SCOR PROCEEDINGS

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Virtual meeting – October 2020

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Scientific Committee on Oceanic Research
2020

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SUMMARY

This proceeding summarizes the discussions during the 2020 SCOR Annual Meeting held virtually between the 20-22 of October of 2020. Following a decision from the SCOR Executive, this proceeding also compiles all the background information for the meeting, including the proposals for new working groups, the reports from current SCOR working groups, projects, capacity development activities, and the reports of affiliated and partner organizations all of which were traditionally included in the SCOR Annual meeting background book. All of these can also be accessed online through the SCOR website at: *https://scor-int.org/events/2020-scor-annual-meeting/*. Following this decision, from this year onwards, the SCOR Annual Meeting Background Book, and the SCOR Annual Meeting Proceedings will be merged in one document.

The SCOR 2020 Annual Meeting was attended by 121 participants from 34 countries representing all continents. All SCOR Working Groups, research, infrastructural, and affiliated projects, along with the affiliated and partner organizations reported on their activities. Some of the main highlights of the SCOR 2020 Annual Meeting include: (1) the approval of a SCOR revised Constitution, (2) the renovation of the SCOR Executive Committee, (3) the incorporation of a new member to SCOR, and (4) the approval of three new Working Groups.

Following recommendations from SCOR's parent organization the International Science Council (ISC), the SCOR constitution was revised and updated by a Review Committee composed by Peter Burkill (UK Nominated Member and SCOR Past-President), Bob Duce (USA, SCOR Past-President), Julie Hall (New Zealand Nominated Member and SCOR Past-Secretary), Danielle Su (France / Australia), and Xiaoxia Sun (China-Beijing). This revised constitution was unanimously approved by all SCOR nominated members and representative members. The revised constitution can be found at (**https://scor-int.org/scor/about/constitution/**)

The SCOR Executive Committee (**https://scor-int.org/scor/about/officers/**) was renovated. Sinjae Yoo (Korea) is the new SCOR President replacing Marie-Alexandrine Sicre who has become Past-President and the co-chair of the IIOE-2 project. Peter Burkill (UK, SCOR Past-President), David Halpern (USA, SCOR Vice-President) and Nuria Casacuberta-Arola (Switzerland, Early Career representative) stepped down from their roles, and three new members were engaged: Stefano Aliani (Italy) and Bradley Moran (USA) as Vice-Presidents, and Charlotte Laufkoetter (Switzerland) as the early career co-opted member.

A new country, Colombia, joined SCOR through the Instituto de Investigaciones Marinas y Costeras de Colombia (INVEMAR: http://www.invemar.org.co/). INVEMAR is the Colombian national institute of marine science aimed at conducting scientific research on natural renewable resources and marine and coastal ecosystems to support policy and management of marine natural resources. INVEMAR is also a Regional Training Center for the Ocean Teacher Global Academy committed to building capacity in the Latin American and Caribbean region.

The competition among proposals was strong this year, with 10 proposals submitted and three funded. The three proposals approved were:
Analysing ocean turbulence observations to quantify mixing (ATOMIX), co-chaired by Cynthia Bluteau (Canada), Ilker Fer (Norway), and Yueng-Djern Lenn (UK) (*https://scor-int.org/group/analysing-ocean-turbulence-observations-to-quantify-mixing-atomix/*)
Respiration in the Mesopelagic Ocean (ReMO): Reconciling ecological, biogeochemical and model estimates, co-chaired by Carol Robinson (UK), Iris Kriest (Germany), and Javier Arístegui (Spain) (*https://scor-int.org/group/respiration-in-the-mesopelagic-ocean-reconciling-ecological-biogeochemical-and-model-estimates-remo/*)

Developing an Observing Air-Sea Interactions Strategy (OASIS), co-chaired by Meghan Cronin (USA) and Sebastiaan Swart (Sweden) (*https://scor-int.org/group/developing-an-observing-air-sea-interactions-state-oasis/*)
SCOR continued to support capacity development activities by sponsoring 5 Visiting Scholars in 2019 and approving 6 for 2020, and by co-sponsoring with POGO 5 POGO-SCOR Visiting Fellows. All the travel of the Visiting Scholars and POGO-SCOR fellows has been postponed until further notice due to COVID-19.

The 2021 SCOR meeting is scheduled for the week of 25-29 of October 2021 in Busan, Korea, hosted by the Korean Institute of Science and Technology (KIOST). The 2022 SCOR meeting is scheduled to take place in Guayaquil, Ecuador, hosted by the Instituto Oceanográfico y Antártico de la Armada del Ecuador (INOCAR) between September-October.

Narrated presentations reporting on SCOR project and working group activities and progress in 2020 can be found in YouTube (*https://youtube.com/channel/UCv-dZLizFYDOC2UTweiWj0Q)*

LOGISTICS OF THE SCOR 2020 VIRTUAL MEETING

The SCOR 2020 Annual Meeting was the first SCOR annual meeting to be held virtually due to the COVID-19 global pandemic and all the associated travel restrictions. In this new virtual modality, the time of interaction was reduced from three 8-hour days to three 3-hour connections. This required significant preparation and performing previous actions along with special logistics.

The meeting was organized in three sessions, one for each day. On the first day, the agenda topics included the reports from the SCOR President and from the Executive Director, the results of the 2020 election for SCOR Officers, the results of the 2020 selection of Early Career Scientist, the approval of the revised SCOR constitution and the presentation and discussion of new SCOR working group (WG) proposals. On the second day, the agenda topics included the reporting of all current SCOR working groups, research projects and infrastructural projects. On the third day, the agenda topics included the report of the Ad Hoc Finance Committee, the reports from the affiliated projects and partner organizations, the report on SCOR capacity development activities and setting the venue for the next SCOR annual meeting.

In preparation for the virtual meeting, the logistics were organized in the following way:

All written reports and documents were available in advance at the SCOR website (https://scor-int.org/events/2020-scor-annual-meeting/).
In preparation for **Session 1**, SCOR Executive Committee (SCOR EC) monitors for the proposed new WGs produced a 10-15-minute narrated presentation of the WG proposal summarizing the proposal and the recommendations from the reviews. These were available for all the Executive Committee and Nominated Members on-line prior to the meeting for everyone to watch at its own convenient time.
In preparation for **Session 2**, SCOR WGs and project chairs produced a 10-15-minute narrated presentation that was available on-line on the SCOR website prior to the meeting.
In preparation for **Session 3**, representatives of affiliated projects and affiliated/partner organizations were also invited to produce a 10-15-minute presentation to be available on-line prior to the meeting.
For the virtual sessions, each of the groups mentioned above (SCOR EC monitors of new WG proposals, current WG and project chairs/representatives and representatives of affiliated organizations, projects, and partner organizations) provided a synthesis of 1-3 slides with the main highlights and the required actions for a maximum of a 5-minute intervention to allow time for discussions. The summary slides for the new WGs included the Terms of Refence, membership and a summary of the reviews/recommendations by the national SCOR committees and affiliated organizations.
All the summary slides for each session were compiled by the SCOR Executive Director in one single file (one summary file /session) to facilitate the discussions during the virtual sessions and avoiding the sharing of multiple screens.
All participants had to register for the meeting and this gave an indication of how many people would be connecting for each of the sessions, helping to plan the connection platform (e.g., GoToMeeting, Zoom).
The sessions were recorded, both in video and audio, and the transcripts of the chat comments were saved to help in the production of the proceedings.
The co-chairing and note taking for each of the three sessions involved several members of the SCOR EC.

1. INTRODUCTION

1.1. Opening remarks and arrangements

Marie Alexandrine Sicre, the SCOR President welcomed the participants and provided an overview of the logistic arrangements. No further additions to the agenda were suggested. Sicre pointed out that all written reports, documents, and narrated presentations from WGs, projects and affiliated organizations were available at the SCOR website (*https://scor-int.org/events/2020-scor-annual-meeting/*). She thanked the new Executive Director for organizing the virtual meeting.

SCOR pays tribute to the life and contributions of members of the oceanographic community who pass away. Sicre noted those that had died in the past year along with their scientific contributions and involvement with SCOR.
See document: *https://scor-int.org/wp-content/uploads/2020/10/Tab-1_In_memoriam_2020.pdf*

- **Sir Anthony Laughton** (1927-2019) (UK) - Nominated member to SCOR for the UK and associate member of Working Group 107 on Improved Global Bathymetry
- **Robert (Bob) Dickson** (1941-2019) (UK) - Nominated member to SCOR for the UK, a full member of WG 68 on North Atlantic Circulation, and a member of the Scientific Steering Committee of the Global Ocean Ecosystem Dynamics (GLOBEC) project.
- **Karl Föllmi** (1954-2019) (Switzerland) - Nominated member to SCOR for Switzerland.
- **Taro Takahashi** (1930-2019) (Japan / USA) - A member of the Scientific Steering Committee of the Joint Global Ocean Flux Study (JGOFS) and a full member of the Joint Committee on Climatic Changes and the Ocean (CCCO).
- **Trevor Platt** (1942-2020) (UK) - Vice-chair of WG 73 on Ecological Theory in Relation to Biological Oceanography, the chair and a member of the Joint Global Ocean Flux Study (JGOFS) between SCOR and the International Geosphere-Biosphere Programme (IGBP), a full member of the Joint SCOR/IOC (Intergovernmental Oceanographic Commission) Committee on Climatic Changes and the Ocean (CCCO) with SCOR, IAMAP, and IAPSO, and a member of the SCOR/IGBP/WCRP ad Working Group For the Global Ocean Euphotic Zone Study.
- **Ron O'Dor** (1944-2020) (Canada) - Senior Scientist for the Census of Marine Life, a SCOR affiliated project 2000-2010.
- **George Hemmen** (1926-2020) (UK) - The first Executive Director of SCOR from 1972-1980 (called Executive Secretary then). He also served the Scientific Committee on Antarctic Research (SCAR) for more than 27 years, first as Assistant Secretary then as Executive Secretary. In the picture below, three generations of SCOR Executive Directors.
- **Jacco Kromkamp** (1956-2020) (The Netherlands) - Full Member of SCOR Working Group 156 on Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity.

A minute of silence was observed.

1.2. Report of the President of SCOR

The SCOR President briefly reported on her activities for SCOR since the SCOR Annual Meeting in September 2019 in Toyama, Japan. In January 2020 she participated and co-chaired the special session "Harnessing the Resources of International Ocean Science Organizations to develop Sustainable Ocean Science and Actions in the Indian Ocean" at the Regional Consultation Workshop for Africa and the Adjacent Island States of the United Nation Decade of Ocean Science for Sustainable Development held in Nairobi, Kenya. With Ed Urban and later with Patricia Miloslavich, she continued to participate in the monthly webinars of Future Earth Ocean Knowledge Action

Network (O-KAN) Development Team that has now produced its "Guidelines and Strategic Plan". She indicated that as sponsors, SCOR is now part of the selection committee for the International Project Office (IPO) host of the O-KAN. Due to the Covid-19 situation, several meetings that she should have attended were cancelled, these included: the IIOE-2 meeting scheduled 22-26 March 2020 in Goa, India; the International Science Council (ISC) meeting scheduled 27-28 March 2020 in Paris, France; the Ocean Conference scheduled 2-6June, 2020 in Lisbon, Portugal; and the IOC session scheduled 30June-3 July 2020 in Paris, France. She participated in parts of the virtual SCAR conference 3-7 July 2020.
See document: *https://scor-int.org/wp-content/uploads/2020/10/1.3.-President-report-2020.pdf*

1.3 Report of SCOR Executive Director

The new SCOR Executive Director (SCOR ED), Patricia Miloslavich reported on the current condition of SCOR and on her activities for SCOR since taking the position in January 2020. Miloslavich reported that the SCOR community currently has more than 400 active members involved in WGs and project Scientific Steering Committees (SSC) representing 49 countries and five continents, with the USA, the UK, Germany, France, and Australia having the largest number of involved researchers. Around 38% are female scientists and 62% are male scientists, this proportion being more balanced in the SCOR early career scientists (44% males and 56% females). In 2020, a new Early Career Scientist for the SCOR EC was recruited (Charlotte Laufkoetter) from a total of 39 applications. Miloslavich summarized the meetings held by the SCOR WGs, some of which were held at the Ocean Sciences conference in February 2020, while others met online. She also reported on some SSC renovations or IPO changes taking place in the projects GEOTRACES, SOLAS, IMBeR, GlobalHAB, the IOCCP and SOOS, and on some renovations in the Nominated Members of eight countries along with the addition of a new National Committee (Colombia).
In addition to holding WG meetings at the Ocean Sciences conference, the SCOR community organized special sessions, tutorials, townhalls and had live demonstrations at the SCOR booth. Overall, the SCOR WGs and the IOCCP produced about 30 scientific publications in 2019-2020. Following recommendations of the Ad Hoc Visibility Committee, efforts were made to increase the visibility of SCOR through social media, significantly increasing the number of followers for Twitter and Facebook, producing online Newsletters, and updating the News section on the website more frequently.

In addition to activities related to SCOR organization, administration and finances, project and WG management, communication, outreach, and other community services, Miloslavich regularly had training sessions with Ed Urban. She is also contributing to four scientific papers.

See document: *https://scor-int.org/wp-content/uploads/2020/10/SCOR_status_ExecDirector_activities2019-2020.pdf*
Narrated presentation: *https://www.youtube.com/watch?v=RaWPs08qUxk*

1.4 Appointment of ad hoc Finance Committee

The SCOR Constitution requires that a Finance Committee be appointed at every SCOR meeting. It must consist of at least three members of SCOR who are not members of the SCOR EC. The Finance Committee reviews the administration of SCOR finances during the previous fiscal year and the current year and will propose a budget for 2021 activities and dues for 2022. Members of the 2020 Finance Committee approved by the SCOR EC (by email consultation on the 14th of September 2020) were Isabel Ansorge (South Africa), Peter Croot (Ireland), Daniel Weihs (Israel) and Sun Song (China). The Committee reported to the meeting on Day 3 under Agenda item 8.3.

1.5 Results of the 2020 Elections for SCOR Officers

Peter Burkill, chair of the Nominating Committee presented the process and outcomes of the 2020 elections for SCOR Officers. The SCOR President and all three Vice-President positions were open for nominations for the 2020 elections. The Nominating Committee composed by Past President Peter Burkill, Isabelle Ansorge (South Africa), Dr Lennart De Nooijer (The Netherlands) and Dr Sun Xiaoxia (China) reviewed the nominations, prepared a final slate of candidates, and confirmed their availability to serve in the SCOR EC. The slate of candidates was sent to all nominated members for their comment / approval and the new slate was unanimously approved. The newly elected positions were: (1) Sinjae Yoo (Korea) as the new SCOR President replacing Marie-Alexandrine Sicre (France) who has become Past-President replacing Peter Burkill (UK), and (2) Stefano Aliani (Italy) and Bradley Moran (USA) as the new Vice-Presidents replacing former Vice-Presidents David Halpern (USA) and Sinjae Yoo (Korea). The final composition of the 2020-2022 SCOR Executive Committee is:

- President, Sinjae Yoo (Korea)
- Secretary, Paul Myers (Canada)
- Past President, Marie Alexandrine Sicre (France)
- Vice-Presidents Jing Zhang (Japan), Bradley Moran (USA), Stefano Aliani (Italy)
- Ex-Officio Members: IABO-Enrique Montes (USA), IAMAS-Joyce Penner (USA), IAPSO-Trevor McDougall (Australia)
- Co-Opted Members: Charlotte Laufkoetter (Switzerland), Jacqueline Uku (Kenya)

See nomination and selection process at: *https://scor-int.org/wp-content/uploads/2020/07/2020-Slate-of-new-SCOR-Officers2.pdf*

Bio of the SCOR Executive Committee 2020-2022 at: *https://scor-int.org/scor/about/officers/*

1.6 Results of the 2020 selection of the Early Career Scientist to the SCOR Executive

Patricia Miloslavich informed that 39 applications to the position of Early Career Scientist (ECS) to the SCOR Executive Committee were received. Each applicant was reviewed by three members of the EC and the reviews were ranked. The top three candidates were interviewed by SCOR President (Sicre), Secretary (Myers) and Vice-president (Yoo), moderated by the SCOR Executive Director (Patricia Miloslavich). The selected applicant is Dr. Charlotte Laufkoetter currently working at Bern University, Switzerland as an Ambizione Fellow. Her area of expertise is marine biogeochemistry, in particular biological carbon cycling and plankton communities, extreme events, and marine plastic pollution. The SCOR EC welcomed Charlotte and acknowledged Nuria Casacuberta-Arola, the former Early Career Scientist to the SCOR EC for her contributions and service to the SCOR Executive Committee.
More about Charlotte at: *https://scor-int.org/wp-content/uploads/2020/10/Charlotte.pdf*

1.7 Changes to the SCOR constitution

The SCOR's Constitution defines how SCOR works at high level. It is revised periodically to ensure it is "fit-for-purpose". A Constitution Committee was established composed by Peter Burkill (Chair), Bob Duce, Julie Hall, Danielle Su, and Xiaoxia Sun to draft a revised SCOR Constitution following recommendations by the ICS. Peter Burkill explained the process. The aims of the review were to simplify and make it logical while minimising change. Some of the major changes included: (1) to make it suitable for US tax purposes, (2) reordering sections of the text, (3) clarifying membership terms including the change of name of the former International Council for Science (ICSU) to the current International Science Council (ICS), (4) standardizing nomenclature terms, (5) add Appendices on officers' election and voting. The revised draft was sent to all Nominated Members for their informal comments on the 26 August 2020 and after receiving all feedback, a second

revised draft was sent to all Nominated Members again for the formal vote. At the meeting, the Nominated Members voted electronically through an email to the SCOR Executive Director expressing either their acceptance, not acceptance, or abstention, identifying their organization/country. Clause 22 states when a vote is taken at an Annual Meeting, only one Nominated Member from each National SCOR Committee shall have a vote. One Representative Member from each Organization in Clause 4 may also vote. A total of 26 bodies (76.5% of the total SCOR bodies) voted for accepting the revised constitution (23 countries and 3 affiliated organizations). Votes were received from Australia, Belgium, Canada, Chile, China – Beijing, Colombia, Ecuador, Finland, France, Germany, Ireland, Israel, Italy, Japan, Korea, Netherlands, Poland, Russia, South Africa, Sweden, Switzerland, UK, USA, IAMO, IAMAS and IAPSO. A total of 8 bodies did not send their votes. These were Brazil, China-Taipei, Mexico, Namibia, New Zealand (NZ nominated member Julie Hall was a member of the Constitution Committee so abstained of sending a vote), Norway, Pakistan, Turkey.
To approve the revised constitution there needs to be the agreement of two-thirds of the SCOR members which was met by the votes received. A description of the process and its results will be sent to the ISC to formalize the new constitution. Sinjae Yoo thanked the Constitution Committee for the excellent work.

See final revised SCOR Constitution at: *https://scor-int.org/scor/about/constitution/*

2. WORKING GROUPS

2.1. New Working Group proposals

The SCOR EC monitors for the proposed new WGs produced a 10-15-minute narrated presentation of the WG proposal summarizing the proposal and the recommendations from the reviews. These were available for all the Executive Committee and Nominated Members on-line prior to the meeting for the members and SCOR EC to watch at their own convenient time. During the meeting, each of the SCOR EC monitors presented a 5-minute synthesis of the WG proposals along with a summary of the comments and recommendations received.

2.1.1. Analysing ocean turbulence observations to quantify mixing (ATOMIX)

Trevor McDougall summarized the proposal, as well as the comments from the SCOR National Committees and affiliated organizations. Almost all national committees rated this proposal as "must fund" or "may fund" and found the activity timely, and important for SCOR and the broader ocean science community. The proposal was found to be truly relevant as turbulence is one of the key processes in oceanic energy budgets and the transport of heat and water exchanges in climate models are very sensitive to the choice of mixing parameterisations. Given the importance that SCOR gives to geographic balance and the inclusion of developing countries in the full membership, some specific membership changes were suggested. These suggestions included bringing one (or two) of the Associate members from developing countries (South Africa and India) as Full Members, and to include one or more Asian researchers as Associate members (e.g., Japan, Korea, China) or even as Full Members. The proposal should also be more explicit about the open access availability of the software packages that are developed by the Working Group – as wide and free availability will be a SCOR requirement.

The reviews by national SCOR committees before the meeting yielded 15 "must fund", seven "may fund", and no "do not fund". The proposal was selected as one of three to start in 2021.

Full proposal at: https://scor-int.org/wp-content/uploads/2020/05/SCOR_WG_ATOMIX.pdf

2.1.2. TRACE element SAMplers and sensORS (TRACESAMORS)

Jing Zhang summarized the proposal, as well as all the review comments. In general, most of the reviews considered this proposal timely and a priority for ocean science as it will help develop a new generation of highly accurate sensors to measure the trace metals (which control global primary production) through autonomous sensors, and therefore, a way to resolve the limitations of traditional onboard sampling and data. On the other hand, many of the reviewers were not convinced that the topic was ready to be tackled through a SCOR WG given the uncertainty in the current sensor development and that this could be considered a research/engineering challenge in which incentivizing developers would be the priority rather than going to scale.

The reviews by national SCOR committees before the meeting yielded two “must fund”, 13 “may fund”, and three “do not fund”. The group was not funded.

Full proposal at: *https://scor-int.org/wp-content/uploads/2020/05/SCOR_WG_ATOMIX.pdf*

2.1.3. Benthic Foraminifera as Ecological Sentinels of Marine Systems Health (FORAM-ECO)

Marie-Alexandrine Sicre summarized the proposal, as well as all the review comments. In general, most of the reviews considered this proposal timely. Coordination of the efforts at international scale, involving biologists, DNA-people and micro-palaeontologists is needed to develop the approach for a more universal use of benthic foraminifers as ecological tool. However, there were several concerns regarding the Terms of Reference (ToRs) and the membership composition.
The first three ToRs form a core group to evaluate, and develop best practice for, existing metrics. ToR#1 was found to be ambitious and would require more focus. Characterizing organic matter quality is quite challenging as well as distinguishing between natural and anthropogenic sources. The fourth (evaluation of historical change) needs to be better defined and the fifth (molecular proxies) reflects a new direction that currently is not likely to be ready for consolidation. Finally, while foraminifera are sensitive to environmental parameters, their distribution and ecology is not only controlled by contaminants (e.g., but also by the nature of the substrate and associated sedimentary processes). So, in general, more convincing arguments need to be articulated to justify the ToRs.
In general, the membership was found to be good in terms of gender balance plus in involvement of early career scientists, however, the membership was too USA/Europe oriented and needs to be more balanced geographically, with the inclusion of members from developing countries in the full membership. It would also be good to expand membership to more Asian countries, particularly China, where population density and land-based pollution has placed great pressure upon the health of its coastal seas. Finally, to address the challenge of distinguishing between natural and anthropogenic sources, one or two chemists should be included as full members. In the same way, additional expertise in coastal sedimentary and hydro-dynamics processes would be needed to address the ToRs.

The reviews by national SCOR committees before the meeting yielded 15 “may fund” and four “do not fund”. None of the reviews indicated “Must fund”. The group was not funded.

Full proposal at: *https://scor-int.org/wp-content/uploads/2020/05/FORAM-ECO_SCOR_v7.pdf*

2.1.4. Elucidating THreats tO Sandy beaches: a global synthesis (ETHOS)

Sinjae Yoo summarized the proposal, as well as all the review comments. In general, most of the reviews considered this proposal timely and an important and multidisciplinary topic given the importance and value of beaches in coastal zone management and ecosystem functioning and to the fact that the response to multiple stressors and over different scales is unknown. Regarding if SCOR was a good mechanism for this WG, reviews were divided, with some saying the topic did fit due to its multidisciplinary science but others thought that other bodies such as Future Earth or the Ocean KAN (Knowledge Action Network) would be more appropriate. The reviewers found positive that the proponents considered the potential restrictions of COVID and planned for intervening video meetings and making virtual meetings more effective. The capacity building plans were also considered a strength of the proposal.

On the other hand, there were several concerns regarding the ToRs and the membership composition. Some reviewers found this proposal to be too broad and insufficiently focused on un-resolved or uncoordinated science research questions to be appropriate for a SCOR Working Group. Sandy beaches and their ecosystems are characterised by complex interplays between environmental, economic, and social factors, so focus is needed to make progress in the timespan of a SCOR Working Group. Other than the growing level of threat resulting from continuing urbanisation of global coastlines, the proposal does not identify why this subject should be given priority.

In general, the membership was found to be good in terms of gender balance plus in involvement of scientists from developing countries, however it was suggested to bring more scientists from Asia and from countries facing the Indian Ocean. With regards to expertise, the proponents describe the complex interplay of ecosystems at sandy beaches, e.g., human use of beaches, including engineering and recreational aspects plus economic exploitation, yet the scientific expertise of the proposed membership (full and associate) is almost entirely based on scientists with ecosystem expertise. For this, bringing the expertise physicists/sea-level/climate scientists, geomorphologists, engineers, along with other potential stakeholders (e.g., oil industry, municipalities) was suggested.

The reviews by national SCOR committees before the meeting yielded one “must fund”, 12 “may fund”, and six “do not fund”. The group was not funded.

Full proposal at: *https://scor-int.org/wp-content/uploads/2020/05/WG_ETHOS.pdf*

2.1.5. Integration of international ocean acidification research at CO2 seeps (InterSEEP)

Nuria Casacuberta-Arola summarized the proposal, as well as all the review comments. The strengths of the proposal were that it is was considered timely and a priority for ocean science as increasing ocean acidification (OA) is a major threat to marine ecosystems. In general, SCOR was considered a good mechanism to bring together scientists working in CO2 seeps.

On the negative side, some reviewers thought the Terms of Reference (ToRs) were unclear and not specific enough. There were several comments regarding the proposed capacity building plans and some comments with regards to the WG membership. In general, the reviewers pointed out that this second-year submission seemed less focussed and weaker with many aspects of the previous proposal remaining unchanged without proper updates (including the timeline – e.g., years 1 and 2 identified as 2021). The reviewers also pointed out that the proposal still does not make the case of why CO2 seeps are so important compared to atmospheric CO2 for the ocean acidification nor how the pH-gradients in the vicinity of the seeps (which are often very steep both in time and space) will reflect the long term changes that marine organisms will have to adapt to due to effects related to global change.

The reviews by national SCOR committees before the meeting yielded five “must fund”, 12 “may fund”, and three “do not fund”. The group was not funded.

Full proposal at: *https://scor-int.org/wp-content/uploads/2020/05/InterSEEP-SCOR-Working-Group-Proposal_20202.pdf*

2.1.6. Mapping climate change refugia for marine conservation (MarCCR)

Jacqueline Uku presented the proposal and a summary of comments from national SCOR committees. The strengths of the proposal were that it is was considered timely and a priority for ocean science because of the increasing impact of climate change on marine ecosystems and the need to rigorously design climate change refugia for marine conservation. On the other hand, many of the reviewers were not convinced that a SCOR WG would be the best way to tackle this issue nor that the ToRs were sufficiently clear.

Reviews agreed that it is relevant to consider the impact of climate change when selecting MPAs and that the initiative of looking for CCR is new and challenging. However, the problem is quite complex and the concept of estimating climate change refuges to contribute to the allocation of MPAs needs to be better articulated given the variability between species, habitat, and areas. The approach can be improved by providing a better background on the existing knowledge, on being more explicit on what can be achieved and on redefining the ToRs.

The proposal and ToRs mention the preparation of material for conservation and planning practitioners, and delivery of policy briefings. To achieve a long-lasting impact from this WG the outcomes will need to be formally endorsed by decision makers and promoted at intergovernmental level, such as the IOC. It was suggested that the proposal could make more of the role of MPAs in the open ocean (and included an expert on the law of the sea in its membership, e.g., UNCLOS) as to how CCR might cut across national boundaries. Finally, some reviewers found the plan ambitious, but it was unclear how it would be carried out. The problem of competing scales outlined by the authors is known to be very difficult and the approach to address this was unclear. For example, it was unclear how global maps would be produced while considering the required level of details necessary for ecosystem response. It was also unclear how “stability” was defined, and how will the proponents estimate future stressor evolution.

The reviews by national SCOR committees before the meeting yielded five “must fund”, 10 “may fund”, and four “do not fund”. The group was not funded.

Full proposal at: *https://scor-int.org/wp-content/uploads/2020/05/MarCCR-SCOR-Working-group-proposal-May_2020_for-submission.pdf*

2.1.7. Respiration in the Mesopelagic Ocean (ReMO): Reconciling ecological, biogeochemical and model estimates

Peter Burkill presented the proposal and a summary of comments from national SCOR committees. Almost all national committees rated your proposal as "must fund" or "may fund" and found the activity timely, and important for SCOR and the broader ocean science community. The proposal was found to be relevant to reconcile ecological, biogeochemical and model estimates of mesopelagic respiration to improve projections of the decline of oxygen in the world's oceans.

Reviewers suggested the inclusion of a member from an African country given the importance of the Benguela system, ideally an early career scientist. The South African nominated member suggested the name of Dr. Moagabo Ragoasha who is an ocean modeller focused on the Benguela system.

The reviews by national SCOR committees before the meeting yielded 14 "must fund", six "may fund", and one "do not fund". The proposal was selected as one of three to start in 2021.

https://scor-int.org/wp-content/uploads/2020/05/ReMO-application-SCOR-WG-2020.pdf

2.1.8. Are global indicators of COastal and Nearshore benthic fish assemblage status in agreement if derived from disparate visual CENSUS techniques? (CoNCENSUS)

Enrique Montes presented the proposal and a summary of comments from national SCOR committees. The proposal was generally perceived as timely because of impacts of climate change on a major food source for society, that the membership was well balanced offering a strong capacity building component, and that activities are scientifically sound and interesting, particularly the intercalibration of different methods to advance the state of knowledge. Other positive comments were that the WG would address societal issues like hunger and malnutrition, blue economy, and people's livelihood, with a strong focus on the coastal zone where both natural and human pressures drive fish communities. There was general agreement in that the effort would tackle major knowledge gaps in our understanding of how fish communities are changing throughout the world's oceans. In summary, the WG proposal was thought as a good approach for uniting the community and developing indicators needed for understanding fish communities and vulnerable ecosystems.

However, several reviewers thought the proposal was biased toward coral and temperate reefs (e.g., not clear whether there was sufficient expertise in polar waters) and that the ToRs were too ambitious, and their deliverables could be more specific (e.g., what ecological or species indicators would be examined?). There was a long discussion about the inclusion (or not) of data from environmental metabarcoding (eDNA) observations. While some reviewers pointed out that the WG should build on eDNA measurements and not doing so was a missed opportunity, others argued that information from the proposed work is critical for eDNA validation, and that while this is a promising technique, including eDNA was beyond the scope of this working group which already had ambitious ToRs. Another comment was that the proposal lacked references to new technologies for collecting or analysing data and thus lacked a 'forward looking' vision. One reviewer considered that this WG would be better suited for support under the International Council for the Exploration of the Seas (ICES).

The reviews by national SCOR committees before the meeting yielded six "must fund", 11 "may fund", and two "do not fund". The group was not funded.

Full proposal at: *https://scor-int.org/wp-content/uploads/2020/05/20-05_CoNCENSUS_SCOR-proposal.pdf*

2.1.9. Developing an Observing Air-Sea Interactions Strategy (OASIS)

Paul Myers presented the proposal and a summary of comments from national SCOR committees. Most of the national committees rated this proposal as "must fund" or "may fund" and found the activity timely, and important for SCOR and the broader ocean science community. The proposal was found to be relevant to harmonize observational strategies as presented at OceanObs'19 to create a unified vision for an Observing Air-Sea Interaction Strategy focused on air-sea fluxes of heat, momentum, moisture, important greenhouse gasses, and biogenic trace gases, and their boundary layers.
Reviewers suggested that some information is added for each TOR from the Work Plan in terms of what will be produced, when, and to whom it will be directed; that the membership is re-considered to include members from South America and/or more members from Asia (e.g., Korea, Japan); and to improve their capacity building plan.

The reviews by national SCOR committees before the meeting yielded 8 "must fund", seven "may fund", and five "do not fund". The proposal was selected as one of three to start in 2021.

Full proposal at: *https://scor-int.org/wp-content/uploads/2020/05/OASIS_SCORWG_Proposal.pdf*

2.1.10. Atmospheric aerosol deposition as forcing factor for microbial ecology and biogeochemistry in the ocean (AEROS)

Joyce Penner presented the proposal and a summary of comments from national SCOR committees. In general, most of the reviews considered this proposal timely. Aerosols are active constituents in the atmosphere affecting critical processes like albedo or cloud formation and depositing materials into the ocean that drive critical biogeochemical cycles. These are key drivers of weather, productivity, and climate; hence they are high priorities for ocean science and SCOR with its history of investment in multiple WG on Ocean Carbon and flux processes, however, most of the reviews also agreed that the proposal in general lacked detail, was very general, and the ToRs vague.

The proposal was considered premature and potentially unfeasible considering the lack of comprehensive data. For example, it was not clear how ToR 1 would be achieved as there is currently very little active research on actual deposition rates, so obtaining information on the quality control for the database is critical undoubtedly a very complex task. It is suggested that a better description of deposition is supplied as well as more clarification about where wet deposition fits into the overall schemes outlined in the TORs.

The reviews by national SCOR committees before the meeting yielded two "must fund", 13 "may fund", and five "do not fund". The group was not funded.

