoplankton through changes in the viscosity of its physical environment?" At that time, the state-of-the-art (Jenkinson & Sun, 2010) was that viscosity η of seawater and freshwaters was composed of an aquatic component ηW due to water (and salts) plus an excess organic component ηE due mainly to EPS.

Total viscosity,

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

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

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

where k is a coefficient and P is an exponent, both related to phytoplankton-produced EPS concentration and type. P can vary from 0 to ~-1.4 (shear thinning), and has exceptionally been found positive (shear thickening). Using chlorophyll a concentration chl as a proxy for phytoplankton, then

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

where Q is the phytoplankton concentration exponent, found to be about 1.3 generally. Further research, however, has shown that Q can vary locally with the growth phase of the bloom (Seuront & Vincent, 2008).

EPS thickening, moreover, is generally lumpy, probably associated with polymer spontaneous assembly (Chin et al., 1998; Ding et al., 2008, 2009). This produces length-scale dependent viscosity, which can be modelled using a lumpiness exponent.

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

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

where L is the length-scale of interest, M is the length scale of measurement, and d is the length-scale exponent. A model of whether lumpy EPS could thicken the water enough to stabilize a pycnocline (Jenkinson & Sun, 2011a) found that the value of d in Eq. 4 was very critical. To investigate d, η of phytoplankton and bacteria (PB) cultures was measured in capillaries of different radii. While η was increased in some combinations of shear rate, capillary radius, 0.35 to 1.5 mm, and PB species, presumably by EPS, η was surprisingly decreased in other combinations (Jenkinson & Sun, 2014). This may be associated by superhydrophobic conditions, sometimes called the *Lotus Leaf Effect*, at the surfaces of PB and EPS (scales nm to possibly 100s µm).

2.4.1 **Some effects of increased viscosity (with suggested primary length scales) include:**

1. Damping of turbulence and of sub-Kolmogorov-scale water movement: 1 nm – 1 m (Jenkinson, 1986);
2. Due to elasticity and lumpiness, complex changes to patterns of water movement, and de-coupling of shear rate from dispersion: 1 nm – 1 m (Jenkinson, 1986);

3. Partial and/or total clogging of the gills of fish (Jenkinson, 1989; Jenkinson et al., 2007), molluscs, tunicates, sponges, polychaetes, etc.: 1 nm – 1 mm;
4. Due to rising organic matter and adsorption to the air-sea surface, reduction of air-sea gas h exchange (Calleja et al., 2009), wave and ripple damping (Carlson, 1987): 10 µm – 10 m;
5. Complex situations, illustrated by *Phaeocystis*, which produces closely associated stiff mucus holding cells together in colonies (~50-2000 µm), while also producing looser diffuse mucus that increases viscosity at larger scales (Seuront et al., 2006), as studied in sludge organic aggregates (Liu et al., 2010): 50 µm – 1 m;
6. Flocculation into mucous aggregates, thus increasing sinking or rising speed and hence vertical organic flux (Mari et al., 2012): 100 µm – 1 mm.
7. Possible reinforcing of pycnoclines by PB EPS (Jenkinson & Sun, 2011, 2014): 10 cm–10 m;
8. Trapping of toxins close to metabolically active surfaces, such as cell membranes and gills (Jenkinson, 1989): 10 nm – 1 mm.

2.5 <u>Investigation techniques of seawater and lakewater thickening include:</u>

2.5.1 **Rheology**

1 Rheometry: a) concentric cylinder; b) sliding piston; c) capillary flow; d) ichthyoviscometry;
2 Studies of fluid movement at small scale: a) 3D particle image velocimetry (PIV); b) 3D particle tracking velocimetry (PTV);
3 Studies of small forces at small scale: Atomic Force Microscopy (AFM)
4 Combination of electrochemical techniques with rheometry, microscopy and PIV/PTV, ***in situ* if and when possible**;

2.5.2 <u>Nano- and microfluidics of biosurfaces (particularly sticking layers and slip layers at surfaces)</u>

1 High-speed video with PIV and PTV of flow through capillaries coated with organic sculptured layers of hydrophobic (Rothstein, 2010), hydrophilic (Bauer & Federle, 2009) and omniphobic (Wong et al., 2011) surfaces. To be combined with transmission electron microscopy (TEM), scanning electron microscopy (SEM), pressure/flow curves, and possibly standard rheometry of the test materials.
2 Scanning electrochemistry of organic matter film dynamics: Hanging mercury drop.
3 Use of electrochemical techniques developed to study the effects of biological coatings on corrosion dynamics;
4 Studies of attraction-repulsion fields, electrical double layers (EDLs).
5 Immunological type radicle-radicle recognition and adhesion.

2.5.3 <u>Biofouling, with adhesion, recognition and repulsion</u>

1 Fouling organisms need to encounter suitable surfaces, recognise them as suitable, then initiate a series of actions to adhere to the surface, and possibly to use means to penetrate it. Organisms subject to fouling are likely to have evolved antifouling mechanisms to avoid being fouled. Related to fouling and antifouling actions can be

considered:

a. Predation and avoidance of predation;
b. encounter and avoidance of "unwanted" sexual encounter;
c. Parasitism/symbiosis and avoidance of unwanted parasitism/symbiosis;
d. Pathogenic infection (by bacteria, viruses) and its avoidance;
e. Colonisation of different substrates (macrophytes, corals, rocks) by benthic dinoflagellates (*Gambierdiscus*, *Ostreopsis*) involved in harmful and toxic algal blooms (especially in tropical and subtropical regions, but apparently expanding their range associated with global warming);
f. By diffusion reduction and binding of toxins to mucus, protection of cells against nutrient competition and "stealing" by other microbial organisms.

2. The aim will be to use techniques developed largely for "green" biomolecule-modulated industrial antifouling techniques (for ships, cooling intakes, fish-farm cages and nets, etc.) to investigate fouling by organisms of other organisms and of non-living substrates in the sea (plankton, fish and benthic organisms, organic aggregates, sediment, rocks, etc., possibly already covered by biofilms).
3. The techniques to be used require further discussion by the WG members.

3. Terms of Reference

3.1 Vision

The ocean science community lacks expertise in (1) Rheology (the study of deformation in non-Newtonian materials); (2) nano- and microfluidics; (3) fouling and antifouling; (4) surface-surface recognition and adhesion. These domains affect trophic, sexual, parasitic, pathogenic and other types of encounter, that take place close to electrically controlled surfaces including glycocalyxes. Only when this knowledge is shared among ocean researchers, modellers and engineers, can there be more fundamental understanding of the processes occurring at the cell-size small scale. Without such knowledge sharing, which requires strong CD, future models of how the oceans will react ecologically and biogeochemically to future global changes will be unnecessarily flawed.

3.2

Objectives

A. Through capacity development (CD) of younger scientists, particularly in emerging countries, the multidisciplinary team of experts create a corps of ocean researchers, modellers and engineers literate in: (1) Rheology; (2) Nano- and microfluidics; (3) Fouling and antifouling at surfaces; (4) Electrochemical investigation tools, that they will teach to their students and graduate students in the decades to come.

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

4. Work plan

Year 1

Actions

- Before the Workshop, produce the kick-off draft SCOR Core Research Project (CRP) for RheFFO.
- **Workshop 1.** Objective: "Define the implementation plan for the Core Research Project"
  - Interdisciplinary CD by multidisciplinary team of experts of key younger scientists.
  - All experts and younger scientists participate. Each expert gives one or two 1.5-h lecture(s) on his/her expertise.
  - Each younger scientist outlines his/her expertise, and how (s)he believes the WG is needed to help solve bottlenecks in ocean research.
  - Experts give practical demonstrations of their techniques, and give the others hands-on experience.
  - The experts work together to write a keynote paper for a high impact open access scholarly journal, led by designated chair. Younger scientists may be invited to participate.
  - A terminal task of the Workshop will be to go through and refine the Core Research Project, and produce the final version.
  - Back in their home institutes, the experts lecture on these topics, incorporating *RheFFO* expertise. Between meetings, using electronic media, they help younger scientists to seek funding and write ocean-science proposals, incorporating *RheFFO* expertise.
  - They finalise the keynote paper for publication.
  - They shall incorporate *RheFFO* material in other ocean work.
  - The Rheology and micro- and nanofluidics experts raise funds and recruit PGs and PDs in their home labs to work on ocean-related problems using their expertise, as well as helping the trained younger scientists around the world.
  - Progress report 1.
  - Keynote paper 1.

Year 2

- Workshop 2
  - All WG members participate, with their PGs and PDs as suitable.
  - Continued CD –. One lecture course per expert, with major contribution by younger scientists, and contribution by the PGs and PDs.
  - Appropriate reports by Experts' and PDs and PGs report on research done back home.
  - One or two multi-editor books should be initiated with chapters written by members of the WG and others. The authors should take advantage of the meeting

to work together on their books and chapters, as well as on the second keynote annual paper.
  - Experts' reports on progress in achieving WG deliverables.
  - The experts work together to write a paper on a topic different from that in Year 1.
- Social activities will be strongly encouraged liaison between PDs and PGs from different institutes and disciplines, as long-term friendship will be crucially important for maintaining the developed corps of expertise after the end of the WG.
- Back home, each expert shall recruit more PDs and PGs. Experts should invite their colleagues and their PDs and PGs to work together in their home institutes and if possible on sea cruises.
- Progress report 2.
- Keynote paper 2.

Year 3

- Workshop 3
  - As above
  - The books should be nearing completion or in press. Finalising should be done.
  - The workshop also needs to focus on preparing the winding up of the WG at next year's workshop.
- Progress report 3.
- Keynote paper 3.

Year 4

- Before the workshop, the final report should be drafted, for finalisation at the workshop.
- Workshop 4
  - As above. The last annual paper will be prepared.
  - All the books and monographs will be already completed or in press.

- The WG has to be wound up with a final paper for online publication by SCOR, that will be a scientific review of new discoveries made during the WG in relation to other progress made in ocean science, rheology and nano- and microfluidics, pointing out new questions and gaps in knowledge.
- Annual progress report 4.
- Final report for whole period of WG.
- Final report, incorporating progress report for Year 4.
- Keynote paper 4.

5. <u>Deliverables</u>

- One Kick-off Core research project
- One finalised Core Research Project

- Four keynote papers in top learned journals.
- Two multi-editor books (or a book and a monograph).
- 4 annual progress reports
- 1 Final Report, for publication by SCOR.

6. Capacity development

6.1 Production of a corps and a network of interdisciplinary expertise worldwide.

An important aim of this WG is to produce a world-wide nucleus of scientists with expertise in rheology, nano- and microfluidics, and biofouling and antifouling, along with the electrochemistry tools to do some of this research, all in relation to plankton ecology, biogeochemistry and other aspects of oceanography. EECB will continue throughout the WG to progressively deepen interdisciplinary understanding. A principal aim will be to develop a corps and a network of young scientists and engineers trained in all aspects of *RheFFO* knowledge. We will aim so that these young scientists become friends and remain friends for the rest of their careers, publishing together, co-mentoring each other's students, and thus continuing CD into the future.

6.2 Cross-disciplinary knowledge transfer

The experts in different fields, physical oceanography, plankton biology and harmful algal blooms, biogeochemistry, rheology, nano/microfluidics, biofouling, electrochemistry and atomic force microscopy, shall develop interdisciplinary capacity in exceptionally talented young scientists from different backgrounds, specially invited to joint the WG workshops.

7. Working Group composition

7.1 Full Members

Name	Gender	Place of work	Expertise relevant to proposal
Ian R. JENKINSON Chair	M	Institute of Oceanology Chinese Academy of Sciences, Key Laboratory of Marine Ecology and Environmental Sciences, Qingdao, P.R. China	Physical-Chemical-Biological coupling, particularly related to p harmful algal blooms. Rheology and ocean turbulence. Superhydrophobic surfaces. Ecological engineering;

Elisa BERDALET Chair	F	Institut de Ciències del Mar (CSIC). Barcelona, Spain	Physical-biological interactions. - Harmful Algal Blooms. - Biochemical methods. - Microplankton physiology. Vice-chair of the Scientific Steering Committee of the SCOR/IOC-UNESCO program GEOHAB, Global Ecology and Oceanography of Harmful Algal Blooms
Laurent SEURONT Chair	M	Centre National de la Recherche Scientifique and Université de Sciences et de Technologies de Lille, Wimereux, France.	Phytoplankton, zooplankton, coastal oceanography, multiscaling and (multi) fractals in physical, biological and economic systems, and particularly in marine ecology, seawater viscosity in relation to phyto- and bacterioplankton.
Jinju (Vicky) CHEN	F	Lecturer in Nano-Biomechanics, Newcastle University, UK	Modelling and experimental characterisation of rheology of biofilms, biofilm formation, and biofilm attachment. Microfluidics for biofilm characterization
Mariachiara CHIANTORE	F	Associate Professor in Ecology at DiSTAV, Università di Genova, Italy	Modeling and mitigation of benthic harmful algal blooms. Ecology of *Ostreopsis* spp., especially environmental triggers, toxic effects.
Wei-Chun CHIN	M	School of Engineering, University of California, Merced, USA	Experience with marine gels and EPS aggregation mechanism. Applying various techniques from nanotechnology and engineering. Impact of environmental factors (pH, temperature and pollutants) on marine microgels and EPS.
Stephen HERMINGHAUS	M	Max Planck Institute of Dynamics and Self- Organization, Head of Dept. Dynamics of Complex Fluids, Göttingen, Germany	Rheology, nano/microfluidics, rheological effects of swarming cells, rheological effects of marine plankton, rheological effects at surfaces. Experience in organization

Sophie LETERME	F	Plankton Ecology Laboratory, Flinders University.	Senior Lecturer,
Zhuo LI	F	Tongji University, College of Environmental Science & Engineering, Shanghai, P.R. China	Associate professor, rheology, developing micro/nano- fluidic biosensors, and computational fluid dynamics (CFD).
James G. MITCHELL	M	School of Biological Sciences, University of Flinders, Adelaide, Australia	Heads a group focusing on nanometer to micrometer scale processes and marine ecosystems. Lessons learned have been applied to nanotechnology, including microfluidics and nanofabrication.

7.2 Associate Members

Name	Gend	Place of work	Expertise relevant to proposal
Myriam BORMANS	F	National Centre for Scientific Research and Université de Rennes I, Rennes, France	Research director. Role of turbulence in phytoplankton dynamics, colony formation and EPS production, morphological traits based ecology. Provides experimental grid stirred tank, and NanoSIMS (Secondary Ion Mass Spectrometry) expertise
Valentina GIUSSANI	F	Department of Earth and Environmental Science, University of Genoa, Italy	Doctorante, Ecotoxicology and management of benthic harmful algal blooms, especially in relation to their mucilaginous matrix.
Moshe HAREL	M	CEO, Sha'ked Microbial Solutions Ltd., Tel Aviv, Israel	Mutual relationship of a green-alga and the freshwater cyanobacterium *Microcystis* sp., and dynamics of EPS.

Xavier MARI	M	Researcher, Institute of Research for Development, Marseille, France	Characterisation of TEP, measuring sinking and rising, cohesive properties, aggregation dynamics in estuaries
Javeed Shaikh MOHAMMED	M	Head, Faculty of Innovative Design and Technology, Universiti Sultan Zainal Abidin, Kuala Terengganu, Malaysia	Biological microelectromechanical systems (BioMEMS), Nanotechnology, Microfluidics, Hydrogels
Michael ORCHARD	M	Physical Ecology Laboratory, University of Lincoln, UK	Research Assistant. High-speed video- microscopy of predation in marine protists. Adhesion, rheology and surface science
RI QIU	M	State Key Laboratory for Marine Corrosion and Protection, Luoyang Ship Material Research Institute, Qingdao, P.R. China	Assistant professor. Prevention of marine biofouling and corrosion, using “green” organic techniques and surface properties. Superhydrophobic surfaces. Electrochemistry as a tool to measure ion migration and for changing behaviour of fouling organisms.
Massimo VASSALLI	M	CNR – The Biophycs Institute, Genoa, Italy	Using physical tools such as atomic force microscopy and optical tweezers to measure physical properties of biological systems (mainly mechanics and rheology of cells, gels and proteins).
Peng WANG	M	Institute of Oceanology Chinese Academy of Science, Key Laboratory for Marine Corrosion and Biofouling, Qingdao, P.R. China	Associate professor. Prevention of marine corrosion and biofouling, using “green” organic techniques and surface properties. Electrochemistry. Superhydrophobic surfaces.

Tim WYATT	M	CSIC, Institut de Investigaciones marinas, Vigo, Galicia, Spain	Senior Research Fellow, HABs, fisheries, organic matter and ecological engineering, eclecticism and excellent writing skills.

8. Working Group contributions

BERDALET, E.

1. Berdalet shall provide CD in (i) Physical-biological interactions; (ii) Harmful Algal Blooms; (iii) Biochemical methods; (iv) Microplankton physiology. She is Vice-chair of the Scientific Steering Committee of GEOHAB.
2. Berdalet will provide world level expertise on ocean pelagic ecology and biogeochemistry, as well as project leadership and co-ordination.

CHEN, J.

1. Chen's research team shall contribute to Multiscale modelling and characterisation of biofilms, nanobiomechanics of bacteria (DTA award).
2. Chen's group shall also provide infrastructure for research on and characterisation of microfluidic devices.

HERMINGHAUS, S.

1. Herminghaus heads the department 'Dynamics of Complex Fluids' at the Max-Planck-Institut for Dynamics and Self-Organization, Göttingen, that investigates collective behavior and pattern formation in soft matter systems, important for understanding the dynamics of self-propelled entities, such as some plankton.
2. Herminghaus shall provide CD in microfluidics, rheology and structure formation in complex matter, shall provide infrastructure for the study of the interaction of active swimmers with surrounding flow fields.

JENKINSON, I.R.

1. Jenkinson pioneered and give CD in: (i) measurement of viscosity and elasticity in algal cultures and in seawater; (ii) measurement of reduced viscosity in algal cultures in capillary flow, e.g. Lotus leaf effect); (iii) incorporate of such findings into models of ocean fluidics.
2. Jenkinson will provide CD in seawater rheology, and an interface between (i) ocean scientists and (ii) rheologists and fluidicists, and will direct CD in both directions.

LETERME, Sophie

1. Leterme's group of two research associates and a PhD shall provide infrastructure and expertise on transparent exopolymeric polymer (TEP) production by microbes in desalination systems.

2. Biofouling potential of microbes in desalination systems, and expertise in plankton ecology in relation to surface nano/microstructure.

LI, Zhuo

1. ZL's research group consists of ten members focusing on rheology in polymer solutions and activated sludge
2. The group shall provide micro/nano- fluidics infrastructure and CD for fluid dynamics investigation and nano-biosensors for monitoring chemical components, as well as running computational fluid dynamics (CFD) software.

MITCHELL, J.G.

1. Mitchell's research 27-member group focuses on the influences of nanometer to micrometer scale processes on marine ecosystems.
2. Mitchell will provide expertise and CB on nanometre to micrometre surface structure in relation to NMF in plankton and other pelagic particles.

SEURONT, L.

1. Seuront is internationally recognized for his expertise in micro-scale patterns and processes in the ocean.
2. Seuront's shall provide CD on: (i) biologically-driven viscosity and its temporal dynamics and (ii) inferring the potential impact of this excess viscosity on structure and function in pelagic ecosystems, as well as bioproduction of excess viscosity, and its effects on structure and function in pelagic ecosystems.

ZHANG, D.

1. Zhang is head of the Key State Lab of Marine Corrosion and Biofouling. Her laboratory shall provide electrochemical tools to work on marine antifouling based on superhydrophobicity and slippery liquid-infused porous surfaces (SLIPS), related to marine biofouling and corrosion control.
2. Zhang's team shall provide CD, particularly in relation to surface-based and electrochemically-based control by organisms of surface fouling, and defeat of antifouling activity.

9. Relationship to other international programs and SCOR Working groups

9.1 GEOHAB – Global Ecology and Oceanography of Harmful Algal Blooms

There are close links between some *RheFFO* members and GEOHAB. Berdalet is Vice-Chair of GEOHAB. Wyatt and Jenkinson have participated in GEOHAB meetings and scientific activities for many years. GEOHAB (2013) has recommended that measurements of viscosity and rheology be carried out in relation to harmful algal blooms. It is foreseen that strong relations between *RheFFO* WG and GEOHAB (or its successor organization) will continue.

9.2 SCOR WG 141 – Surface Microlayer (SML) Working Group

There are strong cross-cutting subjects between *RheFFO* and SCOR WG 141. These particularly concern the accumulation of dissolved, colloidal and particulate organic matter in the SML, and its modulation of processes including air-sea gas exchange (Calleja et al, 2009), ripple damping (Carlson, 1987), upward flux of salt, water vapour (evaporation and spray) and plankton spores during storms, and downward entrainment of gas as bubbles. In October 2014, Jenkinson accepted a very kind offer by YANG Gui-Peng, to participate in a SCOR WG 141 Workshop at Qingdao, PR. China. This experience will provide input to *RheFFO* in organising SCOR workshops, while the subject matter is also relevant to RheFFO.

9.3 Other organisations

- Other organisations with which *RheFFO* will make contact are
- SOLAS, WOCE,
- Turbulence programmes, GOTM, GETM, FABM
- IMBER
- Programmes in Rheology, Nano/microfluidics, Corrosion, Biofouling and antifouling.

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2.2.7 Translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT) *Smythe-Wright*

Summary/Abstract
Sinking particles transport organic carbon to the deep sea, where they form the base of life. The magnitude of particle export and the rate at which particles are consumed determine carbon sequestration in the oceans, and directly influence atmospheric carbon dioxide concentrations and global climate.

Traditionally, sinking particles have been collected using sediment traps. However, the limited spatial and temporal coverage of sediment traps have led to new technologies that focus on optical measurements to allow the collection of large data sets describing both frequencies and types of sinking particles. These can be used from ships or installed on remote platforms, promising greater spatial and temporal coverage. Yet, whilst technologies to image particles have advanced greatly during the last two decades, techniques to analyze the often immense data sets have not. One short-coming is the translation of optical particle properties (e.g. the image) into particle characteristics such as carbon content and sinking speed.

Moreover, different devices often measure different optical properties, leading to difficulties in comparing results. This working group aims to bring together experts in observation, experimentation, theoretical modelling, and data analyses to systematically improve the process of converting in-situ particle measurements to global export estimates. Final outcomes will include publications detailing intermediate steps and a framework outlining the most efficient way of converting large volumes of particle measurements into export estimates. The output of this working group should have high impact on future ocean research by enabling efficient use of the rapidly developing field of optical sensors.

Scientific Background and Rationale
The oceans play a critical role in controlling the climate by storing large quantities of carbon dioxide (CO_2) in the interior. The interaction between atmosphere and deep ocean storage is driven in large parts by the biological processes associated with production, sinking and remineralization of organic matter in the ocean. These processes, collectively known as the biological carbon pump, keep atmospheric CO_2 concentrations ~200 ppm lower than if the oceans were abiotic (Parekh et al. 2006). The size of ocean carbon storage is determined by the amount of organic matter exported and the rate at which sinking organic matter is reworked and respired in the mesopelagic zone (region between 100-1000 m depth) (Kwon et al. 2009). Accurate estimates of these two processes (export and remineralization of sinking organic matter) are therefore key to understanding the ocean carbon cycle and how it regulates atmospheric CO_2 concentrations.

One of the big challenges in estimating export and remineralization is the accurate measurement and characterization of sinking particle fluxes. Traditionally, export flux is collected using sediment traps, which collect particles at a certain depth over a period of several days to months. Owing to the limited spatial and temporal coverage of sediment traps, characterization of export flux is restricted. Short-comings include the inability to resolve variations in export flux over short time periods and across space. Moreover, particles are pooled in the sediment traps, making it hard to characterize the origin and composition of the individual particles. Rather, sediment traps give bulk estimates only and no information on the individual particles making up the bulk flux. Especially particle size is an important parameter determining how and how fast it sinks, how much material an object contains, and who can find and eat it. Knowing the sizes and abundance of the settling particles is the starting point for understanding how they interact with the marine environment.

As an alternative to sediment traps, most current large-scale assessments on the role of sinking particles in the marine carbon cycle focus on measuring dissolved biogeochemical tracers such as nutrients, oxygen or pH. These tracers reflect the net processes of particle transport and the circulation. Major observational programmes that use dissolved tracers include GO-SHIP (Global Ocean Ship-Based Hydrographic Investigations Program) and SOCCOM (Southern Ocean Carbon and Climate Observations and Modeling), which uses biogeochemical sensors on profiling floats. The focus on dissolved tracers is partly driven by two advantages; the sensor techniques are relatively advanced, and estimated rates are integrated over space and time thus reducing observational needs. However, these observations are unlikely to deliver any predictive understanding of how particle fluxes will respond to environmental change as they fail to identify the processes that control the sinking and transformation of particles.

Recent developments in in situ optical sensors may offer the opportunity to overcome some of these problems. Optical sensors use in situ photography (‘imaging’) or information on light transmission (‘non- imaging’) combined with automatic particle recognition to estimate particle type, size and distribution.

Commonly used devices include the Video Plankton Counter (VPR, Davis et al. 1992), the Underwater Video Profiler (UVP, Gorsky et al. 1992), Laser Optical Plankton Counter (LOPC, Herman et al. 2004), and backscattering sensors. Optical devices can be used from ships or installed on remote platforms (e.g. Argo floats), allowing greater spatial and temporal coverage than sediment traps. They provide high- resolution descriptions of particle frequencies and types and can inform about particle origin. Information about the particle transformation mechanisms can be inferred from observations of particle abundance and size-distributions at different water depths. Lastly, the use of optical devices has become increasingly attractive as they are becoming constantly more affordable.

The translation of optical particle properties into export flux estimates is, however, difficult due to missing information on carbon content and sinking speed. To understand the functioning of the ocean’s biology and chemistry, it is necessary to determine how much mass is contained in each particle, their sinking velocity, and the summed contribution of all particles at different depths through the water column. The interpretation of optical measurements is further complicated as different optical devices often measure different optical properties leading to difficulties in comparing results.

The challenge now is to systematically improve the use of optical devices for understanding particle dynamics and export. This includes the comparison and inter-calibration of the outputs of available optical particle devices, as well as collation and distribution of knowledge on how to efficiently convert such optical information into particle export estimates. The working group would advance the processing of data from both imaging and non-imaging instruments, with a strong emphasis on comparing results from field programmes that have deployed both types of systems simultaneously. This will allow for optimization of information gained from already collected data (e.g. non-imaging sensors on profiling floats) and is expected to lead to recommendations on how to enhance current and future programmes by using optical devices. One of the most important aspects of the working group would be to assess which optical properties (e.g. backscattering, transmission or spectral information) and which processing techniques can best provide information on particle densities and chemical compositions, as this - along with sinking rates - is one of the weakest links between obtaining images and estimating material fluxes.

This working group would tackle an extremely timely challenge as the volume of data from optical sensors is steadily increasing, but much of the data are not worked up. This effort thus relies heavily on international collaboration and knowledge exchange, not least as it requires the collection of data from a broad range of ocean environments.

Terms of Reference

This working group will focus on converting optical particle information into sensible characterization of particle flux and export. It aims to

(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.

Working plan (logical sequence of steps to fulfil terms of reference, with timeline.

The working group would be comprised of individuals with a wide range of expertise (observation, experimentation and theoretical modelling), which will help to facilitate discussion and problem solving. The working group will focus on four stepping stones to fulfill the terms of reference. The starting point for each stepping stone is the initial workshop that will bring together the experts and share the current state of knowledge. The working group will then identify sub-groups (where considered sensible), leaders, and will finalize a timeline for data analysis, synthesis and publication. The working group will meet once a year to ensure timely progress.

The first step would be the technology analysis, which will focus on optical instruments that have been deployed in various regions of the world's oceans and have collected an extensive database on particles. The working group will compare the outputs of these instruments. The main questions will address

- What data format is produced?
- Are the data comparable between instruments?
- Are there products that could be produced/recorded, but are not currently produced, which would facilitate either data analysis and/or data comparison between instruments?
- Is there a technology which seems to excel and appears particularly promising?

This step will further focus on validation and inter-calibration of the different devices. The working group would develop recommendations for standard methods to calibrate any of the instruments across different size ranges of particles. Subsequently, the working group would coordinate field programmes in different oceanic regions to cross-calibrate different optical sensors, taking particular focus on comparing imaging (UVP/LOPC/VPR) and non-imaging (backscatter/beam attenuation) techniques. We have identified three cruises across the Atlantic (40°N, 20°S, and 54°S; lead by the National Oceanography Centre, Southampton, UK) that will provide the opportunity for inter-calibration throughout the mesopelagic zone (the region between 100-1000 m depth).

Next, the working group will discuss information on how optical properties correspond to particle characteristics such as sinking speed and carbon content, which are key to estimating export fluxes. Special emphasize will further be put on identifying the type and source of the particles, and how particles change with depth. This step aims to discuss our current knowledge and hypotheses, and drive the community to focus research on filling the knowledge gaps. The final product should be a quantitative relationship between the optical properties of particles (whatever appears to be the most sensible in view of the available technologies) and particle characteristics (sinking speed and biochemical contents).

The third step will be to test the proposed relationship with the large data sets that have been collected so far. One of the outcomes should include a sensitivity analysis of how good optical measurements translate into real fluxes. If more research is needed, the details should be highlighted in this phase. An important outcome will be a better understanding of the frequency and resolution that is needed for reasonable export estimates. Overall, the resulting synthesis should greatly advance our understanding of spatial and temporal patterns of particle export.

Finally, a framework will be written that recommends the most efficient way of converting large-volume optical measurements into export estimates. This framework should have high impact on future ocean research as it will enable efficient use of the fast-developing field of optical sensors on remote platforms.

<u>Deliverables</u>

(1) Review paper prioritizing research to fill identified knowledge gaps
(2) Publication on inter-calibration of currently used optical devices
(3) Sensitivity analysis of how good optical measurements translate into real fluxes

(4) Framework of how to convert optical measurements into export fluxes and how to cope with large data sets
(5) Data synthesis showing spatial and temporal patterns of particle export globally (high-impact publication)
(6) Development of software examples and codes, placed on a public repository such as GitHub
(7) Deposition of optical particle data in a common database that can be actively added to as new data is collected

Table 1. Time line of activities related to Terms of Reference

TOR		2016				2017				2018				2019			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Meetings																
1	Review paper																
2	Inter-calibration efforts																
2.1	Fieldwork/cruises		40°N				20°S		54°S								
2.2	Publication & recommendation																
3	Key parameters for conversion																
4	Improve algorithms																
5	Tackling large data sets																
6	Code repository																
7	Database																
8	Framework																

Capacity Building

Only a few nations use optical devices to measure in situ particles, a fact which is reflected in the composition of the list of proposed Full Members. We hope that the outcomes of this working group will highlight the benefits of optical measurements and encourage both collaboration as well as increased investment into their application, which may be especially attractive as optical devices are becoming increasingly more affordable. To realize these goals, the working group will seek funding to organize a summer school/training course on use of optical particle counters and how to access and analysis data from these instruments. The group will also develop and release example codes (e.g. in R and Matlab) on a public repository (such as GitHub) thereby allowing other researchers access to the codes for their own research. The group will also encourage students from developing countries to apply for the POGO-SCOR Fellowship Program for Operational Oceanography to transfer technology to developing countries.

We will further recommend standardized data documentation (i.e. units, etc.) and encourage submission of data on optical particles to a common database. We would encourage that every deployment of an optical instrument would be registered, so that even if the data is not available, details of the deployment are recorded to facilitate data sharing, data synthesis and collaboration.

The database will be supported by the British Oceanographic Data Centre (BODC). BODC is a UK national facility for looking after and distributing data concerning the marine environment.

BODC has 26 years' experience in making high-quality data readily available to UK research scientists in academia, government and industry. They play an active role in the international exchange and management of oceanographic data, sitting on panels such as the International Oceanographic Data and Information Exchange (IODE). BODC will contribute to the working group by

- advising on best data practices and help formulate metadata standards to facilitate the collation of data into a database and its re-use in the wider scientific community, ensuring knowledge exchange. This will not only ensure the longevity of these important and valuable data but will help make them interoperable with other knowledge bases.
- using their experience of working on a wide range of national and international projects to help develop a suitable data policy.
- using their expertise in data-basing to develop a central inventory of deployments and will make data accessible through a central repository, hosted at BODC.