Full proposal at: *https://scor-int.org/wp-content/uploads/2020/05/proposal-AEROS.pdf*

After the presentations of the ten new WGs, Patricia Miloslavich showed the rankings based on the reviews. The WGs fell within four ranking categories: ATOMIX and REMO ranked exceedingly high, CONCENSUS and OASIS ranked as middle high, INTERSEEP and MARCCR ranked as middle-low, and TRACEAMORS, AEROS, FORAM-ECO and ETHOS ranked as low.

Nominated members agreed that ATOMIX and REMO should be funded if they addressed the reviewer's recommendations. Since a third new WG could potentially be funded, most of the nominated members thought, based on the reviewer's comments and recommendations, that the discussions should be focused on deciding between CONCENSUS and OASIS.

Enrique Montes (IABO) indicated that CONCENSUS was a good approach for uniting community and developing indicators needed for understanding fish issues and vulnerable ecosystems which is crucial for targeting how life in the sea is changing, and that while this was done with physical and biogeochemical data, ecosystem data was lagging. Ilka Peeken (Germany) indicated that conservation was a new hot topic. To the question if this WG was more focused on science or on monitoring, IABO indicated that the WG is more focussed on trends from methods and how these approaches work together. Peter Croot (Ireland) and Katja Peijnenburg (Netherlands) thought it was a missed opportunity to ground truth eDNA, however the US expressed that issues related to eDNA raised by some reviewers were overstated. Furthermore, Dan Costa from the USA added that eDNA was a promising technology, but it was beyond the level of this working group which was already ambitious. Peter Burkill (UK) also thought that the lack of eDNA was not relevant and that it would be a topic for another proposal and agreed on the scope put forward in the proposal.
The UK believed CONCENSUS had the potential for SCOR to make a real contribution to UN Decade and SGDs. IABO indicated that the WG topic was crucial for future management, as well as building capacity; these last aspects being well represented in working group. Isabel Ansorge (South Africa) agreed with this view. Dan Costa (USA) agreed with IABO and added that the community is trying to self-organize on how data sets being put together, so this would feed in with those activities. Marie-Alexandrine Sicre (France) questioned if there was enough existing data and if the WG ToRs could be achieved within the timeframe. Enrique Montes pointed out that presently eDNA discussions are on methodological biases; so would be at a very early stage and thus too early to be merged with others data sets. Stefano Aliani and Annalisa Griffa (Italy) believed that CONCENSUS was very timely and important but that it lacked reference to new technologies for collecting or analysing data; thus, a lack of vision to bring forward into the future. To this comment, Dan Costa clarified how much effort is needed to just put data sets together and that advanced learning must be done after initial data sets harmonized.

With regards to OASIS, Trevor McDougall (Australia, IAPSO) highlighted that it had strong leadership from the OceanObs19 community white papers, that it was an ambitious proposal to broker what is crucial to many groups and considered it a high-risk reward that could potentially become the birthplace for a new project. Fangli Qiao (China) expressed that air-sea fluxes were extremely important for ocean and climate, and the WG would have strong links to UN decade being strong on capacity building. Italy pointed out that OASIS was building on the gaps in knowledge assessed at OceanObs19 and considered this group positively as very mature and well suited for SCOR. Marie Alexandrine Sicre believed both WGs would be relevant to UN decade. Peter Burkill reminded that the SCOR criterion for WG selection is science excellence and need. Sinjae Yoo (Korea) added that an important function of a SCOR WG is to make a breakthrough in ocean research that has high ripple effects to various areas, so we need to consider what the groups will tackle. Marie Alexandrine Sicre believed that OASIS had more linkages with SCOR and IMBeR, while CONCENSUS was less linked within SCOR and raised the question if SCOR wanted to support areas in which it is already strong or alternatively to strengthen areas where it is not strong yet and build those links. Germany thought that OASIS should not be funded as it considered the ToRs were not all achievable and therefore it was a high-risk proposal. Paul Myers (Canada) asked the question of how big of a service to the whole community would CONCENSUS serve if successful and Enrique Montes responded that it was hard to compare global coverage from a big physics program versus a more focussed coastal marine group. He assured that this group had put together a strong work. Dan Costa added that the physics community has gone through these inter-comparisons but biology still must do this so he saw CONCENSUS as one of those steps that will help the field mature. The Netherlands pointed out that we must assume that most national committees have broad specialities, so the bottom line was that whatever came out of a working group would significantly help expanding the coverage of the data. Alessandro Tagliabue (UK) had a strong lean-to OASIS but agreed both proposals were strong. Carmen Morales (Chile) inquired if SCOR could support four new WGs but with reduced funding each given that travel has been reduced due to COVID-19, however Daniel Weihs (Israel) from the Finance Committee believed that by committing to the next 3-4 years, with hopefully full travel in the future, funding four WGs could become problematic financially. Elva Escobar (Mexico) supported this statement noting that Mexico had cut payments for many of its international commitments, and this could be expected to occur in more countries.

Given that both proposals were very strong and there was no agreement about which of the two proposals approve, a voting was done. The resulting vote was eight votes for CONCENSUS and 15 for OASIS. The final approved new SCOR working groups were ATOMIX, ReMO and OASIS.

2.2. Current Working Groups

A designated member of each working group presented an update on working group activities and progress and made recommendations on actions to be taken. Each of the WGs prepared a 10–15-minute narrated presentation which are posted on the annual meeting webpage (*https://scor-int.org/events/2020-scor-annual-meeting/*) and also prepared 3-5 summary slides to present live at the meeting. The compiled synthesis slides with the reports of the current SCOR WGs, as well as the Large-Scale Research and Infrastructural Projects can be found at the following link: *https://scor-int.org/wp-content/uploads/2020/11/SCOR_Annual2020_Day2.pdf*

2.2.1. 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

Sam Wilson presented the progress of the group. The group presented a poster at OceanObs19 and participated in an OCB workshop in October 2019. The group met during Ocean Sciences 2020. ToRs 1 ,2 and 4 are completed and the group is working on completing ToR 3 which are the Standard Operating Procedures (SOPs) for methane and nitrous oxide. Best practices for Dissolved Methane and Nitrous Oxide measurements in preparation are: SOP1 Sampling, SOP2 Calibration, SOP3 Internal controls, SOP4 Purge-and-trap measurements, SOP5 Headspace measurements, SOP6 Underway measurements, SOP7 Data reporting, SOP on Process measurements of CH4, and SOP on Process measurements of N2O. Each SOP will be posted on the Ocean Carbon & Biogeochemistry website for 2 months, prior to uploading to the Ocean Best Practice portal (presented to the OBP platform at their 4th Workshop in September 2020). They are also preparing a perspective paper for Biogeosciences. Maciej Telszweski from the IOCCP noted that the IOCCP could provide some support to this WG if necessary. The recommended action was to consider disbanding the WG when these planned products for 2021 are completed.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG143_2020_Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/hxnqbjgah8wjp7w/WG143_zoom_0.mp4?dl=0

2.2.2. WG 145 on Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC)

David Turner presented the update for this group. Their vision is for the marine science community to have free access to fully documented, state of the art, user-friendly software for chemical speciation calculations, including uncertainty estimates. To achieve this vision, the group has engaged in several activities, their current status being: (1) Communication: the draft code was presented at OSM 2020 and a paper on "Best practices in chemical speciation modelling" is in preparation, (2) Code development: the draft code is available on the web, (3) Documentation: is complete for pH buffer in artificial seawater, and standard seawater, (4) New measurements: underway at multiple institutions, and (5) Model improvement: the group has worked on uncertainties, and is identifying key systems for study, at UEA.
The WG does not require further financial support from SCOR since they have leveraged substantial resources to support their work. These include: (1) A three-year research grant (ending in 2022) from the U.S. National Science Foundation and the UK Natural Environment Research Council (NERC/NSF: GEO joint program), (2) In-kind contributions from GEOMAR (Germany), the University of Bristol (UK), City University of Hong Kong, and the national metrology institutes in France, Germany, Japan, and the USA, and (3) An IAPSO study group. They have also established effective collaboration with the IAPWS/SCOR/ IAPSO Joint Committee on Seawater (see **item 4.5**). The group met at the 2020 Ocean Sciences Meeting and organized a Town Hall along with tutorials at the SCOR booth providing software demonstrations. Four activities are planned for next year including extending the modelling to trace metals, document key knowledge gaps, complete the Best Practice paper, and the general release of the speciation software (planned for early 2022).
The group requested to continue as a SCOR WG until mid-2022, so that the software release can be clearly identified as a SCOR product. The benefits of this include a clear SCOR contribution to the development of marine science, and that SCOR sponsorship will help to ensure acceptance and use by the marine science community. Marie-Alexandrine Sicre, liaison of this group to the SCOR EC recommended to approve the request for extension until the products planned for 2021 and early 2022 are completed (until May 2022). Jing Zhang (Japan) noted that this WG was important for the GEOTRACES program.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG145_2020_-Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/oslf0td1fehykb0/SCOR%202020%20MARCHEMSPEC%20presentation%20WG%20145%20final.mp4?dl=0

2.2.3. WG 148 on International Quality Controlled Ocean Database: Subsurface temperature profiles (IQuOD)

Guilherme Castelhão presented the updates for this group. Matt Palmer stepped down as co-chair of the goup and was replaced by Simon Good, one of the full members. The group has continued to develop and improve the Open Source code for QC which is available at a GitHub (AutoQC: *https://github.com/IQuOD/AutoQC; CoTeDe: https://github.com/castelao/CoTeDe*). The group had a workshop in Brest, France (October 2019) focused on the developing a roadmap for the v1.0 data release. The group published 4 papers in 2019-2020 and has several products planned to be released in 2021 (e.g., Publication of the IQuOD v1.0 product – a machine learning approach to QC oceanographic data (Castelão et al., in review), of the Auto QC benchmarking paper associated with the v1.0 product (Good et al., in prep), and of the Uncertainties paper associated with the v0.1 product). Another product is a WebApp to integrate experts around the world (*https://expertqc.castelao.net/)*. To improve the efficiency of the manual QC, the experts are paired with an interactive learning schema of Machine Learning to combine the high skill of the human with the speed of the machine. This benefits the community in two ways: Expert QC flags on the WOD;

and public access to the calibrated open source CoTeDe. QC is extending for salinity and chlorophyll. The group is actively looking for more funding and seeking endorsement form the UN Decade. May request letter of support from SCOR for funding proposals in the future. Paul Myers, liaison of this group to the SCOR EC recommended to approve the request for extension and to draft a letter of support if requested.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG148_2020_Report.pdf*
Slide presentation at: *https://scor-int.org/wp-content/uploads/2020/10/IQuOD_SCOR_2020.pdf*

2.2.4. WG 150 on Translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT)

Sara Giering presented the updates of this group. The group produced 3 publications since the last annual meeting and most of the ToRs have achieved either totally or partially. For next year they are planning a Summer School and may potentially meet one more time back-to-back during the Summer School. They share publishing optical methods via the JETZON data sharing platform (*www.jetzon.org*) which will continue to be used as to share data and methods. The group has also developed networking with the AtlantOS program and SCOR Working Group 154 (P-OBS) and is carrying out intercalibration between different systems and traps. Peter Burkill, liaison of this group to the SCOR EC recommended to approve the request to hold a meeting and support the Summer School in 2021.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG150_2020_Report.pdf*

2.2.5. WG 151: Iron Model Intercomparison Project (FeMIP)

Alessandro Tagliabue presented the updates of this group. The group met during the Ocean Sciences meeting, with 23 people (2 remotely) attending, including most of the working group members and several guests. The major topics covered mapped onto the WG objectives: Iron inputs and internal cycling; iron model evaluation; role of dust in ocean iron cycle; role of biology in ocean iron cycle. The group made clear plans for taking objectives forward and made good progress however subsequent events due to the pandemic reduced their momentum on plans. They are planning to meet next year. The group is asking for the feasibility of SCOR hosting a FeMIP specific website to group all code and fields for public availability. Núria Casacuberta, liaison of this group to the SCOR EC recommended to approve the requests.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG151_2020_Report.pdf*

2.2.6. WG 152 on Measuring Essential Climate Variables in Sea Ice (ECV-Ice)

Brent Else presented the updates for this group. The group published three papers and have continued to update the website. They met on 16-18 August 2019 in Winnipeg, Canada along with BEPSII. They are expecting to have 2-3 virtual meetings and were planning to meet in August 2020 in Hobart with the Expert Group on Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII) but this was postponed to 2021. They will attempt to make another intercalibration experiment in 2021 in Cambridge Bay, Canada. The group requests support for a last meeting in 2021. Trevor McDougall, liaison of this group to the SCOR EC recommended supporting the 2021 meeting and disband the group once this has been achieved.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG152_2020_Report.pdf*

Narrated presentation at: *https://www.dropbox.com/s/rczszmxwpfteazj/WG152-ECV-Ice_presentation.mp4?dl=0*

2.2.7. WG 153 on Floating Litter and its Oceanic TranSport Analysis and Modelling (FLOTSAM)

Stefano Aliani presented the updates of this group. This group has participated in many workshops, conferences, and symposia, including a keynote talk at Ocean Sciences 2020. The group has published 10 papers. The first major outcome is a review of the physical processes affecting transport of marine debris published in Environmental Research Letter in which a wide and diverse community contributed as co-authors. It was published open access and it has been considered a highly cited paper by Scopus. Another relevant outcome is the possibility of an Integrated Marine Debris Observing System. The idea was presented at Ocean OBS19 in Hawaii and resulted on a second highly cited paper. The group had exploratory contacts with the Global Ocean Observing System (GOOS) and other global initiative, and the topic will be implemented in the next FLOTSAM meeting to be held in Japan in 2021 (co-sponsored by the Lounsbery Foundation). Another innovative outcome of FLOTSAM is the idea that marine debris can be monitored from space by satellites. Three years ago, it was almost impossible to imagine that we could monitor marine debris from space, but now there are projects working on remote sensing of marine litter with promising preliminary results. Paul Myers, liaison of this group to the SCOR EC recommended to approve the request for funding for the 2021 meeting. Marie-Alexandrine Sicre suggested to attend webinars in microplastics.

Full presentation at: *https://scor-int.org/wp-content/uploads/2020/07/WG153_2020_Report.pdf*

2.2.8. WG 154 on Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)

Anya Waite presented the updates for this group. Most of the ToRs have been finalized and still working on documenting potential applications and measurement protocols. The manual for OceanSites is currently being drafted. The GO-SHIP manual for plankton measurements was uploaded at the Ocean Best Practice platform. For both manuals, technologies and sampling protocols were grouped into six broad categories: genetics, quantitative imaging, flow cytometry, pigments and elemental analysis, bioacoustics, and bio-optics. The group met this year at Ocean Science and had a tutorial session, they want to continue to do more outreach activities. They also met virtually in September 2020 to finalize the draft of the OceanSites report. The main recommendations in the GO-SHIP manual for plankton measurement include: (1) Methods should be standardized, (2) Plankton samples associated with environmental variables should be acquired simultaneously, (3) Sampling should include complete spectrum of plankton size and function, (4) Methods should be inter-calibrated, (5) Protocols drafted (BPS), and (6) Physical plankton samples should be archived. The meeting planned in Halifax in fall 2020 was postponed to 2021. Enrique Montes, liaison of this group to the SCOR EC recommended to approve the request to fund the 2021 WG meeting.

Full presentation at: *https://scor-int.org/wp-content/uploads/2020/06/WG154_2020_report.pdf*
Narrated presentation at: *https://www.dropbox.com/s/eeoam3ze3xluxhc/P-OBS_SCOR_Report_2020_AMW2_EB.mp4?dl=0*

2.2.9. WG 155 on Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change

Rubén Escribano presented the updates of the group. The group cancelled the Summer School planned in Senegal in 2020 as well as the Open Science Conference on Eastern Boundary Upwelling Systems (EBUS): past, present, and future to be held in conjunction with the 2nd International Conference on the Humboldt Current System in 2020. These events may be postponed up to 2022 if travel conditions do not improve in 2021. The group met virtually in June and produced three papers in 2019-2020. One of the papers to which the group contributed was the OceanObs19 paper on Global Perspectives on Observing Boundary Current Systems. They will continue to work online until meetings can be rescheduled, mostly in the review paper ("From physics to ecosystem services and beyond: a review of Eastern Boundary upwelling systems" by lead authors Ivonne Montes, Ruben Escribano, Boris Dewitte, Véronique Garçon and with the full and associated WG members as co-authors) and in the data web portal which will link to existing data portals but aiming to a global observing system for EBUS. David Halpern, liaison of this group to the SCOR EC was not at the meeting, nor was Bradley Moran who was the new vice-president to the SCOR EC so Sinjae Yoo recommended to approve the request to continue to fund the 2021 WG meeting. Marie-Alexandrine Sicre will be the new liaison of this group to the EC and she will follow up with the group on the delivery of the ToRs.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG155_2020_Report.pdf*
Narrated audio at: *https://www.dropbox.com/s/b5xk8syv25yrfi3/EBUS%20SCOR%20WG-155%20Report.wav?dl=0*

2.2.10. WG 156 on Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity

Nina Schubak presented the updates for this group. The group met at Ocean Sciences 2020 and have made significant progress to achieve ToRs. Following on the deliverables of Year 1, the group has finalised the inter-comparison data (2019 workshop), advance the "Best Practice" volume, and advanced the fluorometry (F) data processing hub. They have initiated Year 2 activities including compiling the F-Carbon comparison data, plan for the field and lab work for F-Carbon data gaps and explored the global F database (NASA). They are working on in the development of their flagship paper (distilled "Best Practice") to be submitted to Frontiers in Marine Science (submit end 2020). The group has created a new shared Wiki page to organize the content of their SCOR WG activities (*http://scor156.com/*), currently password protected, but aiming to share resources. Currently working on their first publication and drafting a second high-profile perspective type publication on how fluorometry can transform understanding of marine primary productivity. New meta-data compiled for this publication may also contribute to other papers led by the WG ECR members. Will continue to meet virtually if travel limitations persist but if not, will meet in 2021. Other on-going activities include: (1) Data analysis of past-current campaigns (Vancouver workshop, Polar cruises Tropical cruises, new F-Carbon meta-analysis), (2) New campaigns to road-test 'Best Practice" (Atlantic Ocean - multiple sensors aligned to PACE, pursue FALKOR discussions), (3) Developing training workshops in South and central America. Sinjae Yoo, liaison of this group to the SCOR EC recommended to approve the request to fund the 2021 WG meeting.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG156_2020_Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/bfp099xsiws988p/WG156_narrated_updates_October2020.mp4?dl=0

2.2.11. WG 157: Toward a new global view of marine zooplankton biodiversity based on DNA metabarcoding and reference DNA sequence databases (MetaZooGene)

Ann Bucklin presented the updates of this group. The group met in Gothenburg in September 2019 and organized a SCOR Symposium. It met again at Ocean Sciences 2020 and they provided demonstrations at the SCOR booth. The group has one publication in press in the Philosophical Transactions of the Royal Society B and two other publications in PNAS and PLoS ONE. Another major product is "MZGdb: Web Portal and Atlas for DNA Barcodes of Marine Zooplankton" which has over 154,000 DNA sequences of ~9,000 species, contains data from NCBI GenBank, BOLD and MZG members, the data can be downloaded by taxonomic group and ocean region, and it provides a completeness view as well as gaps in an interactive visual "atlas ". The ToRs are in progress, and for next year there are several planned publications, including a special issue in the ICES journal ("Patterns of Biodiversity of Marine Zooplankton Based on Molecular Analysis") and capacity building workshops. The group requests to use their budget for the 2022 Ocean Sciences meeting in Hawaii. Enrique Montes, liaison of this group to the SCOR EC noted that this group has been doing excellent work and the outputs are already benefiting many other activities. Montes recommended to accept this request which Patricia Miloslavich confirmed was totally feasible from the SCOR secretariat.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG157_2020_Report.pdf*
Narrated presentation at: *https://www.dropbox.com/s/ds82hs1wh5xs4ua/SCOR-WG157-MetaZooGene_Narrative%20Bucklin-7Oct2020__with-Todd-audio-added.mp4?dl=0*

2.2.12. WG 158: Coordinated Global Research Assessment of Seagrass System (C-GRASS)

Emmett Duffy presented the updates for this group. The group had planned the first international C-GRASS meeting in Colombia in early May but had to cancel due to COVID restrictions. They met virtually throughout September and have organized in four core teams: (1) data schema, (2) data synthesis, (3) community of practice, and (4) best practices. The group members were organized in subgroups within each of these themes and tasks. Several members of the WG—including the co-PIs—were involved the production and launch of the Out of the Blue global seagrass synthesis report. While not a direct output of the C-GRASS WG, the report will form the basis of the WG's work moving forward along with the OceanObs19 paper "Toward a Coordinated Global Observing System for Seagrasses and Marine Macroalgae" (Frontiers of Marine Science, 2019). There has been significant progress of the ToRs and these will continue next year. Jing Zhang, liaison of this group to the SCOR EC noted that the group is doing very well and recommended to approve the request to fund the 2021 WG meeting.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG158_2020_Report.pdf*
Narrated presentation at: *https://www.dropbox.com/s/hw7f02tkm8y66xy/C-GRASS_presentation_SCOR_202010.mp4?dl=0*

2.2.13. WG 159: Roadmap for a Standardised Global Approach to Deep-Sea Biology for the Decade of Ocean Science for Sustainable Development (DeepSeaDecade)

Kerry Howell presented the updates for this group. The group held its first meeting in January 2020 in Portugal. The group outlined two papers to be developed over the next 4 months. One outlining a blueprint for the UN Decade and the other focused on barriers to deep-sea science for developing nations. The last day of the meeting was given over to a public event discussing needs and plans for the Decade. Many students and early career researchers were invited to this meeting. The second meeting was planned in Brazil in August 2020 but was cancelled and will be rescheduled for 2021. They group plans to submit a proposal to the UN Decade for Ocean Science and Sustainability and will request a support letter from SCOR. Enrique Montes, liaison of this group to the SCOR EC noted this group is doing important progress. With regards to providing a letter of support for their submission to the UN Decade, Peter Burkill requested further clarification on what this would entail. Howell clarified that this would be a recognition/endorsement from SCOR, so whichever way SCOR could commit/support would be fine. Burkill noted that the SCOR EC would discuss how to best approach these requests in anticipation to the call for projects of the UN Decade. Montes recommended to approve the request to fund the 2021 WG meeting.

During the discussion of the WG's progress, Fangli Qiao (China) noted that it had been incredibly good to listen directly from the WGs what the ToRs are, their main tasks, how many meetings have been organized and how many products and papers have been delivered. However, he suggested that for the next time the WGs report, it would be interesting and attractive to also hear, in a simple language, about their one or two major scientific breakthroughs.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/WG159_2020_Report.pdf*

3. LARGE-SCALE OCEAN RESEARCH PROJECTS

SCOR currently sponsors five large-scale research projects; four of them are co-sponsored by other organizations. Each project has its own scientific steering committee (SSC) to manage the project. SCOR and other co-sponsors are responsible to oversee the projects, which they do primarily through responsibility for the project SSC memberships and terms of reference, although sponsors also oversee the results of the projects' activities. Each of the projects has an assigned liaison person to the SCOR Executive Committee. Any proposed changes in membership or terms of reference are considered by the SCOR Executive Committee, in partnership with other co-sponsors, throughout the year. The SCOR Secretariat oversees the use of grant funds provided to the projects through SCOR. SCOR uses solely grant funds for IMBER, SOLAS, and GEOTRACES, but is providing SCOR support for IQOE and IIOE-2 until they are self-supporting.

3.1. GEOTRACES

Alessandro Tagliabue presented the updates for GEOTRACES and acknowledged SCOR's and NSF's support to the program. GEOTRACES organized a Summer School in September 2019, and in 2020 it organized a special session at Ocean Sciences and had live demonstrations at the SCOR booth. Due to COVID, all the rest of the meetings (SSC and data management team) was done virtually. GEOTRACES is preparing the release of the third Intermediate Data Product for 2021, and continues its scientific activities related to publications, intercalibration, data management and capacity building. The SSC received the SCOR review and has addressed its recommendations in a response to the SCOR Executive. No action was required. GEOTRACES funding is provided by specific funding from an NSF grant to SCOR.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/GEOTRACES_2020_Report.pdf*
Slide presentation at:
https://www.dropbox.com/s/wa1a7dst1rq63re/2020_GEOTRACESforSCOR.pdf?dl=0

3.2. Surface Ocean – Lower Atmosphere Study (SOLAS)

SOLAS is co-sponsored by SCOR and Future Earth with additional co-sponsoring from the World Climate Research Programme (WCRP) and the international Commission on Atmospheric Chemistry and Global Pollution (iCACGP). Lisa Miller presented the updates for SOLAS. SOLAS organized live demonstrations at the SCOR booth at Ocean Sciences and has held all meetings since virtually including the SSC meeting. The IPO is working on organizing the SOLAS Summer School 2021 to be held in Cape Verde if travel restrictions allow. SSC Chair Lisa Miller ends her term in December and two new SSC co-chairs were approved by SCOR and the other SOLAS sponsors. They will begin their terms in January 2021 (Minhan Dai and Cliff Law). Marie-Alexandrine asked about the workshop in the Indian Ocean late September and if SOLAS already knew how much of the African countries were attending. Lisa Miller said they had some but would have liked to have more. Most of the participants were from India, Bangladesh, Africa, Australia and South Africa, while they had no participants from the islands which was a disappointment for SOLAS. Maciej Telszewski from the IOCCP mentioned that it would be beneficial to inform each other about new dates of events, so that meetings do not happen at the same time. Jessica Gier (SOLAS) suggested that it would be useful to have a calendar where all the SCOR community could add their major activities like summer schools, conferences, etc, to help avoid overlapping activities. She argued that it seemed difficult to inform everyone individually, or follow each postponement, and that some events were not relevant to all SCOR projects and sending an email to a big mailing list might not be needed. Maciej Telszewski agreed and further expanded that since SCOR seems to be the hub for many projects/programs that do capacity building in the form of summer school, SCOR could be a good place to host such calendar. Alternatively, the community could start from bottom-up and start a G-calendar to share it with 20-30 organizations to use. Patricia Miloslavich noted that SCOR already has a calendar of events on the SCOR website that is used to advertise SCOR events and activities, that is constantly updated as she receives or is aware of new events or changes to events already posted. She will continue to ask for input from the community to keep the calendar updated and encourages everyone to look at it for information of events. Robin Brown added that having a centralized calendar for posting ocean activity meetings, workshops, and capacity building activities like summer schools, would be a great help in attempting to minimize overlap of activities in time. No further action was required regarding SOLAS. SOLAS funding is provided by specific funding from NSF and NASA grants.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/SOLAS_2020_Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/rj8lidsmeq4ygtn/SOLAS_Overview_for%20SCOR_narrated.mp4?dl=0

3.3. Integrated Marine Biosphere Research (IMBeR)

IMBeR is also co-sponsored by SCOR and Future Earth. Carol Robinson presented the updates for IMBeR. The IMBeR IPO moved to its new host institution, Dalhousie University in Canada. Four new members joined the SSC in January 2020 including an early career researcher, and two African (female) scientists. The group organized a special session and had live demonstration at the SCOR booth during Ocean Sciences 2020. The SSC met virtually in June 2020 and addressed nine common tasks leading to development of publications, strategic direction for IMBeR, ability to assess IMBeR's impact and planning for the next conference in IMBeR's innovative IMBIZO series. Peter Burkill, the liaison to IMBeR in the SCOR Executive acknowledged the support from NSF and NASA to IMBeR and expressed that IMBeR is doing a great job, so that anything that SCOR is doing on top is good news. No further action was required. IMBeR support is provided by specific funding from NSF and NASA grants to SCOR.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/IMBeR_2020_Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/rp1tmg1eg7qah2b/IMBER_zoom_0.mp4?dl=0

3.4. International Quiet Ocean Experiment (IQOE)

The IQOE is co-sponsored by SCOR and the Partnership for the Observation of the Global Ocean (POGO). Peter Tyack presented the updates for the IQOE. IQOE working groups have continued their activities virtually. IQOE scientists presented at the Ocean Sciences meeting and the ocean soundscapes related session resulted in in a Research Topic on the journal Frontiers of Marine Science. A paper on Changes in Ambient Sound in the Ocean from the COVID-19 Pandemic was submitted to JASA Express letters, and the group is preparing a workshop in 2021 to plan the implementation of ocean sound as an Essential Ocean Variable (EOV). Ed Urban, former Executive Director of SCOR will continue to act as Project Officer for the IQOE. SCOR will provide support for the 2021 workshop as approved in the 2021 budget.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/IQOE_2020_Report_Newsletter5.pdf*
Narrated presentation at: *https://st-andrews.cloud.panopto.eu/Panopto/Pages/Viewer.aspx?id=06cac409-cf3a-42fc-8aa9-ac5000f4ca4f*

3.5 Second International Indian Ocean Expedition (IIOE-2)

The IIOE-2 is co-sponsored by SCOR and the IOC. Peter Burkill presented the updates for the IIOE-2. The IIOE-2 Core Group has met virtually four times since November 2019 to deal with strategic issues. The SSC meeting to be held along with the Indian Ocean Science Conference earlier this year was postponed until further notice. Cruises have also been postponed; however, the community has remained productive with several publications. The Core Group has discussed a replacement for the leadership of the Data and Information Management WG (former lead Cyndy Chandler who retired). Peter Burkill stepped down as co-chair of IIOE-2 on behalf of SCOR and was replaced by Marie Alexandrine Sicre. SCOR will provide support for the 2021 IIOE-2 activities as approved in the 2021 budget.

Full report at: *https://scor-int.org/wp-content/uploads/2020/10/IIOE-2-Report-for-SCOR-Burkill.pdf*
Narrated presentation at: *https://www.dropbox.com/s/p3g8wsokr37gbsm/IIOE-2%20Burkill.mp4?dl=0*

4. INFRASTRUCTURAL PROJECTS

4.1. Changing Ocean Biological Systems (COBS)

Sinead Collins presented the updates for COBS. The former working group has drafted the new ToRs and a proposed membership as it transitions from a WG to a SCOR project. The group has carried out mentoring and capacity building in national and international venues (e.g., IAEA, Ocean Sciences 2020) and developed a 24-slide workshop template for the growing team of national advocates. The online 'Experimenting with multistressors" resource (**https://meddle-scor149.org/) has been used for publicity, lecturing and research. Maciej Telszewski acknowledged the work done by this project in understanding the effect of multistressors like acidification and increased temperature because of increased CO2. Sinead Collins appreciated the comment. Action for the project is to deliver to the SCOR Executive the revised ToRs and membership composition.** Funding to COBS is provided from NSF specifically for the group through SCOR.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/COBS_2020_Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/4jlm6jf8ksqub6z/Narrated%20talk%20for%20COBS%20SCOR%20WG149.pptx?dl=0

4.2. GlobalHAB

GlobalHAB is co-sponsored by SCOR and the IOC. Elisa Berdalet presented the latest updates of GlobalHAB. The GlobalHAB SSC renewed its composition and organized around strategic themes. The GlobalHAB symposium on automated in situ observations of plankton to be held in June 2020 in Sweden was postponed to 2021. For this year, the SSC met virtually, and for 2021, the project is planning to hold a face-to-face SSC meeting as well as Modelling Workshop. SCOR still holds past funds from GlobalHAB to support their activities in 2021 or in 2022 if needed depending on when face to face meetings are possible again.

Full report at: *https://scor-int.org/wp-content/uploads/2020/10/GlobalHAB_2020_Report2.pdf*
Narrated presentation at:
https://www.dropbox.com/s/8ovac9oaeip3tgk/GlobalHAB_2020%20SCOR%20Anual%20meeting_recorded.mp4?dl=0

4.3. International Ocean Carbon Coordination Project (IOCCP)

The IOCCP is co-sponsored by SCOR and the IOC. Masao Ishii presented the updates for the IOCCP. The IOCCP incorporated new members in the SSG, and one of the co-chairs (Masao Ishii) will rotate off in 2021. The review of IOCCP by SCOR and IOC was completed and the IOCCP will be sending a formal response letter on how it plans to address all recommendations. The group had a special session at Ocean Sciences 2020. The SSG had planned to meet in Auckland in November 2020 but this meeting will be held virtually. No further action was required. IOCCP funding is provided by specific funding from an NSF grant to SCOR.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/IOCCP_2020_Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/bhal9a6eu56qb45/IOCCPforSCOR2020.mp4?dl=0

4.4. The Southern Ocean Observing System (SOOS)

SOOS is co-sponsored by SCOR and the Scientific Committee on Antarctic Research (SCAR). Eileen Hofmann presented the updates of SOOS. The SOOS SSC had a renewal process, with two new co-chairs coming in along with other three members. The 2020 SSC meeting was going to be held in

Hobart in conjunction with the SCAR meeting, but this was held virtually. The data portal for the Southern Ocean, SOOSMap, continues to be used and all SOOS WGs continue to be active virtually. Several opportunities have been advertised with the Weddell Sea/Dronning Maud Land and the Amundsen/Bellingshausen Sea groups. No further action was required. SCOR has already committed funding for SOOS for 2021 and Trevor McDougall ratified this decision.