Working Group composition

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

Name	Gender	Place of work	Expertise relevant to proposal
1 Sari Giering (chair)	F	United Kingdom	Biological carbon pump, particle export measurements using sediment traps and Marine Snow Catcher, measuring optical properties of particle characteristics
2 Klas Ove Möller	M	Germany	Video Plankton Recorder (VPR), expertise in automatic particle recognition and characterization from photos, large volume data acquisition
3 Sünnje Basedow	F	Norway	Laser Optical Plankton Counter (LOPC), expertise in particle recognition from transparency and size, size spectra, large data acquisition
4 Lionel Guidi	M	France	Underwater Video Profiler (UVP), expertise in automatic particle recognition and characterization from images, large volume data acquisition and analysis
5 Morten Iversen	M	Germany	In situ and ex situ photogrammetry of particles, connecting optical properties of particle characteristics
6 Andrew McDonnell	M	USA	Marine particle dynamics, in situ imaging of particles and zooplankton

7 Adrian Burd	M	USA	Theoretical modelling of particle dynamics
8 Catarina R Marcolin	F	Brazil	Automatic particle recognition LOPC and Zooscan, size spectra, large data acquisition and analysis
9 Sandy Thomalla	F	South Africa	Linking Southern Ocean optical property measurements and biogeochemistry to characterize plankton community and particle export
10 Tom Trull	M	Australia	Southern Ocean particle flux measurements, In situ measurement of particle sinking rates, use of gel traps to collect and characterize sinking particles, deployment and interpretation of optical sensor equipped moorings and Bio-Argo profiling floats.

Associate Member (no more than 10)

Name	Gender	Place of work	Expertise relevant to proposal
1 Emma Cavan	F	United Kingdom	Observations of dynamics of slow and fast sinking particles, correlation between particle images and sinking speed
2 Uta Passow	F	USA	Combination of lab-based experiments, mesocosm studies and field work to better understand particle dynamics and processes
3 George Jackson	M	USA	Modelling coagulation processes and sedimentation in marine ecosystems. Analyzing particle distribution data taken with multiple instruments. Comparing observations of particle size distribution with model predictions.
4 Nathan Briggs	M	France	Use of backscatter and fluorescence data to estimate large particle concentration, chlorophyll content, and export, esp. from autonomous platforms.
5 Dhugal Lindsay	M	Japan	In situ imaging, trophic level interaction
6 Lou Darroch	F	United Kingdom	Data management, collating data from research cruises and physical data repositories, standardising metadata from in-situ marine sensor networks

Working Group contributions

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

Sari Giering (Researcher at the National Oceanography Centre, Southampton, UK):
Sari is a marine biogeochemist with research focus in carbon export, zooplankton ecology and particle dynamics. She has extensive expertise in using a combination of field measurements, models and data synthesis to better constrain the ocean carbon cycle.

Morten Iversen (Head of Helmholtz Young Investigator Group SeaPump at the Alfred Wegner Institute, Germany):
Morten's research focuses on understanding how food web composition influences particle export dynamics, specifically how particle size and composition determine sinking speed and particle remineralization. His group is developing several new camera systems and new in situ methods to collect intact marine particles.

Andrew McDonnell (Associate Professor at the University of Alaska Fairbanks, USA):
Andrew's research focuses on assessing the biogeochemical role of various particle processes such as particle formation, sinking, lateral transport and remineralization. He uses a wide range of laboratory and field methods including sediment traps, in situ photography and particle incubations.

Adrian Burd (Associate Professor at the University of Georgia, USA):
Burd's research focuses on mathematical and computer modeling of marine particles and their transformations relevant to biogeochemical cycling. His work has shown how particle aggregation and disaggregation are important for interpreting particle measurements and in understanding and predicting export flux, biogeochemical cycles, and trace metal cycling in the oceans.

Klas Ove Möller (Researcher at the University of Hamburg, Germany):
Klas' expertise is in optical sampling methods (e.g. Video Plankton Recorder) and automatic image classification. He further looks at biological and physical forcing on plankton and particle distribution patterns from small- to mesoscale as well as patchiness structures.

Sünnje Basedow (Researcher at the University of Nordland, Norway):
Sünnje uses the laser optical plankton counter (LOPC) to look at spatial distributions and size spectra of zooplankton and particles. She has compared the LOPC to the VPR and Multinet for intercalibration of instruments and currently focuses on calculating energy flow and trophic linkages within the pelagic community based on size spectrum theories.

Lionel Guidi (Researcher at Laboratoire d'Océanographie de Villefranche sur Mer, France):
Lionel's expertise is optical sampling measurements (especially the Underwater Vision Profiler, UVP), automatic particle recognition, large data compilation and analysis, and conversion of imaging data into flux estimates. Recent efforts included a global synthesis of particle size distribution and related estimate flux profiles as calculated from the UVP.

Catarina Marcolin (Researcher at University of São Paulo, Brazil):
Catarina uses optical systems such as the LOPC and ZooScan to automatically detect and measure plankton and particles in situ and ex situ. Her expertise includes coding for large data set analysis.

Sandy Thomalla (Senior Scientist at Southern Ocean Carbon and Climate Observatory, South Africa):
Sandy's research focuses on linking optical property measurements (scattering, absorption, attenuation) with the biogeochemistry (species composition, carbon content, size structure, photophysiology) in order to optically characterize the plankton community and predict carbon export potential. She further uses bio-optics floats with upward facing transmissometers to estimates particle flux.

Tom Trull (Professor of Marine Biogeochemistry at the Antarctic Climate and Ecosystems Cooperative Research Centre University of Tasmania, and Senior Principal Research Scientist CSIRO Oceans and Atmosphere Flagship Hobart, Australia)
Tom is an expert in Southern Ocean particle flux measurements, including in situ measurement of particle sinking rates, use of gel traps to collect and characterize sinking particles, deployment and interpretation of optical sensor equipped moorings and Bio-Argo profiling floats. He further aims to expand the global use of biogeochemical and bio-optical sensors on Argo floats to measure ocean ecosystem productivity and export.

Relationship to other international programs and SCOR Working groups

To our knowledge the only SCOR working group that focused on particle export was WG116 'Sediment Trap and ^{234}Th Methods for Carbon Export Flux Determination' (approved 1999). As outlined above, the development of optical sensors would complement sediment-trap-based export estimates and help to understand the biological carbon pump. This working group would further complement WG134 'The Microbial Carbon Pump in the Ocean' (approved 2008) in the effort of understanding the ocean carbon cycle.

Key References

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Appendix

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

Basedow:

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2.2.8 Global Assessment of Nutrient Export Through Submarine Groundwater Discharge (NExT SGD)

Naqvi

Summary

We propose to establish a new working group that will initiate and develop a new global model for assessing nutrient and constituent export through submarine groundwater discharge (SGD) to nearshore coastal areas and offshore SGD fluxes from artesian aquifers - **the NExT SGD model**. The proposed multi-national NExT SGD working group would consist of scientists whose research crosses disciplinary boundaries (hydrogeologists, geochemists, oceanographers, and global water cycle modelers). This collaboration will provide the mechanistic understanding of controls on groundwater-derived water and constituent fluxes to the ocean necessary for global extrapolations and predictions with this novel NExT SGD model. The currently available data on SGD and nutrient fluxes is extensive and has increased exponentially during the last years (e.g., more SGD data is available now than what previously existed for initiating the NEWS global river flux model 10 years ago) and it is representative of a broad array of aquifer, coastal zone and climate regimes. To ensure the success of this working group we will interact with other working groups and programs (e.g., GEOTRACES, GlobalNEWS and LOICZ) as well as with members of former SCOR working groups (e.g., SCOR 112 "*Magnitude of Submarine Groundwater Discharge and its Influence on Coastal Oceanographic Processes*") and learn from their experiences in compiling large databases, identifying and filling potential data gaps and developing and distributing protocols for best practices.

Rationale

The overarching goal of this proposed SCOR working group is to develop a global model for assessing water and constituent (nutrients, gases, carbon, metals) fluxes to the ocean via groundwater (NExT SGD). Current data availability (**Fig 1**) and conceptual understanding of the processes controlling groundwater discharge to near-shore coastal regions and the associated nutrient and other constituent fluxes is sufficient for formulating a numerical global model for assessing land–ocean material transport fluxes, similar to the river flux global model (GlobalNEWS) constructed about a decade ago (*Seitzinger and Harrison*, 2005). Indeed, the first global models of river constituent fluxes were developed based on a far smaller database than available for SGD today (e.g., *Gibbs and Kump, 1994).*

Figure 1 Snap-shot of the newly created web site by the working group for compiling the available data (>100 locations worldwide presented as red dots). More data are available but not plotted on the map yet. (*from* *http://sgd.snu.ac.kr/home/gis_main.jsp*).

The global NExT SGD model, will not only enable prediction of SGD and constituent fluxes for any location worldwide for present, past and future climate conditions, but provide the tools to test potential feedbacks in the ocean-land-atmosphere earth system. Such a global model will transform our predictive abilities of this important, yet poorly constrained part of the hydrological cycle. Indeed, one of the pioneers in the SGD field advised, "*The* ***oceanographic and hydrogeologic*** *communities should recognize the* ***local and global*** *importance of SGD and* ***work together*** *to achieve a better understanding of the processes that control SGD and its constituents*" (*Moore,* 2010).

Because the model will be capable of capturing nutrient and flow changes triggered by short and long- term anthropogenic activities and climate, it will allow the examination of various scenarios and their *ecological effects on ecosystems and economic effects on societies*. For example, excess nutrient loading due to SGD can initiate and sustain harmful algal blooms (HABs) in coastal areas (*Lee et al*., 2010, *Lecher et al*., 2015). The predictive power of a large-scale model will allow the identification of locations susceptible to HABs triggered by SGD. Thus, the NExT SGD model will not only significantly improve our understanding of the magnitude of groundwater-derived nutrients and other constituent budgets for the global ocean, but will be extremely useful as a tool to highlight the need for water management assessments in some areas where no data are available.

The global NExT SGD model will enable us to *improve Earth System Models (EMS)*, which at this stage neglect groundwater as a transport pathway from land to sea. For example, alkalinity supplied by groundwater may change the modeled pH response to increased atmospheric CO_2 concentrations (*Cyronak* et al. 2013). Given the potential importance of SGD for material fluxes into the ocean, its inclusion in the EMS will be important for allowing accurate predictions of the effect of global change, including changes in sea-level on the oceans, and a global SGD model is a necessity to enable that inclusion. EMS, like the ORCHIDEE model (http://orchidee.ipsl.jussieu.fr/) could easily be extended to include subsurface material fluxes by forcing existing parameters with outputs from the NExT SGD model.

The NExT SGD model will include coastal aquifer systematics and related controls on SGD (**Fig. 2*b***) and will *aid in determining fluxes from the little explored offshore* *freshwater seepages* on the continental shelf (**Fig. 2a**) which could have future value as a fresh water source in densely populated coastal regions (*Post et al*., 2013).

Scientific Background

What is SGD and where does it occur? Submarine groundwater discharge (SGD) "*includes any and all flow of water on continental margins from the seabed to the coastal ocean, regardless of fluid composition or driving force*" (*Burnett et al.* 2003, *Moore,* 2010) (**Fig. 2*a*,*b***).

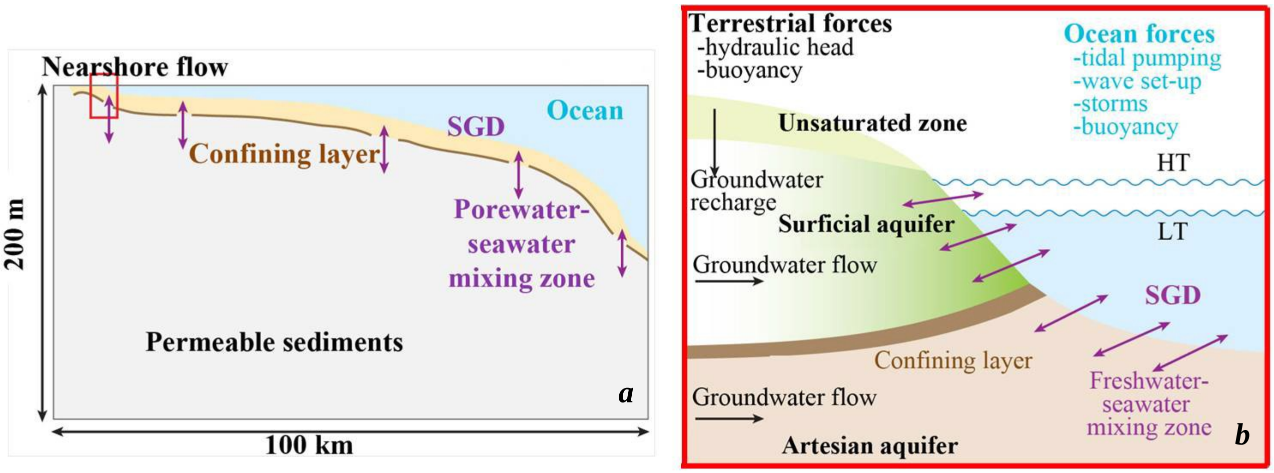

Figure 2 (***a***) SGD extends from the red box labeled "*Nearshore flow*" throughout the continental shelf. The offshore flow on the continual shelf is driven by interactions of ocean forces with geothermal heating and over-pressurized zones beneath discontinuous confining layers. ***(b)*** Near the shoreline SGD (red box) is driven by a combination of terrestrial and ocean physical forces operating in a complex geological environment (*modified from Moore,* 2010).

The NExT SGD model *will capture nearshore fluxes* (**Fig. 2b**) that include (*i*) fresh and (*ii*) recirculated seawater where most of the SGD data were collected and where most of the terrestrial groundwater- derived constituents are discharged (**Fig. 1**). However, the NExT SGD model can be expanded to include offshore fluxes on the continental shelf once sufficient data from these areas are available. This will be possible because the offshore flows on the continental shelf are channeled through artesian aquifers that have the same hydrogeological properties as nearshore shallower aquifers and will be already embedded in the global model. Moreover, knowing the near-shore fluxes will enable general estimates of the offshore component to be calculated based on ocean-scale radium (Ra) mass-balance models (*Moore,* 2010, *Kwon et al*., 2014).

Despite the rich body of literature characterizing the transport of material fluxes via SGD to the nearshore environments (**Fig. 1**), to date attempts to upscale and evaluate water fluxes on regional or global scales are limited. However, in a recent study of global upscaling, *Kwon et al*. (2014) estimated SGD to amount to 3-4 times the river flux. Nevertheless, the radium mass-balance approach used in this and other studies is not based on a mechanistic understanding of driving forces; hence its predictive and exploratory abilities are limited. The lack of a process-oriented model is a very substantial knowledge gap, especially considering the links between ***SGD, the global carbon cycle, and climate change***. For example, in a key study, *Cole et al*. (2007) showed that SGD could contribute a similar amount of DIC to the coastal ocean as rivers. *Beusen et al*. (2013) established a global model on SGD-derived nitrogen fluxes, but neglected the marine recirculated SGD component, which often has a much larger volume than freshwater SGD (e.g., *Burnett et al.*, 2003; *Waska and Kim,* 2011). The proposed multifaceted modeling approach will allow connecting ***hydrogeological and marine factors*** (e.g., net precipitation, surface runoff, recharge, groundwater pumping rates, hydraulic heads, aquifer size and aquifer characteristics, topography, lithology, beach morphology, the presence and level of development of stream systems, waves, and tides) affecting SGD to ***nutrient and other constituents loading controls*** (e.g., land use, sewage and agriculture influxes, population growth, groundwater redox state and residence time) in coastal areas on a global scale. For most of the above-listed controls, spatial data are available at very high resolution. For example, a similar approach was used by *Seitzinger and Harrison* (2005) to estimate export from ~6,000 watersheds globally. Results from these modeling efforts demonstrated the power of numerical models, which can be used not only *to create geospatial databases* of the magnitude of water fluxes but also *to reveal relationships* between controlling factors and drivers, which in turn, transform our understanding about the coupled nature of these export fluxes at larger scales. Physical measurements from field-based studies are crucial for calibrating models and performing sensitivity analyses. Sufficient data are now available through the abundant SGD tracer- based coastal oceanographic studies of the last 20 years (**Fig. 1**) and the some assimilation of many local studies in large databases is done (e.g., *Moosdorf et al.*, 2015). The model will help identify data gaps if any exist.

The available spatial SGD data is *highly heterogeneous*; it was produced by many different research groups and government agencies employing different measurement techniques and reporting standards. Hence, the planned NExT SGD model will require a sophisticated data compilation process. The international scientific network of the proposed SCOR working group will set guidelines for compilation of available data in a unified manner and suggest best practices for future data collection.

In addition, the parameters needed for the NExt SGD model development will be identified and assessed and model feasibility tested in a cutting-edge *proof-of-concept* study.

Terms of Reference

Disciplinary boundaries in the scientific community working at the land-ocean interface (i.e., oceanography community, hydrogeologists, and experts in global water flux modeling) have hindered the advancement of the mechanistic understanding of the significance of groundwater-derived water and constituent fluxes to the ocean on a global scale. The NExT SGD WG recognizes SCOR as the perfect platform to encourage and stimulate the unique and timely needed collaboration between these disciplines, an issue that was previously also recognized by the SCOR 112 WG.

The group's work will focus on the following terms of reference:

1. Set up a database of available SGD data and initiate the global NExT SGD model (*deliverable 1*, **Table 1**).
2. Collaborate with other working groups and projects (GEOTRACES, Global NEWS, LOICZ, members of former SCOR working groups) to inform the NExT SGD model and connect it to ESM (e.g. ORCHIDEE) (*deliverable 2*, **Table 1**).
3. Produce a "*best practices*" handbook recommending sampling strategies, parameter measurements, and guidelines for sample processing, and handling and sharing of acquired data (*deliverable 3*, **Table 1**).

We foresee the initiation and development of this unique collaboration proceeding in several stages (**Table 1**) which will be centered on in-person meetings, held in conjunction with international conferences or hosted by the National Water Center (NWC) of the University of Alabama. We will organize a virtual seminar series (Webinar) to be delivered quarterly, by different members of the SCOR WG with focus on the progress of the NExT SGD modeling.

Working Plan and Deliverables

Constructing a global model to assess constituent fluxes via SGD is a pressing task. Our in-person meetings (as shown in **Table 1**) will be structured to address specific stages of model development necessary to establish the foundation for successful model outcomes. The groundwork for the NExT SGD model will be achieved through the following specific goals:

Deliverable 1: Set up a database and initiate global NExT SGD model

The NExT SGD SCOR working group will develop specific technical guidelines in the form of *metadata forms* that will be embedded in an existing Global SGD webpage (see URL) and will be filled out for each site. Aquifer-specific regions will be assigned to research groups based on their involvement in data collection. Previously, a SCOR WG (112), which had mainly focused on the detection and quantification of SGD, had come to the conclusion that six major types of aquifers determine SGD dynamics. These types of aquifers will now be used for our NExT SGD model.

Scientific sub-groups will be assigned to aquifer types and collaborate to ensure that all available data are compiled and correctly inserted. After filling out the available information, each form will be saved in the SGD database. This will ensure (*i*) *quality control* of the data to be used for the model; and (*ii*) the creation of a *uniform record* that will be independent of the field data collection and techniques. For areas without published data on a specific type of aquifer, high-resolution lithological data from *Hartmann and Moosdorf* (2012) will be used in combination with hydrogeological interpretation (e.g. Gleeson et al., 2014). To adjust the model in terms of constituent fluxes, conceptual understanding of weathering influences on water chemistry will be used until data become available (**Fig.3**). The result will be used as input data into the Next SGD model, which will be developed as process-oriented empirical model by the workgroup members.

Deliverable 2: Set up a global network of scientists and "ecosystem task force" through collaboration with other working groups to advance the NExT SGD model (NEWS Model and GEOTRACES)

The working group will discuss with developers of earth system models to implement SGD water and constituent fluxes into their terms. This should be done based on the controls and structure of the NExT SGD model. The group thus ensures information transfer both from the ESM community into the NExT SGD model development and in the other direction. In particular, potential ecosystem feedbacks of SGD will be focused. Relevant factors for inclusion in the NExT SGD model will be identified by adding field knowledge of the submarine groundwater discharge community to factor setups of existing models (e.g., Global NEWS by *Seitzinger and Harrison*, 2005). The unique combination of terrestrial and marine factors and their interplay is a special challenge to this working group. This will be reflected in the model input data (e.g. land cover and population density, as well as tidal range and wave intensity). This part of the work ensures the compatibility of the NExT SGD model with other global scale nutrient flux models and Earth System models, and the necessary simplification. While at the same time the group will safeguard a realistic representation of the complex processes associated with the subterranean estuary.

Deliverable 3 Establish a handbook of best practices for sampling strategies, sample processing, and data handling and reporting for SGD data collection to be used in the NExT SGD model

Constructing a model that has the ability to be improved and updated by including future data is important. The NExT SGD model *will capture nearshore fluxes* that include fresh and recirculating seawater where most of the SGD data was collected in the last two decades (**Fig. 1b**). We will seize the opportunity of this international network of hydrogeologists and biogeochemists to compare, assess, and optimize *in situ* investigations of SGD magnitudes and associated constituent fluxes from local to regional scales. Furthermore, our working group will collaborate with the GEOTRACES community to plan for the collection of offshore SGD data and make sure it is compatible with the model requirements (http://www.geotraces.org/science/science-highlight/1019-submarine-groundwater-discharge-as-a- major-source-of-nutrients-in-the-mediterranean-sea). This will enable an expansion of the model to include offshore fluxes from the continental shelf. Based on these recommendations and model needs a best practices handbook will be composed and disseminated broadly.

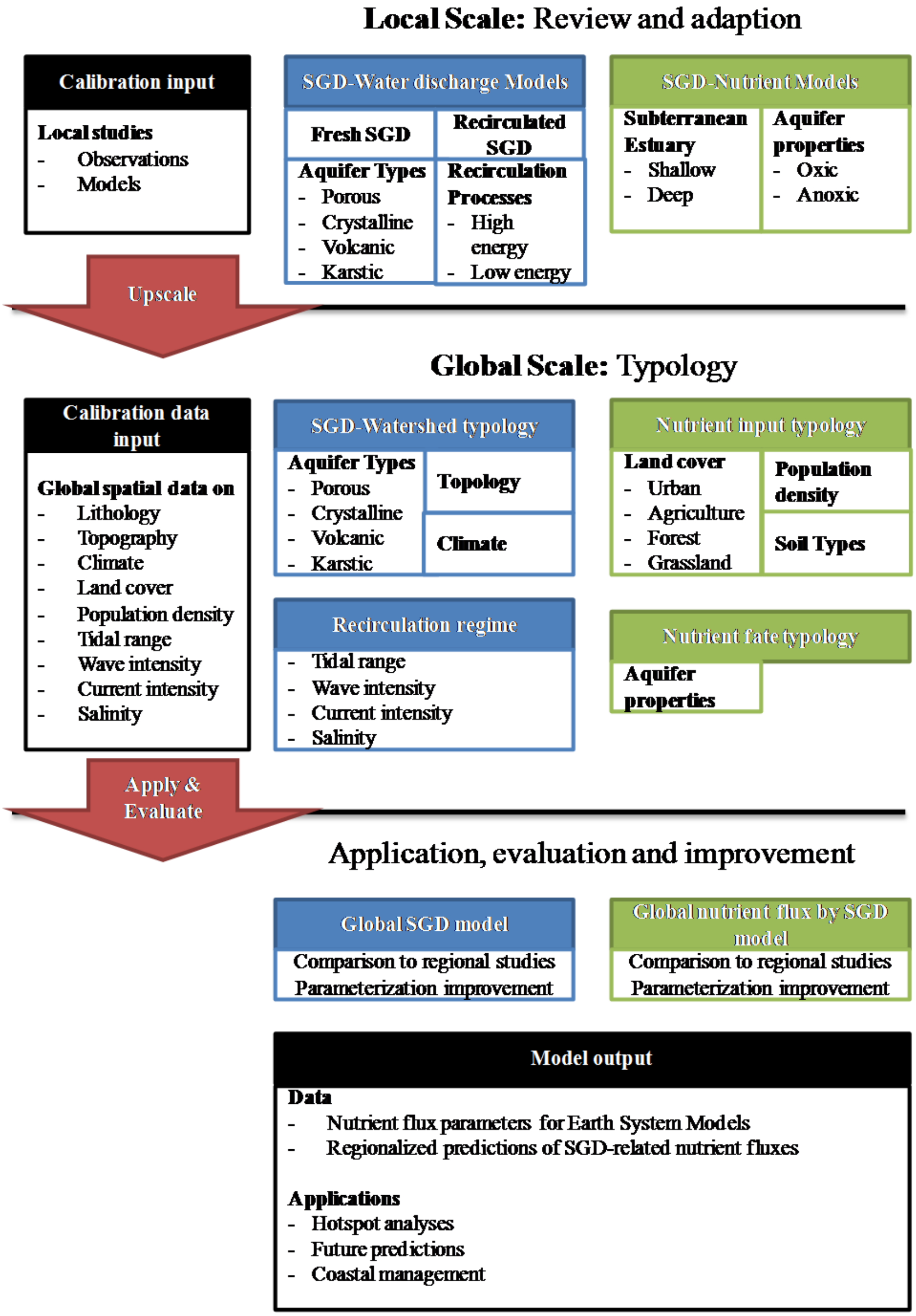

Figure 3 Flowchart presenting the logical step-wise procedure in developing the NExT SGD model

Table 1 Detailed timetable of the scientific activities, and expected deliverables of the working group

	Group activities and deliverables	Deadlines/meeting reports
Initial coordination and data management	1. Classifying sites into the 6 major domains based on aquifer type. 2. Developing specific technical guidelines for building a uniform metadata base of hydrogeological and nutrient parameters and topology. 3. Making initial decisions on governing parameters and boundary conditions for groundwater flow model 4. Extending participation on regional level to facilitate compilation process and disseminate future results.	SPRING: 2016 Ocean Sciences Meeting (proposed special session), 21-26 February, New Orleans, USA followed by first meeting at NWC Tuscaloosa, UA campus. FALL 2016: 26th Goldschmidt Conference, Yokohama, Japan
Global Model Development	1. Performing real-time simulations of flow models in different domains at the NWC University of Alabama; discussing model parameters and sensitivity. 2. Making decisions on constituents adjustments and data gaps: a) Land coverage and use b) Identifying sources and sinks of nutrients: natural (non-point-) versus anthropogenic (point-) sources c) Climate and climate change effects via sea level change and glacial melting.	SPRING 2017: European Geosciences Union (EGU) 17-22 April, Vienna, Austria FALL 2017: Second meeting at NWC Tuscaloosa, UA campus; USA
Model Calibration	1. Performing real-time simulations of constituents flux models in different domains at the NWC University of Alabama; discussing model parameters and sensitivity. 2. Working on model parameterization and refinement 3. Obtaining first assessments of significance of nutrient fluxes (fresh and recirculated) versus river fluxes. 4. Working on dissemination of results in publications (G3) and meetings. 5. Writing and dissemination of the best practices handbook.	SPRING 2018: Third meeting at NWC Tuscaloosa, UA campus, USA FALL 2018: Final meeting December 2018 AGU Special session, San Francisco, USA

Capacity Building

Within the proposed group, we bring together global modeling experts from the riverine and groundwater *modeling communities* (e.g., Cohen, Harrison, Michael, Slomp) with specialists in *large database* creation and management and holders of large SGD datasets (e.g., Kim, Moosdorf, Michael) as well as field scientists for SGD from the *terrestrial* (Cable, Dimova, Santos) *and marine* (Burnett, Dimova, Paytan, Waska) realm. In addition to the broad scientific backgrounds, the proposed working group was assembled on the principle of geographical, economical (developed and countries in transition), gender and career stage diversity. The NExT SGD WG includes members from 15 countries spanning four continents with 30% female representation, and 30% members from developing and transition countries (**Tables 2 and 3**). Opportunity for broader involvement of the scientific community will be made possible through open thematic sessions in large meetings and via open Webinars.

The uniqueness of this working group is its initiation largely by early-career young scientists, which has helped crossing traditional boundaries between the research fields of coastal oceanography, hydrology, and global numerical modeling. We will expand on traditional approaches for outreach and funding by actively including social media via Facebook, Twitter, NExT SGD webpage Blogs, virtual seminars (Webinars) and crowdsourcing as part of our portfolio. Establishing the SCOR NExT SGD working group will foster further interdisciplinary collaboration and may catalyze new studies in areas where data gaps are identified during the compilation process. Developing this network will facilitate information exchange between scientists from developed countries and countries in transition. In most developing countries, nutrient enrichment of coastal waters due to SGD is unknown phenomenon. Interactions among group members will aim to create opportunities for student exchange and contribute to the enhancement of graduate programs in these counties which in turn, will promote wider public understanding of the effects of groundwater discharge to the ocean.

Working group meetings (as shown in **Table 1**) will be organized at least twice a year. We plan to meet each year at the NWC on University of Alabama campus, for which most of the funding from SCOR (US$15,000) will be utilized (e.g., to support travel and meeting expenses). The use of the building, audio-visual and computer facilities will be provided at no cost for this project. To allow for broader participation and more frequent interactions we plan to also meet during large international meetings (through town halls and special sessions) in which most WG members participate. The location of these meetings will rotate between the USA, Europe and Asia to distribute the cost of participation among group members.

We will seek funding from additional sources such as UNESCO, IAEA, LOIZ, as well as national and bi-national organizations (NSF, NERC, etc.). We will also establish a donation link on our web page to create an opportunity for private organizations to support our group. Funding through these alternative sources will be independent of that provided by SCOR.

Table 2 Full Members of the SCOR Working Group on Global Groundwater Fluxes to the Ocean

	Member	**Gender**	**Place of work**	**Expertise relevant to proposal**
1	Natasha Dimova (co-chair)	female	University of Alabama, USA	Radionuclides, coastal and freshwater hydrology
2	Nils Moosdorf (co-chair)	male	Leibniz Center for Tropical Marine Ecology (ZMT), Bremen, Germany	Global empirical modeling
3	Guebuem Kim	male	Seoul National University, Korea	Radionuclides and nutrient cycling
4	Isaac Santos	male	Southern Cross University, Australia	Carbon cycling
5	Holly Michael	female	University of Delaware, USA	Numerical & field modeling of coastal groundwater dynamics
6	Caroline Slomp	female	Utrecht University, The Netherlands	Geochemical modeling

7	Makoto Taniguchi	male	Research Institute for Humanity and Nature, Japan	Regional and global groundwater hydrology
8	Bo Chao Xu	male	Ocean University of China	Coastal hydrology, geochemistry
9	Gopal Krishan	male	National Inst. of Hydrology, Uttarakhand, India	Hydrology
10.	Robert Delinom	male	Indonesian Institute of Sciences, Indonesia	Hydrogeology of tropical islands

Table 3 Associate Members* of the SCOR Working Group on Global Groundwater Fluxes to the Ocean

	Member	Gender	Place of work	Expertise relevant to **proposal**
1	Hannelore Waska#	female	University of Oldenburg, Germany	Groundwater hydrology and geochemistry
2.	Adina Paytan#	female	UC Santa Cruz, USA	Biogeochemistry and nutrient cycling
3.	Jaye Cable	female	University of North Carolina, USA	Groundwater hydrogeology
4	Sagy Cohen	male	University of Alabama, USA	GIS, global numerical modeling, geomorphology
5	Kazi Matin Uddin Ahmed	male	University of Dhaka, Bangladesh	Groundwater contamination
6	Howard Waldron	male	University of Cape Town South Africa	Coastal zone water quality
7	Thomas Stieglitz	male	Institut Universitaire Européen de la Mer, France	Geophysics and SGD
8	Yishai Weinstein	male	Bar-Ilan University, Israel	Hydrogelogy
9	Felipe Luis Niencheski	male	Fundação Universidade Federal do Rio Grande, Brazil	Environmental Chemistry
10	John Harrison	male	Washington State University, Vancouver, USA	River-derived nutrient fluxes

**We realize that there are 4 associate members from the USA in the team, however we emphasize that the members represent distinct strengths and areas of expertise needed for a successful WG, (Cable – Hydrology and SGD; Paytan – Biogeochemistry; Cohen – Modeling; Harrison – River fluxes and GlobalNEWS. These are key areas instrumental for the WG and involvement of world experts is needed regardless of nationality.*

#*We would like to acknowledge specially HW and AP whose insightful comments were critical in preparation of this proposal.*

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Appendix

Natasha Dimova (co-chair): Dr. Dimova is a coastal oceanographer and hydrogeologist with expertise in the radon-based tracer techniques in marine and freshwater systems. Dimova initiated the SCOR NExT SGD working group proposal and has been ***working on compilation of SGD data*** with Sagy Cohen (associate member) for establishing a global SGD model. She is an early-career female scientist who has been collaborating with scientists worldwide, including Asia, USA and Europe.

1) Paytan, A., Lecher, A., L., Dimova, N., Sparrow, K. J., Kodovska, F. G-T., Murry, J., Tulaczyk, S., and Kessler, J. D., 2015. Methane transport from the active layer to lakes in the Arctic using Toolik Lake, Alaska as a case study, *Proceedings of National Academy of Sciences*, doi/10.1073/pnas.1417392112.
2) Dimova, N.T., W.C. Burnett, J.P. Chanton, and J.E. Corbett, 2013. Application of radon-222 to investigate groundwater discharge into small shallow lakes, *Journal of Hydrology*, 486: 112–122.
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4) Dimova, N.T., W.C. Burnett, K. Speer, 2011. A natural tracer investigation of the

hydrological regime of Spring Creek Springs, the largest submarine spring system in Florida, *Continental Shelf Research*, 31: 731-738.
5) Dimova, N.T. and W.C. Burnett, 2011. Evaluation of groundwater discharge into small lakes based on the temporal distribution of radon-222, *Limnology and Oceanography*, 56 (2): 486– 494.