Full report at: *https://scor-int.org/wp-content/uploads/2020/08/SOOS_2020_Report_2019activities.pdf*
Narrated presentation at: *https://www.dropbox.com/s/2od8zuhrv05hylz/SCOR-SOOS_2019.mp4?dl=0*

4.5. Joint Committee on Seawater (JCS) (IAPWS/SCOR/IAPSO)

The JCS is co-sponsored by SCOR, the International Association for the Properties of Water and Steam (IAPWS), and the International Association for the Physical Sciences of the Oceans (IAPSO). Rick Pawlowicz presented the updates for this group. This group was formed to continue the work of SCOR/IAPSO WG 127 on Thermodynamics and Equation of State of Seawater. SCOR provides a small amount of funding each year to enable the JCS chair and others to attend annual meetings of the IAPWS. The JCS has been responsible for continued implementation of TEOS-10, as well as conducting experimentation and modeling for proper description of seawater properties in models. The JCS has been working with SCOR WG 145 in terms of pH and its effects on trace metals and other components of seawater and held a workshop together at Ocean Sciences 2020. Plans to meet at the 2020 IAPWS Annual Meeting (Turin Italy, September 2020) were abandoned as the meeting was cancelled due to COVID-19. SCOR will provide support for JCS activities as approved in the 2021 budget.

At the end of the three-hour session of Day 2, Sinjae Yoo acknowledged all the work done by the WGs and the projects. He thanked the presenters and the participants in the discussions and closed the session.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/JCS_2020_Report.pdf*
Narrated presentation at:
https://www.eoas.ubc.ca/~rich/SCOR/JCS_REPORT_TO_SCOR.mp4

5. AFFILIATED PROJECTS AND NON-GOVERNMENTAL ORGANIZATIONS

5.1. International Ocean Colour Coordinating Group (IOCCG)

The IOCCG is sponsored by a NASA grant managed by SCOR. Venetia Stuart presented the updates for the IOCCG. IOCCG has a system of working groups that produce scientific monographs to advance the field of ocean colour observations from satellites. IOCCG and the SCOR/IOC GlobalHAB project co-sponsor a working group on Harmful Algal Blooms. Another important IOCCG activity in recent years has been the biennial International Ocean Colour Science meetings, which are open meetings designed to bring together the international ocean colour community to discuss important issues related to their science. The annual IOCCG-25 Committee meeting was scheduled to take place from 27–29 March 2020 in Tokyo, Japan hosted by the Japan Aerospace Exploration Agency (JAXA) but had to be cancelled. There are plans to conduct several teleconferences with various groups to discuss pressing matters. The next full IOCCG Committee meeting is scheduled to take place in early February 2021. Elba Escobar asked if the IOCCG could consider virtual courses for the future maintaining the capacity building initiatives for developing countries as vaccines may not be ready to apply but after August 2021. Venetia Stuart responded that they ran virtual" Summer Lecture Series" discussion sessions which were well received, although it was difficult to accommodate lecturers and students in all different time zones. The group may consider other virtual courses in future. Claudia Delgado indicated that to reach a wider audience they could also contact IOC (**ioc.training@unesco.org**) as they could help advertising webinars and other capacity development activities. Stefano Aliani noted that FLOTSAM groups were quite successful to spot debris using sentinel 2 and were also deploying a calibration target in the Aegan under ESA projects. No further action was required.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/IOCCG_2020_Report.pdf*
Narrated presentation at: *https://www.dropbox.com/s/wwscl5dkl0yed9i/IOCCG-narrated-SCOR-presentation-Oct_2020.mp4?dl=0*

5.2. InterRidge - International, Interdisciplinary Ridge Studies

Sang-Mook Lee presented the updates for InterRidge. The InterRidge Steering Committee met online in May 2020 and Seung-Sep Kim from Korea joined the Steering Committee. The Steering Committee approved a new working group focused on biological issues, MacroCHESS, to expand on the current IR Vents Database. Alessandro Tagliabue asked if the database on the website would be updated and Sang-Mook Lee responded that this work is ongoing. No further action was required.

Full report at: *https://scor-int.org/wp-content/uploads/2020/07/InterRidge_2020_Report.pdf*

5.3. Global Alliance of CPR Surveys (GACS)

Anthony Richardson presented the updates for GACS. The most recent GACS annual meeting was held in November 2019 in Hobart, and it was followed by a molecular workshop. COVID has made the work challenging but the community is currently working in several papers using Continuous Plankton Recorder (CPR) data to validate a global ecosystem size spectrum model, test ecological theory, and a global CPR methods paper. Richardson focused on (1) how GACS data are evolving, (2) on GACS data uses, and (3) on its geographical expansion. There is now a global CPR database, with all data from CPR surveys globally and the latest taxonomic identifiers. GACS has been endorsed by GEOBON engaged with SOOPIP (SOOP Implementation Panel), contributing to Ocean Best Practices and continues to be strongly engaged with POGO. Enrique Montes asked if there were any plans to expand coverage in the tropical seas, to which Anthony Richardson responded that lack of funding support in developing nations was the main limiting factor in those regions. Elva Escobar asked if GACS could benefit from ships of opportunity, either science cruises in developing countries and/or from the industry. Richardson responded that one of the main limiting factors of using ships of opportunities was the speed of the ship and length of the leg when trawling the CPR. No further action was required.

Full report at: *https://scor-int.org/wp-content/uploads/2020/07/GACS_2020_Report.pdf*

5.4. International Association for Biological Oceanography (IABO)

Enrique Montes presented the updates for IABO. IABO has focused on the implementation of the new organizational structure following the Terms of References (ToRs) approved during the previous year by the IABO Executive Committee. Several updates have been made to the IABO site to highlight information of new members, new logo and about the upcoming 5th World Conference on Marine Biodiversity to be held in Auckland, New Zealand in December 2020 (mix of virtual and attended). SCOR is providing $5,000 USD for registration of scientists from developing countries to attend the 5th WCMB. IABO recognized two scientists with the Carlo Heip Award, Graham Edgar (Australia) for 2019 and Steve Hawkins (UK) for 2020. They will receive the awards at the 5th WCMB. Enrique Montes invited to identify areas of future cooperation between SCOR and IABO and Samuel Mafwila (Namibia) expressed that he would like to join IABO.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/IABO_2020_Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/sdrpou677qw54eg/IABO_SCOR2020.mp4?dl=0

5.5. International Association for the Physical Sciences of the Oceans (IAPSO)

Trevor McDougall presented the updates for IAPSO. He highlighted that IAPSO is celebrating 100 years of its establishment. IAPSO was actively organizing the IAPSO-IAMAS-IACS Joint Assembly in Busan, South Korea, 18-23, July 2021, but they all agreed to cancel this in-person joint assembly, due to the COVID-induced uncertainty surrounding international travel, the meeting may be either organized virtually or postponed 12 months. This IAPSO ECS group has now produced a website (https://www.iapsoecs.org) and a twitter account (https://twitter.com/iapso_ecs?s=20) for this working group, where the newsletters, job and research cruise opportunities and ECS-related events get routinely updated.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/IAPSO_2020_Report.pdf*

5.6. International Association for Meteorology and Atmospheric Sciences (IAMAS)

Joyce Penner presented the updates for IAMAS. The IAMAS sponsored meetings have had the following changes: (1) Quadrennial International Radiation Symposium planned to be held in Thessaloniki, Greece (July 2020) postponed to 14 to 18 June 2021, (2) Quadrennial Ozone Commission planned for October 2020 at Yonsei University, South Korea, postponed until October 3 to 9, 2021, (3) International Commission on Clouds and Precipitation conference planned for August 3 to 7 2020 in Pune, India postponed to 2021, and (4) International Global Atmospheric Chemistry (in collaboration with the IAMAS sponsored Commission on Atmospheric Chemistry and Global Pollution) meeting planned for September 14 – 18, 2020 in Manchester, U. K. postponed to September 12 – 16, 2021.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/IAMAS_2020_Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/soiolpzaahvompp/IAMAS_narrated_GMT20200913-172341_Joyce-E-Pe_1760x900.mp4?dl=0

6. INTERGOVERNMENTAL AND PARTNER ORGANIZATIONS

6.1. Intergovernmental Oceanographic Commission (IOC)

Salvatore Arico presented the updates for the IOC. The IOC and SCOR have long successfully cooperated and thereby strengthened research and scientific programmes. The IOC Secretariat looks forward to sharing with SCOR its views on those proposals for new and to-be-renewed SCOR Working Groups that more closely reflect the current priorities of IOC in ocean science and support the UN Decade for Ocean Science and Sustainability. IOC co-supports with SCOR GlobalHAB, the IOCCP, and the IIOE-2, but other activities involving close cooperation between the IOC and SCOR are the COBS project, the International Group for Marine Ecological Time Series (IGMETS), formerly

SCOR WG# 137, ocean acidification, and other jointly ocean carbon activities with the contributions of SOLAS and IMBeR. Salvatore Arico focused on the outcomes and challenges for the UN Ocean Decade for Ocean Science and Sustainable Development, and on how to engage with the Decade.

Full report at: *https://scor-int.org/wp-content/uploads/2020/07/IOC_2020_Report.pdf*

6.2. North Pacific Marine Science Organization (PICES)

Hal Batchelder presented the updates for PICES. SCOR and PICES have developed cooperative methods that have made it possible for an international non-governmental organization and a regional intergovernmental organization to share their strengths. Continuing and expanding collaboration between PICES and SCOR is based on the recognition that PICES can play an important role in bringing a North Pacific perspective to the global activities of SCOR, and that by participating in and implementing these activities in the region, PICES can advance its own scientific agenda. PICES has been helpful in regionalizing several international SCOR projects and provides expertise to GlobalHAB, IMBeR, SOLAS, GACS and the IOCCP. PICES has sponsored members of several SCOR working groups. SCOR and PICES have provided capacity building support for each other's activities and have cooperated more broadly in capacity building. In 2019, SCOR supported seven early career scientists from developing countries to attend their 2019 meeting. PICES is requesting SCOR support for the Small Pelagic Fish: New Frontiers in Science for Sustainable management meeting to be held in 2022 in Portugal. This request will be reviewed by the SCOR Capacity Development Committee. Hal Batchelder serves as a liaison to the SCOR Committee on Capacity Building. Lisa Miller asked if any progress were being made toward bringing Mexico into PICES, to which the response was that the political environment of Mexico is complex and very uncertain and that it was hard to say how involving Mexico would be possible in the short term.

Full report at: *https://scor-int.org/wp-content/uploads/2020/08/PICES_2020_Report.pdf*

6.3. Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP WG38)

Bob Duce presented the updates of the GESAMP WG 38. During the past year GESAMP WG 38 focused its attention in three areas: 1) Development of a workshop on the ocean management and policy implications of the air/sea exchange of chemicals; 2) Development of a workshop on the atmospheric transport of microplastics to the ocean; and 3) Completion of the peer-reviewed publications arising from the 2017 workshop "The impact of the changing acidity of the ocean and atmosphere on the air/sea exchange of chemicals", as well as from other WG 38 activities. GESAMP WG38 was planning a workshop in South Africa in Fall 2020 but this was postponed to 2021. SCOR is holding funding for this workshop and granted the extension of their use to 2021. To the question of what the criteria was for inviting people to the micro-plastic workshops, the response was that these were not open activities and were intended for experts in air-sea exchange and other relevant research areas. Funding for GESAMP WG 38 had been provided by an NSF grant to SCOR and has now been completed.

Full report at: *https://scor-int.org/wp-content/uploads/2020/06/GESAMP_2020_Report.pdf*

6.4. Partnership for Observation of the Global Oceans (POGO)

Sophie Seeyave presented the updates for POGO. SCOR and POGO co-sponsor the POGO-SCOR Operational Oceanography Visiting Scholars, as well as the International Quiet Ocean Experiment (IQOE). The three pillars of POGO are (1) innovation and development of the ocean observing system, (2) capacity development, and (3) outreach and advocacy. The POGO website was recently updated to reflect more accurately these three pillars. Sophie Seeyave explained how to get involved with POGO which may be through becoming a member, becoming an ocean training partner and/or contributing to Oceanscape (Oceanscape.org).

Full report at: *https://scor-int.org/wp-content/uploads/2020/07/POGO_2020_Report.pdf*
Narrated presentation at:
https://www.dropbox.com/s/2dyis5hszd32hpi/POGO%20recording2020.mp4?dl=0

6.5. International Science Council (ISC)

Martin Visbeck presented the updates for the ISC. The ISC was launched in June 2018 and has since been focused on establishing a new governing structure. Martin Visbeck presented the key developments since the publication of the renovated ISC Action Plan 2019-2021. These included COVID19 related activities, their global policy engagement, the ISC-endorsed initiatives, the funding programmes, the co-sponsored programmes and affiliated bodies and the action plan projects and programmes. The ISC also signed a Memorandum of Understanding (MoU) with the IOC to work together on the UN Decade of Ocean Science for Sustainable Development. The ISC was organizing an 'International Initiatives Leadership' (IIL) meeting for March 2020 in Paris to discuss the science we need for sustainability and how the science community can strengthen its collective impact on global decision-making. The goal of this meeting was to better understand the role of Unions and Organizations in the coordination of global science efforts, identify synergies and opportunities for interoperability. The meeting was cancelled due to COVID. The SCOR President and ED were going to attend this meeting. To the ICSU review of SCOR held in 2019, the SCOR Executive Committee and Executive Director provided a response. One of the issues to address from this review was the updating of the SCOR Constitution which was approved in this annual meeting. Peter Burkill who chaired the SCOR Constitution Review Committee noted that the approved Constitution with the amendments will be sent to the ISC.

Full report at: *https://scor-int.org/wp-content/uploads/2020/07/ISC_2020_Report.pdf*
Slide presentation at: *https://scor-int.org/wp-content/uploads/2020/10/Visbeck-ISC-update-Oct-2020.pdf*

6.6. Scientific Committee on Antarctic Research (SCAR)

Eoghan Griffin presented the updates for SCAR. SCOR and SCAR currently co-sponsor the Southern Ocean Observing System (SOOS). The Covid-19 pandemic has had several impacts on SCAR including the cancellation of its 2020 Open Science Conference and Delegates meeting in Hobart. However, key elements of the conference were moved online during the original conference dates 3-7 August. The online conference had 2712 registrations and the program included plenary presentations and medal ceremonies. It was a combination of live-streaming and recorded presentations (the presentations available in YouTube). Six SCAR's programs are ending in 2020 and these will be replaced by three new programmes: (1) INStabilities and thresholds in ANTarctica (INSTANT) which aims to quantify the Antarctic ice sheets contribution to past and future sea level rise, (2) the Integrated Science to Inform Antarctic and Southern Ocean Conservation (Ant-ICON), research to drive and inform international decision-making and policy change, and (3) the Near-term Variability and Prediction of the Antarctic Climate System (AntCLIMNow) aiming for prediction of near-term conditions in the Antarctic climate system. In relation to the UN Decade of Ocean Science for Sustainable Development, SCAR co-organised a Workshop at the 2020 Ocean Sciences Meeting in San Diego on the Southern Ocean contribution to the UN Decade of Ocean Science. The workshop had the participation of representatives from ocean sciences, policy, governance, and science communication, from all career stages. In September 2020, SCAR along with other partners (including SOOS) was a partner (as was SCOR) on a proposal to the Belgian Federal Science Policy Office (BELSPO) for funding to host a second workshop (results of application still pending).

Full report at: *https://scor-int.org/wp-content/uploads/2020/07/SCAR_2020_Report.pdf*

6.7. Future Earth – Ocean

Clément Brousse, the liaison of Future Earth ocean-related activities presented the updates for Future Earth. Future Earth Secretariat is carrying activities related to ocean science on a regular basis. In addition of liaising with the research projects SOLAS and IMBeR (through funding, sharing of opportunities etc.), Future Earth Secretariat is working in close relation with the Ocean KAN (Knowledge Action Network). The Ocean Kan Development Team (19 members from 15 countries) recently developed their Implementation Plan in which all sponsors including SCOR provided input. Future Earth is currently in the process with the other sponsors of reviewing applications to host the Ocean KAN IPO. It is expected that the Ocean KAN will have an International Project Office and an Executive Director to implement its strategy for action in early 2021. The Ocean KAN will actively engage in the IOC-UNESCO Ocean Decade, and has commented on its implementation plan. It has also partnered to organize online events such as the Virtual Blue Decade aside of the UNFCCC 2019. As for Future Earth actions, they have co-sponsored through the PEGASuS grant two postdocs (Alfredo Giron and Erin Satterthwaite) who participated in the First Global Planning Meeting of the decade and contributed to launch ECOPs (Early Career Ocean Professionals); are working with the Belmont Forum and the Joint Programme Initiative (JPI) Ocean on 13 international projects working on approaches towards the achievement of SDG 14 (~14 million Euro from 16 countries); and working in the organization of the Science-Based Pathways for Sustainability Initiative – Ocean Workshop on how to reach SDG 14 in this context and interactions with other SDGs. The Earth Commission of Future Earth has 19 commissioners from 13 countries and is building on and complementing existing assessments from IPCC and IPBES to identify thresholds for protecting Earth's life support systems such as biodiversity, freshwater, oceans, and land, and on how governance and institutions of our societies can be designed to achieve a desired transformation. Lisa Miller expressed that there are many things going on and wished to continue the conversation offline. To the question of how many international offices did Future Earth have, the response was that Future Earth has five Global Hubs located in Canada, France, Japan, Sweden, and the USA.

Full report at: *https://scor-int.org/wp-content/uploads/2020/08/2020_Future_Earth_Report.pdf*
Narrated presentation at: *https://www.dropbox.com/s/6tj1p2c3uayjh48/Clement%20-%20Future%20Earth.mp4?dl=0*

6.8. World Climate Research Program (WCRP)

Mike Sparrow presented the updates for the WCRP. WCRP is over 40 years old and is implementing its new research strategy (WCRP Strategic Plan 2019-2028) by reviewing its entire structure and improving its functionality, including its interaction with partners. The four science objectives of the Strategy are (1) the fundamental understanding of the climate system, (2) prediction of the near-term evolution of the climate system, (3) long term response of the climate system, and (4) bridging climate science and society. Major elements of the implementation plan include strengthening support for core research, and to extend and deepen our engagement with scientific partners at the national and international levels. The priority is to regionalize climate science and predictions in support of decision-making. The WCRP will prioritize its science and implement its Strategy by pursuing a series of Lighthouse Activities (intended to be high profile and drive the science priorities) along with other core research activities, to deliver and achieve critical outcomes over the next decade. The proposed (draft) new structure of the WCRP will include the Joint Scientific Committee, the WCRP Secretariat, the Lighthouse Activities, and the International Offices, all of them cross-cutting through ongoing and additional activities and fora. The "WCRP Academy", one of the Lighthouse Activities, is planned to have physical presence and an online version. There are summer schools and others that allow to engage everyone through different mechanisms, and the Academy can play an important role in engaging with the global community and next generation and connecting the global north and south. The WCRP carries most of its activities through four core projects: CLIVAR (oceans and climate - www.clivar.org), CliC (cryosphere and climate - www.climate-cryosphere.org), GEWEX (water and climate www.gewex.org) and SPARC (upper atmosphere and climate - http://www.sparc-climate.org). Both CLIVAR and CliC are endorsers of the SCAR/SCOR Southern Ocean Observing System (SOOS). Of these core projects the work of CLIVAR is of relevance to SCOR, particularly through the Ocean Model Development Panel (http://www.clivar.org/clivar-panels/omdp). WCRP has gone almost wholly online since the start of the COVID-19 crisis. Major meetings such as the Joint Scientific Committee meeting were held with over 80 people attending remotely. The WCRP provides support for climate-relevant meetings and workshops. It has regional offices in China and in India.

Full report at: *https://scor-int.org/wp-content/uploads/2020/09/WCRP_CLIVAR_to_SCOR_2020_v2.pdf*

7. CAPACITY DEVELOPMENT ACTIVITIES

7.1. SCOR Committee on Capacity Development

Patricia Miloslavich reported on SCOR's capacity development activities. In the past year, the committee reviewed one set of requests for travel support to scientific meetings and reviewed the 2020 SCOR Visiting Scholar applications. The committee helped compile information on examples of capacity-building activities carried out by SCOR working groups (see https://scor-int.org/work/groups/capacity-dev-examples/). The committee is also discussing potential new sources of funding for SCOR capacity-building activities. Rui Seabra, from Portugal, one of the finalists for the Early Career Scientist position to the SCOE Executive will join the Capacity Building Committee.

7.2. SCOR Visiting Scholars

Five SCOR Visiting Scholars were approved in 2019, to work in Angola, Argentina, Brazil, Ecuador, and Mauritius. In 2020, six Visiting Scholars were approved to work in Fiji, Angola, India, Philippines, and India. Due to COVID none of them was able to travel but SCOR will support their travel when they reprogram for 2021. This is the first year that SCOR Visiting Scholars will be sent to Fiji and the Philippines, and the first time a Visiting Scholar from China-Beijing has been selected. The call for 2021 Visiting Scholars was issued and closes in December 2020. Ed Urban and Sophie Seeyave (POGO Executive Director) submitted an article on the SCOR Visiting Scholar Program and POGO Visiting Professor Program for to Oceanography magazine and are now working on revisions to the article.
Funding for this activity is provided from a variety of sources. To expand the program, further sources of funding for the program from other countries need to be identified.

7.3. POGO-SCOR Fellowships for Oceanographic Observations

Four Fellows were funded in 2019. In 2020, 45 applications were received this year, 40% of which were from female candidates. Applications were received from 24 countries in all continents, except Oceania. With the combined available budget from POGO and SCOR, 5 candidates were selected from India, Venezuela, Argentina, Colombia, and Morocco. The review of the applications was done by SCOR and POGO. None of the selected candidates has been able to travel this year but SCOR/POGO will support their travel when they reprogram for 2021. SCOR and POGO have been cooperatively funding this program since 2001. Funding for this activity is provided by an NSF grant to SCOR.

7.4. NSF Travel Support for Developing Country Scientists

A renewal proposal to NSF was submitted in early 2020 and approved. Since the 2019 SCOR meeting, 8 requests have been received for a total amount of $47,911 to support attendance of scientists from developing countries to attend SCOR relevant conferences or meetings. Funding for this activity is provided by an NSF grant to SCOR.

7.5. Research Discovery Camps at the University of Namibia

The 2020 Research Camp was postponed from April to December 2020, and then to 2021 because of the pandemic. For now, it appears that the camp will have access to the Namibian government research vessel at that time, which has become an integral part of the program. This program is supported through grants from the Agouron Institute and the Simons Foundation. Funding for this activity is provided by grants from the Agouron Institute and Simons Foundation to SCOR.

Annkatrien Lescrauwaet asked if a centralized effort to make available SCOR Capacity Development programs in a single site could be made. Martin Visbeck further added that the UN Decade of Ocean Science for Sustainable Development is calling for proposal for developing programs to support capacity development efforts. Patricia Miloslavich indicated that the Ocean Teacher Global Academy (OTGA) would be a good avenue to centralize global and regional capacity development opportunities and content related to ocean sciences. Currently the SCOR website centralizes all SCOR capacity development opportunities and links to the POGO website for the joint POGO-SCOR fellowship program. Paula Sierra noted that the INVEMAR in Colombia has a Regional Training Center of the OTGA, with different courses for Spanish speakers in Latin America and the Caribbean since 2014 and with new on-line courses and materials. She invited the community to contact them if they want to share courses in Spanish (**paula.sierra@invemar.org.co**). The OTGA is also working closely with the Marine Biodiversity Observation Network (MBON) and other organizations in capacity development and in the centralization of resources.

Full report of capacity development activities at: *https://scor-int.org/wp-content/uploads/2020/07/Tab-5_Capacity_development.pdf*

8. SCOR ORGANIZATION

8.1. Membership

Patricia Miloslavich reported on current SCOR Member Nations and Nominated Members and changes in composition of the Nominated Members since the 2019 SCOR Annual Meeting. There are currently 32 countries affiliated to SCOR. Since the 2019 SCOR Annual Meeting, Colombia joined as a new SCOR member and the following changes in the SCOR nominated members were made:

- Belgium: Jan Mees, Bruno Delille and Marc Kochzius replaced J. Nihoul and Francois Ronday
- China-Beijing: Fangli Qiao is the new president, with Minhan Dai as vice-president and Sun Song the past-president. Hong Huasheng rotated off.
- Colombia: new membership in SCOR. Nominated members are Francisco Arias-Isaza, Paula Cristina Sierra and Constanza Ricaurte-Villota.
- Israel: two new nominated members are Steve Brenner and Amatzia Genin.

- Mexico: Elva Escobar, Mario Martinez Garcia and Clara Morán have been replaced by Carlos Robinson and Alfonso Araiza Marroquin.
- Netherlands: Caroline Slomp, Gerald Ganssen and Maria van Leeuwe have been replaced by G.M. (Gerald) Ganssen, Katja T.C. Peijnenburg and Lennart de Nooijer.
- Poland: Adam Sokolowski has been incorporated as the third nominated member.
- Turkey: Gülsen Avaz has replaced Bilge Tutak.
- USA: Daniel Costa replaced Kevin Arrigo.

The nominated members as for October 2020 are:

Nation	Nominated Members
Australia	Peter Doherty, Trevor McDougall, Andreas Schiller
Belgium	**Jan Mees**, Bruno Delille, Marc Kochzius
Brazil	José Maria Landim Dominguez, Mauricio M. Mata, Ilana Wainer
Canada	**Paul Myers**, David Greenberg, Robie Macdonald
Chile	Patricio Carrasco, Carmen Morales, Carlos A. Zuniga
China – Beijing	**Fangli Qiao**, Minhan Dai (Vicepresident), Sun Song (Past-president)
China – Taipei	**Chau-Ron Wu**, Kuo-Ping Chiang, Shu-Kun Hsu
Colombia	**Francisco Arias-Isaza**, Paula Cristina Sierra, Constanza Ricaurte-Villota
Ecuador	Leonor Vera San Martin, Mario Hurtado, Francisco Medina
Finland	**Jorma Kuparinen**, Riitta Autio, Heidi Pettersson
France	Catherine Beltran, Marie-Alexandrine Sicre, Catherine Goyet
Germany	Tatiana Ilyina, Ilka Peeken, Oliver Wurl
India	**M.M. Sarin**, D. Sengupta, K. Somasundar
Ireland	Peter Croot, Eleanor O'Rourke, Brian Ward
Israel	**Daniel Weihs**, Steve Brenner, Amatzia Genin
Italy	**Annalisa Griffa**, Stefano Aliani
Japan	Kaoru Kubokawa, Toshio Yamagata, Jing Zhang
Korea	**Sinjae Yoo**, Chan Joo Jang
Mexico	**Carlos Robinson**, Alfonso Araiza Marroquin, CONACyT (TBD)

Namibia	**Samuel Mafwila**, Chris Bartholomae, Nhlanhla Lupahla
Netherlands	G.M. (Gerald) Ganssen, Katja T.C. Peijnenburg, Lennart de Nooijer
New Zealand	Julie Hall
Norway	**Peter Haugan**, Dag Aksnes
Pakistan	**Ali Rashid Tabrez**, Asif Inam, Samina Kidwai
Poland	**Waldemar Surosz**, Waldemar Walczowski, Adam Sokolowski
Russia	Sergey Dobrolubov, Andrey Kostianoy, Sergey Shapovalov
South Africa	**Isabel Ansorge**, John Compton, Coleen Moloney
Sweden	**Bengt Karlsson**, Helén Andersson, Göran Björk
Switzerland	**Daniel Ariztegui**, Núria Casacuberta Arola, Kurt Hanselmann
Turkey	Gülsen Avaz
United Kingdom	**Alessandro Tagliabue**, Peter Burkill, Gideon Henderson
United States	Carol Arnosti, Daniel Costa, S. Bradley Moran

Membership of the National SCOR Committees can be found at: *https://scor-int.org/scor/committees/*

8.2. Publications Arising from SCOR Activities

Miloslavich reported that SCOR projects and working groups produced many publications in the past year. Working Groups publications acknowledging SCOR summed 24 papers in 2019 and 14 papers in 2020. The project's publications summed ~320 in 2019 and ~270 in 2020, however most of these publications do not acknowledge SCOR or NSF. Proper SCOR acknowledgement when deserved is an ongoing topic that is reminded to the projects and working groups. While there is no standardized definition of what a "SCOR publication" is for the different projects, we must continue to stress the need of acknowledging the sponsors as this is critical for our own funders (e.g. NSF). All WG publications are updated on the SCOR website (*https://scor-int.org/work/publications/*). Several SCOR working groups have special issues or significant papers under development, which will appear in the next year.

8.3. SCOR Finances – Ad Hoc Finance Committee

The appointed SCOR Ad Hoc Finance Committee reported to the SCOR Executive and Nominated Members on the SCOR Financial situation based on the following documents: (1) the SCOR 2019 auditor's report, (2) the final vs actual 2019 budget, (3) the financial reports and charts from the Secretariat, (4) the 2020 revised budget and draft of 2021 budget. These documents were prepared by the SCOR Executive Director with the help of Ed Urban, who accepted the role of "Financial Consultant" for SCOR. The Finance Committee found the Auditor's report in accordance with SCOR financial report, with no special remarks in the Audit to consider.
Based on the documents provided and reviewed, the recommendations of the Finance Committee were:
The cash situation for 2020 allows the planned establishment of up to 3 or 4 new WGs in 2020 (financial situation indicates it is highly likely to be able to fund two additional WGs in 2021).

The WG underspending was substantial in 2020 due to the ongoing pandemic and the move to online meetings.
Given the current pandemic and associated financial uncertainty they would recommend that it is not necessary in 2022 to change the current dues (Policy previously has been for dues to incrementally increase 3% in recent years).
In addition, the Finance Committee recommends that in the future that this committee meet via online meetings in the weeks prior to the SCOR meeting.

Following this report and recommendations, the nominated members discussed if 3 or 4 new working groups would be approved this year. To this regard, most of the nominated members expressed caution about overcommitting funds to support four new working groups. Elva Escobar pointed out that funding was not coming the way it was. Using her country Mexico as an example, she noted that the budgets to defray international memberships has been cancelled, science funds in general reduced by more than 50%, and science trust funds have disappeared. Carol Arnosti asked about the groups that have not yet been able to spend as anticipated, if they would be allowed to have more time to carry out their projects and spend some of the funds after the date that they were originally allocated for. Patricia Miloslavich indicated that the time of the groups will be extended as needed for them to accomplish their ToRs. Marie Alexandrine Sicre indicated that underspending will also be likely in 2021. Peter Burkill informed that the SCOR Executive Committee would make the final decision (based on the recommendations of the Finance Report and the feedback received from nominated members) about whether funding 3 or 4 working groups at the closed meeting, later in the week. The decision at the SCOR EC closed meeting was to approve three new working groups this year. These were ATOMIX, ReMO and OASIS as stated in **section 2.1.**

9. SCOR RELATED MEETINGS

The SCOR 2020 meeting was originally planned to be in Guayaquil, Ecuador hosted by the Instituto Nacional de la Armada (INOCAR). Due to the COVID pandemic, the 2020 meeting was held virtually. The 2021 meeting was scheduled to be in Busan, Korea hosted by the Korea Institute of Ocean Science and Technology (KIOST) and this plan will continue. Regarding the dates for the 2021 meeting, Sinjae Yoo (who will host the meeting) noted that we should avoid the September holiday in Korea, with the October being the preferred month depending on availability of the SCOR Executive Committee members. Since the INOCAR hosts remain enthusiastic about having a SCOR meeting in Ecuador, it was suggested that they could organize it in 2022. Patricia Miloslavich opened the discussion for suggestions for venues in 2023 and both Francisco Arias and Fangli Qiao expressed their interest to host the 2023 SCOR Annual Meeting in Colombia and China, respectively.

APPENDICES

APPENDIX 1. PARTICIPANTS OF THE SCOR 2020 VIRTUAL MEETING

The SCOR 2020 Annual Meeting was attended by 121 participants from 34 countries (Figure 1). On the first day, which was open only to the SCOR Executive Committee and Nominated Members, there were 50 participants including 24 SCOR National Committees and the three affiliated bodies to the Executive Committee (IABO, IAPSO, IAMAS). On the second and the third days, which were open to all, there were 95 and 78 participants, respectively (Figure 2).