Nils Moosdorf (co-chair): Dr. Moosdorf is a hydrogeologist, specialized in estimating large scale geochemical material fluxes via statistical methods based on large datasets. His experience lays in ***large scale river constituent flux modeling.*** Since August 2014 Dr. Moosdorf leads a junior research group on ecological impacts of SGD at different scales. He also specialized on global scale datasets based on lithological information. He is involved in several cooperative projects with scientists primarily in the USA, but also in Europe and Asia.

1) Moosdorf, N., Stieglitz, T., Waska, H., Dürr, H.H. & Hartmann, J., 2015. Submarine groundwater discharge from tropical islands: a review, *Grundwasser*, 20(1): 53-67.
2) Gleeson, T., Moosdorf, N., Hartmann, G. & Van Beek, L.P.H., 2014. A glimpse beneath earth's surface: GLobal HYdrogeology MaPS (GLHYMPS) of permeability and porosity, *Geophysical Research Letters*, 41(11): 3891-3898.
3) Hartmann, J. & Moosdorf, N., 2012. The new global lithological map database GLiM: A representation of rock properties at the Earth surface, *Geochemistry Geophysics Geosystems*, 13: Q12004.
4) Moosdorf, N., Hartmann, J., Lauerwald, R., Hagedorn, B. & Kempe, S., 2011. Atmospheric CO2 consumption by chemical weathering in North America, *Geochimica et Cosmochimica Acta*, 75(24): 7829-7854.
5) Moosdorf, N., Hartmann, J. & Dürr, H.H., 2010. Lithological composition of the North American continent and implications of lithological map resolution for dissolved silica flux modeling, *Geochemistry Geophysics Geosystems*, 11:Q11003.

Guebuem Kim: Dr. Kim's expertise is in radionuclides (Rn and Ra), organic matter, REE and ***nutrient cycling in subterranean estuaries on a regional and global scale***. Dr. Kim established a webpage for SGD data compilation for initiating the NExT SGD working group.

1) Yan, G., and G Kim, 2015. Sources and fluxes of organic nitrogen in precipitation over the southern East Sea/Sea of Japan, *Atmospheric Chemistry and Physics*, 15(5): 2761-2774.
2) Kwon, E. Y., G. Kim, F. Primeau, W. S. Moore, H-M. Cho, T. DeVries, J. L. Sarmiento, M.
A. Charette, Y-K. Cho, 2014. Global Estimate of Submarine Groundwater Discharge Based on an Observationally Constrained Radium Isotope Model, *Geophysical Research Letters*, 41(23): 8438–8444.
3) Kim, I, and G. Kim, 2014. Submarine groundwater discharge as a main source of

rare earth elements in coastal waters, *Marine Chemistry*, 160 (20): 11-17.

4) Kim, T-H., and G. Kim, 2013. Changes in seawater N:P ratios in the northwestern Pacific Ocean in response to increasing atmospheric N deposition: Results from the East (Japan) Sea, *Limnology and Oceanography*; 58(6): 1907-1914.
5) Kim, T-H., H. Waska, E. Kwon, I. Gusti Ngurah Suryaputra, G. Kim, 2012. Production, degradation, and flux of dissolved organic matter in the subterranean estuary of a large tidal flat, *Marine Chemistry* 142-144: 1-10.

Isaac Santos: Dr. Santos was invited to be part of the NExT SGD working group because of the wide spectrum of research topics he has been involved with and his knowledge of the ***carbon and nutrient cycling in subterranean estuaries*****,** specifically in carbonate sandy aquifers and coral reef environments.

1) Santos, IR, S Ruiz-Halpern, DT Maher, 2013. Carbon dioxide dynamics driven by groundwater discharge in a coastal floodplain creek ML Atkins, *Journal of Hydrology* 493: 30-42
2) Santos, IR., B.D Eyre, and M. Huettel, 2012. The driving forces of porewater and groundwater flow in permeable coastal sediments: A review, *Estuarine, Coastal and Shelf Science* 98: 1-15
3) Santos, IR, R.N. Glud, D. Maher, D. Erler, B.D Eyre, 2011. Diel coral reef acidification driven by porewater advection in permeable carbonate sands, Heron Island, Great Barrier Reef, *Geophysical Research Letters* 38 (3), doi: 10.1029/2010GL046053.
4) Santos, IR, D Erler, D Tait, B.D Eyre, 2010. Breathing of a coral cay: Tracing tidally driven seawater recirculation in permeable coral reef sediments, *Journal of Geophysical Research*: *Oceans*, 115, C12, doi: 10.1029/2010JC006510
5) Santos, IR, W. C Burnett, J. P. Chanton, B. Mwashote, and IGNA Suryaputra, 2008. Nutrient biogeochemistry in a Gulf of Mexico subterranean estuary and groundwater-derived fluxes to the coastal ocean, *Limnology and Oceanography* 53 (2): 705-718

Holly Michael: Dr. Michael was invited to this working group because of her unique expertise in both ***numerical modeling and radio tracer field techniques***. Holly has established a connection between the two fields and plays an important role in breaking the boundaries between hydrogeology and coastal oceanography.

1) Sawyer, AH, O Lazareva, KD Kroeger, K Crespo, CS Chan, T Stieglitz, and HA Michael, 2014. Stratigraphic controls on fluid and solute fluxes across the sediment-water interface of an estuary, *Limnology & Oceanography,* 59(3):997–1010.
2) Michael, HA, CJ Russoniello, and LA Byron, 2013. Global assessment of vulnerability to sea-level rise in topography-limited and recharge-limited coastal groundwater systems, *Water Resources Research*, 49 (4): 2228-2240.
3) Michael, HA, MA Charette, and CF Harvey, 2011. Patterns and variability of groundwater flow and radium activity at the coast: a case study from Waquoit Bay,

Massachusetts, *Marine Chemistry,* 127: 100-114.
4) Michael, HA, AE Mulligan, and CF Harvey, 2005. Seasonal oscillations in water exchange between aquifers and the coastal ocean, *Nature*, 436: 1145-1148.
5) Michael, HA, JS Lubetsky, and CF Harvey, 2003. Characterizing submarine groundwater discharge: a seepage meter study in Waquoit Bay, Massachusetts, *Geophysical Research Letters*, 30 (6): doi: 10.1029/2002GL016000, 6.

Caroline Slomp: We invited Dr. Slomp as a full member because of her in-depth quantitative understanding of the cycling of elements in marine environments that will be essential in the mechanistic understanding of nutrient fluxes via SGD in nearshore coastal areas. Additionally, Dr. Slomp's research is broad in scope and involves field and laboratory work that is typically ***integrated with large scale ocean and river modeling*.**

1) Beusen, A.H.W., Slomp, C.P. and Bouwman, A.F., 2013. Global land-ocean linkage: direct inputs of nitrogen to coastal waters via submarine groundwater discharge, *Environmental Research Letters*, 8 (3), doi:10.1088/1748-9326/8/3/034035.
2) Dürr, H.H., Laruelle, G.G., van Kempen, C.M., Slomp, C.P., Meybeck, M., Middelkoop, H., 2011. Worldwide Typology of Nearshore Coastal Systems: Defining the Estuarine Filter of River Inputs to the Oceans. *Estuaries and Coasts*, 34(3): 441-458.
3) Spiteri, C., Slomp, C.P., Tuncay, K. and Meile, C., 2008. Modeling biogeochemical processes in subterranean estuaries: Effect of flow dynamics and redox conditions on submarine groundwater discharge of nutrients, *Water Resources Research*, *44*, W02430, doi:10.1029/2007WR006071.
4) Slomp, C.P. and Van Cappellen, P., 2007. The global marine phosphorus cycle: sensitivity to oceanic circulation, *Biogeosciences*, 4: 155-171.
5) Slomp, C.P. and Van Cappellen, P.S.J., 2004. Nutrient inputs to the coastal ocean through submarine groundwater discharge: controls and potential impact, *Journal of Hydrology*, 295: 64-86.

Makoto Taniguchi: Dr. Taniguchi has long-term experience in working on different aspects of groundwater and its significance for the global hydrological cycle. His contribution will be specifically in ***connection between societies - water resources-climate change***. Dr. Taniguchi is also a former member of the SCOR 112 WG *Magnitude of Submarine Groundwater Discharge and its Influence on Coastal Oceanographic Processes*

1) Taniguchi, M., 2015. The basic act on the water cycle with groundwater, *Journal of Groundwater Hydrology* 57(1):83-90.
2) Taylor, RG, B. Scanlon, P. Döll, M. Rodell, R. van Beek, Y. Wada, L. Longuevergne, M. Leblanc, J. S. Famiglietti, M. Edmunds, L. Konikow, T.R. Green, J. Chen, M. Taniguchi, M. F. P. Bierkens, A. MacDonald, Y. Fan, R. M. Maxwell,

Y. Yechieli, J. J. Gurdak, D. M. Allen, M. Shamsudduha, K. Hiscock, P. J.-F. Yeh, I. Holman & H. Treidel, 2013. Groundwater and climate change, *Nature Climate Change*. DOI:10.1038/nclimate1744.

3) Taniguchi, M., Yamamoto, K., and Aarukkalige, P. R. 2011, Groundwater resources assessment based on satellite GRACE and hydrogeology in Western Australia, *GRACE, Remote Sensing and Ground-based Methods in Multi-Scale Hydrology (Proceedings of Symposium J-H01 held during IUGG2011 in Melbourne, Australia, July 2011)* 343 :3-8.
4) Taniguchi, M, 2011. What are the Subsurface Environmental Problems? Groundwater and Subsurface Environmental Assessments Under the Pressures of Climate Variability and Human Activities in Asia, *Groundwater and Subsurface Environments: Human Impacts in Asia Coastal Cities* :3-18. DOI:10.1007/978-4-431-53904-9_1.
5) Taniguchi, M., A. Aureli, and J.L. Martin, 2009. Groundwater resources assessment under the pressures of humanities and climate change. *IAHS Publication* 334.

Bo-chao Xu: The contribution of Dr. Xu for this working group will be primarily in his understanding of ***SGD impacts on large estuaries*** and the geochemical transformations of nutrients at the sediment-water interface.

1) Meng, J., P. Yao, T. S. Bianchi, D. Li, B. Zhao, B. Xu, Z. Yu, 2015. Detrital phosphorus as a proxy of flooding events in the Changjiang River Basin, *Science of the Total Environment*, 517: 22-30.
2) J. Sui, Z. Yu, X. Jiang, B. Xu, 2015. Behavior and budget of dissolved uranium in the lower reaches of the Yellow (Huanghe) River: Impact of Water-Sediment Regulation Scheme, *Applied Geochemistry*, 61: 1-9.
3) Xu, Bo-Chao, W. C. Burnett, N. T. Dimova, H. Wang, L. Zhang, M. Gao, X. Jiang, Z. Yu, 2014. Natural ^{222}Rn and ^{220}Rn Indicate the Impact of the Water-Sediment Regulation Scheme (WSRS) on Submarine Groundwater Discharge in the Yellow River Estuary, China, *Applied Geochemistry,*http://dx.doi.org/10.1016/j.apgeochem.2014.09.018
4) Xu, Bo-Chao, W. C. Burnett, N. T. Dimova, G. Liu, T. Mi, Z. Yu, 2013. Hydrodynamics in the Yellow River Estuary via radium isotopes: ecological perspectives, *Continental Shelf Research*, doi.org/10.1016/j.csr.2013.06.018.
5) Xu, Bo-Chao, N. T. Dimova, L. Zhao, X-Y. Jiang, and Z.-G. Yu, 2013. Determination of water ages and flushing rates using short-lived radium isotopes in large estuarine system, the Yangtze River Estuary, China, *Estuarine, Coastal and Shelf Science,* 121-122: 61–68.

Gopal Krishan: Dr. Krishan's research is in the field of natural resource management, isotope hydrology, RS and GIS applications. His extensive work in ***groundwater systems in India*** and coastal areas on Bengal Bay is extremely valuable for the NExT SGD working group because of the relatively sparse data available in this part of the world.

1) Krishan, G., M. S. Rao, C.P. Kumar, S. Kumar, and M. R. A. Rao, 2015. A study on identification of submarine groundwater discharge in northern east coast of India, *Aquatic Procedia,* 4: 3 – 10.
2) Lohani AK and Krishan G, 2015. Application of Artificial Neural Network for Groundwater Level Simulation in Amritsar and Gurdaspur Districts of Punjab, India, *Earth Science and Climate Change*, 6 (4), doi: 10.4172/2157-7617.1000274.
3) Krishan, G., Rao, M.S. and Kumar C.P., 2014a. Estimation of Radon concentration in groundwater of coastal area in Baleshwar district of Odisha, India. *Indoor Built Environ.* doi:10.1177/1420326X14549979.
4) Krishan, G., Rao, M.S. and Kumar C.P., 2014b. Radon Concentration in Groundwater of East Coast of West Bengal, India. *Journal of Radioanalytical and Nuclear Chemistry*. doi: 10.1007/s10967-014-3808-4.
5) Krishan, G., M.S. Rao, R.S. Loyal, A.K. Lohani, N.K. Tuli, K.S. Takshi, C.P. Kumar, P. Semwal, and S. Kumar, 2014. Groundwater level analyses of Punjab, India: a quantative approach, *Octa Journal of Environmental Research*, 2(3): 221-226.

Robert Delinom: Prof. Delinom is ***hydrogeologist*** who leads a working group which researched submarine groundwater discharge on different Indonesian islands. His perspective will highlight the ***tropical regions***, where particularly tropical islands can contribute significantly to global fluxes and show strong local impacts of SGD.

1) Bakti, H., Naily, W., Lubis, R.F., Delinom, R., Sudaryanto, S., 2014. PENJEJAK KELUARAN AIRTANAH DI LEPAS PANTAI (KALP) DI PANTAI UTARA SEMARANG DAN SEKITARNYA DENGAN ^{222}RADON. Riset Geologi dan Pertambangan, 24(1): 43-51. (In Indonesian)
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3) Umezawa, Y., Onodera, S., Ishitobi, T., Hosono, T., Delinom, R., Burnett, W.C., Taniguchi, M., 2009, Effects of urbanization on groundwater discharge into Jakarta Bay, Trends and Sustainability of Groundwater in Highly Stressed Aquifer. IAHS Publication 329, IAHS Press, Vamsi Art Printers Pvt. Ltd. Hyderabad.
4) Lubis, R., Sakura, Y., Delinom, R., 2008. Groundwater recharge and discharge processes in the Jakarta groundwater basin, Indonesia. *Hydrogeology Journal*, 16(5): 927-938.
5) Umezawa, Y., Hosono, T., Onodera, S., Siringan, F., Buapeng, S., Delinom, R., Yoshimizu, C., Tayasu, I., Nagata, T., Taniguchi, M., 2008. Sources of nitrate and ammonium contamination in groundwater under developing Asian megacities. *Science of the Total Environment*, 404(2-3): 361-376.

2.2.9 International Quality Controlled Ocean Database: Subsurface temperature profiles (IQuOD) *Turner*

1. Summary

Historical ocean temperature profile observations provide a critical element for a host of ocean and climate research activities. These include providing initial conditions for seasonal-to-decadal prediction systems, evaluating past variations in sea level and Earth's energy imbalance, ocean state estimation for studying variability and change, and climate model evaluation and development. The International Quality controlled Ocean Database (IQuOD) initiative represents a community effort to create the most globally complete temperature profile dataset, with comprehensive metadata and uncertainty information to promote progress in all of the above research avenues. In particular, IQuOD will facilitate improvements in expendable bathythermograph (and other) bias corrections and improved ocean state estimate products for forecast initialization and climate change studies through more complete metadata and uncertainty information. Internationally agreed "best practice" approaches to data quality control will be developed, documented and shared with the wider research community through open-source code bases. The freely available IQuOD database will be based on, and served alongside, the World Ocean Database – the most complete and widely used ocean profile database in the world. An IQuOD SCOR working group will be fundamental to progress 5 key elements of the wider IQuOD initiative: (1) development and application of algorithms to populate missing profile metadata; (2) development and documentation of "best practice" automated quality control procedures; (3) development and application of uncertainty estimates for each observation in a profile; (4) assembly and distribution of the IQuOD database; and (5) knowledge transfer and capacity building through international collaboration.

2. Scientific Background and Rationale

2.1 Importance of subsurface ocean temperature observations

Subsurface temperature is an essential ocean variable required to monitor variability and change in the physical ocean, Earth's energy flows, global and regional sea level, and also the overall state of health and wealth of the marine environment (FOO, 2012).

Variations in ocean temperature give rise to changes in mixed-layer depth, stratification, mixing rates, sea ice extent, and atmosphere and ocean circulation. All of these changes in the physical environment can affect marine biology, directly and indirectly through changes in marine biogeochemistry, such as nutrient and oxygen recycling, uptake of (anthropogenic) carbon emissions, ocean acidification, etc (Pörtner et al., 2014).

Changes in ocean heat content are directly derived from subsurface temperature. Since 1970s, heat uptake by the global ocean accounts for more than 90% of the excess heat accumulated in the Earth system associated with anthropogenic climate change (Rhein et al., 2013). While this ocean heat uptake mitigates surface warming, it increases the ocean's volume through thermal expansion, accounting for about 1/3 of the observed global mean sea level rise (Church et al., 2013).

Subsurface ocean temperature observations also underpin a number of modeling activities (e.g., www.godae.org/What-is-GODAE.html). In particular, high quality long-term ocean temperature records with well characterized uncertainty estimates are needed to evaluate and constrain global climate and Earth system models in order to better quantify the physical drivers of past and current change, and also to predict future changes in both the marine and terrestrial environment (Flato et al., 2013).

Improved understanding of global climate change represents one of society's most pressing challenges and also the most demanding application of subsurface ocean temperature data. This is because it requires the highest quality, most consistent and complete database, to place modern changes in the context of past changes (e.g., mean trends and extremes), to separate the influence of natural drivers from human activities (Bindoff et al., 2013), and to improve the effectiveness of risk management assessments (identification of vulnerabilities, adaptation and mitigation responses).

2.2 The challenge

There is an increasing demand for a climate-quality global ocean temperature profile database (including complete metadata and well charaterized uncertainty estimates) to underpin a host of climate change research activities carried out by both observational and modeling communities. Historical subsurface temperature observations, however, have been largely collected for purposes other than understanding global change, by a mix of evolving technologies (e.g., instruments with various accuracies and biases), and in many instances only available with reduced vertical resolution and/or incomplete metadata. Despite dedicated efforts by independent groups, the global historical database still contains a relatively large fraction of biased, duplicate and poorly quality controlled temperature observations that can confound global ocean and climate change research.

2.3 The IQuOD initiative

The overarching goal of the IQuOD initiative is to produce and to freely distribute the highest quality, most complete and consistent historical subsurface ocean temperature global database, along with (intelligent) metadata and assigned uncertainties.

With an internationally coordinated effort organized by oceanographers, with data and ocean instrumentation expertise, and in close consultation with end users (e.g., climate modelers), the IQuOD initiative will assess and maximize the potential of an irreplaceable collection of ocean temperature observations (tens of millions of profiles collected at a cost of tens of billions of dollars, since 1772) to fulfil the demand for a climate-quality global database that can be used with greater confidence in a vast range of climate change related research and services of societal benefit. Current IQuOD membership includes groups from Argentina, Australia, Brazil, Canada, France, Germany, India, Japan, Mexico, Norway, Russia, Senegal, Spain, South Africa, UK, and USA.

2.4 Rationale and timeliness for an IQuOD-SCOR working group
Only by focusing expertise and resources into a single best practice international community effort, we will be able to deliver a much needed historical "climate quality" subsurface temperature database to the global ocean and climate research communities. No single group has the combined expertise and resources to develop, implement and apply the best standard quality control procedures, in an effective and timely manner.

An internationally coordinated SCOR working group, potentially co-sponsored by IAPSO, and with formal support from the IOC Committee on International Oceanographic Data and Information Exchange (IODE), will provide the best mechanism to progress 5 critical steps towards the overarching goal of the IQuOD initiative during the next 3 years. These are: (1) development and application of algorithms to populate missing profile metadata; (2) development and documentation of "best practice" automated quality control procedures; (3) development and application of uncertainty estimates for each observation in a profile; (4) assembly and distribution of the IQuOD database; and (5) knowledge transfer and capacity building through close international collaboration.

Strong international participation is essential to draw on the widest possible pool of expertise and for IQuOD to be adopted as the definitive database for ocean and climate research activities. The IQuOD community has shown itself to be a well-organized international group – having already held two international workshops (in Hobart, Australia June 2013 and Silver Spring, USA in June 2014). However, insufficient funding has prevented key members from attending these workshops. Funding from SCOR would allow the IQuOD initiative to gain 'critical mass' to ensure good progress over the next 3 years. This progress would be used to leverage further funding for task team activities as well as to expand the membership of the IQuOD community.

There are two main elements to the timeliness of the IQuOD-SCOR working group. The first is that there is an urgent need to capture and retain the knowledge of the older instrumentation types from researchers who are nearing retirement age. The second is that the Argo array of profiling floats has now provided about a decade of quasi-global observations and improved understanding of the ocean mean state and variability with which to refine our quality control procedures and better discriminate between good and bad data points in the historical record.

3. 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.

4. Work Plan

The IQuOD working group will progress the Terms of Reference in Section 3 by convening annual meetings over the next 3 years (upon funding by SCOR), together with regular email exchange, online meetings, information exchange through web-based access (www.iquod.org) and code development via the Mozilla Science Lab (gitHub) validation suite forum (www.mozillascience.org/projects/autoqc).

SCOR-funded meetings will be scheduled to coincide with relevant group meetings (e.g., SOT/SOOPIP, GTSPP, XBT Science Team, GO-SHIP, Argo, IAPSO/IUGG, GODAE) to encourage interactions with both data experts and user groups, and maximize visibility and community participation in IQUOD activities. We will seek joint sponsorship and/or endorsement for IQuOD from IAPSO, WCRP/CLIVAR and US CLIVAR (Section 9).

The main activities for the work plan are:

(1) Development and application of algorithms for inclusion of intelligent metadata

We will develop and apply algorithms to attach "intelligent metadata" to historical temperature profiles with missing metadata. These algorithms will be developed as informed guesses, based on the available metadata. For instance, XBT manufacturer can often be inferred by the nationality of the vessel or research cruise, and likely probe type can be inferred from profile termination depth. Our initial focus will be on improving XBT metadata, but will later be expanding to include additional instrument types. XBT data comprise the largest fraction of the historical temperature observations and about 50% of these observations in the World Ocean Database have missing metadata (e.g., probe type, manufacturer, logging system, etc; Abraham et al., 2013). Inclusion of intelligent metadata will facilitate refinements to instrumental bias corrections and will promote a more homogeneous long-term ocean record critical for climate change research, data assimilation and modeling efforts.

(2) Development, implementation and dissemination of best practice automated quality control procedures

We will share expertise by performing a series of quantitative "benchmarking" automated quality control (AutoQC) tests among several data center groups and will establish an agreed best practice approach. Benchmarking results will be published in an open access peer-reviewed journal and will form the basis of the SCOR-funded IQuOD AutoQC toolkit, including open access reference guides and software tools made freely available to the wider oceanographic community. Data flagged as questionable by the best parctice AutoQC tests will be carried forward to an IQuOD Task Team on "Enhanced Quality Control Procedures" (these activities are outside the scope of the SCOR working group).

(3) Development of uncertainty estimates

We will develop and document estimates of the random error for each individual observation, based on the current literature and manufacturer specifications. In liaison with end user communities, we will consider the wider treatment of uncertainties – such as that associated with XBT bias corrections in light of incomplete metadata – and how to best combine several sources of uncertainty.

(4) Global database assembly and distribution

The starting point for the IQuOD database will be NOAA's National Centers for Environmental Information (NCEI) World Ocean Database, which is the most complete global repository of ocean temperature profiles. We will ensure that the data format can accommodate all of the additional information that the IQuOD working group will provide. NCEI will also serve the IQuOD database (interim) versions (and any related gridded products), as it becomes available along the course of the next 3 years. IQuOD data products will also be served alongside Coupled Model Intercomparison (CMIP) data for climate model evaluation in collaboration with colleagues from the Program for Climate Model Diagnostics and Intercomparison (PCMDI, see attached letter of support).

Timeline

Year 1: will focus on the development and delivery of 'first cut' algorithms for intelligent metadata and random error assignments. We will also work towards coding up of all partner AutoQC procedures in a standard, open-source programming language (python). Version 1 of the IQuOD database will include intelligent metadata and initial uncertainty estimates. The first SCOR working group meeting will focus on achieving an agreed roadmap to progression of these tasks.

Year 2: will focus on the benchmarking of the various AutoQC procedures using a number of high quality regional reference data sets. These reference datasets have been quality controlled by skilled operators familiar with the regional oceanography, e.g., the QuOTA dataset (http://www.marine.csiro.au/~cow074/quota/quota.htm). The benchmarking analysis will identify the most effective combination of AutoQC checks and the work will be submitted to an open access scientific journal. The AutoQCed database, in combination with any advances in random error and intelligent metadata assignment, will constitute version 2 of the IQuOD database. The second SCOR working group meeting will serve to discuss the outcomes of Year 1, to share the results of the benchmarking tests and to provide an international forum for a consensus on best practices for AutoQC procedures for temperature observations.

Year 3: will focus in the preparation and submission of scientific papers related to the AutoQC benchmarking exercise; on the publication of version 3 of the IQuOD database with updates and improvements from the previous two years, including related documentation (reference guides and software tools). We will also be report on the feasibility of using machine learning (or other novel computational) methods for the expert quality control step, through publication of a discussion article. The third SCOR working group meeting will be organized as a large international workshop for knowledge transfer and capacity building, to encourage rapid and wide adoption of best standards for quality control of historical temperature profile data, inclusion of intelligent metadata and uncertainty. We will also seek additional funding sources to ensure maximum international participation, particularly from developing countries not yet involved in IQuOD.

5. Deliverables

1. (Years 1-3 and ToR 1-7) Versions 1 to 3 of the IQuOD database will be served from the NCEI website annually. Version 1 will contain all available metadata and intelligent metadata for XBTs, with initial uncertainty estimates. Version 2 will contain Automated QC flags and any other improvements to version 1. Version 3 will further contain updates and improvements from version 2.
2. (Years 1-2 and ToR 1, 5) Algorithms developed for assigning intelligent metadata and uncertainties will be published in an open-access peer-reviewed journal as part of the IQuOD v1 documentation. The source code will be made publicly available.
3. (Years 2-3 and ToR 2, 3) The IQuOD Automated QC algorithms will be documented and the source code made available on an open source software repository. The benchmarking results will be published in an open-access peer-reviewed journal as part of the IQuOD v2 documentation.
4. (Year 3 and ToR 4) The IQuOD community will publish a discussion article on the potential for novel methods (e.g. machine learning) to improve automated quality control systems.

6. Capacity Building

One of the key aims of IQuOD is to provide a long-lasting database for oceanography and climate change studies. It will be maintained at the National Centers for Environmental Information (formerly the National Oceanography Data Center, USA) alongside the World Ocean Database. IQuOD will facilitate new ocean and climate research based on the highest possible data quality with the most complete uncertainty and metadata information. All data, documentation and processing algorithms will be placed in the public domain to ensure maximum utility of working group activities for the wider research community.

The global IQuOD database will draw on and preserve knowledge and skills from a large community of data experts. These skills and knowledge pertain to a number of areas, including: instrumentation; quality control methods; data homogenization techniques; and regional oceanography. Knowledge transfer will be initially facilitated through international workshops but we expect to achieve longevity through fostering a new community of ocean scientists from both developed and developing nations. Guidance on "best practices" and open-access documentation will ensure that the progress made by this community is recorded and long lasting.

The SCOR working group will actively help build capacity by funding participants from developing nations to attend workshops and working with the community to leverage further funding from other sources.

7. Working Group Composition

7.1 Full members

	Name	**Gender**	**Place of work**	**Expertise**
1	TVS Udaya Bhaskar	M	Indian National Centre for Ocean Information Services (INCOIS), **India**	Automated and manual quality control; data processing; development of gridded products; web hosting; and ocean climate science.
2	Tim Boyer	M	National Centers for Environmental Information (former NODC), NOAA, **USA**	Data aggregation, quality control; database management; interoperability (file format); gridded data products; web hosting, and ocean climate change science.
3	Marcela Charo	F	Departamento Oceanografía, Servicio de Hidrografía Naval, Ministerio de Defensa, **Argentina**	Quality control; database management (Southwestern Atlantic Ocean); calibration and sensor expertise; software development, and ocean climate science.

4	Christine Coatanoan	F	Coriolis Data Center, IFREMER, **France**	Quality control procedures, data validation, management and objective analysis.
5	Catia Domingues (co-chair)	F	University of Tasmania, **Australia**	User: Global ocean content and implications for sea level. Steering team member of the WCRP Grand Challenge on sea level change and coastal impacts. Steering team member of the CLIVAR Research Foci CONCEPT-HEAT. Member of the CLIVAR Global Synthesis and Observations Panel.
6	Viktor Gouretski	M	University of Hamburg, Center for Earth System Research and Sustainability, **Germany**	Ocean instrumentation, quality control of hydrographic data, data processing and analysis, instrumental bias assessment and correction, uncertainty estimation, ocean climate change science (Southern Ocean and global).
7	Shoichi Kizu	M	Tohoku University, **Japan**	Theoretical knowledge on quality control, ocean instrumentation and bias corrections.
8	Alison Macdonald	F	Woods Hole Oceanographic Institute, **USA**	Quality control of temperature and salinity in density space, production of hydrographic data sets, database management, ocean instrumentation and calibration, uncertainty estimation, property transports and decadal scale property differences.
9	Matt Palmer (co-chair)	M	Met Office, **UK**	User: Climate modeling, ocean reanalysis. WCRP CLIVAR Global Synthesis and Observations Panel co-chair. Steering member for CLIVAR Research Foci CONCEPT-HEAT.
10	Ann (Gronell) Thresher	F	CSIRO, **Australia**	Auto and manual quality control procedures, ocean instrumentation and sensors, data management and software development. Extensive scientific, GTSPP, WOCE and Argo quality control experience.

7.2 Associate members

	Name	Gender	Place of work	Expertise
1	Lijing Cheng	M	International Center for Climate and Environment Sciences, Institute of Atmospheric Physics Chinese Academy of Sciences, Beijing, **China**	XBT bias assessment, development of bias correction, and ocean climate science.
2	Mauro Cirano	M	Oceanographic Modeling and Observation Network (REMO), Tropical Oceanography Group (GOAT), Federal Univ. of Rio de Janeiro, **Brazil**	Data assimilation, numerical modeling, observational and modeling network.
3	Rebecca Cowley	F	CSIRO Marine and Atmospheric Research, **Australia**	Hydrographic data calibration and processing, quality control, data management, instrumental bias correction, and ocean climate science. Chair of XBT SOOPIP (Ship of Opportunity Implementation Program) under WMO-IOC JCOMMOPS (Joint Technical Commission for Oceanography and Marine Meteorology in situ Observations Programme Support Centre).
4	Sergey Gladyshev	M	P.P. Shirshov Institute of Oceanology, Moscow, **Russia**	Quality control, data management, ocean instrumentation and ocean climate science.
5	Simon Good	M	UK Met Office Hadley Centre, **UK**	Data aggregation, quality control; database management; interoperability (file format); gridded data products; software development, web hosting, and ocean climate change science.
6	Francis Bringas Gutierrez	M	Atlantic Oceanographic and Meteorological Laboratory, (AOML, NOAA), **USA**	Data acquisition, quality control, and management.

7	Katherine Hutchinson	F	University of Cape Town - Department of Oceanography (UCT), **South Africa**	Instrumental bias assessment and Southern Ocean science.
8	Gabriel Jorda	M	University of the Balearic Islands, Mediterranean Institute for Advanced Studies (IMEDEA CSIC-UIB), **Spain**	Hydrographic data analysis, atlas production (Mediterranean), ocean modeling and ocean climate science.
9	Sergio Larios	M	Centro Nacional de Datos Oceanograficos, Universidad Autonoma de Baja California, Instituto de Investigaciones Oceanologicas (CENDO - IIO – UABC), **Mexico**	Data acquisition and processing, quality control, database management, web hosting, outreach (teaching data visualization tools).
10	Toru Suzuki	M	Marine Information Research Center, **Japan**	Data archaeology, quality control and data management.