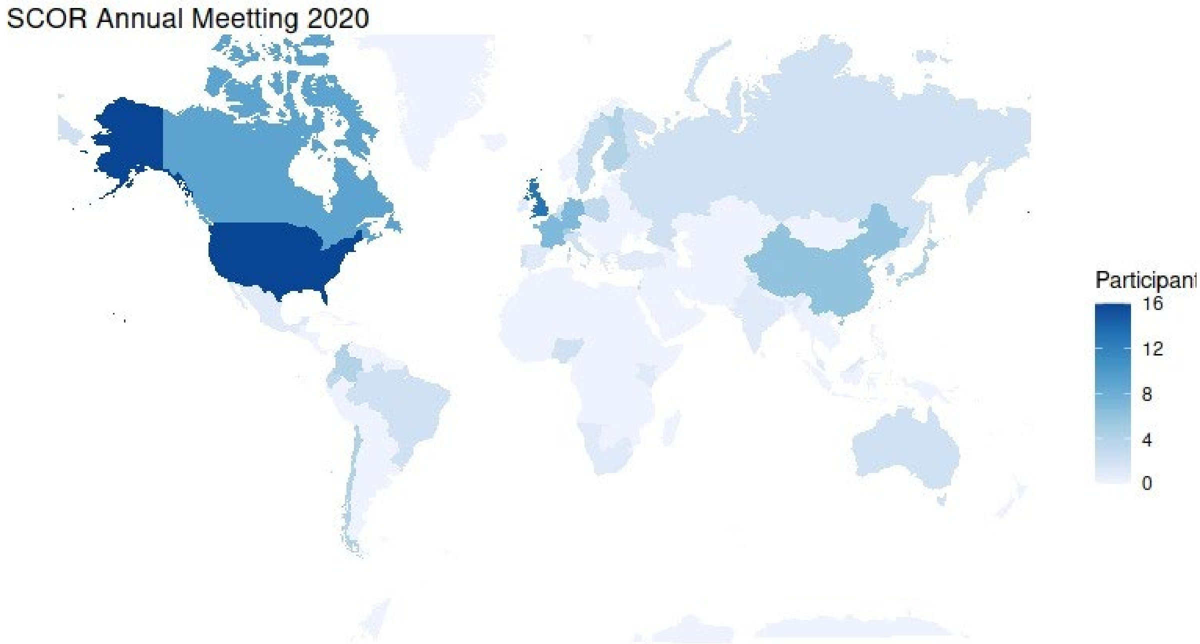

Figure 1. Distribution map of the 121 participants to the SCOR 2020 Annual Meeting

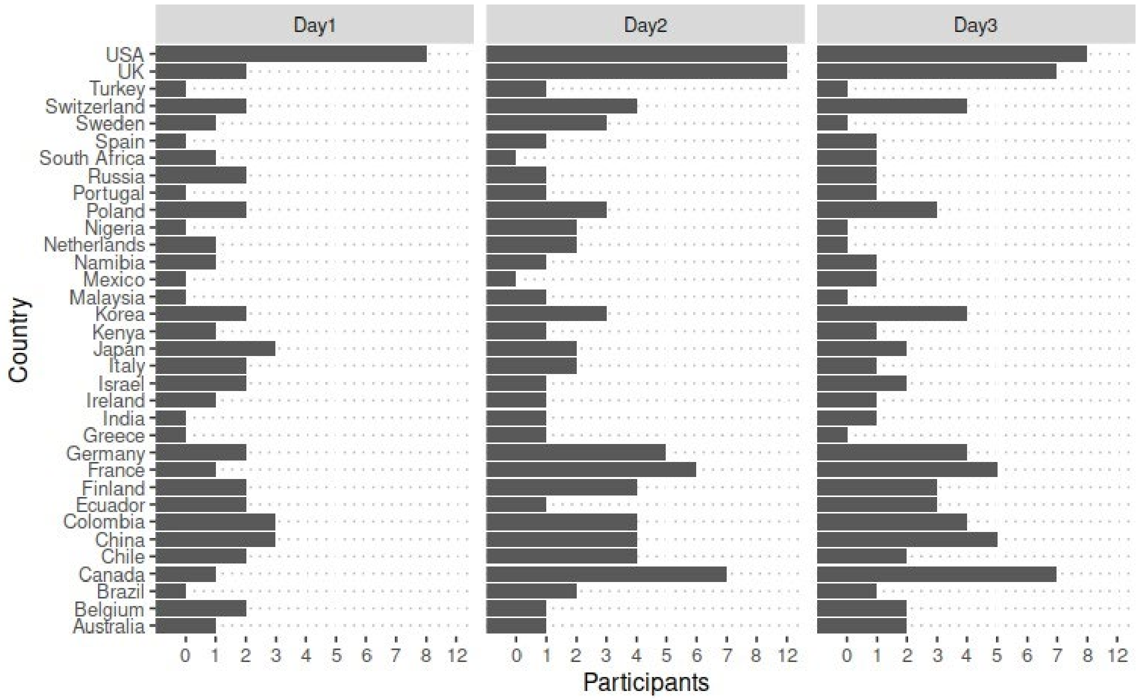

Figure 2. Number of meeting participants per country for each of the three days.

Participants – SCOR Executive and staff

Last name	First name	Organization	Country
Burkill	Peter	University of Plymouth	UK
Casacuberta	Nuria	ETH Zurich	Switzerland
Laufkotter	Charlotte	Bern University	Switzerland
McDougall	Trevor	University of New South Wales / IAPSO	Australia
Miloslavich	Patricia	SCOR	USA
Montes	Enrique	University of South Florida / IABO	USA
Moran	Bradley	University of Alaska Fairbanks	USA
Myers	Paul	University Alberta	Canada
Penner	Joyce E	University of Michigan / IAMAS	USA
Sicre	Marie-Alexandrine	Centre National de la Recherche Scientifique (CNRS)	France
Uku	Jaccqueline	Kenya Marine and Fisheries Institute (KEMFRI)	Kenya
Yoo	Sinjae	Korea Institute of Ocean Science and Technology (KIOST)	Korea
Zhang	Jing	University of Toyama	Japan

Participants – Nominated Members

Last name	First name	Organization	Country
Aliani	Stefano	ISMAR - National Research Council	Italy
Ansorge	Isabelle	University of Cape Town	South Africa
Arias	Francisco	INVEMAR	Colombia
Arnosti	Carol	University of North Carolina-Chapel Hill	USA
Autio	Riitta	Finnish Environment Institute	Finland
Björk	Göran	University of Gothenburg	Sweden
Brenner	Steve	Bar-Ilan University	Israel
Burkill	Peter	University of Plymouth	UK
Casacuberta	Nuria	ETH Zurich	Switzerland
Costa	Dan	University of California Santa Cruz	USA
Croot	Peter	National University of Ireland Galway	Ireland
Dai	Dejun	First Institute of Oceanography	China
Escobar	Elva	Universidad Nacional Autónoma de México	Mexico
Fgriffa	Annalisa	ISMAR - National Research Council	Italy
Goyet	Catherine	University of Perpignan	France
Granados	Alejandra	INVEMAR	Colombia
Hanselmann	Kurt	ETH Zurich	Switzerland
Harada	Naomi	JAMSTEC	Japan
Hibiya	Toshiyuki	University of Tokyo	Japan
INOCAR	Ecuador	INOCAR	Ecuador
Jang	Chan Joo	Korea Institute of Ocean Science and Technology (KIOST)	Korea
Karlson	Bengt	Swedish Meteorological and Hydrological Institute	Sweden
Kostianoy	Andrey	P.P. Shirshov Institute of Oceanology	Russia
Kuparinn	Jorma	University of Helsinki	Finland
Lescrauwaet	Ann-Katrien	Flanders Marine Institute	Belgium
Mafwila	Samuel	University of Namibia	Namibia
McDougall	Trevor	University of New South Wales	Australia
Mees	Jan	Flanders Marine Institute	Belgium
Morales	Carmen	Universidad de Concepción	Chile
Peeken	Ilka	Alfred Wegener Institute	Germany
Peijnenburg	Katja	Naturalis Biodiversity Center	Netherlands
Pettersson	Heidi	Finnish Meteorological Institute	Finland
Qiao	Fangli	First Institute of Oceanography	China
Ricaurte	Constanza	INVEMAR	Colombia
Shapovalov	Sergey	P.P. Shirshov Institute of Oceanology	Russia
SHOA Chile	Director	Servicio Hidrográfico y Oceanográfico de la Armada	Chile
Sierra Correa	Paula	INVEMAR	Colombia
Sokowlowski	Adam	University of Gdansk	Poland
Song	Sun	Institute of Oceanology	China
Tagliabue	Alessandro	University of Liverpool	UK
Twigg	Emily	Ocean Studies Board	USA

Vera San Martin	Leonor	INOCAR	Ecuador
Walczowski	Waldemar	Institute of Oceanology	Poland
Weihs	Daniel	TECHNION	Israel
Wurl	Oliver	University of Oldenburg	Germany

Participants – SCOR Working Groups

Last name	First name	Organization	Country
Bange	Hermann	GEOMAR	Germany
Bucklin	Ann	University of Connecticut	USA
Castelhao	Gui	University of California San Diego	USA
Collins	Sinead	University of Edinburgh	UK
Croot	Peter Croot	National University of Ireland Galway	Ireland
Domingues	Catia	National Oceanography Centre	UK
Duffy	Emmett	Smithsonian Institute	USA
Else	Brent	University Calgary	Canada
Escribano	Ruben	Universidad de Concepción	Chile
Giering	Sari	National Oceanography Centre	UK
Howell	Kerry	University of Plymouth	UK
Peeken	Ilka	Alfred Wegener Institute	Germany
Schubak	Nina	Swiss Federal Institute of Technology	Switzerland
Sian	Henley	University of Edinburgh	UK
Tagliabue	Alessandro	University of Liverpool	UK
Turner	David	University of Gothenburg	Sweden
Uku	Jaccqueline	Kenya Marine and Fisheries Institute (KEMFRI)	Kenya
Voelker	Christoph	Alfred Wegener Institute	Germany
Waite	Anya	Dalhousie University	Canada
Weatherdon	Lauren	World Conservation Monitroing Center (WCMC)	UK
Wilson	Sam	University of Hawaii	USA

Participants – SCOR projects

Last name	First name	Organization	Country
Adjou	Mohamed	British Oceanographic Data Centre / GEOTRACES	UK
Bange	Hermann	GEOMAR / IIOE-2	Germany
Berdalet	Elisa	Institute of Marine Sciences (ICM-CSIC) / GlobalHAB	Spain
Burkill	Peter	University of Plymouth / IIOE-2	UK
Casciotti	Karen	Stanford University / GEOTRACES	USA
Claydon	John	Dalhousie University / IMBeR	Canada
Gier	Jessica	GEOMAR / SOLAS	Germany
Hofmann	Eileen	Old Dominion University / SOOS	USA

Ishii	Masao	Meteorological Research Institute of Japan / IOCCP	Japan
Maddison	Lisa	Dalhousie University / IMBeR	Canada
Masferrer	Elena	University of Toulousse / GEOTRACES	France
Miller	Lisa	Department of Fisheries and Oceans - MPO / SOLAS	Canada
Pawlowicz	Rich	EOS-UBC / JCS	Canada
Richardson	Anthony	Commonwealth Scientific and Industrial Research Organisation / GACS	Australia
Robinson	Carol	University of East Anglia/ IMBeR	UK
Sang-Mook	Lee	Seoul National University / Inter-Ridge	Korea
Stuart	Venetia	Bedford Institute Oceanography / IOCCG	Canada
Tagliabue	Alessandro	University of Liverpool / GEOTRACES	UK
Telszewski	Maciej	Institute of Oceanology / IOCCP	Poland
Tyack	Peter	University of At. Andrews / IQOE	UK
Urban	Ed	SCOR / IQOE	USA

Affiliated project
Research project
Infrastructural project

Participants – Affiliated Organizations

Last name	First name	Organization	Country
Arico	Salvatore	Intergovernmental Oceanographic Commission (IOC)	France
Batchelder	Hal	North Pacific Marine Science Organization (PICES)	Canada
Brousse	Clement	Future Earth - OCEAN	France
Delgado	Claudia	International Oceanographic Data and Information Exchange (IODE)	Belgium
Duce	Robert	Texas A&M / Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP WG38)	USA
Griffin	Eoghan	Scientific Committee on Antarctic Research (SCAR)	UK

Krug	Lillian	Partnership for the Observation of the Global Ocean (POGO)	Portugal
McDougall	Trevor	University of New South Wales / International Association for the Physical Sciences of the Oceans (IAPSO)	Australia
Montes	Enrique	University of South Florida / International Association for Biological Oceanography (IABO)	USA
Penner	Joyce E	University of Michigan / International Association of Meteorology and Atmospheric Sciences (IAMAS)	USA
Seeyave	Sophie	Partnership for the Observation of the Global Ocean (POGO)	UK
Sparrow	Mike	World Climate Research Programme (WCRP)	Switzerland
Visbeck	Martin	GEOMAR / International Science Council (ISC)	Germany

Participants – General

Last name	First name	Organization	Country
Aguilera	Victor		Chile
Ausubel	Jesse	Rockefeller University	USA
Carreira	Renato	Pontifical Catholic University of Rio de Janeiro	Brazil
Chung	Alexandra	University of Sao Paulo	Brazil
Di lorio	Lucia	CHORUS Institute	France
Fanini	Lucia	Hellenic Centre for Marine Research	Greece
Igbo	Juliet	Nigerian Institute for Oceanography and Marine Research	Nigeria
Kim	Intae	Korea Institute of Ocean Science and Technology (KIOST)	Korea
Lednytskyy	Olexandr	University of Greifswald	Germany
Naranjo	Christian	Instituto Nacional Oceanográfico de la Armada (INOCAR)	Ecuador
Ayokunmi	Olapoju	Nigerian Institute for Oceanography and Marine Research	Nigeria
Qin	Kai	East China Normal University	China

Seabra	Rui	Research Centre in Biodiversity and Genetic Resources, InBIO	Portugal
Singh	Arvind	Physical Research Laboratory	India
Süheyla			Turkey
Ukpong Okon	Samuel	Akwa Ibom State University	Nigeria
Usup	Gires		Malaysia
Virtasalo	Joonas	Geological Survey of Finland	Finland
Vorrath	Maria Elena	Alfred Wegener Institute	Germany
Yanxu			France
Zuo	Fang	East China Normal University	China

APPENDIX 2. MEETING AGENDA

Session 1. Tuesday, 20 October 2020. Chair: Marie A. Sicre / Note taker: Paul Myers
SCOR Executive Committee and National Committee nominated members only

Time (am)	Topic	Presenter
7:00	Welcome and introduction to agenda	M.A. Sicre
7:05	Report from SCOR President	M.A. Sicre
7:10	Report from SCOR Executive Director	P. Miloslavich
7:15	Results of the 2020 election for *SCOR Officers*	P. Burkill
7:20	Results of the 2020 selection of Early Career Scientist	P. Miloslavich
7:25	Approval of *revised SCOR constitution*	P. Burkill
	Presentation of new Working Group proposals:	
7:30	1. Analysing ocean turbulence observations to quantify mixing (*ATOMIX*)	T. McDougall
7:35	2. TRACE element SAMplers and sensORS	J. Zhang
7:40	(*TRACESAMORS*)	M. A. Sicre
	3. Benthic Foraminifera as Ecological Sentinels of Marine	
7:45	Systems Health (*FORAM-ECO*)	S. Yoo
	4. Elucidating THreats tO Sandy beaches: a global synthesis	
7:50	(*ETHOS*)	N. Casacuberta
	5. Integration of international ocean acidification research	
7:55	at CO2 seeps (*InterSEEP*)	J. Uku
	6. Mapping climate change refugia for marine conservation	
8:00	(*MarCCR*)	P. Burkill
	7. Respiration in the Mesopelagic Ocean (*ReMO*):	
8:05	Reconciling ecological, biogeochemical and model estimates	E. Montes
	8. Are global indicators of COastal and Nearshore benthic fish assemblage status in agreement if derived from	
8:10	disparate visual CENSUS techniques? (*CoNCENSUS*)	P. Myers
	9. Developing an Observing Air-Sea Interactions Strategy	
8:15	(*OASIS*)	J. Penner
	10. Atmospheric aerosol deposition as forcing factor for microbial ecology and biogeochemistry in the ocean (*AEROS*)	
8:20	***Break (10 minutes)***	
8:30	Discussion of new Working Group proposals	SCOR Executive and National Committee nominated members
9:50-10:00	Wrap up and final decision	M.A. Sicre

Session 2. Wednesday, 21 October 2020. Chair: Sinjae Yoo / Note taker: Nuria Casacuberta. Open to all registrants

Time (am)	Topic	Presenter / EC liaison
7:00	Introduction to Day 2 session	S. Yoo
	Working Group reports:	
7:05	WG 143. *Dissolved N2O and CH4* measurements: a global network of ocean time series measurements	S. Wilson / Casacuberta
7:10	WG 145. Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (*MARCHEMSPEC*)	D. Turner / M.A. Sicre
7:15	WG 148. International Quality Controlled Ocean Database: Subsurface temperature profiles (*IQuOD*)	G. Castelhão / P. Myers
7:20	WG 150. Translation of Optical Measurements into particle Content, Aggregation & Transfer (*TOMCAT*)	S. Giering / P. Burkill
7:25	WG 151. Iron Model Intercomparison Project (*FeMIP*)	Tagliabue /Casacuberta
7:30	WG 152. Measuring Essential Climate Variables in Sea Ice (*ECV-Ice*)	B. Else / T. McDougall
7:35	WG 153. Floating Litter and its Oceanic TranSport Analysis and Modelling (*FLOTSAM*)	S. Aliani / P. Myers
7:40	WG 154. Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (*P-OBS*)	A. Waite / E. Montes
7:45	WG 155. Eastern boundary upwelling systems (*EBUS*)	R. Escribano / Halpern
7:50	WG 156. *Active Chlorophyll fluorescence* for autonomous measurements of global marine primary	N. Schubak / S. Yoo
7:55	productivity WG 157. Marine zooplankton biodiversity based on DNA	A. Bucklin / E. Montes
8:00	(*MetaZooGene*) WG 158. Coordinated Global Research Assessment of	E. Duffy / J. Zhang
8:05	Seagrass System (*C-GRASS*) WG 159. Deep-Sea Biology for the Decade of Ocean Science for Sustainable Development (*DeepSeaDecade*)	K. Howell / E. Montes
	Research project reports:	
8:10	*GEOTRACES* – Trace elements and isotopes	A. Tagliabue / Halpern
8:15	*SOLAS* – Ocean/atmosphere interactions	L. Miller / J. Penner
8:20	*IMBeR* – Marine biosphere research	C. Robinson / P. Burkill
8:25	*IQOE* – Quiet Ocean	P. Tyack / D. Halpern
8:30	*IIOE-2* – Indian Ocean expedition II	P. Burkill / P. Burkill
8:35	***Break (10 minutes)*** ***Infrastructural project reports:***	
8:45	*COBS* – Changing ocean on biota	S. Collins / S. Yoo
8:50	*GlobalHAB* – Harmful Algal Blooms	E. Berdalet / S. Yoo
8:55	*IOCCP* – Ocean carbon	M. Ishii / D. Halpern
9:00	*SOOS* – Southern Ocean observing	Hofmann / McDougall
9:05	*JCS* – Joint Committee on Seawater	Pawlowicz / McDougall

9:10	Discussion of WG and project progress and actions	Open to all
9:50-10:00	Wrap up and final decision	S. Yoo

Session 3. Thursday, 22 October 2020. Chair: Peter Burkill / Note taker: Enrique Montes
Session 3a. SCOR Executive Committee and National Committee nominated members only

Time (am)	Topic	Presenter
7:00-7:15	Report of Ad Hoc Finance Committee (10 minutes)	Nominated member

Session 3b. Reports from affiliated and partner organizations and capacity development activities - Open to all registrants

Time (am)	Topic	Presenter / EC liaison
7:15	Introduction to Day 3 session	P. Burkill
	Affiliated projects reports:	
7:20	*IOCCG* – Ocean colour	V. Stuart / S. Yoo
7:25	*InterRidge* – Ridge studies	S.M. Lee / J. Zhang
7:30	*GACS* – Alliance of Plankton Recorders	A. Richardson / P. Burkill
	Affiliated organizations reports:	
7:35	*IABO* – Biological Oceanography	E. Montes
7:40	*IAPSO* – Physical Oceanography	T. McDougall
7:45	*IAMAS* – Meteorology and Atmosphere	J. Penner
	Partner organization updates:	
7:50	*IOC* – Intergovernmental Oceanographic Commission	S. Arico / M.A. Sicre
7:55	*PICES* - North Pacific Marine Science Organization	H. Batch / S. Yoo
8:00	*GESAMP* – Group on marine environmental	B. Duce / TBD
8:05	protection	S. Seeyave / S. Yoo
	POGO – Partnership for Observation of the Global	
8:10	Ocean	M. Visbeck / M.A. Sicre
8:15	*ISC* – International Science Council	E. Griffin / P. Myers
8:20	*SCAR* – Scientific Committee Antarctic Research	C. Brousse / M.A. Sicre
8:25	*Future Earth-Ocean*	M. Sparrow / D. Halpern
	WCRP – World Climate Research Program	
8:30	***Break (10 minutes)***	
8:40	Report on SCOR **capacity development** activities	P. Miloslavich
8:45	Discussion of partner and affiliated organizations and capacity activities	Open to all
9:25	2021-2023 meetings: Korea 2021, Ecuador 2022, suggestions for 2023	Open to all
9:30-10:00	Close of meeting and summary of actions	M.A. Sicre

APPENDIX 3. WORKING GROUP PROPOSALS

ATOMIX: Analysing Ocean turbulence observations to quantify mixing

Summary
Reliable representation of ocean mixing is critical for quantifying the fluxes of heat, salt, energy and nutrients that are fundamental to climate and ecosystems. Turbulence observations enable quantifying the dissipation rate of turbulent kinetic energy *s* that, together with background conditions, allow us to infer vertical fluxes in the ocean. The increased availability of measurement technologies has rapidly expanded both the mixing research community and the volume of data collected. This rapid growth, compounded by the absence of standards, has caused concerns about the validity and quality of current mixing estimates. The proposed SCOR Working Group will thus develop best-practice procedures and quality-control indicators for determinating *s* – a critical turbulence quantity for estimating mixing from shear probes and velocity sensors. These best-practices will support observations from commonly-deployed platforms such as profilers, fixed and moored instruments, and self-propelled gliders. To enable validation of existing (and future) algorithms, benchmark datasets with agreed-upon *s* estimates will be made available for a variety of platforms and ocean environments, along with quality metrics. These benchmarks are designed to remain relevant irrespective of the programming language used for data processing, as a lasting legacy for the ocean mixing community. The guidelines will be communicated through a peer-reviewed synthesis article, an open-access wiki, and a training workshop geared towards early-career researchers. These outputs will increase the confidence in turbulence estimates used to constrain or improve mixing parameterisations in ocean models. Finally, the Working Group will seek to expand the global community engaged in this critical science.

Scientific Background and Rationale
Turbulence plays a key role in oceanic energy budgets and transport of heat, salt, dissolved gases, and nutrients in the ocean. Turbulence observations are required to assess and improve how mixing is represented within regional and global ocean models. Model predictions of ocean stratification, heat and deep-water exchanges, and therefore the earth’s climate, are sensitive to the choice of mixing parameterisations (e.g., *MacKinnon et al.*, 2017; *Melet et al.*, 2016; *Wunsch and Ferrari*, 2004). Mixing parameterisations embedded in models are developed from theoretical arguments and experimentation, but their ease of implementation and required computational resources must also be considered (*Fox- Kemper et al.*, 2019). Many mixing parameterisations in models are constrained using observational datasets, especially to impose enhanced mixing and energy dissipation at ocean mixing “hot-spots” (e.g., *Melet et al.*, 2016; *MacKinnon et al.*, 2017). These “hot-spots” can be continental shelves, zones with regular tidal upwelling, rough topography in the abyss, surface or bottom boundaries. The use of sophisticated ship-based instruments, which were historically only accessible to a few research groups, has resulted in sparse sampling of turbulence in the world’s oceans (*Waterhouse et al.*, 2014). This in turn has created further challenges in characterizing mixing processes and modelling ocean behaviour.
The largest effort in collating observational datasets has been by a US-funded initiative via the Climate Process Team who were tasked with consolidating knowledge to develop new mixing parameterisations for the ocean interior (*MacKinnon et al.*, 2017). The microstructure database contained turbulence estimates from 5200 profiles collected via 25 projects largely funded by US agencies (see Fig.1 reproduced from *Waterhouse et al.*, 2014), and continues to grow as more research programs deposit processed data. These estimates, however, are obtained from different microstructure instru- ments, theories, and algorithms developed by individual research groups mainly in the USA. No data quality indicators are provided with these estimates, because none have been

internationally agreed upon — researchers use an inconsistent variety of indicators that are based on intuition and experi- ence.

Standards for analysing raw turbulence observations do not exist either. Many groups have shared their software in, as yet, unconsolidated code repositories for the expanding user-base of commercially-produced turbulent instrumentation, which became available in the last decade. Others have developed toolboxes for turbulence measurements collected during multi-disciplinary field campaigns such as the MOSAIC expedition in the Arctic for rotating teams of scientists. The above algorithms have been tried and tested under specific oceanic environments, typically for a specific measurement platform. Running the same data through two different sets of routines, which rely on the same concepts and theories, can cause widely different results (*MacKinnon et al.*, 2017). The computed turbulence estimates can vary by one to two orders of magnitude because of subtle differences in identifying common issues such as instrument noise. These errors then propagate through to mix- ing estimates contained in databases, which are ultimately used to develop mixing parameterisations in global ocean circulation models.

The quality of turbulence estimates is further compromised by the lack of curated and centralised information sources. New users must wade through specialised papers in journals such as *Journal of Atmospheric and Ocean Technology* to appreciate the subtleties of analysing turbulence measured from increasingly more complex platforms. Historically, turbulence measurements were collected from ship-based profilers and to some extent bottom-landers. Longer-term datasets, of weeks to several months, are now being collected by autonomous platforms such as gliders, self-propelled vehicles, wave-powered profilers (moored and drifting), and even Argo floats. The commercialisation of turbulence instruments has also dramatically increased the number of users collecting these observations. New users rely on algorithms, from the manufacturer or larger research groups, to process

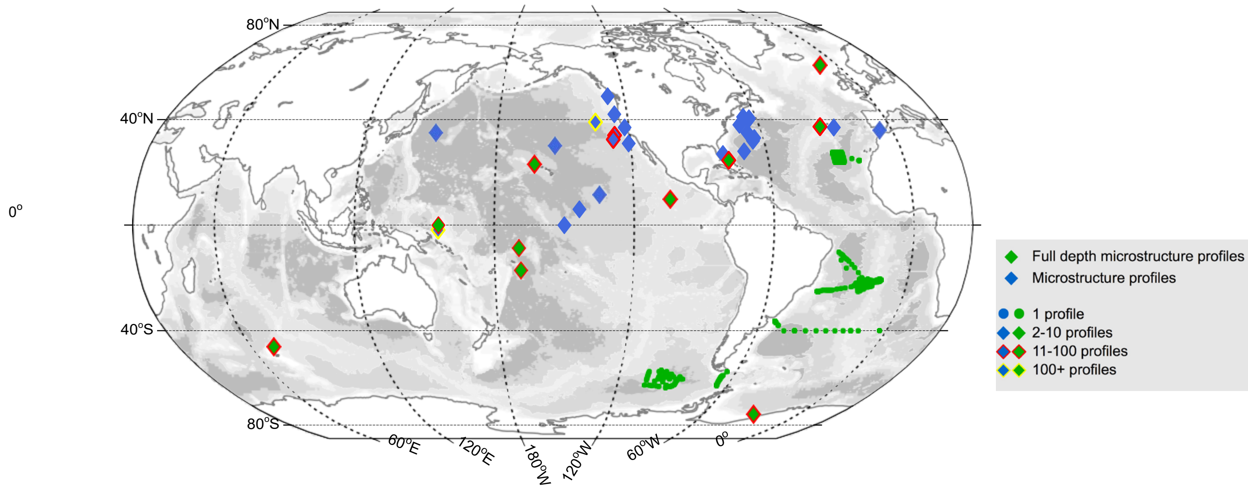

Figure 1: World map of the microstructure turbulence observations compiled by *Waterhouse et al.* (2014). This figure was provided by the paper's first author after modifications to illustrate *s* estimates obtained from the most direct techniques — turbulence microstructure measurements collected from ship-based profilers.

their measurements. Some lack an appreciation of the theoretical tenets used to analyse the observa- tions; others have difficulty assessing the quality of raw measurements or of the processed turbulence quantities. The explosion of raw data has created a need for bringing the field together, to develop raw benchmark datasets with processed turbulence estimates so that users can validate their algorithms. A concerted effort is also required for developing quality-control measures to increase confidence in reported mixing estimates, whether these are published in the literature or deposited into open- access databases. By providing centralised sources of curated information, users can also learn about common pitfalls in data analysis to save weeks, or even months, analysing potentially flawed measure- ments. This, in turn, will improve the development of mixing parameterisations that are applicable across the world's ocean basins. This development requires turbulence estimates derived from diverse sources, but also devoid of potential biases caused by the algorithms used for processing, or of the research group who has assessed data quality.

Our proposed SCOR Working Group (WG) will enable the international ocean mixing community to participate in developing best practices for estimating one of the most fundamental turbulence quantities: *s* – the dissipation rate of turbulence kinetic energy. This quantity is the one that is most commonly used for computing the diapycnal eddy diffusivity:

$$K = \Gamma \frac{s}{N^2} \quad (1)$$

with the background stratification *N* and a mixing coefficient, Γ (*Osborn*, 1980). This mixing model applies primarily in the ocean interior and is useful for estimating vertical turbulence fluxes of any scalar *C* such as heat, dissolved gases, or nutrients, from a first-order flux law: $F = K \, \partial C$. Mod- ellers still prefer developing parameterisations using the concept of energy and power (*MacKinnon et al.*, 2017). The rate of energy dissipation *s* is thus more dynamically-relevant quantity than *K*. By focusing on *s*, the present WG will also address challenges with measuring and modelling tur- bulence near boundaries. For example, accurate estimates of *s* improves predictions of turbulence fluxes of scalars (e.g., heat and oxygen) at the sediment-water interface (e.g. *Bluteau et al.*, 2018). Turbulence measurements near the bottom are also used in the context of sediment suspension and transport studies (e.g., *Brand et al.*, 2010), while measurements near the surface are used in the con- text of air-(ice)-sea flux studies (*McPhee*, 2008). Therefore, the WG seeks to create a framework for standardising how *s* estimates are derived from raw observations collected from a wide range of platforms through the water column. These guidelines, along with the development of quality-control measures, will also facilitate inter-comparisons between studies from different research groups and ultimately, *in situ* processing and satellite transmission of data.

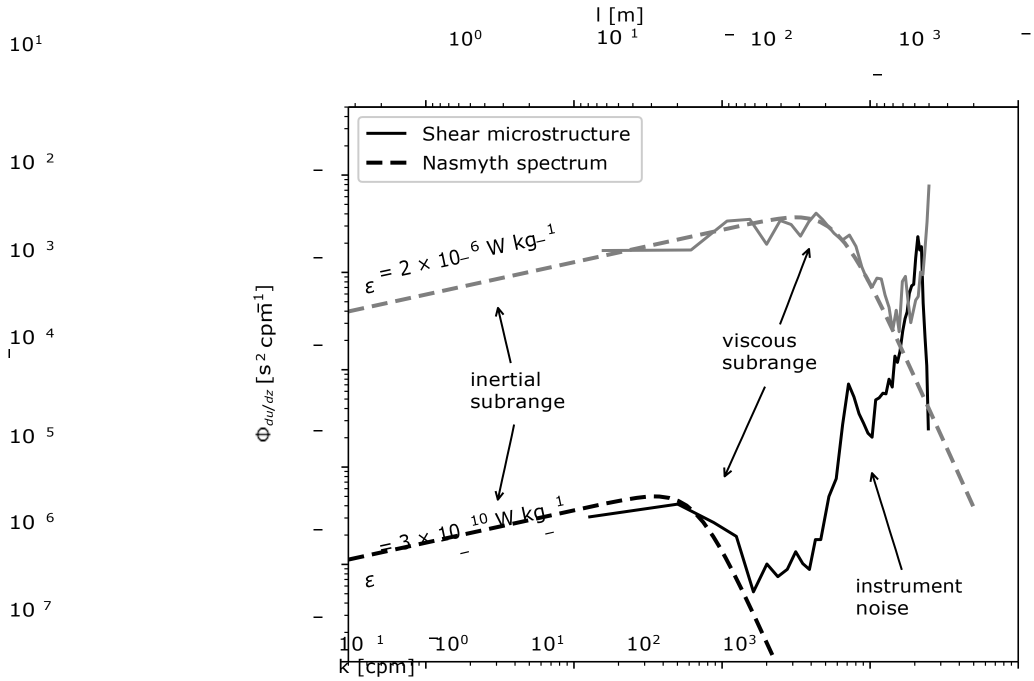

Figure 2: Examples of the spectra of the vertical shear of horizontal velocity, collected with a vertical microstructure profiler, for $s = 2 \times 10^{-6}$ W kg^{-1} (gray) and $s = 3 \times 10^{-10}$ W kg^{-1} (dark). The dashed lines are the Nasmyth empirical spectra for these values of *s* (*Oakey*, 1982). The top x-axis denotes the length scales of motion that must be resolved by velocity-based turbulence instrumentation.

Several methods currently exist for estimating *s*, each capitalizing on different turbulence theories, which may only be appropriate for specific instruments and in certain environments. The most direct way to estimate *s* requires measuring all nine turbulent velocity gradients with 3D particle imagery, which is rarely feasible or, at the very least, impractical in the field (*Nimmo Smith et al.*, 2005). The most direct, and practical, estimators of *s* that are currently available in the field are based on *in- situ* measurements from shear probes, acoustic velocimeters, and acoustic current profilers. These techniques rely on fundamental theories that have been studied and validated using laboratory studies and/or specialised turbulence modelling. They require instrumentation that can accurately measure the time-(milli-seconds to minutes) and length-(milli-meters to meters) scales within the inertial and/or viscous subranges of ocean turbulence (Fig. 2). Other techniques also exist for estimating *s*, such as measuring the dissipation rate of thermal variance, χ_T, from fast-response thermistors, and inferring *s* from finescale (internal-wave) parameterisations based on O(10m) shear and/or strain measurements. These two categories of techniques are deemed too specialised for inclusion in the WG by virtue of the sensors involved or because their theoretical foundations are still actively debated by the science community. The WG will thus focus on developing best practices for obtaining *s* from velocity and velocity gradient sensors. These *s* estimates are critical to processing and interpreting data collected with an ever increasing number of instruments deployed on traditional and autonomous platforms, and can also be used to validate finescale and temperature-based methods.