8. Working Group Contributions

TVS Udaya Bhaskar is Scientist-in-Charge for ocean observational data and is involved in data search, rescue and archaeology of historical in situ data of the Indian Ocean. He has considerable experience in quality control of in situ data and is involved in developing new quality control methods.

Tim Boyer oversees the World Ocean Database (WOD) project for the National Center for Environmental Information (NCEI, former National Oceanographic Data Center (NODC)) at the National Oceanographic and Atmospheric Administration (NOAA) in the United States. He has been involved in collaborative international work for the World Data Center – Oceanography (WDC-O) and in using ocean temperature profile data to study ocean heat content change.

Marcela Charo is a data scientist with wide experience in planning and acquisition of oceanographic data, on-board sensor calibration, quality control of various instruments (XBT, CTD, Thermosalinograph) and sensors (temperature, conductivity, oxygen, fluorescence). She also has extensive experience in post-processing and data management after cruise acquisition to ensure high quality measurements now and in the future.

Christine Coatanoan is an expert on quality control applied to oceanographic datasets (floats, buoys, research vessels, ships of opportunity, drifters, gliders, sea mammals), which are collected at the Coriolis data center in France. She is also involved in the Argo program, and has experience in data validation using objective analysis.

Catia Domingues (co-chair) is an expert on the application of observational data sets to the understanding of variability and change in ocean heat content and implications for sea level. Her role in the project is scientific oversight and end user engagement to promote the greatest utility of IQuOD products for downstream applications (e.g., climate science and services).

Viktor Gouretski is responsible for quality assessment and analysis of global hydrographic data as a member of the Integrated Climate Data Center (ICDC) at the University of Hamburg, Germany. He has considerable experience in the quality assessment of hydrographic data obtained during the World Ocean Circulation Experiment (WOCE) and during pre-WOCE period, particularly from the Southern Ocean. His role in the IQuOD project is the development and assessment of automated quality control procedures and the development of bias correction schemes for the bathythermograph data and uncertainty estimation.

Shoichi Kizu is an Associate Professor at Tohoku University. He has carried out numerous studies on oceanographic instruments through data analysis and field and laboratory experiments, and participates in a Japanese research project on the management, service and application of observational data.

Alison Macdonald has expertise in quality controlling and analysing multiple parameters from large hydrographic data sets including repeat hydrographic sections. She is currently an active participant in the GO-SHIP program and was previously involved in large global observational programs (WOCE/CLIVAR). She is particularly interested in contributing to the discussions and formulation of the uncertainty estimates for the IQuOD database.

Matt Palmer (co-chair) is Lead Scientist for Sea Level Research at the Met Office Hadley Centre with expertise in ocean observations and climate model applications. He has considerable experience in delivering science through teamwork, having been involved in coordinating coupled model assessment and leading the delivery of scientific projects for UK government, the European Union, and commercial research projects.

Ann (Gronell) Thresher has been working in upper ocean temperature (UOT) data since the inception of WOCE, developing the principles of scientific quality control and applying this to both the data collected by Australian institutions and further developing this and applying it to the QuOTA database of Indian Ocean UOT data, a similar effort to that proposed for IQuOD. This includes development and implementation of a semi-automated quality control system which has helped illustrate the need for the IQuOD project.

9. Relationship with Other Programs and SCOR Working Groups

International Oceanographic Data and Information Exchange (IODE)

Recommendation IODE-XXIII.3: ESTABLISHMENT OF THE IODE PROJECT INTERNATIONAL QUALITY CONTROLLED OCEAN DATABASE (IODE-IQUOD)

The IOC Committee on International Oceanographic Data and Information Exchange,

Recognizing that the goal of the International Quality-controlled Ocean Database

(IQuOD) is to construct the most complete, consistent and high quality ocean temperature (later including other Essential Climate Variables) historical database, with intelligent metadata and assigned uncertainties, to freely distribute for use in ocean, climate and Earth system research and applications of societal benefit,

Recognizing further that the IQuOD effort is organized by the oceanographic community and includes experts in data quality and management, data instrumentation, oceanographers, climate modelers and the broader climate-related community,

Noting the interlinked relationship with the Global Oceanographic Data Archaeology and Rescue (GODAR) and the World Ocean Database (WOD) Projects through Recommendation IODE-XXII.10 (2013) and the Global Temperature and Salinity Profile Programme (GTSPP) established through Recommendation IODE-XV.4 (1996),

Noting further the potential contribution of the IQuOD to the JCOMM-IODE Marine Climate Data System (MCDS),

Convinced that joint work between the IODE and the IQuOD will be mutually beneficial,

Recommends the establishment of IQuOD as an IODE project; the establishment of the IODE Steering Group for the International Quality controlled Ocean Database (SG-IQuOD); and that the membership of the Steering Group shall initially include the Chair of GTSPP, representatives of WOD and GODAR projects and of the Task Team on the MCDS.

Encourages all IOC Member States, Programmes, relevant organizations and projects, to collaborate with the IQuOD,

Invites the IQuOD Project Leaders to report on progress of the project to the Sessions of the IODE Committee.

In addition to being IQuOD members, Toru Suzuki, Charles Sun and Tim Boyer are also involved with IOC/IODE-related projects, such as GTSPP, GODAR, MCDS and WOD.

Global Ocean Data Assimilation Experiment (GODAE)

GODAE OceanView

15 April 2015

Letter of support for "IQuOD: International Quality-controlled Ocean Database"

To Whom It May Concern:

In our function as co-chairs of the international programme GODAE OceanView which provides coordination and leadership in consolidating and improving global and regional ocean analysis and forecasting systems, we hereby state our support for the IQuOD (International Quality Controlled Ocean Database) initiative. IQuOD represents the first globally coordinated effort with the goal to develop the most complete, consistent and high quality ocean profile database to support a range of ocean, climate and Earth system research and services of societal benefit.

The particular aspects of the project that we would like to highlight as of direct benefit to the GODAE OceanView community are:

- Provision of a highest quality reference data set, which can be used for bench-marking ocean data assimilation systems and producing global and regional ocean analyses
- Comprehensive uncertainty estimates on a per observation basis, which will enable refinements to data assimilation schemes and could also be adopted in operational systems
- Development of improved and internationally agreed "best practice" automated QC algorithms that can be adopted by the operational data centers of the GODAE community

We intend to follow the project's progress and, as a community, be directly involved in using IQuOD data products, promoting dialogue on data quality and articulating our requirements and priorities as an end user. There are existing linkages between IQuOD and GODAE OceanView through the Ocean Reanalysis Intercomparison Project (ORA-IP) and through the activities of the CLIVAR Global Observations and Synthesis Panel, which we hope to exploit fully as IQuOD gathers momentum.

With best wishes,

Andreas Schiller, CSIRO, Australia *Fraser Davidson, Fisheries and Oceans, Canada*

Co-Chairs of the GODAE OceanView Science Team (GOVST)

For further information about GODAE OceanView please visit our website (www.godae-oceanview.org)

Program for Climate Model Diagnostics and Intercomparison (PCMDI)

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PCMDI

IQuOD Science Team
23rd April 2015

REF: IQuOD Project ("International Quality-controlled Ocean Database") Case for Support

To Whom It May Concern:

We are writing in support, and with the intention to collaborate with the IQuOD (International Quality Controlled Ocean Database) initiative. IQuOD represents the first globally coordinated effort with the goal to develop the most complete, consistent and high quality ocean profile database to support a range of ocean, climate and Earth system research and services of societal benefit.

IQuOD data products will be of direct benefit to a diverse range of climate modeling and research activities, including:

- Initial conditions and hindcast skill assessment for seasonal-to-decadal prediction
- Climate model evaluation and development
- Detection and attribution of historical climate change
- Development of observational constraints on future climate change

As part of this collaboration, we will work with the IQuOD team to help facilitate the integration of IQuOD data products into the World Climate Research Program's (WCRP) and Coupled Model Intercomparison Projects (CMIP) Earth System Grid Foundation (ESGF) data infrastructure. Making the IQuOD data available in this way will ensure maximum utility of IQuOD data products in climate and Earth system modeling research. We are also interested in working closely with the IQuOD team as the database evolves to include salinity observations in the future, which will be a valuable extension for assessing changes in the hydrological cycle.

We believe that a lack of critical diagnostic analyses of the ocean component of coupled climate models remains a key weakness in our understanding of future climate change – as the global oceans provide a fundamental control on the rate of climate change experienced. The IQuOD initiative is very much required.

Yours sincerely,

Paul J. Durack and Peter J. Gleckler
Program for Climate Model Diagnosis and Intercomparison
Lawrence Livermore National Laboratory
pauldurack@llnl.gov

US CLIVAR

IQuOD activities will be strategically placed to support the new 15-year US CLIVAR Science Plan (http://www.usclivar.org/sites/default/files/documents/2014/USCLIVARSciencePlanFINAL-v3.pdf). To achieve its mission, a list of scientific goals has been set with progress dependent on assessments of the adequacy of historical records, including the historical ocean temperature database (the focus of the IQuOD initiative). IQuOD activities will underpin the following US CLIVAR Science Plan goals:

- Understand the role of the oceans in observed climate variability on different timescales.
- Understand the processes that contribute to climate variability and change in the past, present, and future.
- Better quantify uncertainty in the observations, simulations, predictions, and projections of climate variability and change.
- Improve the development and evaluation of climate simulations and predictions.
- Collaborate with research and operational communities that develop and use climate information.

Janet Sprintall (Scripps Institution of Oceanography, USA) is the IQuOD representative and has previously been a member of the US CLIVAR Science Steering Committee (2012-2014).

CLIVAR Research Foci (RF) on planetary heat balance and ocean heat storage (CONCEPT-HEAT)

To advance understanding on the magnitude of the Earth's energy imbalance, how it is changing over time and implications for future climate change, there is a need to reduce inconsistencies between data and model products as well as to properly assess uncertainties in global and regional estimates – including the contribution from ocean heat storage, for both historical and modern periods. One activity recommended by the CONCEPT-HEAT RF is the improvement of the quality and completeness of the global database of historical ocean temperature profiles and its consistency with modern observations from the Argo era, including coordinated support for data and metadata archaeology. IQuOD will be coordinating with CONCEPT-HEAT to achieve the above goals. Catia Domingues and Matt Palmer (IQuOD co-chairs for the proposed SCOR working group) are members of the Science Steering Committee for CONCEPT-HEAT.

CLIVAR Global Synthesis and Ocean Panel (GSOP)

The IQuOD will be one of the future priorities for the World Climate Research Programme (WCRP) CLIVAR GSOP panel, as noted during the SSG meeting in Moscow, November 2014 (ICPO Informal Report 196/14). Matt Palmer and Catia Domingues (IQuOD co-chairs for the proposed SCOR working group) are respectively a co-chair and a panel member of the CLIVAR GSOP.

WCRP Grand Challenge on regional sea level change and coastal impacts

Thermal expansion induced by ocean heat storage is one of the two major contributions to the global mean sea level rise observed during the late 20th century. Thermal expansion is also expected to be a major component of future sea level rise. Improvement of the data quality, consistency and completeness of the global temperature database as part of the IQuOD activities will be critical to refine the global and regional sea level budgets as well as to constrain sea level predictions (near term) and projections (long term scenarios). Catia Domingues (one of the IQuOD co-chairs for the proposed SCOR working group) has been a co-chair for the scoping team and is now co-leading one of the work packages for the WCRP Grand Challenge on sea level change.

Other WCRP and CLIVR research activities (not listed above)

Improvement of the quality and completeness of the global database of historical ocean temperature profiles and its consistency with modern observations from the Argo era, through IQuOD will also be relevant to the progress of a number of international community activities, such as the following WCRP Grand Challenges (http://www.wcrp-climate.org/gc-regionalclimate) and CLIVAR Research Foci (http://www.clivar.org/science/clivar-research-foci):

- Regional climate information (from seasonal to decadal prediction and long term projections)
- Intraseasonal, seasonal and interannual variability and predictability of monsoon systems
- Decadal variability and predictability of ocean and climate variability
- Understanding and predicting weather and climate extremes

The International Association for the Physical Sciences of the Oceans (IAPSO)

We are planning to submit a proposal to IAPSO to financially co-sponsor IQuOD jointly with SCOR. There have been already some discussions with Isabelle Ansorge, Chris Meinen and Ken Ridgway, who were fully supportive of our plan and encouraged us to submit a proposal. As noted above, IQuOD has been already endorsed by IOC/IODE.

SCOR sponsored project – Southern Ocean Observing System (SOOS)

One of the objectives of the SOOS is to facilitate and enhance global southern ocean observations, including historical records. In addition to being IQuOD members, Steve Diggs (Scripps, USA) and Roger Proctor (IMOS, Australia) arealso co-chair and steering member of the SOOS data management sub-committee, respectively.

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

Hernan Garcia is an associated member of SCOR WG 142 and an IQuOD member with interests to use the IQuOD operating template to improve the quality of global databases for historical ocean salinity and oxygen.

SCOR/IAPSO WG 127 – Thermodynamics and Equation of State of SeawaterThe thermodynamic equation of state for seawater, 2010 (TEOS-1)

IQuOD activities will be using the seawater tools derived by TEOS10 (e.g., conservative temperature) to more accurately estimate ocean heat content changes.

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11. Appendix – 5 key publications for full members

TVS Udaya Bhaskar

1. A Chaterjee & co-authors (incl. **TVS Udaya Bhaskar**) (2012) "A new Atlas of temperature and salinity for the Northern Indian Ocean", Journal of Earth System Science, Vol 121(3), pp 559 - 593.
2. **TVS Udaya Bhaskar** & co-authors (2013) "GUI based interactive system for visual quality control of Argo data", Indian Journal of Geo-Marine Sciences, Vol 42 (5), pp 580 - 586.
3. **TVS Udaya Bhaskar** & co-authors (2013) "A note on three way quality control of Argo temperature and salinity profiles - A semi-automated approach at INCOIS" International Journal of Earth Sciences and Engineering, Vol 5 (6), pp 1510 - 1514.
4. RV Shesu & co-authors (Incl. **TVS Udaya Bhaskar**) (2013)" Open Source Architecture for Web-Based Oceanographic Data Services" Data Science Journal, Vol 12, pp 47 - 55.
5. **TVS Udaya Bhaskar** & co-authors (2006) "Inferring mixed layer depth variability from Argo observations in the western Indian Ocean", Journal of Marine Research, Vol 64(3), pp 393 - 406.

Tim Boyer

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Christine Coatanoan

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2.2.10 The dynamic ecogeomorphic evolution of mangrove and salt marsh coastlines (DEMASCO) *Miloslavich*

Summary/Abstract

The goal of this working group is to unravel the interdisciplinary feedbacks between physical and ecological processes, and to develop a robust framework to understand and manage the future of vegetated shorelines. The world's coastlines are highly dynamic regions subject to oceanic energy in the form of waves, tides and storm surge. Marine vegetation like tidal marshes and mangroves have been shown to provide defense against these often-destructive forces while simultaneously providing ecological co-benefits, such as providing critical habitat for economically-valuable flora and fauna and serving a vital role in the sequestration of blue carbon. All of these roles are threatened by the predicted hydrodynamic changes associated with a changing climate (such as sea level rise and increased storminess) and anthropogenic developments (such as reservoir and dam construction). However, the complex biophysical feedbacks between sediment, hydrodynamics and vegetation are still not well understood, and these gaps in knowledge limit our ability to successfully apply ecosystem-based management of these threatened and highly populated regions. This proposed working group includes members spanning the globe and encompassing the many different areas of expertise required to make significant jumps forward in this interdisciplinary space. The group aims to meet yearly for three years and produce two peer-reviewed scientific reviews (one focused on physical processes and one on management) and an applied report for managers and policy-makers, in addition to keeping the wider community involved through development of a website and the proposal to organize an AGU Chapman Conference.

<u>Scientific Background and Rationale</u>

<u>Rationale</u>

A growing amount of attention and research has focused on the roles that marsh or mangrove vegetation plays in estuaries. From an ecological perspective, coastal vegetation supports functions that are critical to numerous ecosystem services and the economic value of this natural capital is being increasingly recognized (Costanza *et al.*, 1997, Barbier et al., 2008). Furthermore, coastal wetlands have been shown to play a substantial role in blue carbon storage. Both tidal marshes and mangrove swamps posses the ability to sequester disproportionately large quantities of CO_2, with a burial capacity, which is estimated at six times that of the Amazonian rainforest and 180 times that of the open ocean (Nelleman et al., 2009; Donato et al., 2011; McLeod et al., 2011; Breithaupt et al., 2012). Lastly, in addition to providing ecosystem services, attention in recent years has focused on the ability of coastal wetlands to provide protection, buffering shorelines against damage (Arkema *et al.*, 2013; Temmerman *et al.*, 2013), even during extreme conditions such as large wave events (Möller *et al.*, 2014) or tsunamis (Wolanski, 2007).