Terms of Reference

Develop best practices for acquiring and processing turbulence observations collected from con- ventional and emerging autonomous platforms, which measure velocity or velocity gradients.

Establish an open-access database of benchmark datasets collected in diverse ocean environ- ments via different measurement techniques. These raw datasets will be accompanied by agreed- upon "best" processed *s* estimates to enable validating data processing algorithms irrespective of programming language.

Develop quality control measures and guidelines for publishing and archiving turbulence quan- tities computed from velocity or velocity gradients.

Build capacity by creating a collaborative, living wiki-platform that consolidates knowledge on processing of turbulence observations, both from existing and future technologies, as they become available.

Working Plan

Achieving the ToRs

The Terms of Reference (ToRs) will be achieved by splitting the proposed work into three subgroups that focus on (*i*) shear probes – lead by co-chair Fer, (*ii*) acoustic point velocimeters – lead by co-chair Bluteau, and (*ii*) acoustic Doppler profilers lead by co-chair Lenn (6). These co-chairs will engage the other WG members so that there will be at least two full members in each subgroup and supported by § associate members (ToR#1).

Each WG subgroup will identify, test, and make available benchmark data sets (ToR#2). To facil- itate this and other WG goals, quarterly teleconferences of the entire WG will discuss progress. Sub- groups will meet more frequently as required. Annual in-person meetings, held in conjunction with major international conferences, will focus on issues not amenable to remote conferencing. These conferences will be an opportunity to engage the Ocean Mixing Community (OMC) by presenting our results and soliciting feedback.

The collaborative wiki platform will provide open access to the best-practices documentation, and the algorithms and their flowcharts, throughout the WG's term. Benchmark data sets will also be available for download so researchers can evaluate their own code and upload their estimates of *s* to build a community resource (ToR#3). The final documentation and benchmark data sets will be placed on a permanent open-access repository with their own digital object identifiers (DOIs).

Capacity building (ToR#4) and the achievement of underpinning themes (Fig. 3) are inherent in the WG composition (5 and 6), subg§oup ac§tivities and planned workshops (5). The wiki platform will enable the wider community to fully engage with the §development and provides a mechanism for their feedback.

Work Sequence and Meetings

The work will be sequenced into the three following phases (§3.3 and Fig. 3).

Establish the basic framework, required turbulence and auxiliary data, and produce the first draft of the guidelines.

Detail the best practices algorithms, identify and test benchmark datasets to obtain agreed-upon "best" *s* estimates.

Finalise the best-practices guidelines after collaborative peer-review, and publish the assessment results in peer-reviewed journal(s).

The meetings will be held at major conferences to best connect with the OMC and to access in-kind support, such as free meeting rooms and sponsorship from instrumentation manufacturers. These are;

Warnemünde Turbulence Days, Germany, Dec. 2021.

Gordon Ocean Mixing Conference, New Hampshire, USA, July 2022,

Asia-Oceania Geosciences Society (AOGS) Oceania 2023. Date and location to beannounced.

Work Details

Phase 1 The groundwork will be laid for the best-practice guidelines for each of the three sensor types. Each subgroup will review, itemize, and create flowcharts of the data processing steps that must be employed to derive *s*. The subgroups will co-develop the overall layout of the wiki and determine the required content of benchmark data files. Finally, the subgroups will identify potential quality assurance (qa) and quality control (qc) metrics useful for assessing *s* estimates. The co-chairs will co-ordinate the work and address feedback from the OMC before the first in-person WG meeting (Fig. 3). At the meeting, a consensus will be reached on each method's key processing steps, the quality control measures to be tested, and the number, type, content and (temporary) location of data files.

Phase 2 This phase will first document in detail on the wiki the data-processing algorithms for each subgroup's sensor type, along with examples of high- and low-quality observations from diverse platforms (e.g. profilers, gliders, moorings). Potential benchmark datasets will be uploaded to a temporary repository for testing software currently available within the WG. The community at large will be invited to participate in testing their own routines against the proposed benchmark datasets.
These datasets will be used first for testing key processing steps (e.g., noise removal or fitting algorithms) to obtain a consensus for what constitutes a best practices for each step. These remote discussions will lead to improved information in the wiki related to specific processing steps. Once a consensus is reached for each step, existing routines will be applied against the benchmark datasets, to determine why differences exist on the final estimated *s*.
The sources of discrepancies will be discussed during the second in-person meeting in June 2022 and develop a work plan for further testing of tools and quality-control measures. The WG intends on reaching a consensus on what constitutes a best practice *s* result, so the processed estimates can be tentatively deposited with the benchmark datasets along with qa/qc indicators before the end of 2022.

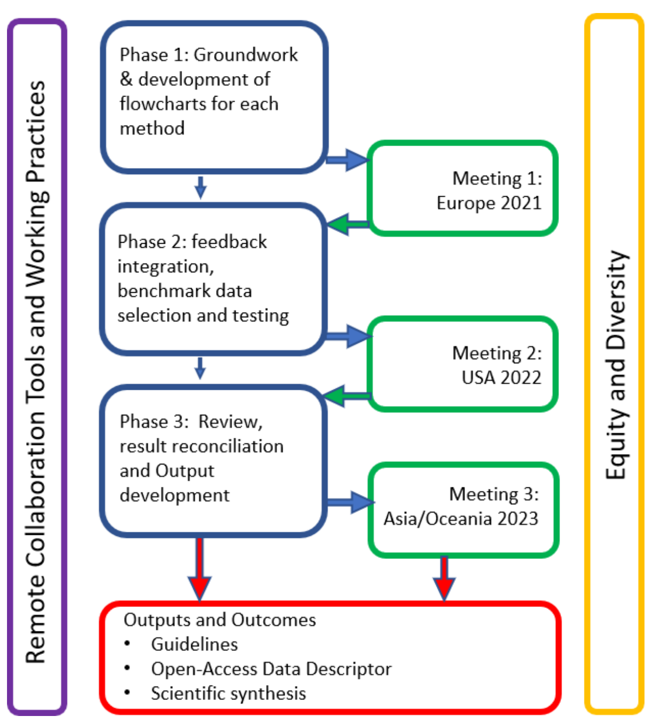

Figure 3: Project framework with work phases anchored by meetings working towards deliverables encapsulated in publications. The framework supports the use of advanced collaborative tools that enables receiving feedback from the community at large irrespective of career stage and geographic location.

A detailed description of the procedures used to convert raw data into the rate of dissipation of kinetic energy, *s* will also be available on the wiki for collaborative review by the OMC during the second half of 2022.

Phase 3 This phase will focus on outputs. The WG's third in-person meeting will be held at the Asia-Oceania Geosciences Society (AOGS) conference in 2023. The WG's progress will be pre- sented at the conference to advertise its impact on increasing the reliability of ocean mixing estimates published in databases and journal articles. We will also provide a workshop on best practices tai- lored to early-career scientists in an emerging country within the Asia-Oceania region near the AOGS conference site. The associated third in-person WG meeting will focus on developing the primary peer-reviewed manuscript. This article, with a proposed submission date of mid-2024, will synthe- sise improvements in the repeatability of analyses while quantifying the impact of consistent data processing on global mixing estimates.
In addition, the WG will finalise documenting algorithms and benchmark datasets in the form of a best practices guidelines using feedback received by the OMC. These outputs will enable researchers to assess any toolbox, irrespective of the programming language used in analyses (open vs closed source) after the completion of the WG's activities.

Deliverables
The deliverables, detailed below, include best-practices documents, a living wiki-platform, bench- mark datasets and peer-reviewed publications. All deliverables will be open access, archived under the Creative Commons Attribution 4.0 International license with a digital object identifier (DOI). The best practices documents will be archived in the Ocean Best Practices System Repository, an open access, permanent, digital repository of community best practices in ocean-related sciences and applications maintained by the International Oceanographic Data and Information Exchange of the Intergovernmental Oceanographic Commission of UNESCO. The WG's expected deliverables are:
Best-practices guideline document for estimating the dissipation rate *s* including step-by-step flow charts for the following methods and measurement platforms:
shear-probes attached to conventional gravity-driven vertical profilers, gliders, AUVs, au- tonomous self-propelled floats, etc;
inertial subrange fitting of point-velocity measurements;
structure functions applied to current profiler measurements.
An open-access wiki-platform to compile, organize and collaboratively review guidelines for estimating dissipation rate *s*. Examples of poor and good data will be provided along with suggestions for quantitative quality-control indicators.
Benchmark data sets including raw observations, agreed-upon "best" processed *s* estimates, and quality-control indicators.
A peer-reviewed Data Descriptor aimed for an open-access journal (Nature Scientific Data, Earth System Science Data or similar), to describe and document the benchmark data sets and the standardized methods of data processing for dissipation rate estimates.
A peer-reviewed article that synthesises improvements in the repeatability of analyses while quantifying the impact of consistent data processing on global mixing estimates.

Capacity Building
We expect the WG's long-term outcome to be the development of knowledge, skills and attitudes where best practices are adopted and easily accessible to all. The resulting consensus among the community will

democratize the production of scientific results on significant research topics such as climate change and ecosystem resilience. It will also accelerate the much-needed global coordination of turbulence measurements (i.e., UNESCO-Essential variables, see 8.2). This, in turn, will better serve the scientific community by having improved mixing observations to develop robust parameter- isations. Capacity will be built as follows:

Ensuring active participation beyond the working group: The structure of the proposed work plan has been developed such that scientists who are not part of the WG, but have shown interest in developing best practices (see 6), are encouraged to participate in various ways. The in-person meetings will be held immediately before existing conferences to facilitate partici- pation by early career researchers (ECRs) and scientists from developing countries without a significant added cost. In addition, the datasets will be widely available and scientists will be encouraged to participate in testing algorithms.

Holding a training workshop in an emerging country: A training workshop will be held in an emerging country within the Asia-Oceania region in conjunction with the WG's proposed third in-person meeting. The training will target ECRs, and will provide a great opportunity to both (i) provide education on the reviewed best practices, and (ii) assess the accessibility of the guidelines to early stage researchers who may have limited experience with turbulence observations.

Improving access to knowledge: The best-practices developed by the proposed WG will be shared with the ocean mixing community through (i) a collaborative wiki-platform, (ii) peer- reviewed synthesis articles, and (iii) an open-access database of benchmark datasets. This will transfer skills on processing turbulence observations to the entire ocean research community. The use of remote meetings and the online wiki-platform will remove geographic barriers that might prevent scientists in accessing information and/or participating in the development of guidelines.

Creating a sustainable community: It is vital we support the next generation of researchers. The proposed WG is composed of 60% of early career researchers (6 to 10 years post-PhD) for full members. The WG will also foster mentoring within its "community members" group, connecting the approximately 20% graduate student cohort with more experienced researchers (see 6). This will enable the next generation of researchers to build on the present state of knowledge to make the next major scientific advances in the field.

Working Group Composition

The field of ocean mixing emerged in the 1970s from a very small, geographically constrained group of laboratories (*Lueck et al.*, 2002). The field has since matured significantly, resulting in an inter- national community of scientists with various backgrounds, research foci and experience levels. The membership structure of the SCOR working group was developed to reflect this variation. A group of 10 full members and 5 associate members has been assembled (Tables 1 and 2), and approximately 75 other scientists have been identified as "community members". These community members repre- sent researchers who expressed interest in partaking in testing their processing algorithms, providing benchmark datasets, and/or peer-reviewing the written guidelines on the collaborative wiki. These "community members" were either from over-subscribed countries or had narrow interests within the proposed WG activities.

The process to identify the WG and community members began in September 2019, when over 300 people were contacted to gauge interest in the desired scope and proposed WG's objectives via an online survey. Names for these individuals were initially obtained from abstracts at international conferences. Instrument suppliers also helped identify additional scientists in Asia, South America and Africa. The online survey received approximately 90 responses (available here), which were used to diversify the WG's composition. Particular attention was given to improve the gender balance. Of the 90 individuals surveyed, less than a third were women, with over half of them being doctoral students or recent graduates. Many women had also volunteered themselves as "community mem- bers" in the survey. To increase the WG's gender balance, women with the necessary expertise were contacted directly. The final WG members, listed in Tables 1 and 2, provide the necessary expertise to accomplish the terms of reference, given their experience in analysing turbulence observations for research studies across diverse ocean environments with different platforms.

In addition to the online surveys, feedback on the WG's scope was sought during a Townhall ses- sion convened during the Ocean Sciences Meeting in San Diego last February 2020. About 50 people attended and provided valuable feedback that resulted in narrowing the type of methods addressed by the WG, while extending the development of best-practices for *s* to datasets from emerging platforms such as self-propelled gliders.

Table 1: Full members, gender, place of work, and expertise relevant to proposal. Names of co-chairs are bolded and asterisks (*) denote early-career scientists with up to 10 years post-PhD and less than 40 years of age.

Name	Gender	Place of work	Expertise relevant to proposal
Cynthia Bluteau*	Woman	Institut des Sciences de la Mer, Universite´ du Québec à Rimouski, Canada	Collecting and processing turbulence data from point-velocimeters and shear probes to quantify and param- eterize mixing.
Ilker Fer	Man	Geophysical Institute, University of Bergen, Norway	Collecting, processing and analysing shear probe data from diverse plat- forms in the ocean
Peter Holtermann*	Man	Leibniz Institute for Baltic Sea Re- search, Germany	Measuring, processing and analysing shear probe data, mainly in estuaries and coastal seas.
Arnaud Le Boyer*	Man	Scripps Institution of Oceanography, UC San Diego, United States	Developing the hardware, software and data processing of a modular microstructure profiler using shear probes and high-frequency thermis- tors.
Yueng-Djern Lenn	Woman	School of Ocean Sciences, Bangor University, United Kingdom	Collection, processing & analysis of turbulence in polar oceans and shelf seas, using shear probes and acoustic methods
Zhiyu Liu	Man	State Key Laboratory of Marine En- vironmental Science, Xiamen Univer- sity, China	Collecting, processing and analysing turbulence measurements with shear probes and acoustic velocimeters in various dynamical regimes.
Amelie Meyer*	Woman	University of Tasmania, Australia	Collecting, processing and analysing microstructure data from shear probes in polar waters.
Rolf Lueck	Man	Rockland Scientific Inc., Canada	42 years building and using shear probes, and processing shear-probe data, from multiple platforms in the ocean and lakes.
Craig Stevens	Man	National Institute of Water and Atmo- spheric research - University of Auck- land, New Zealand	Measuring small-scale processes in extreme ocean environments -e.g. ice shelf cavities and tidal channels.
Danielle Wain	Woman	7 Lakes Alliance, United States	Measurements of turbulence in low energy environments through tem- perature microstructure and acoustic methods

Table 2: Associate members, gender, place of work, and expertise. Asterisks (*) denotes early-career scientists with up to 10 years post-PhD and less than 40 years of age.

Name	Gender	Place of work	Expertise
Marcus Dengler	Man	GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany	Measuring, processing and analyzing shear probe data from vessel-based and autonomous platforms
Jenson George*	Man	National Center for Polar and Ocean Research, India	Collecting, processing and analyzing shear probe data from loosely tethered profilers
Justine McMillan*	Woman	Rockland Scientific Inc., Canada	Collecting, processing and analyzing turbulence data from shear probes and ADCPs
Sarah Nicholson*	Woman	Council for Scientific and Industrial Research, South Africa	Collecting and analysing shear probe data from autonomous platforms
Kirstin Schulz*	Woman	Alfred Wegener Institute, Germany	Collecting, processing and analyzing turbulence data from shear probes; tur- bulence modeling

Working Group Contributions

Cynthia Bluteau (co-chair) – quantifies mixing from field observations to develop the predictive capability of models and evaluate their impact on biogeochemical processes in subpolar and tropical regions. She has published methods to quantify turbulence more directly from moored and profiling platforms, in particular point-velocity measurements near bottom boundaries.

Ilker Fer (co-chair) – works on small scale processes in physical oceanography with special at- tention to high-latitudes, ocean mixing and turbulence. Fer has expertise in collecting, processing and analysing microstructure data from shear probes installed on various platforms including microstruc- ture profilers, underwater gliders, as well as moored systems.

Yueng Djern Lenn (co-chair) – focused on polar ocean processes, including diapycnal mixing from turbulence and double diffusion, that impact the global overturning. She has collected, processed and analysed shear-probe turbulence data from free-falling profilers, and her current project utilizes structure function methods for estimating turbulence from ADCPs.

Peter Holtermann – specialises in strongly stratified marine systems like the Baltic Sea. He mainly works with shear and temperature microstructure data from free-falling profilers and au- tonomously profiling systems. He has experience in combining turbulence measurements with the transport of biogeochemically relevant tracers as oxygen and hydrogen sulfide.

Arnaud Le Boyer – works on the interaction between the mesoscale and internal waves. He manages the development of a modular microstructure profiler (the epsilometer) measuring *s* and χ using shear probes and high-frequency thermistors. He is also developing the epsilometer's data processing library and its integration inside ARGO-APEX floats.

Zhiyu Liu – works on turbulence and mixing processes in the ocean, including their characteris- tics, mechanisms, impacts, and representations in ocean and climate models. He studies on dynamical instabilities of oceanic flows, identification and characterization of key mixing processes in different regimes of the ocean, and development of mixing parameterisations for numerical models ofvarious degrees of complexity.

Rolf Lueck – has, for forty years, studied dissipation-scale turbulence over seamounts, canyons, continental slopes, bottom boundary overflows, as well as in double-diffusive regions. He has used shear probes with vertical profilers, towed vehicles, moorings, gliders and AUVs, and has been refin- ing this probe since its original development in the 1970s.

Amelie Meyer – works on ocean mixing and internal waves observations, mostly at high lati- tudes and under sea ice, focusing on energy budgets and fluxes. She has expertise with collecting, processing and analysing data from microstructure probes (MSS90) and has also developed finescale parameterisation techniques for other platforms (EM-APEX ARGO floats).

Craig Stevens – works on mixing processes in extreme environments, primarily from an obser- vational perspective. Extreme in this context refers to a variety of settings like high Reynolds number (tidal channel) flows, ice shelf cavity mixing, and highly stratified water columns with and without substantial shear flows.

Danielle Wain – physical limnologist with expertise in process-based understanding of how tur- bulence and mixing in lakes impacts ecology and biogeochemistry. She primarily measures turbulence in low energy environments through temperature microstructure and acoustic methods, but also has worked with shear probes in oceanic environments.

Relationship to other international programs and SCOR Working groups

Previous SCOR working groups

Working Group 121: Ocean Mixing

The WG 121, initiated in 2002, focused on the knowledge gap between **ocean mixing** and large-scale ocean circulation. It triggered a concerted effort in the collection and interpretation of small-scale mixing observations within the context of much larger scale **climate** processes. A Climate Process Team (CPT, see below) was created in 2010 at the completion of SCOR's WG 121 activities.

WG 121 acknowledged the need to develop innovative measurement systems for collecting data suitable for deriving mixing parameters more routinely. "Routine observation" implies the use of turnkey instruments that can be operated by non-experts. Our proposal addresses the WG 121 recom- mendation by developing best-practices and quality indicators for estimating *s* from raw turbulence observations. Our proposed benchmarked datasets will also provide a means to evaluate the growing number of processing tools being developed within the expanding user-base.

International/ National programs

The Climate Process Team (CPT)

In 2010, the CPT, funded by the US's National Science Foundation and its National Oceanic and Atmospheric Administration, was convened to consolidate knowledge on ocean mixing caused by internal waves (*MacKinnon et al.*, 2017). The CPT worked with the climate and ocean variability organization (CLIVAR) and Carbon Hydrographic Data Office to develop a standardised format for archiving processed turbulence quantities derived from raw microstructure data. *MacKinnon et al.* (2017) found that "many variants of processing code have thus been developed in parallel by different groups. Some variants have **subtle differences in methodology that can potentially lead tosignif- icant quantitative differences in the results**". Our proposed WG is thus relevant for addressing the data analysis concerns raised by the CPT.

Argo

The Argo Program, which is a global array of about 4000 profiling floats, has been implemented and sustained for almost two decades. Argo is a major component of both the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). Owing to recent advances in tur- bulence sensing technology, direct measurements are now feasible on Argo floats (*Roemmich et al.*, 2019) and the results of the first integration of shear sensors are expected within the next two years. **Our WG intends to provide a community-consensus on the processing methods** for existing au- tonomous platforms (e.g., gliders), which will provide a baseline for processing Argo data.

Essential Ocean Variables

The UNESCO initiative GOOS provides a global framework to monitor variables relevant for climate and ocean health. One of its initiatives is to define Essential Ocean Variables (EOVs), while ocean turbulence fluxes drives the variability of several key EOVs. Ocean mixing was previously proposed as an EOV, but, GOOS recommended that the **readiness of observing approaches** needed to be demonstrated by the mixing community. Standardised processing algorithms are an essential step to improving the "readiness" of ocean mixing observations for consideration as an EOV.

National Research Projects

More than fifteen national projects are currently using turbulence measurements in the world's oceans: Arctic (e.g, MOSAiC, SODA, Changing Arctic Ocean), Atlantic (e.g, MerMEED, NISKINe), Indian (e.g, BoBBLE, MISOBoB), Pacific (SFB 754) and Austral (DiMES) oceans. By creating guide- lines for these challenging measurements, the proposed WG will accelerate the creation of large-scale (inter-institutions) programs by improving the collection and interpretation of turbulence measure- ments.

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A Appendix — Key publications of members

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TRACEAMORS: TRACE element SAMplers and sensORS

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Proposal for a SCOR Working Group: TRACE element SAMplers and sensORS (TRACESAMORS) – A step change to observing and understanding trace metal biogeochemistry in the ocean

Abstract (251/250 words)

The availability of essential trace metals (Fe, Zn, Co, Cu, Mn...) controls primary productivity in up to half of the world oceans and modulates the ecological framework of different ocean biomes. One of the biggest remaining challenges to improving our understanding of ocean biogeochemistry is the availability of accurate *in situ* techniques for the determination of the concentration and speciation of these essential trace metals. Our present understanding is severely constrained by the lack of high temporal and spatial resolution observations during critical seasonal and event-driven transitions in remote areas of the oceans. This is due to the absence of sensors that are suitably sensitive, selective and robust to determine elements at extremely low concentrations. Hence, the proposed topic is to initiate international collaborations to foster the application and development of new samplers and sensors, for the determination of trace metal concentrations and speciation in specific parts of the ocean. It builds upon Grand et al. (2019) OceanObs'19 paper recommendations on the creation of an international working group of trace metal sensor developers. This working group will focus on evaluating key analytical issues with existing oceanographic sensors for trace metal analysis, review emerging sensing technologies in other disciplines and their potential for oceanographic use, and provide recommendations for inter-comparison with current remote samplers. The aim is to promote collaborative research to instigate a step change in our ability to monitor trace metal dynamics.

Scientific Background and Rationale (1251/1250 words)

Understanding the role of trace elements and how their supply, abundance and speciation will change with projected global environmental forcings (e.g. increased aridity, ocean acidification, warming, global circulation, and expanding oxygen minimum zones, Turner and Hunter 2001, Bruland and Lohan, 2004, Birchill et al. 2017) is a pressing research need. The international GEOTRACES program (https://www.geotraces.org) has provided a snapshot of the distributions of trace elements and their isotopes using ocean section cruises through all the ocean basins. This has led to significant paradigm shifts, particularly with regards to the micronutrient iron (Fe). For example, discrete sampling in the south Pacific Ocean has shown that hydrothermal inputs of Fe can be detected many thousands of kilometers away from their source (Resing et al., 2015) and recent observational evidence in the Southern Ocean suggests that hydrothermal Fe could trigger massive phytoplankton blooms (Ardyna et al., 2019).

The 'tool box' of methods available to chemical oceanographers to constrain the sources, sinks, transport, residence time and internal cycling of micronutrient trace metals is limited to discrete sampling onboard ships (which has been the cornerstone of GEOTRACES observations). A limited number of autonomous systems capable of observing trace metals at subnanomolar concentrations have been deployed (Bell et al. 2002, van der Merwe et al. 2019) but these require some degree of regular turnaround and maintenance (van der Merwe et al., 2019). Overall, these observational constraints hamper the development of a mechanistic understanding of trace metal cycling, which can then be fed into global ocean biogeochemical models. Micronutrient metals are characterized with short residence times, highly variable source terms, and sub-nanomolar concentrations in open ocean settings. Thus, the development of *in situ* sampling and sensing technologies necessary to capture the spatial and temporal variabilities will undoubtedly induce a step change in our understanding of the biogeochemical cycling of essential trace elements and their role in modulating biological productivity and carbon export.

The international research community now has the capacity and infrastructure needed for this next phase. This includes: (i) enhanced and novel analytical chemistry capabilities (ii) expertise for development of *in situ* sensors for macronutrients and physical parameters (iii) marine platforms (floats, moorings, gliders, submarines, satellite telemetry) for testing and use of sensors including float networks and observations within GOOS and AtlantOS programmes.
This idea of working towards novel sensors for micronutrients combining analytical advances with the gaps in marine biogeochemistry observing techniques was put forward at a Town Hall Meeting at the AGU Ocean Science meeting in Salt Lake City 2012 and ultimately led to the Collaborative on Ocean Chemistry and Analysis (COCA) meeting (http://media.journals.elsevier.com/content/files/cocameeting-30202026.pdf). While the COCA meeting was well received by the community, few sustained collaborations emerged from it, presumably because there was little long-term community or programmatic structure bridging the distinct disciplinary fields of oceanography, analytical chemistry and engineering that is necessary to make trace metal sensors a reality. This is a drawback that TRACESAMORS proposes to address.

Which processes and specific regions of the ocean would benefit the most of remote samplers and trace metal sensors ? Capturing seasonal and short-term variability of trace metals as well as the variability from specific processes, such as hydrothermal dispersal, dust deposition and shelf transport, are essential to determine their (i) supply to the euphotic zone linked to primary production, (ii) residence time and (iii) inventory in various oceanographic regimes. Repeated transects and international programmes (such as GEOTRACES) will help identify 'target zones' where biogeochemical changes and ecological sensitivity which need high frequency monitoring of trace elements.
The objectives pursued by the Working Group (WG) will focus on assessing target zones that are the most appropriate for trace metal sensor deployment, taking into account location, facility of maintenance and maximum value of observed data.
How can we incorporate in situ trace metals sampling and measurements into observational networks and models? To successfully develop trace metal sampling and sensors that are *fit for purpose* for observational networks, will require prior knowledge of the challenges of doing this in remote environments. This includes having a practical knowledge of requirements such as power consumption, automation, signal-to-noise control and calibration. Similarly, contributing the right data at the right resolution requires knowledge of the requirements of modelling regional and global oceanic trace metal distributions by the scientific community. Biogeochemical cycling models often have to make broad assumptions because of poor knowledge about temporal trace element

observations used to inform any simulation. Furthermore, information on the speciation of essential elements, such as Fe, are often missing (Boyd *et al*. 2010, Parekh et al. 2005).
To address this, a project should include direct, structured discussion and dissemination at meetings and workshops between marine analysts and those involved in (i) oceanographic biogeochemical modelling, (ii) ocean observational networks (iii) deployment of sensor platforms. It is also important that lessons learnt from previous programmes and current projects relating to trace element measurements (e.g. CLIVAR, GEOTRACES) are considered. This includes the importance of metadata and recording of measurement uncertainty, but further that we move forward with sensor and sampling development with an understanding of the limitations in model parameterizations and identify what measurements (location, sampling resolution) would critically improve these models.

What are the most promising techniques for remote sampling of important trace elements? What intercalibration and metrics are important to evaluate and to determine if remote samplers are fit for purpose? The extremely low natural concentrations of metals and their ubiquity in traditional sampling equipment (ships, frames, bottles, chemicals) have led trace metal geochemists to develop extreme methodologies to avoid contamination during all phases of sampling and analysis. Taking care of our future choices of materials so that they have less impact on the environment is also essential. Improving the level of interoperability for *in situ* trace metal sampling and analysis via intercomparison and harmonisation of operational technologies as performed for *in situ* macronutrients analysis (GOSHIP manual, Becker et al., (2019) SCOR#147, Daniel et al. (2020)), would be off great benefit to the marine community.
We propose in this WG to bring together the oceanographic community to provide recommendations for inter-comparison of remote samplers as well as consideration on the type and nature of platform on which they can be deployed keeping in mind sustainability goals.
What are the most promising techniques and limitations for in situ sensors of trace elements? Are chemical oceanographers "missing out" on recent developments in other fields? State-of-the-art analytical detection methods and technologies (e.g., 3D printing, nanotechnologies, novel fluorescent probes) are emerging in multiple scientific fields. Therefore, it has become challenging for chemical oceanographers to keep up with all these analytical and technological developments and to anticipate potential application to oceanography, alongside delivering pioneering basin scale ocean observations with high spatial and temporal resolution. The latest trends and developments in analytical chemistry (novel ligands, fluorophores, ionophores, biosensors, miniaturized methods) should be evaluated for their oceanographic potential. Adopting new strategies among other branches of knowledge could help create the synergies that would facilitate new sensor development research in oceanography.
We propose to review and evaluate recent techniques of in situ sensors used in oceanography and to identify new promising technologies in other disciplines through identification of additional associated SCOR workgroup members from the medical, engineering and other environmental research areas. In order to do this we propose a strategy to leave 5 associate member positions open in order to target and recruit key members from these different disciplines (See empty associate members position in table below).

Terms of Reference (245/250 words)

Objective 1: To critically evaluate key analytical issues with currently employed methodologies (samplers and sensors) to establish whether they can be improved, supplemented or eventually replaced.
Objective 2: To define the requirements for measurement conditions and ideal analytical properties of sensors and sampling devices; depending on the context of analysis in different ocean regimes

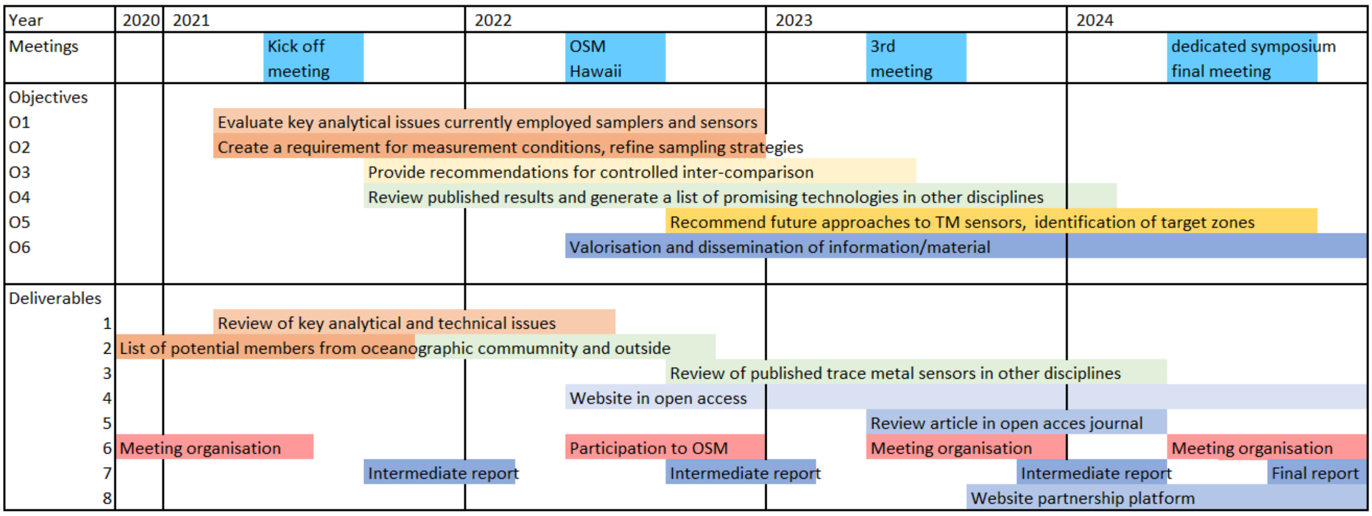
(concentration, pressure…) and the provenance, fate, distribution and biochemical functions of trace elements.
Objective 3: To provide recommendations for controlled inter-comparison of remote samplers and potential in situ sensors on various deployed platforms.
Objective 4: To review published results and identify individuals and communities working on all aspects of trace metal sensors in industry, medicine and other environmental fields (3D printing, nanotechnologies, ligands), to generate a critical review of promising technologies for automated remote marine biogeochemical measurements.
Objective 5: To recommend approaches for future analytical development and deployment of different types of trace metal sensors and samplers (including ongoing GEOTRACES transects and process studies), to identify target zones (with the help of modellers) and techniques suited to extreme environments (e.g. deep sea, sub-zero temperatures).
Objective 6: To develop capacity and disseminate information resulting from the WG outcome in the form of (i) Website (hosted at the University of Plymouth) to share results, reports (Ocean best practices, IOC), tutorials and software, (ii) open access journal special issue (e.g. Limnology and Oceanography-Methods) (iii) platform for partnership collaborative proposals to generate sustained collaboration (*Capacity Building*) and (iv) a final report to SCOR.

Working plan (608/1000 words)

2021: We will first inform the oceanographic and analytical community of this WG via a short summary in AGU Eos, national and international society and research funding newsletters (e.g. GEOTRACES network, chemical societies), publicize this working group through existing international and European observational programs such as GOOS, AtlantOS, Jerico, EMSO, POGO, and french CNRS INSU professional network. Preliminary communications leading up to this meeting will take place during the preceding year and will lead to planning a focused agenda for the meeting, identification of additional Associate Members (**O4**), discussions of plans to address the Terms of Reference. Scheduled video conferences will be 3 monthly amongst members and start immediately leading up to the kick off meeting in 2021 (***Meeting 1***). The WG members will attend the kick off meeting, and set up a framework for investigating a broad variety of analytical technologies and sensor chemistry (**O1, O2**). A reporting database and web page will be formulated ready for implementation, which will also act as a forum for information exchange and details of new meetings and targets (**O6**). Other funding sources for the travel and meeting expenses and final publications will be determined. We will also aim to involve members from the POGO office to help plan capacity building from the start.
2022: Approximately one year after the kick off meeting, an intermediate townhall meeting (***Meeting 2***) with the WG and selected key members of the oceanographic, analytical and engineering communities in the form of an international workshop on marine trace metal sensors will be held. **O3** and **O5** will be discussed then with the feedback from initial work on **O1** and **O2**. One session will be entirely dedicated to new technologies from other disciplines (**O4**). This will allow a nominal one-year period over which to structure and plan the final workshop agendas, issue announcements and invitations, secure needed funds, and make other necessary preparations. To reduce individual costs by sharing funding from other oceanographic research projects, Meeting 2 would occur in combination with the Ocean Sciences Meeting (Hawaii 2022). The workshop will provide the opportunity for all Full and Associate members of the WG to discuss all points of the terms of references and to develop capacity building (**O6**). Groups will be formed and tasks assigned to work on projects and prepare material to be presented at *Meeting 3* and in the special issue or separate book chapter (**O6**).
2023: In year 3 of the project all WG members and associate members will meet again (***Meeting 3***) to record and assess the progress made by different groups and discuss necessary actions to

successfully present at a dedicated symposium in year 4 during 2024. It would also set the date for the final meeting during which the WG will be rounding off the results and outcomes and finalize the publications (**O6**).

2024: The final meeting (***Meeting 4***) and conference will be planned to take place in an emerging country in order to generate new interest, contribute to the local economy, and capacity by sharing and exchange expert knowledge in various science fields by opening sessions to students from local universities. It is anticipated that the major part of the funding from SCOR will be utilised to disseminate the findings, build networks, hold meetings and pay for travel to those meetings. Separate funding will be sought from ISBLUE LabexMer (Fr), California State University (USA), US NSF and Ifremer international organization (France), NERC (UK), the Australian Research Council (ARC) and other sources, such as local universities and institutes. At this meeting we will also hold a training workshop and engage the POGO programme to help advertise and support this (see *6. Capacity Building*). We will also endeavour to invite members of international ocean observational networks (e.g. GOOS and AtlantOS representatives) and key members of the modelling community to disseminate results and engage them in discussion of future work.



Deliverables (227/250 words).

Review of key analytical and technical issues using currently employed methodologies to establish whether they need to be improved, supplemented or eventually replaced. (**O1, O2, O3**)
Select a list of interested researchers in the oceanographic community (GEOTRACES, modellers, physical oceanographers), identify members from other disciplines (**O1, O2, O3**). Invite 5 associate members from communities outside of chemical oceanography to join the group. (**O4**)
Review of published techniques on all aspects of trace metal sensors used in industry, medicine and environmental (3D printing, nanotechnologies, novel ligands, fluorophore…), and generate a list of promising technologies for automated remote marine biogeochemical measurements (make this information publicly available, **O4, O5**)
Produce a Website (at the University of Plymouth) to share results, reports, tutorials and software in open access format (**O6**)
Publish a review article in an open access journal special issue (e,g. Limnology and Oceanography-Methods) combining the currently employed methods and the **future promising technologies** with optimised location and platforms required to easily deploy them (**O2, O3, O6**)
Participation at international ocean science meetings to present the general objectives and progress of the TRACEAMORS WG (**O6**) and organisation of one conference in an emerging country with participation of university students and lecturers
Organize a final meeting and deliver a final report to SCOR (O6)

Generate new sustained collaborations and capacity from the various meetings through a **website and partnership platform** (**O6**)

Capacity Building (713/1500 words)

The lack of robust and accurate sensors and reliable remote sampling platforms for observing event driven and seasonal biogeochemical changes in the oceans, inhibits scientists, governments and non-governmental organizations from effectively monitoring and managing the marine environment. The targeted, interdisciplinary nature of the TRACESAMORS project will enable individuals and research groups from across the world to obtain new knowledge and advanced analytical skills, develop new marine sensors and equipment urgently needed to advance marine global networks.
The success of the aims of this proposal will undoubtedly lead to a step change in approaching in situ sampling and analysis of trace elements by:
(i) involving **international experts in other fields** and disciplines external to marine biogeochemistry through **collective intelligence**
(ii) encouraging a **cultural change** of marine analysts and engineers creating a **learning community** who share analytical ideas and develop a united strategic global effort rather than isolated individuals working on method development
(iii) encouraging **involvement of graduate students and junior researchers** in meetings and interlaboratory collaborative work.
To provide **opportunity for associated members and early-career scientists** who are not members of the WGs to attend the SCOR workshop, the second year meeting will occur in combination with the Ocean Sciences Meeting (Hawaii 2022). TRACESAMORS will apply for travel funds from SCOR and the AGU, for the travel and subsistence of students and scientists from developing countries to the third year meeting. Moreover, the final meeting (Meeting 4) will be planned to take place in an **emerging / developing country** to contribute to the local economy, allow networking and to **share and exchange** expert knowledge.
One of our objectives is also to develop **soft-skills** and **pedagogical innovation** in various science fields by **opening sessions to students** from local universities (Walder, 2014) and enhancing interaction and interactivity between the expert and the graduate communities by performing **a training workshop** in the final meeting and explore ways to generate sustained collaboration in networks including involvement of the POGO programme and its network. In order to optimize the use of the SCOR fundings, extra funding will be requested from ISBLUE LabexMer (Fr) through Permanent call for invited professors and researchers and through a second call for projects workshops, seminars, thematic schools, open to Isblue students and international students.
We promote a project that is more **stimulating** and **enjoyable** to engage with because it carries meaning to the trace metal community and a realistic future vision. The dissemination and **sharing of information** through a website and a platform for partnership collaborative proposals will be built up by **partners co-responsible** for the production, ambition and impacts of the project. Live and recorded Powerpoint-type presentations from the meetings, videos showing innovative technologies selected for the future sensors, recommendations for the use of remote samplers will be part of the website content in order to facilitate productive, effective and stimulating face-to-face or remote knowledge exchange.
Beyond the scope of the SCOR funding, successful ideas and collaboration will ultimately lead to major infrastructure development for the oceanographic community. The latter will help strengthen the skill base of marine biogeochemistry and engineering communities to achieve global future goals towards understanding marine elemental cycles and ecological controls.
Why a SCOR working group ?
A SCOR working group is the best way to create a coordinated approach by assembling an international team from various disciplines and expertise (analytical chemistry, biomedical field, space engineering, other environmental fields and chemical oceanography) from different countries.

This will permit the identification of priority areas and research questions that would immediately benefit from in situ sampling/analysis, a review of existing technologies, the identification of promising technologies from diverse fields as well as the adoption of best practices for trace metal sensing and autonomous sampling. Importantly, a coordinated international approach, avoids duplication of efforts by individual groups.

The opportunity of this international SCOR WG is timely as the international state-of-the-art technology observation networks and platforms are well developed. Other organizations cannot ensure that the activity is suitably interdisciplinary, involving scientists from a wide range of fields, countries and developing nations, while helping train young scientists. We aim to highlight community or programmatic structure on an international scale and with emerging countries combining senior and young scientists in order to bridge the distinct disciplinary fields of oceanography, analytical chemistry and engineering.

Working Group Membership (149/500 words)

TRACESAMORS is composed of 10 full members and currently 5 associated members with expertise in chemical oceanography, including nutrient and metal *in situ* analysis, remote sampling and analysis via flow injection techniques, and electrochemical methods. The 5 associate members are experts in atmospheric chemistry, ice core sciences, analytical development, nanotechnology, electronic instrumentation and microfluidics. Several associated positions were not yet allocated *intentionally*, because one deliverable of the working plan of the SCOR WG TRACEAMORS is to identify and invite new collaborators from other disciplines in order to adopt innovative strategies among other branches of knowledge. The 10 full members are from 9 different nations including 4 emerging/developing nations (South Africa, China, India and Chile) and they represent 5 women and 1 early career researcher (Max Grand). The full members are responsible for the delivery of our objectives, while the associated members provide important input from other fields (nanotechnology and modelling).

7.1 Full members

	Name	**Affiliation**	**Gender**	**Specialty within the field of trace metal, analysis and speciation in seawater**
1	Simon Ussher (proposed co-chair)	University of Plymouth, United Kingdom	M	Flow injection techniques (FIA), fluorescence and chemiluminescence detection. simon.ussher@plymouth.ac.uk
2	Agathe Laës-Huon (proposed co-chair)	IFREMER, Brest, France	F	Nutrients, trace metal analysis and deep sea automated analysers Agathe.Laes@ifremer.fr
3	Maxime Grand	Moss Landing Marine Laboratories, USA	M	Application of Flow injection techniques and microfluidics to chemical oceanography (trace metals, nutrients) mgrand@mlml.calstate.edu
4	Andrew Bowie	University of Tasmania, Australia	M	Chemical oceanographer and analytical chemist andrew.bowie@utas.edu.au
5	Maija Iris Heller	Pontificia Universidad Católica de Valparaíso | PUCV · Facultad de	F	Trace metal, analysis and speciation in seawater maija.heller@pucv.cl

		Ciencias del Mar y Geografía, Chile		
6	Susanne Fietz	Department of Earth Sciences, Stellenbosch University, Stellenbosch, South Africa	F	Biogeochemist, focusing on links between phytoplankton and trace metals sfietz@sun.ac.za
7	Mariko Hatta	Institute of Arctic Climate and Environment Research (IACE), JAMSTEC, Japan	F	Chemical oceanographer for shipboard flow injection analysis for trace metals, and analytica chemist adapting microfluidics techniques to determination of nutrients. (Currently at Department of Oceanography, University of Hawaii). mhatta@hawaii.edu
8	Sunil Kumar	CSIR, National Institute Of Oceanography, Goa, India	M	Geochemistry & Isotope Chemistry, Nutrient Cycling & Biogeochemistry sunil@nio.org
9	Maeve Lohan	University of Southampton, UK	F	Expert in electrochemical methods, organic complexation, Flow injection analysis M.Lohan@soton.ac.uk
10	Jian Ma	Xiamen University, China	M	Expert in field nutrient and metal analysis, flow analysis and automatic instrumentation jma@xmu.edu.cn

7.2 Associate

	Name	Affiliation	Gender	Specialty within the field of analytical chemistry, engineering, nanofrabrication…
1	Joe Resing	University of Washington, USA	M	Instrument automation and data acquisition, flow injection analysis.
2	Vincent Raimbault	Laboratory for analysis and architecture of systems, Toulouse, France	M	Nanotechnology, nanofabrication, electronic instrumentation, sensor development, microfluidics
3	Manuel Miro	Universitat de les Illes Balears, Spain	M	Automatisation of analytical methods based on the new generations of flow analysis and 3D-printed mesofluidic platforms
4	Roberto Grilli	Institut des Géosciences de l'environnement, Grenoble, France	M	Laser spectroscopy, Atmospheric chemistry, Ice core sciences, Trace gas analysis, Isotope geochemistry
5	Geng Leng	University of Electronic Science and Technology of China	M	Development of analytical techniques including microextraction, spectrophotometry chemiluminescence, atomic fluorescence, gas anc liquid chromatography.

6-10	**Positions left to make strategic recruitment of international experts engineers, analysts, chemists, modellers when funded.**

Working Group contribution (496/500 words)

Agathe Laës-Huon is involved in analytical chemistry dedicated to seawater analysis and development of in situ instrumentation for monitoring marine chemicals and pollutants in coastal and deep-sea waters (FIA, electrochemistry, extraction and water sampling). She is in charge of the in situ chemical analyzers CHEMINI project.

Simon Ussher has >20 years of research experience as an analytical chemist and marine biogeochemist. His research has advanced our understanding of trace metal biogeochemistry in the Atlantic Ocean, including basin scale processes of iron (Fe) biogeochemistry from the atmosphere to the deep ocean. He employs expertise in techniques including FIA and ICP-MS to analyse Fe and trace elements in aerosol and marine samples.

Maxime Grand has pioneered the application of micro-Sequential Lab-On-Valve techniques to trace metal analysis at the sub-nanomolar level and worked on the development of the first generation in situ Lab-On-Chip phosphate analyzers at the NOC, UK. His research interests are focused on the biogeochemical cycling of Fe and Al in open-ocean settings such as the Indian Ocean.

Andrew Bowie is a chemical oceanographer and analytical chemist whose research investigates the biogeochemistry of trace elements in Southern Ocean and Antarctic environments. He has developed novel analytical techniques and instrumentation to probe trace element cycling in remote marine environments. He is currently co-chair of the GEOTRACES program.

Maija Heller is an analytical chemist and chemical oceanographer working in the global oceans on GEOTRACES, SOLAS and GO-SHIP related topics. In 2019 she started a position in Chile and she is currently building analytical and human capacity for the analysis of trace metals in seawater.
Susanne Fietz is a biogeochemist studying the dust deposition and the links between trace metals and phytoplankton in the Atlantic sector of the Southern Ocean. She is a current national representative of the GEOTRACES programme.

Mariko Hatta is a chemical oceanographer and analytical chemist, conducting shipboard determination of dissolved metals using flow injection analytical methodologies during CLIVAR, GEOTRACES, and Southern Ocean projects. She has developed a novel programmable flow injection technique for nutrient determination using a microfluidic platform, and planning to participate in the international nutrient inter-calibration cruise.

Maeve Lohan is Professor of Marine Chemistry at the National Oceanography Centre Southampton and an internationally recognised trace metal biogeochemist specialising in voltammetric and flow injection techniques. Maeve is the GEOTRACES co-chair of Standards and Intercalibration Committee and GEOTRACES Scientific Steering Committee member.

Jian Ma is an environmental analytical chemist dedicated to trace analysis using flow techniques. He has developed a robust integrated Syringe-pump-based Environmental-water Analyzer (*i*SEA) for real-time analyzing the nutrients, metals and carbonate ion in seawater.
Sunil Kumar Singh is Professor at the Physical Research Laboratory and the director of the National Institute of Oceanography (India). He is specialised in the biogeochemistry of Trace Elements and

Isotopes (TEIs) in the Indian and Southern Oceans and in the Indian Estuaries and in micro-nutrient cycling, erosion and weathering studies in the Indian River System. He is a past member of the GEOTRACES Scientific Steering Committee.

9- Relationships to Other Programmes and SCOR Working Groups (198/500 words)

TRACESAMORS will be closely linked to a broad variety of programmes and networks:
Biogeochemical modeling: The SCOR working group FeMIP on iron model intercomparison aiming to produce guidelines for how models can best represent the iron cycle and develop tools for objective interpretations of models skill relative to observations.
Methods and best practice: We will also take advantages of the recent SCOR International Nutrient Working Group #147 who delivered the GOSHIP manual for best practice in performing nutrient measurements at sea. Both chairs (Laes-Huon and Ussher) are funded investigators and partners in the AtlantOS programme and the best practice workgroup (https://www.atlantos-h2020.eu/project-information/ best-practices). WG member Lohan is also a leader in the GEOTRACES Standards and Intercalibration Committee.
GEOTRACES: A close link with GEOTRACES programmes and planned follow-up programme BioGeoSCAPES will also be maintained as some of the full members are already leaders in this trace metal community (Bowie, Lohan, Kumar Singh, Fietz)
Capacity building: we would like to link up with the POGO programme and in particular the NANO alumni programme (NF-POGO Alumni Network for Oceanspast networks of students).
International observational programs: through membership of members in GOOS, AtlantOS (Ussher), Jerico (Laes-Huon) and EMSO (Laes-Huon).

10- Key References (499/500 words)

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ACRONYM:

GOOS: Global Ocean Observing System
AtlantOS: Optimizing and Enhancing the Integrated Atlantic Ocean Observing Systems
AGU: American Geophysical Union
CLIVAR : Climate and Ocean -Variability, Predictability, and Change
GOSHIP: Global Ocean SHIP based hydrographic investigation program
EMSO: European Multidisciplinary Seafloor and water column Observatory
POGO: Partnership for the Observation of the Global Ocean
CNRS: Centre National de la Recherche Scientifique
ICP-MS Inductively coupled mass spectrometry
INSU: Institut National des Science de l'Univers
ISblue : Interdisciplinary School for the blue planet
LABEX-Mer: LABoratoire d'EXcellence Mer
US NSF: National Science Foundation
NERC: Natural Environment Research Council
CHEMINI: Chemical MINIaturised analyser
NOC: National Oceanography Center
SOLAS: Surface Ocean - Lower Atmosphere Study
IOC: Intergovernmental Oceanographic Commission
FIA: Flow Injection Analysis

FORAM-ECO: Benthic Foraminifera as Ecological Sentinels of Marine Systems Health

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1. Summary

The development and implementation of a cost effective and high-impact method for long-term marine monitoring is much needed. Benthic foraminifera are excellent candidates due to their high sensitivity to environmental changes and ability to provide an estimate of natural baseline conditions. Due to their tests (shells) good preservation in sediment archives and hence, unlike most macrofauna, it allows the evolutionary reconstruction of marine environment thus providing a snapshot to pre-industrial times and *in-situ* ground-reference conditions of environmental health changes over time (deterioration vs. restoration). Many studies link changes in foraminiferal density, diversity, and dominance to environmental stress and designed different biotic indices. However, there is still a knowledge gap in environmental constraints of benthic foraminiferal distribution patterns, and hence a robust biotic index suitable for different environments is missing. Furthermore, promising results obtained with the application of eDNA in biomonitoring studies advocate for a larger implementation of this technique in foraminiferal studies.

The aim of the international FORAM-ECO working group is to improve the understanding of the environmental constraints of benthic foraminiferal distribution patterns in order to develop a robust biotic index to be implemented and widely used by authorities in marine environments following these goals: (i) assessment and implementation of the best foraminiferal index; (ii) implementation of metabarcoding to complement morphologically-based indices; (iii) determination of pre-industrial baseline conditions; and (iv) knowledge transfer and capacity building among members and beyond.

2. Scientific Background and Rationale

2.1 Importance of foraminifera in bioindicator monitoring

In order to protect and restore marine ecosystems, many nations have enacted legislations such as, for instance, the Clean Water Act (CWA) or Oceans Act in USA, Australia or Canada, the Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategic Framework Directive (MSFD, 2008/56/EC) in Europe. As a consequence, a plethora of methodologies, based on benthic macrofauna (Borja et al., 2000; Leshno et al., 2016), seagrasses (Krause-Jensen et al., 2005), fishes (Coates et al. 2007) and, more recently, benthic foraminifera (e.g., Bouchet et al., 2012; Barras et al., 2014; Alve et al., 2016 and references therein), have been suggested to assess the health of marine ecosystems. In particular, benthic macrofauna are currently the most widely used group to assess ecological quality status (EcoQS) in marine environments (Dauvin et al., 2012).

Lately, concerns arose about macrofaunal indices, pointing out drawbacks of these methods (see review in Spilmont, 2013). For example, macrofaunal benthic indicators suffer from expert judgment dependence (Texeira et al., 2010), methodological dependence (Karakassis et al., 2013), inconsistent methods to assign species to ecological groups (Zettler et al., 2013), inconsistency among indices (Bouchet & Sauriau, 2008), and temporal variability (Reiss & Kröncke, 2005). There is, hence, an urgency to develop an alternative method, which can be used to bridge an important knowledge gap concerning determination of recent pre-industrial reference conditions.

Benthic foraminifera are protozoans that have increasingly been acknowledged as indicators of human-induced environmental stresses (e.g., Schwing et al., 2017), such as oil spills (Morvan et al., 2004;), heavy metals (Martínez-Colón et al., 2018), urban sewage (Hyams-Kaphzan et al. 2009), and aquaculture (Oron et al., 2014). Due to their short life cycles (3 months to 2 years; Murray, 1991), they respond quickly to environmental changes and adapt their population density and species composition accordingly (e.g., Kenigsberg et al., 2020). An important advantage compared to soft-body macrofauna is that foraminiferal tests (shells) composed of calcium carbonate or agglutinated grains, are preserved in the sediments. The high fossilization and preservation potential make them reliable paleoecological indicators of marine environments, thus providing a historical aspect to ecosystem deterioration or remediation, which have taken place during the last centuries (Dolven et al., 2013; Polovodova Asteman et al., 2015; Francescangeli et al., 2016; Hess et al., 2020). Such records are essential to assess pre-industrial conditions. Foraminifera occur in almost all marine environments and have much higher abundances than macrofauna. Thus, quantitative and statistically valid data are obtained from a small sediment sample volume (i.e., 50 cm^3). Recently proposed benthic foraminiferal biotic indices (Bouchet et al., 2012; Alve et al., 2016; Dimiza et al., 2016) provide opportunities for the further development and implementation of foraminifera as an acknowledged biological quality element considered by legislations for marine EcoQS assessment. Foraminiferal indices are based either on species diversity (Alve et al., 2009; Bouchet et al., 2012) or their sensitivity to environmental stressors (Barras et al., 2014; Jorissen et al., 2018; Prazeres et al., 2019). Foraminiferal indices have been particularly designed and applied to assess EcoQS of environmentally impacted marine habitats (e.g., Bouchet et al., 2018; Alve et al., 2019; El Kateb et al., 2020). Furthermore, eDNA studies (i.e., metabarcoding) were successfully applied to assess the impact of pollution e.g. from mercury, oil drilling and gas platform and aquaculture (Laroche et al., 2016; Cordier et al., 2019; Frontalini et al., 2018; He et al., 2018). However, benthic foraminifera are not yet acknowledged as a biological quality element by marine legislations, and, hence, foraminiferal indices are occasionally considered by legislations only in few countries (France, Israel, Norway, Australia).

2.2 The Challenge and Relevance to SCOR

Since 2011, the international FOraminiferal BIo-MOnitoring initiative (FOBIMO) has standardised methods for the use of benthic foraminifera in environmental monitoring. They unified the effort of foraminiferologists based worldwide to establish a common biotic index to assess the EcoQS. Amongst numerous protocols to assess the EcoQS (Birk et al., 2012), the AMBI index based on benthic macrofauna (Borja et al., 2000) is the most successful (Borja et al., 2019). Inspired by this work the, Foram-AMBI was introduced by Alve et al. (2016) for the North-East Atlantic and Arctic, including their fjords, continental shelves and slopes. Specifically, benthic foraminiferal species were assigned to ecological groups according to their response (e.g., tolerance, sensitivity, etc.) to organic matter enrichment in soft sediments (following Pearson & Rosenberg, 1978; Glémarec & Hily, 1981). Following the guideline of the FOBIMO working group, much emphasis was given on further development and testing of the Foram-AMBI index.

Other critical foraminiferal biotic indices were developed and successfully tested. Based on diversity indices H' (Alve et al., 2009) and Exp(H'_{bc}) (Bouchet et al., 2012), EcoQS were accurately assessed against different pollution sources (Bouchet et al., 2012, 2018; Dolven et al., 2013; Melis et al., 2016; Francescangeli et al., 2016; Dijkstra et al., 2017; El Kateb et al., 2020). In addition, sensitivity-based indices were designed like the Tolerant Species Index for the Mediterranean (TSI-med) (Barras et al. 2014) and the Foram Stress Index (FSI) (Dimiza et al., 2016) to assess the current health of marine environments. Few applications of these evolving indices highlighted their good performance in assessing EcoQS (Damak et al. 2020, El Kateb et al., 2020, Minhat et al., 2020). Finally, a multi-metric foraminiferal index has been adapted from the Norwegian macrofaunal index NQI (NQIf; Alve et al., 2019). Promising work using metabarcoding have not yet been formalized into a molecular-based index like the gAMBI (see review in Borja et al. 2019). Our community is hence putting a huge effort into the development of a robust benthic foraminiferal index to be used in environmental assessment and monitoring. The biggest challenge is now to thoroughly test these indices to determine how relevant they are in assessing EcoQS in different types of marine and climatic regimes and against different sources of pollution. The ultimate aim of the FORAM-ECO SCOR working group will be to work on the integration of benthic foraminifera in environmental monitoring guidelines as well as in governmental monitoring efforts.

2.3 Rationale and Timeliness of FORAM-ECO SCOR working group

As above-mentioned, there has been an increasing number of publications assessing EcoQS using benthic foraminifera over the last few years. These contributions highlighted (i) the urgency to revise and extend the existing species lists of sensitivity-based indices, (ii) the need to provide a suitable method for intertidal, estuarine and transitional environments, in which it is particularly challenging to decipher between natural and human-induced stressors, (iii) to solve taxonomical issues, also by molecular methods, and (iv) establishment of pre-industrial environmental conditions that will assess the validity of current restoration

practices. Moreover, benthic foraminifera may be used for establishing the reference (pre-impacted) conditions for the sake of marine conservation assessments by utilizing the fossilization potential of foraminiferal tests in sediments. The establishment of a SCOR working group would allow to formalize what has been started by the informal FOBIMO working group. More important, our community is at a key moment of the development of an environmental health index based on benthic foraminifera. In order to achieve the establishment of an EcoQS assessment method based on benthic foraminifera, a SCOR working group is
the best format to achieve this goal.

3. Terms of Reference

ToR #1: Assess state-of-the-art methodologies for organic matter characterizations in marine sediments. This will address the issue of identifying the origin of organic matter to disentangle between natural and anthropogenic sources. Identifying the type(s) of organic matter (i.e., lipids) via multiple methods (i.e., molecular) will delineate which type of organic matter is the most appropriate assessment measure for biomonitoring of environmental quality status.

ToR #2: Expand the benthic foraminiferal species assignment to distinct ecological categories as a function of organic matter gradients. This will be done regionally to consider the species local ecological requirements. This would help establishing region-specific reference conditions.

ToR #3: Assess the applicability of existing foraminiferal diversity indices [H' and $Exp(H'_{bc})$], sensitivity indices (TSI-med, FSI and Foram-AMBI) and the multi-metric index NQI_f against different types of pressures. This would require defining appropriate reference conditions for each of the indices. By doing inter-calibrations, priority will be given to the best practice when using benthic foraminifera as a biomonitoring tool for environmental health assessments.

ToR #4: Apply the suitability and effectiveness of benthic foraminifera as a tool to assess pre-industrial conditions recorded in sediment archives in order to understand if current environmental settings have potentially degraded or recovered.

ToR #5: Evaluate the correspondence of taxonomic inventories between morphology- and molecular-based analysis. The unassigned molecular sequences will also be screened for ecological signature along organic matter and other impact gradients to expand the range of molecular-based bioindicators. This will contribute to design a molecular-based foraminiferal biotic index.

4. Working Plan

FORAM-ECO will timely accomplish all ToRs over a window of four years (2021-2024). Although they may appear ambitious, the preliminary studies of the FOBIMO initiative and from other researchers provide a solid base for our research. The FORAM-ECO encompasses a number of synergistic activities including networking, data collection, data analysis through collaboration amongst all members and stakeholders, placing data in a global context, dissemination and publication. FORAM-ECO meetings will coincide with relevant international meetings (e.g., Living Forams 2021) to expand the network and engage other researchers (including early-career) and stakeholders (e.g., resource managers, policy makers) in knowledge transfer. Stakeholder engagement and close collaboration is essential to ensure that the FORAM-ECO outcomes are in alignment with management/policy applications.

The ToR#1 will compile studies from multiple sources to review the methodologies used in environmental studies (including molecular techniques) related to sediment characteristics. From this assessment the best protocol, considered the most scientifically sound and cost-effective, will be used. The expertise of all members will help to disentangle these protocols to assess their reliability, reproducibility and timeliness in order to "ground-truth" the best method when coupled with benthic foraminiferal ecological studies (ToR#2). This will require the acquisition of marine sediments from different climate zones (e.g., tropical, temperate) to be tested. Given the present-day geographical coverage of all the members this is a realistic task. Ongoing funded projects by FORAM-ECO members (PREVENT in Sweden, FORESTAT and Foram-INDIC in France, Foraminiferal Barcoding in Brazil, Gulf of Mexico Foram-AMBI in USA) will serve as synergistic platforms to test this method.

The ToR#2 will identify the ecological characteristics of benthic foraminifera, a pre-requirement to test existing and newly developed indices based on these protozoans. A key factor for the success of this ToR is to revise, update, and complement the current species assignments to be used in all the proposed indices (ToR#3) with the ultimate goal of applying its results to determine the categorization of a foraminiferal species as sensitive or tolerant to a type of organic matter. The outcome will be a new, more reliable data set to be tested with current indices (ToR#3), and its translation into EcoQS in marine environments. We will rely on ongoing projects from several FORAM-ECO members to provide supporting ecological data.

To address ToR#3 the FORAM-ECO project will incorporate other stressors that are directly related to organic matter (e.g., bottom water oxygenation, methane) affecting foraminiferal ecology in different climatic regimes. Thus, we will study the proper implementation of critical and promising foraminiferal biotic indices such as the FSI. The FORAM-ECO will develop an extended data set to quantitatively describe the degree of natural vs anthropogenic stressors (e.g., pollutants, temperature, sediment composition). This multi-proxy approach will require the expertise of all members and stakeholders to produce independent recommendations of the parameters to be routinely used in environmental assessments.

This ToR#4 addresses the need of using fossil foraminifera to establish reference conditions that will help stakeholders assess pre-industrial conditions and will help them understand if current risk-management practices are effective. To attain this, the distribution of historical foraminiferal records from sediment archives will be used to trace their natural faunal variability and establish baselines for a direct comparison with modern (impacted) environments. Assemblage changes will then be scrutinized to assess if they are a result from anthropogenic stressors or natural climate variability or a combination of the two. To validate this approach, several foraminiferal biotic indices (ToR#1, #3) will be implemented to distinguish foraminiferal response in areas known to have been historically impacted by human activities and those less affected, also considering that truly pristine sites no longer exist.

To address ToR#5, the FORAM-ECO will engage in cutting-edge science by implementing the use of benthic foraminiferal molecular barcoding next to a traditional morphospecies approach to identify bioindicator species. Recently, much emphasis has been given to the development of molecular based biotic indices, for instance using benthic macrofauna (Aylagas et al., 2014) or bacteria (Aylagas et al., 2017). Environmental DNA studies in benthic foraminifera highlighted that the molecular "signature" of all the species has not yet been determined (e.g., Pawlowski et al., 2016). On the basis of these very promising works, this ToR#5 will focus on (i) complementing existing barcoding of the benthic foraminiferal species that will help bridging the gap between morphological and molecular taxonomy (ongoing projects FORESTAT and Foram-INDIC will serve as data provider platforms) and (ii) design a molecular-based foraminiferal biotic index that will be highly complementary to eDNA.

Timeline summary:

Month 1-12 (2021): Goals to achieve include: (i) kick-off meeting at the Living Forams 2021 (June) workshop in Germany breakdown of the ToR into tasks; (ii) sub-groups to engage in ToR#1-#2; (iii) compilation of published studies; (iv) review of critical protocols and a manuscript draft; (v) initial engagement of stakeholders; (vi) assign working sub-groups based on regional marine environments; (vii) assign a working group for web development and advertising; (viii) discuss leverage funding sources.

Months 12-24 (2022): Goals to achieve include: (i) sub-groups to engage in ToR#3-#5; (ii) second meeting at the FORAMS 2022 International Symposium on Foraminifera (July) in Italy; (iii) discuss data-set generated from ToR#1-#2 and provide feedback and revisions before publication; (iv) continued stakeholder engagement; (v) host a workshop at the FORAMS 2022 meeting.

Months 24-36 (2023): Goals to achieve include: (i) sub-groups to continue work on ToR#3-#5; (ii) third meeting in Eilat, Israel (to be confirmed for June); (iii) host a bioindicator training session the SCOR Visiting Scholar program in Brazil; (iv) sub-groups to discuss data-set generated and all members and stakeholders provide feedback and revisions for ToR#3-#4 to be published; (v) updates on molecular data from ToR#5.

Months 36-48 (2024): Goals to achieve include: (i) sub-groups to continue work on ToR#3-#5; (ii) fourth and final meeting (June) (location to be decided); (iii) host a workshop at meeting; (iv) all members and stakeholders to discuss data-set generated and provide feedback and revisions for ToR#5 to be published; (v) all members and stakeholders to discuss final protocol article (Ocean Best Practices).

5. Deliverables

A. Development of a website to disseminate/publicize FORAM-ECO: [1] selected methods (ToR#1, #3, #5); [2] meetings and workshops; [3] data base for foraminiferal species assignments and molecular data; and [4] training videos about field sampling, laboratory sample processing, and index calculations/interpretations to benefit the early-career scientists and colleagues from developing countries and countries with economies in transition and help in the implementation of the Foram-ECO SCOR WG outcomes.

B. Intercalibrated foraminiferal index which can be applied in marine environments and in different climate zones.

C. Peer-reviewed publications: [1] a review on recommendations on organic matter analysis (ToR#1);[2] a manuscript on the proof of concept [1] when using foraminifera as biotic indices following trends in organic matter composition (ToR#2-3); [3] a manuscript building on the findings of [1-2], will produce a comprehensive list of benthic foraminiferal species assignments (data base) that will be pivotal in the refinement and implementation of foraminiferal index applications (ToR#2-#4); and [4] a manuscript related to benthic foraminifera in molecular work in order to improve foraminiferal species assignments and bioindicators (ToR#5).