The use of 'ecodefense', or protecting coastlines through nature offers a cost effective alternative to traditional hard structures, which often are accompanied by negative effects such as fragmenting habitats and reducing ecological connectivity (Peterson and Lowe, 2009). Conversely, 'soft' solutions can enhance resilience, improve water quality and provide habitat for biodiversity offsetting (Jones et al., 2012). However, habitat creation has achieved differing degrees of success and improved understanding of the underlying biophysical processes is necessary in order to raise the success of these remediation measures. Moreover, there is growing acknowledgement of the enhanced vulnerability of coastlines in the face of global climate change, with some areas predicted to encounter more frequent and stronger extreme storm events (e.g. Webster *et al.*, 2005; Knutson *et al.*, 2010), while other areas face significant sea level rise (Sallenger *et al.*, 2012). This vulnerability, coupled with the recent disappearance and accelerating rate of decline of estuarine wetlands and mangroves (Duke, 2007; IPCC, 2013), has brought the topic to the forefront of coastal science.

Substantial progress has been made in the area of the interaction between vegetation and flow, at small (Nepf 2012a, 2012b) and large scales (D'Alpaos *et al.*, 2007; Fagherazzi *et al.*, 2012, Coco *et al.,* 2013; Zhou *et al.,* 2014). However, many large challenges persist. At the small scale, much previous work has been conducted in laboratory flumes using mimics or plants with approximately uniform or simplified morphologies. It remains an open question of how to best scale these results to incorporate the huge range of heterogeneity of bathymetry, densities and vegetation characteristics (e.g. stiffness, lengths etc.) observed within even one marsh area (Bouma *et al.*, 2007). One way forward is to develop hydrodynamic models that include vegetation dynamics, and indeed some modeling packages have incorporated flow over vegetation (e.g. Delft3d, Baptist *et al.*, 2007). Further work is needed on how to parameterize and integrate plant growth models (e.g. incorporating effects such as seasonal die back). Vegetation has been observed to both enhance erosion, particularly through scouring at marsh edges, but to also enhance sediment deposition through damping of energy. The precise balance between these two processes and feedbacks with plant growth, particularly on the larger scales from multiple patches to entire marsh scales only begins to be addressed (Marani *et al.*, 2010). Other biota can also modulate these processes through bioturbation and biostabilisation. Combining all of these processes over long-time scales, covering both extreme and normal conditions is a significant challenge (Bouma *et al.*, 2014). Even after these scientific challenges have been addressed, there remains the significant challenge of connecting the existing and future scientific knowledge with societal values, which can then be translated into policy.

Given the broad scope and interdisciplinary nature of these challenges and the relevance for policy-making and management of estuaries, we propose that the research area is ideally suited to being tackled by a SCOR working group. This working group would provide opportunities to bring together specialists whose work encompasses a range of scales, skills and processes. The group would bring together the mangrove and saltmarsh communities and also combine laboratory experimentalists, field-based scientists, and numerical modelers and scientists heavily involved with policy-making and assessment frameworks. Now is an excellent time to make progress on the key questions especially in light of new instrumentation allowing high- resolution measurements (Mullarney *et al.*, 2015) and improved remote sensing techniques (Silvestri and Marani, 2004). We note that to stay within the constraints of working group membership we have focused on saltmarshes and mangroves. However, it is envisioned that the wider community (for example seagrass and kelp researchers) would also be integrated through the proposed Chapman Conference on the broader topic of vegetation ecohydrodynamics.

The working group would provide assistance to integrate scientists from developing countries, who sometimes lack resources to attend international meetings. This involvement is crucial, noting that it is often in these regions that salt marsh and mangrove areas are being destroyed at the fastest rates (e.g. Vietnam, Thu and Populus, 2007).

Scientific Background

The presence of vegetation introduces significant spatial variation to flow, much of which is associated with the heterogeneity of natural canopies. Within a plant canopy, the key length scales are defined by the stem diameter and stem spacing (Figure 1). This change of scale results in damping of larger scale motions, but introduces turbulence (through vortex shedding) at the smaller stem scale. Inside a canopy, the bulk canopy drag increases with the density of vegetation. This additional drag reduces mean flow speeds and turbulence intensities with distance from the seaward marsh edge (Leonard and Luther, 1995) or can cause flow routing around areas of higher densities. Vegetation can also induce mechanical lateral and longitudinal dispersion owing to particles becoming caught in eddies behind stems.

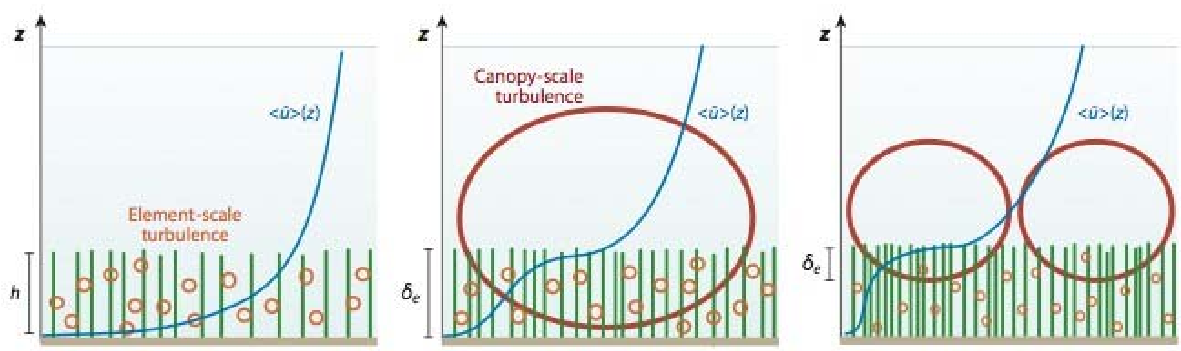

Figure 1: Schematic showing the change in velocity profiles and length scales associated with the presence of vegetation from sparse (left) to transitional (middle) to dense (right) submerged canopies. For the dense vegetation, shear at the top of the canopy induces monami (or waving) and canopy scale turbulence. Figure from Nepf (2012a).

Both laboratory and field studies have demonstrated that seagrass, sedges and mangroves are capable of dissipating wave energy. Indeed, salt marshes have been shown to effectively dissipate waves even during larger wave events and high water levels (Möller *et al.*, 2014). However, the extent of this dissipation is frequency dependent and also depends strongly on the vegetation characteristics (Mullarney and Henderson, 2010).

The tendency for vegetation to slow currents and dissipate waves can create sheltered regions of low flow, where sediments can deposit and marshes typically experience enhanced deposition (Coco *et al.*, 2013). However, recent measurements have demonstrated scour around stems at the marsh edge and the precise balance between the erosional and accretional processes is not yet clear (Tinoco and Coco, 2013). Despite these differences in observed sedimentation between studies, it is generally acknowledged that the three-dimensional structure of the vegetation is an important factor influencing sedimentation patterns within a salt marsh. Hence the vegetation, in part, controls the longer-term marsh scale evolution. However, as noted by Fagherazzi *et al.* (2012), many recent process based models are developed for specific locations and individual species and the wider-applicability of these models is not yet known. A working group would provide an excellent opportunity to answer some of these questions at this critical time.

Terms of Reference

The goals of this working group are as follows:

- Synthesize current knowledge of salt marsh and mangrove swamp evolution, focussing on the key processes (and similarities and differences between the two systems). Hence identify key gaps in understanding and make recommendations for collaborative future research directions. Particular attention will focus on growth and disappearance of marshes, ecosystem services such as wave attenuation, importance for birds/fisheries and carbon sequestration.
- Facilitate collaboration between observational and numerical modeling studies of saltmarsh and mangrove systems. In particular, we aim to:
    - Promote the migration of existing data sets into numerical models
    - Select benchmark dataset(s) that can be used to parameterize and validate numerical models.
    - Identification of existing models and discussion on their strengths and weaknesses.
- Produce a short article on management and restoration of these systems for policymakers. It is envisaged that this article will contain a 'salt marshes for dummies' section on the physics, chemistry and biology of salt marshes and mangroves, describing the key processes from a long-term perspective, and a section that quantifies the ecosystem services (benefits) of these systems that includes several case- studies/lessons learned.
- Convene international working group meetings and document the work of the group on a website.
- Produce two open-access review articles, one focused on the physical processes (possible journals – *Reviews of Geophysics*, *Estuarine Coastal and Shelf Science*, *Advances in Water Research*) and a second focused on management (possible journals - *Conservation Letters*, *Ecological Engineering*, *Restoration Ecology*).
- Write a proposal for a 2018 AGU Chapman Conference on the wider topic of vegetation ecohydrodynamics.

2-218

Working plan

Our first working group meeting will be held in 2016 in conjunction with the Fall AGU meeting in December. This meeting will focus on the following:

- Reviewing the terms of reference and adjusting them as necessary.
- Formulating a concrete action plan for the group.
- Review the state of knowledge and identify critical gaps.
- Discussion of existing data sets. Identify which are best suited for use by modeling community and strategies to make these datasets available.
- In light of the above, compiling components of the review article.
- Discussion and identification of potential sources for further funding.

The second meeting will be held in 2017 (likely at the international conference River, Coastal and Estuarine Morphodynamics) and efforts will be concentrated on the following:

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- Final discussion on the review articles with an aim to submitting shortly after the meeting.
- Initial discussions on a Chapman conference – identifying key participants (i.e conveners).
- Outlining report for policy makers and managers. Discussion on the best strategy for production.
- Ensure the website is up and running

The third meeting should be held in early 2018 (likely at AGU ocean sciences) and involve:

- Final discussion on applied report. Dissemination shortly afterwards.
- Prepare a final report outlining progress made and future directions of research.
- Continued organization for the Chapman Conference, which should be held before the end of the year.

Deliverables

The group will strive to produce the following outputs:

1. A final report detailing the work of the group, including results of discussions on the identification of key knowledge gaps to guide future research.
2. An article designed for policy makers on the management and restoration of salt marsh and mangrove ecosystems.
3. An up-to-date website of the group's activities.
4. Two review papers (one focusing on physical processes and the other on management) in a peer-reviewed open access international journal.
5. A proposal for an American Geophysical Union Chapman Conference

Capacity Building

With members spanning the 5 continents, our proposed group will help to build scientific capacity globally. In particular, we hope to build scientific capacity in Tanzania, Vietnam, and South America. As noted above, many developing regions are threatened by the conversion of wetland and mangrove areas; and by improving capacity in these countries, we hope to raise awareness of the ecological and economic values of these ecosystems. We will also seek advice from the SCOR committee on capacity building on how our working group can further enhance scientific development around the globe. Many members are associated with a range of international programs and this working group will enable all members to widen their professional networks.

Working Group composition

Our proposed group has three co-chairs – Julia Mullarney, Iris Möller and Eric Wolanski. We have selected a chair covering all career stages and from both hemispheres. Each chair will take responsibility for a key deliverable and organizing one meeting (Mullarney will also take on the responsibility of organizing the first meeting and will be the overall point of contact for SCOR).

Our proposed working group contains 10 full members and 10 associate members, representing a balance of geographic locations, interdisciplinary expertise, seniority (all career stages are involved) and gender (see table). Given a large focus of the group is the parameterization of key processes for inclusion into numerical models; we have two members strongly linked to Delft Hydraulics (one associate and one full member). We have ensured membership encompasses scientists bringing together all currently available tools such as field observationalists, laboratory experimentalists, numerical modelers and members with expertise in remote sensing. Additionally, given one of the aims of the group is to bridge the gap between science and policy, we have several members with expertise in coastal policy; ecosystem based management, biodiversity offsetting, and integrated assessment frameworks. We are also currently exploring options for co-funding and support from other organizations such as LOICZ and the United Nations Environment Programme and are currently awaiting responses to our initial inquiries. We note that several other scientists have expressed interest in collaborating with the group in an informal capacity.

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

Name	Gender	Place of work	Expertise relevant to proposal	Career Stage
1 Julia Mullarney Co-chair	Female	University of Waikato, New Zealand	Small scale turbulence inside canopies/vegetation movement	J/I
2 Eric Wolanski Co-chair	Male	James Cook University, Australia	Estuarine ecohydrology	S

3 Iris Möller Co-chair	Female	University of Cambridge, England	Bio-physical interactions in salt marsh systems and their significance for decadal scale marsh stability, wetland science communication and stakeholder involvement	I
4 Hong-Phuoc Vo-Luong	Female	National University of Science, Ho Chi Minh City, Vietnam	Flows and sedimentation within mangroves	I
5 Tjeerd Bouma	Male	Royal Netherlands Institute of Sea Research (NIOZ), the Netherlands	Spatial ecology, conservation ecology, nature based coastal defense	S
6 Jasper Dijkstra	Male	Deltares, The Netherlands	Numerical modeling of vegetated regions	J/I
7 Heidi Nepf	Female	Massachusetts Institute of Technology, USA	Vegetated hydrodynamics and morphodynamics	S
8 Giovanni Coco	Male	University of Auckland, New Zealand	Geomorphology and biophysical interactions	I/S
9 Halima Kiwango	Female	The Nelson Mandela African Institution of Science and Technology, Tanzania	Estuarine ecohydrology (specifically water quality) and mangrove ecology.	J
10 Zeng Zhou	Male	Hohai University, Nanjing, China	Ecomorphodynamics	J

Associate Members (no more than 10)

Name	Gender	Place of work	Expertise relevant to proposal	Career Stage
1 Fernando Mendez	Male	University of Cantabria, Spain	Climate and waves, extremes, coastal climate change	I
2 Andrea D'Alpaos	Male	University of Padova, Italy	Ecomorphodynamics	

3 Dano Roelvink	Male	UNESCO-IHE, The Netherlands	Morphodynamic numerical modeling	S
4 Sergio Fagherazzi	Male	Boston University, USA	Geomorphic evolution of salt marshes/remote sensing of vegetated regions	I/S
5 Gerado Perillo	Male	Argentinian Institute of Oceanography, Bahia Blanca, Argentina	Oceanography, physical- biological interactions, sediment transport	S
6 Alice Newton	Female	University of Algarve, Portugal and Norwegian Institute of Air Research,	Coastal lagoons, integrated assessment frameworks (SAF and DPSIR)	S
7 Gail Chmura	Female	McGill University, Canada	Carbon fluxes and impacts of nutrient enrichment	S
8 Chen Wang	Female	Satellite Environment Center of the Ministry of Environmental Protection, China	Remote sensing/satellite imaging and GIS of coastal wetlands	J
9 Mike Elliott	Male	University of Hull, UK	Effects of human activities on biological systems, coastal policy, biodiversity offsetting	S
10 Marco Marani	Male	Duke University, USA	Observations and modeling interactions between vegetation species, erosion/deposition, intertidal landforms, and biodiversity	S

Working Group contributions

The working group has been designed to bring together people with complementary primary areas of expertise. Mullarney focuses on smaller-scale observation measurements within vegetated environments and the movement of vegetation under hydrodynamic forcing. Wolanski is a leading expert in the areas of coastal oceanography and ecohydraulics. Vo- Luong's research focuses on flows and sediment transport within mangrove forests, and she takes a field and theoretical approach. Nepf is a world expert in flows within vegetated canopies, with particular emphasis on laboratory experiments. Bouma is a spatial ecologist with key research areas of ecological restoration and plants as ecosystem engineers. Dijkstra specializes in numerical modeling of vegetated regions (and salt marshes in particular). Coco has experience in laboratory and numerical modeling of biophysical interactions in estuarine environment; Zhou has recently completed a novel model that addresses feedbacks between marshes, physical processes and carbon dynamics. Moeller is a coastal geomorphologist with a research focus on the linkage between short term (event-based) plant-wave interaction and its significance for decadal scale coastal wetland evolution in the face of climate changed induced alterations to storm frequency and magnitude. More recently Möller has also been actively involved in addressing the communication gap between the academic community and stakeholders involved in coastal management. Kiwango's research into estuarine ecohydrology focuses specifically on water quality (physical, chemical and biological) and mangrove ecology.

Relationship to other international programs and SCOR Working groups

Many working group members have substantial linkages to other international programs and have been involved in successful SCOR working groups in the past (Wolanski, Perillo and Elliott). Mullarney and Vo-Luong (full members) and Fagherazzi and Roelvink (associate) are participants in the USA Office of Naval Research funded departmental research initiative "Dynamics of tropical deltas" studying flows and sediment transport in the Mekong Delta.

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Appendix

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

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