D. Dissemination of the FORAM-ECO: [1] attending international meetings to advertise the international efforts of the group; [2] share the website; FORAM-ECO meetings; and [3] attention to colleagues from developing nations to share knowledge/implementation of foraminifera as bioindicators.

E. A final report to be submitted to Ocean Best Practices (*www.oceanbestpractices.net*) in strong collaboration with stakeholders to finalize the standard use(s) of benthic foraminifera in biomonitoring studies.

6. Capacity Building

The overarching goal of FORAM-ECO is to provide accessibility of the methods available to the international community of environmental scientists, with specific emphasis on early-career scientists and including scientists from developing countries (e.g., Nigeria, Brazil). The worldwide scientific cooperation of this FORAM-ECO project will shape and solidify a gender-balanced, refreshed FORAM-ECO community that will enhance the expertise, know-how, outreach and dissemination, of marine environmental studies. The first initiative is to structure the FORAM-ECO community, which started in 2011 with the FOBIMO have created the platform and the conditions required to generate a substantial project, that will promote foraminiferal biomonitoring across the world, beyond Europe. A sufficient number of leading senior scientists as well as early-career investigators, spread across leading European Institutions, seconded by partners from the wide international community, can presently provide the necessary state-of-the-art knowledge, skills and facilities to educate a much larger generation of young scientists.

Capacity building objectives of FORAM-ECO will include:

Promote knowledge exchange among scientists representing a wide spectrum of disciplines (e.g., biology, sedimentology, chemistry, etc.) including stakeholders
(e.g., policy, resource management) outside the academia.
Stimulating experience and sharing the facilities among academia and other stakeholders (e.g., resource managers); many of the shared facilities are usually very difficult to access from outside a formalized network.
Facilitate exchange of expertise between early-career and scientists from developed countries with those from countries with economies in transition and developing nations by organizing meetings and workshops. Young researchers will be strongly encouraged to take active roles in these research initiatives.

Generation of international archives of various foraminiferal species including a contribution to current molecular banks and their ecological categories based on organic matter gradients.
Participation in the SCOR Visiting Scholar program in a developing nation (Brazil) will expand the reach of FORAM-ECO training and communication efforts. The goal is two-fold: (1) to train scientists; and (2) stakeholder engagement (e.g., policy makers, environmental government agencies) in the applicability of FORAM-ECO.

Through these objectives, FORAM-ECO will obtain a fundamental improvement of capacity building, expertise and facilities at a global level – resulting in a recognized international leadership in the field of foraminiferal biomonitoring. These proposed activities are to be held as training events (2 days) during each FORAM-ECO meeting and as a one-week long workshop for the SCOR Visiting Scholar program. In addition, to ensure the longevity of the FORAM-ECO beyond the SCOR, we will partner with the and the International Symposium on Foraminifera (FORAMS) and to hold special workshops to leverage training sessions for young and early-career scientists from academia, government and industry. These leveraging events will bring together not only the Full and Associated members but will also allow the scientific community at large to attend, receive training, learn about foraminiferal biomonitoring and become part of the goals of the FORAM-ECO.

7. Working Group Composition

The FORAM-ECO is composed of researchers from 16 nations including three from the emerging/developing nations of Nigeria, Brazil, and India. In addition, one early-career fellow (Tristan Cordier- Switzerland) is a Full Member and a second one is an Associated Member (Patrick Schwing- USA) in which both will benefit the most as part of their career development. The transdisciplinary expertise of the members of the FORAM-ECO members will add-value to the fulfillment of the proposed ToRs. This FORAM-ECO provides the opportunity for each member to engage in the knowledge transfer of state-of-the-art research fields such as earth science, marine science, sediment and water geochemistry, biotic indices, marine macro- and microfaunal ecology, trace metal chemistry, chemical oceanography, foraminiferal biology and ecology, molecular biotic indices, and experimental culture work among others. The co-chairs, Michael Martínez-Colón (USA), Vincent Bouchet (France), and Orit Hyams-Kaphzan (Israel) will ensure the progression towards the completion of all the deliverables associated to the ToRs.

7.1 Full Members (*: co-chairs; ^: early-career) (50% female)

Name	Gender	Place of work	Expertise
1. Michael Martínez-Colón*	Male	Florida A&M University, USA	Geochemistry, Earth-/Marine Sciences, foraminiferal ecology-/ paleoecology
2. Vincent Bouchet*	Male	University of Lille, France	Biology, ecology, biotic indices, foraminifera, and macrofauna

3. Orit Hyams-Kaphzan*	Female	Geological Survey of Israel, Israel	Marine ecology and paleoecology, Environmental Sciences, foraminifera
4. Silvia Spezzaferri	Female	University of Fribourgh, Switzerland	Taxonomy, ecology, bioindicators, benthic foraminifera
5. Guillem Mateu-Vicens	Male	University of the Balearic Islands, Spain	Biology, foraminiferal ecology/paleoecology, carbonate sedimentology, isotope geochemistry
6. Magali Schweizer	Female	University of Angers, France	DNA barcoding, phylogeography, trophic strategies, exotic species, foraminifera
7. Akira Tsujimoto	Male	Shimane University, Japan	Earth-/Marine Sciences, radiochemistry, sediment chronology
8. Virginia Martins	Female	Universidade de Aveiro, Portugal	Pollution, ecological bioindicators, Earth Science, transitional environments
9. Tristan Cordier^	Male	University of Geneva, Switzerland	Metabarcoding, molecular biotic indices, geneticist, foraminifera
10. Irina Polovodova Asteman	Female	University of Gothenburg, Sweden	Earth-/Marine Sciences, marine pollution, paleoecology/ ecology

7.2 Associated Members (^: early-career) (50 % female)

Name	Gender	Place of work	Expertise
1. Joachim Schönfeld	Male	Helmholtz Centre for Ocean Research, Germany	Marine Science, bioindicator ecology, protocol development
2. Maria Triantaphyllou	Female	National and Kapodistrian University of Athens, Greece	Foraminiferal ecology and paleoecology, Environmental Micropaleontology
3. Silvia Sousa	Female	University of São Paulo, Brazil	Environmental-/Marine Sciences, Foraminiferal paleoecology/ ecology
4. Sigal Abramovich	Female	Ben-Gurion University of the Negev, Israel	Marine biomonitoring and pollution, ocean warming, foraminiferal geochemistry, molecular Phylogeny
5. Rajeev Saraswat	Male	National Institute of Oceanography, India	Environmental-/Marine Sciences, ecology and geochemistry of foraminifera

6. Luciana Ferraro	Female	Italian National Research Council, Italy	Environmental-/Marine Sciences, foraminiferal ecology/paleoecology
7. Patrick Schwing^	Male	University of South Florida, USA	Paleoecology/ecology, foraminiferal geochemistry, radiochemistry, Earth-/Marine Sciences
8. Olugbenga T. Fajemila	Male	Osun State University, Nigeria	Foraminiferal paleoecology/ ecology, Environmental-/ Marine Sciences
9. Sergei Korsun	Male	Shirshov Institute of Oceanology, Russian Federation	Environmental-/Marine Biology, ecology, bioindicators
10. Silvia Hess	Female	University of Oslo, Norway	Environmental impact assessment, marine biomonitoring, marine ecology/paleoecology, Environmental Geology

8. Working Group Contributions

1) Michael Martínez-Colón (co-chair) is a marine biogeochemist who studies the effects of organic matter and heavy metals on the benthic foraminifera in tropical and subtropical climate regions. He combines ecology, ocean chemistry and geology to reconstruct the natural and/or anthropogenic evolution of marine environments. Also has extensive experience in informal teaching (e.g., school teacher workshops).

2) Vincent Bouchet (co-chair) is involved in what drives general benthic foraminiferal diversity and community patterns to assess present and past anthropogenic impacts on foraminifera to answer the following question: Can benthic foraminifera serve as reliable indicators in the context of the implementation of marine legislations? This includes the development of indices based on benthic foraminifera and direct comparison with benthic macrofauna.

3) Orit Hyams-Kaphzan (co-chair) is involved in many aspects of marine biomonitoring. She uses live and dead benthic foraminifera of the Israeli Mediterranean shallow shelf and deep sea as sensitive indicators for anthropogenic pollution or introduction of alien species. She also uses these as an assessment tool for marine national reserve conservation.

4) Silvia Spezzaferri applies benthic foraminifera as biomonitoring tools since 1992 (AVICENNE EU Project) and is one of the founding members of the FOBIMO initiative and members of the steering committee. She participated in the establishment of the standardize method for the studies of benthic foraminifera in soft-bottom sediments (FOBIMO protocol).

5) Guillem Mateu-Vicens has developed foraminiferal biotic indices for seagrass-dominated ecosystems and is engaged in trophic relationships based on isotopic analysis.

6) Magali Schweizer combines DNA barcoding and morphological criteria to identify benthic foraminiferal species more accurately. She also studies the phylogeography of this group to identify endemic, cosmopolitan and human introduced species and the trophic strategies of foraminifera to better characterize their ecology.

7) Akira Tsujimoto is a benthic foraminiferal specialist in Japan and will provide Asian examples on the relationship between benthic foraminifera and organic matter.

8) Virginia Martins uses meiofauna to establish ecological indicators given special attention to the response of living benthic foraminifera, to various types of pollution such as eutrophication and heavy metal pollution among others. She also engages in establishing ecological descriptors for paleoenvironmental (baseline) reconstructions.

9) Tristan Cordier is a benthic foraminiferal molecular biologist that combines environmental genomics and machine learning to develop a new framework for the monitoring of marine ecosystems health under anthropogenic pressures.

10) Irina Polovodova Asteman studies several aspects of environmental change in coastal regions such as climate change, coastal hypoxia, ocean acidification, pollution and introduction of alien species. In particular, using foraminifera as proxies for establishment of alien species, marine pollution and temporal changes within marine protection areas such as national parks are directly related to marine conservation topic.

9. Relationship to Other International Programs and SCOR Working Groups

9.1 No association with current/past SCOR WG

The initiative proposed by our FORAM-ECO is unique in terms of using benthic foraminifera as the taxonomic group for bioindicator monitoring. Previously, only planktic foraminifera was proposed to be used as a proxy for ocean chemistry by WG-138. FORAM-ECO will for the first time incorporate the application of benthic foraminifera within SCOR WG.

9.2 COST Action 15219- Developing new genetic tools for bioassessment of aquatic ecosystems in Europe (www.dnaqua.net)

This international working group is engaged in the development and application of modern molecular techniques to be used in environmental health assessments of marine environments to determine its ecological status. Networking and collaborating with their WG2 titled “Biotic Indices and Metrics” will benefit our ToR#5 activities and deliverables since both aim towards the development of new genetic tools for bioassessment. We anticipate having them co-host our final meeting in 2024.

9.3 foramBARCODING working group (www.forambarcoding.unige.ch)

This working group will be valuable in providing an independent source of foraminiferal barcoding results of our ToR#5.

9.4 International School of Foraminifera (ISF) (*www.isf.tmsoc.org*)

The ISF offers a summer course every year to train researchers from academia and industry (oil) in the fundamentals of foraminiferal biology and ecology. This will be a great opportunity collaborate with ISF to implement in their program the uses and applications of the indices developed by FORAM-ECO in their training session (Capacity Building) on foraminiferal bioindicator ecology.

9.5 Water Framework Directive (Marine Directive) (www.*ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm*)

Data and studies generated by FORAM-ECO related to organic matter pollution, bioindicator ecology, and inorganic contaminant (e.g., heavy metals) will supplement the data base of the Marine Directive. In addition, this will provide an avenue to share our finding in alignment with the Marine Directive which can help in reaching local stakeholders based in individual countries.

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11. Appendix (5 peer reviewed articles/Full Member)

1) Michael Martínez-Colón

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2) Vincent Bouchet

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4) Silvia Spezzaferri

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ETHOS: Elucidating THreats tO Sandy beaches: a global synthesis

Summary/Abstract (max. 250 words)
The WG intends to gather expertise from different contexts and experiences to elucidate a full picture of the current threats to sandy beaches, extracting viable methods for their monitoring and providing guidelines towards interoperable datasets, finally allowing the scientific community to target threats to sandy beaches on a background of cooperative research. The present situation is in fact characterized by a scatter of data, which do not allow for the synthesis of global patterns in terms of spatial and temporal trends. These trends would indeed be key to face threats to sandy beach functionality posed by human-driven impacts, which often act synergistically. On the other hand, the local dimension is essential for understanding patterns and drivers of this ecosystem. The identification of shared methodologies is therefore key to the study of such multi-dimensionality, allowing also for the progressive integration of a) emerging threats and b) research from different disciplines. To reach its goals, the WG will proceed by aggregating the best available datasets and learning lessons from related methodologies; expanding the research queries with inputs from a representative range of areas and disciplines; accompanying the threats identified with methods for the study of their single and synergistic effects. Actions will hold a strong component of capacity-building by pairing WG meetings with international conferences. Outputs will be open access and accompanied by a communication plan to sustain their broad use and ensure a long-lasting effect of WG contributions.

Scientific Background and Rationale (max 1250 words)
Sandy beaches are globally distributed ecosystems that underpin a diversity of locally and regionally important ecosystem services. These systems are at the land-sea interface and support biodiversity by providing sites for nesting (e.g. turtles), spawning (e.g. fish), foraging and resting (e.g. migratory birds). Additionally, beach sediments filter seawater and cycle nutrients, while sediment, beach-cast wrack and dune systems provide natural shoreline protection. Yet, despite their ecological significance, the ecological functions of sandy beaches are underappreciated, with many considered solely as tourist destinations and recreational assets. Most sandy beaches are managed primarily with respect to their recreational value, and without a strong evidence base on which to assess the efficacy of interventions. (Dugan et al, 2010).
As a consequence, beaches are among the most threatened marine ecosystems due to the combined effects of coastal development and climate change, causing a “squeeze” (Elliott et al., 2019) between increasing urbanization on the landward side and erosion and sea-level rise on the seaward side. This threat is often exacerbated by maladaptive management approaches such as the construction of coastal defense structures (e.g. seawalls, breakwaters) that prevent shoreline retreat in response to sea level rise. At local scales, beaches are also subject to a suite of stressors, including beach cleaning, trampling and off-road vehicle use, plastic and light pollution, nutrient enrichment and unsustainable fisheries management practices. The research on sandy beach ecosystems is, at present, hampered by a lack of a mechanistic understanding of how sandy beaches respond to individual and multiple stressors at scales of meters to 100s of kilometer. The lack of a clear framework depicting to which extent these stressors could threat sandy beach functionality is a severe gap.
Although a number of paradigms regarding the physical and biological processes that structure sandy beach ecosystems have been put forward, the support for these comes primarily from microtidal Southern hemisphere beaches with fine-to-medium sand (McLachlan and Defeo, 2018). Hence, their widespread applicability remains unknown. Other literature points to sandy beach ecosystems displaying considerable small-scale variation in their response to environmental change (Defeo and McLachlan, 2013; Barboza and Defeo, 2015). Research is urgently needed that addresses the response of sandy beach ecosystems to multiple stressors, acting singly or synergistically, with

acute or chronic characteristics, over different time scales at local (single-beach unit) to landscape scales.

In order to address multiple-stressor impacts there is firstly need to comprehensively catalogue the full range of stressors to which sandy beaches are exposed, and the scales at which they act. Although a number of reviews on threats to sandy beaches have been conducted over the years (Defeo et al. 2009, Elliott et al. 2014; Fanini et al., 2020), these have primarily focused on climate-change as a driver of beach habitat loss (see Vousdoukas et al., 2020). Stressors associated with climate change need to be integrated with emerging issues such as plastic pollution (Borja and Elliott, 2019) and urbanization-related impacts (e.g. Artificial Light At Night, ALAN), providing a complete and up-to-date framework for research on threats physically eroding the functionality of beaches.

Secondly, there is need to ascertain the scales at which impacts occur for single and multiple co-occurring stressors. Defining the generality of stressor impacts and the scales at which they are apparent is hampered by variation among studies in the way in which units (e.g. beaches) are defined, making cross-study comparisons difficult. Additionally, most of the available literature examines impacts across relatively short time scales, with only few studies encompassing larger spatial and temporal scales (see e.g. Dugan et al., 2013). Despite several papers now putting forward hypotheses about how impacts may propagate across scales (Heery et al., 2014; Scapini et al., 2019) and calls to examine impacts of stressors at the landscape scale (Schlacher et al. 2015), large-scale studies remain rare. Experimental (rather than observational) and mesocosm studies, together with increasing use of molecular and telemetry approaches, provide opportunities for scaling up impact assessments, yet these approaches are rarely applied to sandy beach studies.

A further challenge is that global knowledge of how stressors impact sandy beaches remains limited to a relatively small sub-set of stressors. While the impacts of direct human use of beaches (e.g. trampling, beach cleaning, off-road vehicles, shell-fishery) and of actions to counteract erosion (e.g. nourishment, construction of hard coastal defenses) are relatively well understood, impacts of emerging stressors are not. Studies on plastics remain dominated by those quantifying debris on beaches, rather than the biological impacts of this debris. Predictions, based on research from other ecosystems, as to how artificial light pollution might affect the behavior and food webs of sandy beaches, are yet to be tested. Although these (and other) stressors have been overlooked, it does not mean that they are any less important. For example, oil spills usually generate short-term investment in clean-up efforts and impact assessments, but their impacts are rarely assessed over longer time scales. Other impacts are severe but localized (e.g. sewage discharge) and the lack of research groups active on the topic at the specific location leaves them invisible to the scientific community.

Indeed, synthesizing research and methods related to the more commonly studied stressors (e.g. beach nourishment) may offer insights about standardized, cost-effective methods and indicators of impact assessment on beaches (see e.g. Peterson and Bishop 2005) that could be applied to the study of other stressors. These reviews of beach responses to individual, well-studied, stressors may also allow the formulation of hypotheses about the scale of impacts of unstudied stressors and how multiple stressors act synergistically.

This WG will (1) develop a comprehensive catalogue of threats to the ecosystem function of sandy beaches and the scales at which they act, (2) compile existing knowledge of stressor impacts to sandy beaches and the methods used to assess them, and (3) integrate this information to develop a framework for progressing our global understanding of how sandy beaches respond to multiple stressors, at a range of spatial and temporal scales, and across a diversity of environmental and socio-economic settings. The outcomes will include a set of protocols which can be used globally, across beach types, to assess the scales at which stressors impact sandy beach ecosystems. These protocols will consider current paradigms and hypotheses, and integrate cutting edge technologies (telemetry, molecular biology, remote sensing) derived from a diversity of disciplines.

This coordinated research effort is expected to provide interoperable data and thoroughly address questions related to changes in beach functionality, finally reconnecting theoretical hypotheses with field and experimental research (Benedetti-Cecchi et al., 2018), thereby generating results of global relevance.
To structure the work around this goal, two main strategies are fundamental:
A multi-scale approach, with both threats and best practice management considered at local (single beach), landscape, and regional scales
The matching of drivers to specific spatial scales (a distal driver at local scale can be a proximate driver at landscape scale; cross-habitat phenomena such as plastic pollution need to be considered in this light too). This will be achieved using existing data sets and the expertise of WG members.
This SCOR WG will for the first time bring together sandy beach ecologists from across the world. While a number of WG and networks are already in place, they are regional (e.g. European or Latin America level) and so lack a global perspective. A communication and implementation plan will be drafted at a nearly stage of working group activities, allowing the outcomes of the project to be broadly distributed and incorporated with existing and prospective research,now and into the future.

Terms of Reference (max. 250 words)

ToR 1: To identify key threats to the ecological function of sandy beaches, and classify these according to a) their spatial and temporal scale and b) their provision of acute or chronic perturbations. This will include: identifying multiple stressors that may act synergistically, identifying appropriate scales of analysis for beaches, exploring methods for mapping the distribution of key threats across a range of spatial scales.
ToR 2: To effectively disseminate knowledge gained through WG actions to a diversity of stakeholders, globally. A multi-level dissemination plan will be prepared in the early stages of the project.
ToR 3: To carry out a broad survey, through online consultation open to the entire community of researchers working on sandy shores, to identify and assess the efficacy of methodologies that have been applied to study ecological impacts of stressors to sandy beaches and eventually rescue grey literature. This will also facilitate the establishment of a network of users for protocols generated by the WG.
ToR 4: To develop a standardized protocol for assessing threats to sandy beaches, that can be applied globally as well as at regional scales. The protocol will identify key ecological and physical variables to be measured, the scales at which they should be assessed, and will be developed following a review of existing datasets and methodologies.
ToR 5: To identify and harmonize research directions of global-to-local relevance based on an analysis of the efficacy of methodologies used to generate existing datasets, while incorporating the survey results, highlighting integrative approaches.
Working plan (logical sequence of steps to fulfil terms of reference, with timeline. Max. 1000 words)

The proposed time-line for meetings and completion of ToRs (i.e. with the finalization of the related deliverables) is reported below, in months from the beginning of the WG activities.

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Y1	Meeting1				Virtual thematic meeting1						ToR1	ToR2
Y2		Meeting2					Virtual thematic meeting 2			ToR3		
Y3	Meeting3		ToR4			Virtual thematic meeting 3						ToR5

WG activities will span 36 months.
Annual WG meetings, held at the beginning of each project year, will be utilized to plan the work towards each ToR, and delegate responsibilities and tasks to WG members. These will be complemented by virtual thematic meetings (of relevance of particular regions or disciplines) which progress specific ToRs. The composition of thematic meetings will be decided at the WG meeting 1.
The dissemination plan (ToR2) will be drafted at the end of year1, setting the background for the survey (ToR3) and for the up-take of WG deliverables. The proposed timing is defined by the fact that the WG will be showcased by the deliverable related to ToR1, supporting the vision and the actions of the WG.
The WG meetings will, where possible, be held back-to-back with international events (e.g. major conferences) that WG members are expected to attend. This will minimize travel costs and maximize the opportunity for capacity building and dissemination of WG activities through these international events. Details on these events, with which WG might be coupled, are provided below. Please note, however, the events are indicative, as many are on hold (e.g. the IX International Sandy Beaches Symposium) or being rescheduled due to the Covid-19 pandemic. Also, we are aware that funding to research groups and networks is uncertain at this time. Irrespective of travel restrictions or funding shortfalls we believe that the deliverables can be completed in the time-frame indicated.
Given the present Covid-19 situation, its short and mid-term effects on the international travel it is anticipated that WG meetings may need (at least partially) to occur via online platforms. The Spanish participant will provide the commercial Zoom license necessary to host online meetings, and the Greek participant can apply for the use of the remote conference room (an infrastructure planned for meetings between HCMR institutes and field stations across islands). Should the meetings listed below be cancelled or postponed, back-up options will be developed and communicated in a timely manner. The community consultation underpinning ToR3 will be performed online using questionnaires developed by the chairs with feedback from WG members. As a starting point, the relevant community of global sandy beach researchers to be contacted will be identified using the mailing from the XIII International Sandy Beaches Symposium, to which full and associate WG members will add personal contacts.
WG meetings are planned to be held back-to-back with:
International Sandy Beaches Symposium, Oldenburg, Germany, 2021 dates TBC (WG meeting 1)
ASLO Ocean Sciences Meeting, Honolulu, Hawaii, USA, February 27-March 4, 2022 (WG meeting 2)
Estuarine and Coastal Sciences Association (ECSA) meeting 2023, dates TBC (WG meeting 3). As the WG will be entering its third year, the possibility of contributing a symposium or special session to the meeting will be explored.
The work will be coordinated by the chairs, using online meeting platforms as the main channel for collaborating on and coordinating actions. Chairs will be in charge of communication with the SCOR secretariat about yearly reporting, as well as meeting planning. Chairs will also be in charge of balancing the general and thematic perspectives, and promoting the adoption of research protocols and practices to participants. The dissemination plan will be shared among all participants and all those who, during the consultation, expressed interest and capability in adopting the protocols and practices proposed. The plan will be periodically (at WG and node meetings) revised and updated.

Deliverables (state clearly what products the WG will generate. Should relate to the terms of reference. Max 250 words).
The actions of the WG are expected to result in the following deliverables:
D1. One open access publication in the target journal, Journal of Marine Policy (related to ToR1).
D2. One protocol detailing methodologies that can be applied to the assessment of stressor impacts at the global and regional scale (derived from ToR3 and ToR4), developed using information derived under ToR1. To be uploaded on Ocean Best Practices platform, obtaining a doi. To be topic of a webinar or integrative course for graduate students.

D3. One best practices manual (derived from ToR3 and ToR4), to be considered a reference for training (targeting secondary and tertiary students, as well as citizen science groups), that is framed around scientific research questions (related to ToR 3 and ToR4). To be uploaded on Ocean Best Practices platform, obtaining a doi.
D4. One open access publication in the target journal, Science of the Total Environment, or Global Ecology and Biogeography (related to ToR5), with links to protocol and best practice manual (D2 and D3).
Note: ToR2 in itself is not producing a deliverable such a paper in a journal or a manual. However we consider it essential to have a strategy for disseminating the outcomes of this WG and building a network of users of these.
Capacity Building (How will this WG build long-lasting capacity for practicing and understanding this area of marine science globally. Max 1500 words)

This WG will build international capacity in sandy beach ecology and management by:
including early career researchers
This will be achieved through: strong representation of ECRS in the WG; a webinar or course for tertiary students (training next generation) about Threats to Sandy Beaches, likely within the graduate program of Coastal and Ocean System (*http://www.cem.ufpr.br/portal/cem_english/*), with Dr. Di Domenico as coordinator.
2) establishing a peer-to-peer learning environment among WG members of diverse backgrounds and experiences, and between the WG and the community of sandy beach researchers and managers more broadly
This will be achieved through: diversity in the composition of the WG; surveying the broader research community on their research perspective to build collective wisdom; pairing meetings with conferences and major international meetings, proposing the topic as a thematic session at conferences [ECSA, WG meeting 3]; sharing the outcomes of the WG with the broader community of sandy beach researchers and managers; building a network of researchers that are ready to capitalize on future funding opportunities
3) developing best practice guides and protocols, that are freely available.
This includes: identifying cost-effective and robust methodologies that are broadly applicable; identifying opportunities for citizen scientist and school participation in field programs; making publications and manuals open-access.

Working Group composition (as table).
Full Members– chairs in bold. Asterisks indicate early career researchers.

Name	Gender	Place of work	Expertise relevant to proposal
1 Lucia Fanini	F	Crete, Greece	Behavioral Ecology, non-oceanic beaches
2 Omar Defeo	M	Montevideo, Uruguay	Ecology of sandy shores, fishery
3 Vanessa-Sarah Salvo	F	Barcelona, Spain	Plastics monitoring and regulation, science-to-policy communication, survey methodology
4 Leonardo Costa*	M	Rio de Janeiro, Brazil	Bioindicators, ghost crabs, REBENTOS network

5 Melanie Bishop	F	Sydney, NSW, Australia	Ocean sprawl, urbanization, World Harbour network
6 Linda Harris*	F	Port Elizabeth, South Africa	Marine conservation and management, spatial coastal ecology, Marine Spatial Planning
7 Kyle Emery*	M	Santa Barbara, California, USA	Nutrient cycling, Long Term Ecological Research Stations
8 Shinji Sassa	M	Yokosuka, Japan	Beach geophysical environment and coastal disasters
9 Maikon Di Domenico	M	Curitiba, ParanàBrazil	Anellidae, MBON-P2P protocol
10 Michael Elliott	M	Hull, UK	Coastal and estuarine ecology, human impacts

Full members of the WG have been selected from the pool of global experts on sandy beach ecology in accordance with the following principles:
The members come from geographically dispersed countries, from across the globe, which collectively cover the full spectrum of beach geomorphology (i.e. micro- to macrotidal beaches) and biogeography, as well anthropogenic modification (e.g. Rio de Janeiro and Sydney harbor to Southern Crete Marine Protected Areas), and whose jurisdictions offer a spectrum of approaches to beach management.
The expertise of the group spans sandy to shingle beaches, island, coastal and estuarine beaches, and highly disturbed to protected beaches.
The researchers lead or represent (in the case of early career researchers) research groups with a strong track-record of studying human impacts to marine ecosystems, and especially to sandy beaches (e.g. impacts of coastal development, beach cleaning, coastal protection).
The members are part of global research networks, which will benefit from this project (e.g. MBON-P2P, Dr. Di Domenico; World Harbour Project, Dr. Bishop; Marine Litter Watch, Dr. Salvo).
The membership includes expertise in beach management (e.g. the experience of Dr. Linda Harris along the South African coast, or the LTERs in California).
The group is inclusive of early- and mid-career researchers, as well as senior researchers, and has a gender-balanced composition.
Associate Members have been selected based on their expertise in fields (e.g. Dr. Mendez, invasive species); the use of stable isotopes to track trophic connectivity of organisms and organic matter between the beach and the coastal subtidal areas (Dr. Rossi) or methodological approaches of relevance to, but often overlooked, in the study of sandy beaches. For example, the field of Artificial Light At Night (Dr. Maggi) is of relevance to urban beaches, but is seldom considered in their study. Ecological approaches in the field (Dr. Li) provide potential for examining impacts of stressors on connectivity but are rarely applied to sandy beaches. The interoperability of data among disciplines and studies will be addressed at the whole WG level through the inclusion of a modeling expert (Dr. Bozzeda). Dr. Riechers will provide expertise in considering stressors and impacts as proximate and distal drivers in social-ecological systems. The group as a whole will hold expertise to confirm causal relationships between drivers and responses observed at different scales.

Associate Member

Name	Gender	Place of work	Expertise relevant to proposal
1 Francesca Rossi	F	Nice, France	Trophic ecology, experimental ecology
2 Elena Maggi	F	Pisa, Italy	ALAN pollution in coastal environments , GLOW network
3 Yoshitake Takada	M	Chuo, Niigata, Japan	Benthic ecology, islands
4 Maraja Riechers*	F	Lueneburg, Germany	Social-ecological systems, leverage points
5 Xinzheng Li	M	Qingdao, China	Taxonomy, benthic ecology
6 Fabio Bozzeda*	M	Valdivia, Chile	Mathematical modeling, machine learning
7 María Mendez	F	Puerto Madryn, Argentina	Impacts related to human recreation, Invasive species

Working Group contributions (max. 500 words)

As the local dimension is extremely relevant, each participant's expertise related to local environment and people attitude is considered a unique contribution in itself, key to the local-regional dimension.

Lucia Fanini has been researching for over a decade the beaches of the Mediterranean, testing ecological paradigms, assessing human impacts and integrating them with an ethology perspective. She was host of the most recent International Sandy Beaches Symposium in Crete (May 2018).

Omar Defeo has been working on sandy beach ecosystems for the last 35 years. His long-term research evaluates the effects of human activities on sandy beaches, including global effects driven by climate change stressors.

Vanessa-Sarah Salvo has been in charge of large NGOs, managing projects of environmental protection and being part as expert of working groups including the Marine Litterwatch group of European Environmental Agency and the Spanish node for the Marine Strategy implementation. As experienced in knowledge communication she will support the survey and dynamization of information of the WG and its deliverables.

Leonardo Costa carried out research along an urbanization gradient of the Rio de Janeiro coastline, with a main focus on bioindicator species. He is testing the application of conservation biology principles to sandy beaches and his work is aligned with the REBENTOS network in Brazil.

Melanie Bishop has over 15 years of experience studying sandy beaches in Australia, and the USA, using a combination of large-scale field sampling and small-scale field and mesocosm experiments. She is leader of the Green Engineering Working group of the World Harbour Project, a global network of collaborating scientists researching and managing urban harbours, and in this capacity has lead global syntheses and experiments addressing stressors to marine systems.

Linda Harris is specializing in spatial coastal ecology, conservation and management, particularly for beaches, with expertise in Ecologically or Biologically Significant Marine Areas (EBSAs), spatial prioritization to support Marine Spatial Planning and Integrated Coastal Zone Management. She leads the Coastal component of South Africa's National Biodiversity Assessment.

Kyle Emery's dissertation research is focused on sandy beach community ecology and ecosystem functions. He is part of the US Long Term Ecological Research program and as part of Prof. Jennifer Dugan's research group has contributed to several ecological synthesis projects.

Shinji Sassa is Head of Soil Dynamics Group and Research Director of Asia-Pacific Center for Coastal Disaster Research at Port and Airport Research Institute. He will bring to the group expertise on the role of the geophysical environment in sandy beach ecology and hydro-geodynamics based coastal disaster prevention and mitigation.

Maikon Di Domenico is coordinating the working group for the development of a Sandy Beach protocol within the MBON-P2P. His research targets the use of marine organisms, especially macrofauna and meiofauna, as adaptive-biological models by applying different methodologies, including morphology, genetics, and ecology.
Michael Elliott has extensive knowledge of coastal and estuarine systems and human impacts. He will supervise the synthesis of the WG activities towards the outcomes, placing them in the global context of research on coastal environments.
Relationship to other international programs and SCOR Working groups (max. 500 words)
The contacts established with the SCOR executive committee for the preparation and submission of the proposal will be kept tight to enhance the collaboration and mutual support of research programs, current and prospective.
The WG members are involved in a range of initiatives and networks, at global and regional scales, which will sustain and promote the activities of the WG: the Marine Biodiversity Observation Pole to Pole (P2P) involving marine scientists collaborating to understand changes in biodiversity of coastal ecosystems of the American continent *https://marinebon.org/p2p/* , the World Harbour Project (a network of researchers and managers representing 27 harbour cities around the world, *http://www.worldharbourproject.org/*), the MarineLitterWatch action of the European Environmental Agency *https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch* , the global GLOW network for the study of light pollution at night *https://www.euromarinenetwork.eu/activities/emergent-impacts-coastal-areas*. Also networks at local scale will result reinforced by the actions of the WG such as the Long Term Ecological Research Stations network in the USA, the coastal benthic habitats monitoring network (REBENTOS, *http://www.rebentos.org/* in Portuguese) and programs for citizen science being developed in Rio de Janeiro and on the Mediterranean coast (CNRS Nice Antipolis), at the local scale. All these would support and get mutual benefit from the actions of the WG, progressively including participants from other areas and serve as example to promote the building of networks covering areas where the attention to sandy beaches is still low.
The WG co-chair Lucia Fanini is part of the program for the development of basic sciences in Uruguay (PEDECIBA, *http://www.pedeciba.edu.uy/indice.php* in Spanish), established in 1986 to act as a platform sustaining high level scientific investigation. The co-chairing with Omar Defeo will therefore be framed within and supported by the PEDECIBA, being in compliance with the program's objectives of consolidation and innovation of the scientific research through collaborations with foreign researchers.
The early career researchers involved in the group are expected to promote the WG activities to their respective research groups, each of which are fully supportive of their participation in the WG. Finally, we intend to explore the possibility of integrating proposed protocols with the actions of the Cientificos de la Basura through Dr. Martin Thiel, who was also part of the SCOR WG 153 "FLOATSAM". The role of beached litter in modifying transitional beach ecosystems would add to their perspective on litter circulation.
The dissemination plan, included within the WG ToRs, will be planned to specially tackle the relationships of the WG actions and outcomes to other programs, maximizing their effects. Platforms such as the Ocean Best Practices platform *https://www.oceanbestpractices.net/* and the EU platform on citizen science *https://eu-citizen.science/* , just made live, will be used for dissemination of WG deliverables, which will receive a doi and remain citable yet open access.

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Appendix

For each Full Member are here reported 5 key publications related to the proposal. Members are listed in alphabetical order by surname:

Melanie Bishop

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InterSEEP: Integration of international ocean acidification research at CO2 seeps

Summary

Ocean acidification (OA) is caused by the uptake of anthropogenic carbon dioxide (CO_2) and its effects on ocean chemistry are well understood. Most OA research has been conducted in laboratories and mesocosms, which isolate organisms from their environment, so the effects of OA on marine communities, species interactions, food web structure, and on ecosystem services are poorly known. Over the past 10 years, the study of shallow marine CO_2 seeps has emerged as a powerful tool to address this knowledge gap, to assess effects of OA on coastal ecosystems. This research community remains fragmented internationally, with a lack of capacity to study CO_2 seep systems in developing nations, so the time is right to form an international forum to exchange knowledge and coordinate efforts.

This working group will coordinate interdisciplinary international studies using natural gradients in seawater pCO_2 worldwide to analyse current data available, plan *in situ* observations, agree a set of standard techniques for work in seeps, and establish a foundation for long-term capacity building. A new global research community will be formed for the exchange of scientific information, to share new technologies/facilities, and to coordinate programs that no single nation can achieve alone. InterSEEP will also strengthen the voice of shallow CO_2 seep researchers worldwide during the UN World Ocean Decade, providing syntheses for policy makers and a legacy through training scientists worldwide.

Scientific Background and Rationale

Atmospheric pCO_2 will almost certainly double from pre-industrial levels by 2100, higher than at any time during the past few million years.[1] CO_2 emissions have caused a 26% increase in [H+] in surface ocean waters since the early 1900s, with a projected drop in seawater pH of up to 0.5 units by 2100.[1] Additionally, increased air-sea heat flux and altered circulation patterns have led to significant warming of the global ocean, while extreme warming of seeps has also intensified in many regions.[1,2] The combined stressors of ocean acidification (OA) and warming are a major threat to marine ecosystems and the goods and services they provide (e.g., food provision and security, coastal defence, mitigation of climate change-blue carbon).[3] However, current understanding of how marine ecosystems will respond to climate change remains severely limited, which restricts our ability to predict and manage for further change.[4] Currently, the only forum that attracts OA scientists to meet on a regular basis are the symposia on The Ocean in a High-CO_2 World every four years, and that this frequency of meeting is not often enough to achieve needed planning and coordination in the CO_2 seep community. This proposal aims to bring together the resources of the global community of CO_2 seep scientists to address important OA research issues, and is explicitly linked to the UN Sustainable Development Goal (# 14.3), which aims to better understand the impacts of climate change on marine ecosystems.

The vast majority of our current understanding of how marine biota will respond to climate change stems from experiments conducted in tanks and mesocosms.[5,6] While these controlled manipulations are useful, they suffer from a lack of realism, as natural populations are influenced by abiotic and biotic processes that operate over multiple spatial and temporal scales.[5] Conversely, the majority of research on the impacts of climate change stems from long-term time series, which document ecological change, but do not generally elucidate underlying causative mechanisms.

Researchers around the globe have begun utilizing existing natural gradients in climate variables to conduct 'space for time' substitution experiments to examine how increased temperature and pCO_2 will likely influence ecosystem services for mankind[7–9]. This approach offers increased realism and inference because (i) marine communities found under the different environmental conditions are naturally assembled, complex and shaped by species interactions; (ii) environmental variables (both climate and non-climate related) exhibit 'real' variability patterns; and (iii) populations and communities have been exposed to the different environmental conditions for periods of time (decades to many centuries) that far exceed that of laboratory experiments. Recent work using spatial gradients (usually latitudinal) in temperature has shown that continued ocean warming will likely lead to changes in primary productivity, decreased resilience to physical disturbance and increased grazing pressure within many habitat types.[10] Similarly, research using CO_2 seeps as natural analogues has shown that OA will likely cause shifts in the relative abundance of calcifying organisms and changes in community structure and biodiversity.[7–9] Furthermore this kind of ecosystem can be found around the globe (Fig. 1). There are other natural analogues for ocean acidification, like upwelling areas, but this proposal is focused on seeps as they allow the study of chronic exposure to high CO_2/low pH conditions. The benthic communities within them are exposed to this form of CO_2 injection for decades which cannot be reproduced in the lab or in upwelling zones.

Of the research focused on CO_2 seeps so far, there have been several high-impact publications.[9,11,12] We feel the time is ripe to create a holistic global synthesis of lessons learned to date and to map future strategies to maximize the use of natural analogues for ocean acidification. Therefore, we propose the creation of a global network of researchers working on CO_2 seeps to create open-access data resources, synthesize the impacts of variability in carbon chemistry, design global joint experiments, develop internationally agreed best practices for data acquisition and build capacity internationally, with an emphasis on developing countries. This proposal is designed to provide a unified forum for shallow CO_2 seeps researchers worldwide.

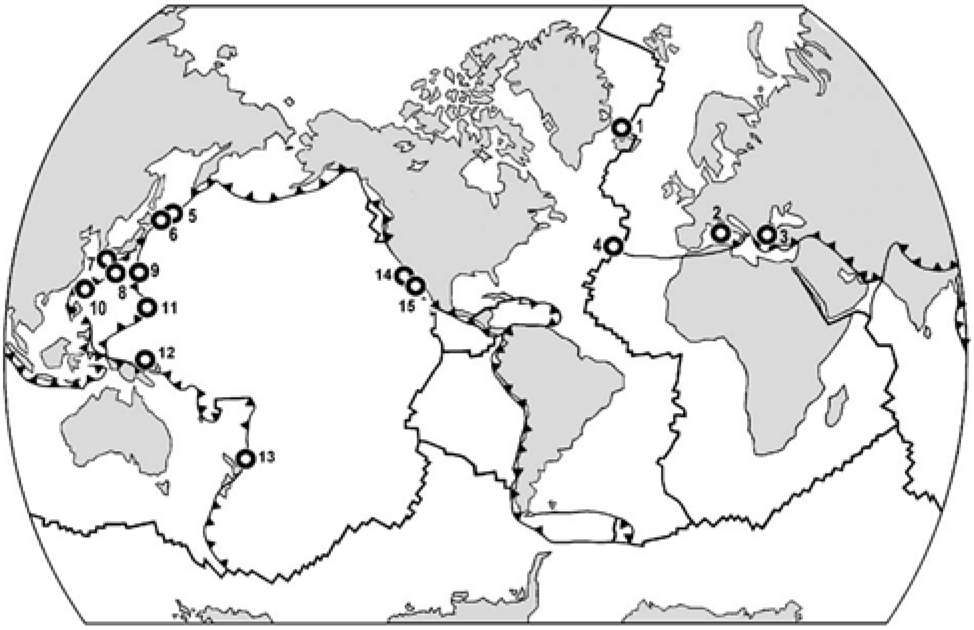

Figure 1, latest map from a peer reviewed publication with the location of shallow seeps.- Areas of shallow-water (<200 m) hydrothermal seeping with known data on biota up to 2005. 1 — Kolbeinsey, 2 — Tyrrhenian Sea (Capes Palinuro and Messino, Baia Pozzuoli, Aeolian Islands), Columbretes Islands 3 — Aegean Islands Santorini and Milos, 4—D. Joao de Castro Bank, Azores, 5— Ushishir Island, Kuril Islands, 6 – Kunashir Island, Kuril Islands, 7— Kagoshima Bay, 8 —Tokora and Iwo Islands, 9— Nishino-shima Sintoh, Ogasawara Islands, 10 — Kueishan Is., Taiwan, 11 — Esmeralda Bank, Mariana Islands, 12 — Matupi Harbour, New Britain Island and Tutum Bay, Ambitle Island, Papua New Guinea, 13 — Bay of Plenty, New Zealand, 14 — White Point, Palos Verdes, California, 15 — Punta Banda and Punta Mita, Baja California. From Tarasov[13]

Terms of Reference (ToR)

To create an open-access data resource based on research made at CO_2 seep sites globally.

Build, based on the observations made in the CO_2 seeps, on an emerging synthesis[7] of the impacts of carbon chemistry variability on marine ecosystems and the goods and services they provide.

To produce a peer-reviewed perspectives article on future seep research, identifying what kind of research is needed and in which locations. Emphasis will be given to a) benthic and pelagic diversity, abundance and biomass; b) sea food quality; and c) resilience of coastal habitats to ocean acidification and temperature increases.

To share knowledge and transfer skills for surveys and experiments, laboratory analysis and data management, in order to build capacity in developing countries.

To develop a document of internationally agreed best practices for data acquisition, standardized output formats and archiving for surveys and experiments that harness the advantages of CO_2 seep research and outreach.

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

Year 1.- February 2021

A kick-off meeting will be led by Ecuador to begin addressing TORs 1-5. The format will depend on social distancing and travel regulations in place at that time.

Goal for ToR 1 at this meeting.- Determine what data are currently available in what format, propose how to structure data, determine what data can be uploaded into the database, and design a Data Team.

One-day session. Participants will be contacted before the workshop and asked to complete a survey where they will state which data they could contribute and its structure.

The working methodology is:

Presentation of the Sustainable Development Goal 14.3.1 in order to have all participants aware of expected data quality and format to be used.
Presentation of the results of the survey of WG members on available data.
Form small groups, based on the expertise of the Working Group members, which will focus on each kind of data in order to propose specifics ways to structure the data.
Each group will present in 15 minutes their proposal for the data structure and will receive comments of all participants.
Designation of a Data Team within the members of the working group, which will be in charge of developing the dataset.
A summary of the proposed methodology.
Design a follow-up plan to develop the database.

Goal for ToR 2 at this meeting.- To create a draft with the structure of a synthesis paper.

One-day session. Before the Workshop, all participants will be asked to create a 10-minute presentation with their current work and results. The presentations will be held at the beginning of the day in order to show the state of the science on CO_2 seeps. The working methodology is:

Presentation of participant's research and results.
Presentation of general guidelines of the content of the synthesis paper.
Separate in work groups to modify/improve the proposed guidelines.
Presentation of work groups' ideas.
Brainstorming to define the structure and content of the synthesis paper.
Designation of a Synthesis Paper Coordinator.
Design a follow-up plan to develop the paper.

Goal for ToR 3 at this meeting.- Design research strategies, with general and specific objectives, plus methodology, for a peer-reviewed perspectives article.

One-day session. Based on the expertise and interest of each participant, the attendees will be separated in small work groups to design research strategies and perspectives with emphasis on each of the ToR's scopes. The working methodology is:

Separate in work groups to design research strategies for each experimental focus.
Presentation of work groups ideas.
Brainstorming to define final content of each approach.
Designation of 3 Research Strategy coordinators, one per topic.
Define collaborators for each Research Strategy.
Design a follow up plan to develop each Research Strategy.

Goal for ToR 4 at this meeting.- Planning of Capacity building event.

One-half day will be devoted to this goal, discussing the following topics:

Decide what capacity will be built at the following year's meeting.
How it will be test/use the best practices manual.
How funding will be raised for the event.

Goal for ToR 5 at this meeting.- To create a draft with the structure of the Best Practices handbook.

One-day session. Before the Workshop, all participants will receive a document with bullet points and a tentative structure of a Best Practices handbook, plus reference material. The working methodology is:

Presentation of general guidelines of the content of the Best Practices handbook.
Separate in work groups to modify/improve the proposed guidelines.
Presentation of work groups ideas.
Brainstorming to define final content of the Best Practices handbook.
Designation of Best Practices handbook chapter leaders and teams.
Design a follow-up plan to develop the Best Practices handbook.

Year 2.- February 2021

The second meeting of the group will be held in Dominica in February 2021. The meeting will address ToRs 2, 4, and 5. In particular, ToR 4 will be addressed through a special capacity building event to be done at the same time (see capacity building section below).

Goal for ToR 2 at this meeting.- Finalise the synthesis paper.

The document started during the previous year will be approved by all Working group members and submitted for review. A half-day session will be devoted to a final check of the synthesis paper.

Goal for ToR 4 at this meeting.- Conduct a training activity focused on the use of CO_2 seeps for ocean acidification studies (see capacity building section below).

Goal for ToR 5 at this meeting.- Review, based on field activities, the Best Practices handbook.

Two sessions, one before and one after the capacity building event, will be carried out to discuss the methods and content of the document. The Best Practices Handbook Chapter leaders and teams will review the work carried out and will propose improvements on the document.

Year 3.- February 2022

The closing meeting of the group will be held in Barcelona for face-to-face interactions, and dial in using Zoom. The meeting will address ToR 5 in detail.

Goal for ToR 5 at this meeting.- Final review of the content, structure and final agreement on the Best Practices handbook.

Two and a half day session. Before the Workshop, all participants will receive the latest draft of the Best Practices handbook. The working methodology is:

Day 1.- Mini symposia
Presentation of the current content of the Best Practices handbook.
Presentation of research results of the "road test" of the Best Practices handbook done at the Capacity building event, as well as research conducted by the participants in the previous 2 years.

Day 2.- Work groups and brainstorming
Separate in work groups to modify/improve the proposed methodologies.
Presentation of work groups' ideas in a plenary session.
Brainstorming to define final content of the Best Practices handbook.

Day 3.- Half day
Summary of the 2 previous days' work.
Discussion of a potential follow-up plan of InterSEEP.
Closing remarks of the Working Group.

Deliverables.

1. ToR 1

Open-access resource of temporal-space data variability created in the *Earth System Science Data* journal to secure accessibility. It will include gas parameters, water parameters, substratum parameters, microbes, meiofauna, plankton, macroalgae, sessile and mobile macrobenthos, and demersal and pelagic fish.

2. ToR 2.

Synthesis paper to be published in a peer-reviewed journal: reanalysis of datasets mentioned above, focusing on the most relevant aspect (building on preliminary work on the effects of ocean acidification on ecosystem functioning and services[7]).

3. ToR 3.

A peer-reviewed perspectives article on future seep research with conceptual models of key future global experiments. A key legacy of this Working Group will be to create a roadmap of globally replicated experiments at CO_2 seeps a reality, focused on socially and economically important aspects of coastal services to mankind. The OA research community can use these perspectives as a basis to design and submit new research projects to funding agencies as Horizon Europe, a €100 billion research and innovation programme that will succeed Horizon 2020, the Environmental Restoration and Conservation Agency from Japan (ERCA), the Japan International Cooperation Agency and NOAA's Ocean Acidification Program, if possible.

4. ToRs 4-5.

Road test our draft of the Best Practices Handbook during the Capacity Building activity in 2021. Then with input of all the participants finalize a guide of best practices on Ocean Acidification research in CO_2 seeps. In the OA and multiple stressors field there are set of best practices recommendations for laboratory studies that we as a community can augment for field-based approaches. Current CO_2 seep research is uncoordinated and uses disparate experimental designs that make comparisons of results and conclusions difficult. A best practice manual, tailor made for analogues of future ocean conditions, is crucial to be able to integrate results and draw conclusions of global significance.

Capacity Building

Our training activity will focus on the use of CO_2 seeps for ocean acidification studies, and will be held in February 2021.

The aim of the workshop is to provide an opportunity for training as well as data collection. A major goal of the workshop will be to educate a new cohort of young scientists from developing countries to the opportunities available to apply their techniques to natural CO_2 gradients to scale-up from laboratory studies and improve predictions about the long-term effects of CO_2 on coastal ocean system functioning.

The training activity will consist on theoretical and review lectures in the mornings about the chemical and physical effects of volcanic marine seeps, the use of natural analogues for high-CO_2 conditions, physiological experiments at CO_2 seeps and work to date on the use of low pH/low saturation states in natural settings. These will be followed by practical field sessions in the afternoons on the intertidal and subtidal coastal ecological shifts along CO_2 gradients, physiological in situ experimentation, pelagic sampling and boat-based water chemistry monitoring plus the deployment of a range of loggers to monitor the system. A total of 12 early-career scientists willing to work on those ecosystems back at their home countries are expected to participate.

During this training course the participants will be trained in different aspects of OA research as:

Standard measurements for carbon system parameters, including analytical chemistry techniques,

The use of stable isotopes as a major tool in food web analysis in the framework of OA research,

In-situ sample collection in a CO_2 seep for chemical and biological analysis,

And the study of benthic community structure and functioning under the influence of high CO_2 conditions.

Upon completion of the training course, participants will have gained increased knowledge in the different issues involved in the training and experimental activities, and they will be able to:

Monitor basic carbonate chemistry, including detailed methodology for collecting samples, measurements of potentiometric pH and total alkalinity (TA), the use of certified reference materials, and specific challenges related to each method.

Understand what ancillary seawater measurements are needed, and at what accuracy to calculate all the parameters of the carbonate system in seawater (i.e., temperature, salinity, nutrients, barometric pressure), as well as to know what algorithms can be used as proxies for aragonite and calcite saturation state in field studies.

Collect and pre-treat seawater samples and biological samples for isotopic analysis, explore data management and interpretation.

Analyse the relationship between seawater carbonate chemistry and benthic community structure in enriched-CO_2 sites, in order to evaluate potential impact of high pCO_2 conditions on ecosystem functioning.

To fund this activity support proposals will be submitted to The Ocean Foundation (TOF), and to the International Atomic Energy Agency (IAEA) Technical Cooperation project INT7019 "Supporting a Global Ocean Acidification Observing Network – towards Increased Involvement of Developing States"; both of which support training initiative in OA research.

Working Group composition

Full Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Cristina Linares	Female	Associate Professor at the Department of Evolutionary biology, Ecology and Environmental Sciences, University of Barcelona, Spain.	Her research focuses on the study of the structure and dynamics of coastal benthic communities and their response to global change
2 Jason Hall-Spencer CO-CHAIR	Male	Professor of Marine Biology. School of Biological and Marine Sciences, Faculty of Science and Engineering. UK.	Seamount ecology , fisheries , ocean acidification, aquaculture and conservation. Fieldwork sites are currently at volcanic CO_2 seeps in the Mediterranean and off Japan.
3 Katharina Fabricius	Female	Senior Principal Research Scientist, Australian Institute of Marine Science (AIMS), Australia.	Coral reefs processes (ranging from ecophysiology to macro-ecology), understanding the effects of cumulative impacts from chronic and acute disturbances, CO_2 seeps, ecosystem resilience.

4 Haruko Kurihara	Female	Assistant Professor, Department of Chemistry, Biology, and Marine Science, University of the Ryukyus, Japan.	Research focus on risk assessment and management of ocean acidification impacts on Japan's coastal habitats and fisheries
5 Rafael Bermúdez CO-CHAIR	Male	Researcher-Lecturer at Galapagos Marine Research and Exploration Program (GMaRE), Ecuador.	Research focus on the effect of Ocean Acidification in the biomolecular composition of primary producers and its concomitant influence in food webs.
6 Riccardo Rodolfo Metalpa	Male	Researcher at ENTROPIE - Écologie marine tropicale des océans Pacifique et Indien, Institute of Research for Development. France.	Research focus on coral reefs, global change, ocean acidification, coral calcification, coral physiology,
7 Salvatrice Vizzini	Female	Professor of Ecology, Università degli Studi di Palermo, Consorzio Nazionale Interuniversitario per le Scienze del Mare-CoNISMa, Italy.	Research activity is focused on the ecology of coastal environments with particular attention on trophic ecology using stable isotopes and fatty acids as trophic markers
8 Sam Rastrick	Male	Associate Research Professor, Research Group of Benthic Habitats and Shellfish, Institute of Marine Research, Norway.	Research focus on the use of physiology to explain the ecological distribution, both temporal and spatial, of species important to both ecosystem function and services.
9 Sylvain Agostini	Male	Assistant Professor. Shimoda Marine Research Center, University of Tsukuba, Japan.	Research activity is focused on the eco physiology of hermatypic corals in temperate and tropical zones.

10 Vanessa Yepes-Narvaez	Female	Marine and Coastal Research Institute INVEMAR, Santa Marta, Colombia.	Ecology, taxonomy, distribution and population genetics of marine deep and shallow bryozoans in the Atlantic Ocean

Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Christopher Cornwall	Male	Victoria Wellington University, Wellington, New Zealand	Research focus on examine how macroalgal dominated ecosystems function today and how this will be altered by future ocean acidification in the context of variability in the environment (e.g. pH, water motion and light)
2 Derek Manzello	Male	Researcher, Ocean Chemistry and Ecosystems Division, NOAA's Atlantic Oceanographic and Meteorological Laboratory, USA	Research focus on how climate change and ocean acidification will, and already are, affecting the construction (coral growth, calcification) and breakdown (bioerosion, dissolution) of coral reefs, as well as the associated ramifications this has for ecosystem function
3 Marco Milazzo	Male	Professor of Ecology, Università degli Studi di Palermo, Italy	Research interests on impacts of humans on marine ecosystems, biological invasions, and marine reserves.
4 Lucia Porzio	Female	PostDoc at Stazione Zoologica Anton Dohrn, Italy	Research focus on the study of anthropogenic pressures and the impacts they cause on macrophytes and on their biodiversity.
5 Yu-Shih Lin	Female	Assistant professor, Department of Oceanography, National Sun Yat-Sen University	Biogeochemistry and isotope geochemistry in CO_2 vents

6 Melissa Chierici	Female	Principal scientist at the IMR in Tromsø, Norway	Chemical oceanography focusing on carbon cycle, biogeochemical processes, ocean acidification, sea ice chemistry, water mass distribution, polar ocean.

Working Group contributions

Cristina Linares.- Associate professor from a developed country. Expertise on the study of the structure and functioning of temperate benthic ecosystems and their response to global change and CO_2 seep research affecting mesophotic communities in Columbretes Islands (NW Mediterranean Sea)

Jason Hall-Spencer.- Senior researcher from a developed country. Expertise on laboratory studies, mesocosms and CO_2 seep research in the Mediterranean, the Azores, Papua New Guinea, China and Japan. Helped organise a previous training workshop on seeps in Italy

Katharina Fabricius.- Senior researcher from a developed country, ongoing collaborative research in developing countries. Coral reef ecologist, with strong focus on using field settings as natural laboratories. Her interdisciplinary CO_2 seeps project in Papua New Guinea has involved ~50 collaborators from over 20 nations to date.

Haruko Kurihara.- Assistant professor from a developed country. Research focus on risk assessment and management of ocean acidification impacts on Japan's coastal habitats and fisheries

Rafael Bermúdez.- Junior Professor from a developing country. Expertise on food webs under ocean acidification conditions. Researcher at the newly found seep at Galapagos. organized previous training on seeps in Ecuador.

Riccardo Rodolfo Metalpa - Researcher from a developing country. Working on coral reefs and other calcifier organisms at CO_2 seep from 2008. Laboratory mesocosms, CO_2 seep and extreme environments in the Med, Papua New Guinea and New Caledonia.

Salvatrice Vizzini.- Senior researcher from a developed country. Expertise on effects of ocean acidification on trophic interactions and benthic communities and processes in CO_2 seeps. Organised previous training on seeps in Italy.

Samuel Rastrick.- Associate research professor in marine ecophysiology form a developed country. Expertise in laboratory, mesocosm and natural analogue studies e.g. CO_2 seeps in Mediterranean, Japan and the Caribbean. Develops traditionally laboratory based methods for use in the field. Chairs an international WG exploring using natural analogies to investigate CC in Arctic ecosystems. Organised previous training on seeps in Dominica.

Sylvain Agostini.- Assistant professor from a developed country in Asia. Expertise on the ecological and physiological effects of ocean acidification on corals and other marine organisms. Researcher at the CO_2 seeps in Japan.

Vanessa Yepes-Narvaez.- Junior researcher from a developing country. Research focus on ecology, taxonomy, distribution and population genetics of marine deep and shallow bryozoans in the Atlantic Ocean with emphasis in seep sites in the Caribbean sea.

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

The Ocean Foundation (TOF) is a community foundation with a mission to support, strengthen, and promote organizations dedicated to reversing the trend of destruction of ocean environments around the world. In parallel, the International Atomic Energy Agency (IAEA) has the Technical Cooperation project INT7019 "Supporting a Global Ocean Acidification Observing Network – towards Increased Involvement of Developing States"; InterSEEP aims to partner with TOF and the IAEA in order to promote Ocean Acidification research on natural CO_2 seep systems on developing countries as a model for predictive future ocean scenarios. InterSEEP also aspires to become a Special Hub (in contrast to Regional Hubs) within the Global Ocean Acidification Observing Network (GOA-ON) in order to promote OA research in Seep sites around the globe.

This proposed group fits perfectly within SCOR's scope on Ocean Carbon Working Groups. It is novel as it focuses on observations of biological responses of Ocean Acidification using the complex marine communities found around natural seeps. InterSEEP is also a timely update to the Working Group 104 "Coral Reef Responses to Global Change: The Role of Adaptation" which published its last report 20 years ago. Additionally, InterSEEP will potentially expand the application of the newly developed tool, created by the Working Group 149, for experiments related to Ocean Acidification and multi-stress factors in laboratory experiments, in order to use it in natural field seep conditions. Additionally the group will link with the Integrate Marine Biosphere Research (IMBeR) in order to help in answering some of the tasks of their Ocean Acidification group as for instance the promotion of international experiments. Also will contact the International Oceanographic Data and Information Exchange group (IODE) of the Intergovernmental Oceanographic Commission" to help in the diffusion of the scientific outcome of the group. Furthermore, following the steps of SCOR/InterRidge Working Group 135 on Deep Sea Hydrothermal systems, InterSEEP will bring together CO_2 seep researchers worldwide to address important issues to improve and coordinate global research.

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13. Tarasov, V. G., *et al*. Deep-sea and shallow-water hydrothermal seep communities : Two different phenomena ? *Chem. Geol*. 224, 5–39 (2005).

ANNEX 1.- Five more relevant publications of the Full Members

Cristina Linares.-

Exploring the oxygen and carbon isotopic composition of the Mediterranean red coral (Corallium rubrum) for seawater temperature reconstruction (2016)
S Chaabane, ML Correa, P Montagna, N Kallel, M Taviani, C Linares, *et al.*
Marine Chemistry 186, 11-23

Experimental evidence of the synergistic effects of warming and invasive algae on a temperate reef-builder coral (2015)
DK Kersting, E Cebrian, C Casado, N Teixidó, J Garrabou, C Linares
Scientific reports 5, 18635

Persistent natural acidification drives major distribution shifts in marine benthic ecosystems (2015)
C Linares, M Vidal, *et al.*
Proc. R. Soc. B 282 (1818), 20150587

Harvesting effects, recovery mechanisms, and management strategies for a long-lived and structural precious coral (2015)
I Montero-Serra, C Linares, M García, *et al.*
PloS one 10 (2), e0117250.

Rapid recovery from injuries in the temperate long-lived coral *Cladocora caespitosa* (2015)
C Casado, DK Kersting, E Cebrian, N Teixidó, J Garrabou, C Linares
Marine Biodiversity 45 (1), 135-137

Jason Hall-Spencer.-

Ocean acidification can mediate biodiversity shifts by changing biogenic habitat (2017)
JM Sunday *et al.* including JM Hall-Spencer
Nature Climate Change, 7, 81-85

Effects of ocean acidification on marine photosynthetic organisms under the concurrent influences of warming, UV radiation and deoxygenation. (2019)
K Gao *et al.* including JM Hall-Spencer
Frontiers in Marine Science 6, 322 doi: 10.3389/fmars.2019.00322

Changes in the biochemical and nutrient composition of seafood due to ocean acidification and warming (2019)
AJ LeMasson, JM Hall-Spencer *et al.*
Marine Environmental Research, 143, 82-92

Changes in fish communities under ocean acidification conditions (2020)
C Cattano *et al.* including JM Hall-Spencer
Science of the Total Environment 725, 138501 doi.org/10.1016/j.scitotenv.2020.138501

Decreased motility of flagellated microalgae long-term acclimated to CO_2-induced acidified waters (2020)
Y Wang et al. including JM Hall-Spencer
Nature Climate Change (*in press*)

Katharina Fabricius.-

Classification and regression trees: a powerful yet simple technique for ecological data analysis (2000)
G De'ath, KE Fabricius.
Ecology 81 (11), 3178-3192

Losers and winners in coral reefs acclimatized to elevated carbon dioxide concentrations (2011)
KE Fabricius, C Langdon, *et al.*.
Nature Climate Change 1 (3), 165

Declining coral calcification on the Great Barrier Reef (2009)
G De'ath, JM Lough, KE Fabricius
Science 323 (5910), 116-119

Declining coral calcification in massive Porites in two nearshore regions of the northern Great Barrier Reef (2008)
TF Cooper, G De'Ath, KE Fabricius, JM Lough
Global Change Biology 14 (3), 529-538

Changes in algal, coral and fish assemblages along water quality gradients on the inshore Great Barrier Reef (2005)
K Fabricius, G De'ath, *et al.*
Marine pollution bulletin 51 (1-4), 384-398

Haruko Kurihara.-

Ocean acidification impacts in select Pacific Basin coral reef ecosystems (2019)

M Lebrec, S Stefanski, R Gates, S Acar, Y Golbuu, A Claudel-Rusin, H Kurihara, *et al*.
Regional Studies in Marine Science, 100584

Effects of CO_2-driven ocean acidification on the early developmental stages of invertebrates (2008)
H Kurihara
Marine Ecology Progress Series 373, 275-284

Effects of increased seawater pCO_2 on early development of the oyster *Crassostrea gigas* (2007)
H Kurihara, S Kato, A Ishimatsu
Aquatic Biology 1 (1), 91-98

Effects of increased atmospheric CO_2 on sea urchin early development (2004)
H Kurihara, Y Shirayama
Marine Ecology Progress Series 274, 161-169

Sub-Lethal Effects of Elevated Concentration of CO_2 on Planktonic Copepods and Sea Urchins (2004)
H Kurihara, S Shimode, Y Shirayama
Journal of Oceanography 60 (4), 743-750

Rafael Bermúdez.-

Phytoplankton blooms at increasing levels of atmospheric carbon dioxide: experimental evidence for negative effects on prymnesiophytes and positive on small picoeukaryotes (2017)
KG Schulz, LT Bach, RGJ Bellerby, R Bermúdez, *et al.*
Frontiers in Marine Science 4, 64

Ocean acidification reduces transfer of essential biomolecules in a natural plankton community (2016)
JR Bermúdez, U Riebesell, *et al.*
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Effect of ocean acidification on the structure and fatty acid composition of a natural plankton community in the Baltic Sea (2016)
JR Bermudez, M Winder *et al.*
Biogeosciences (BG) 13 (24), 6625-6635

Long-term conditioning to elevated pCO_2 and warming influences the fatty and amino acid composition of the diatom *Cylindrotheca fusiformis* (2015)
R Bermudez, Y Feng, *et al*.
PLoS One 10 (5), e0123945

Ocean acidification-induced food quality deterioration constrains trophic transfer (2012)
D Rossoll, R Bermúdez, *et al*.
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Riccardo Rodolfo Metalpa.-

Coral and mollusc resistance to ocean acidification adversely affected by warming (2011)
R Rodolfo-Metalpa, F Houlbrèque, *et al.*
Nature Climate Change 1 (6), 308

Response of the temperate coral *Cladocora caespitosa* to mid-and long-term exposure to pCO_2 and temperature levels projected for the year 2100 AD (2010)
R Rodolfo-Metalpa, S Martin, *et al.*
Biogeosciences 7 (1), 289-300

Effects of ocean acidification and high temperatures on the bryozoan *Myriapora truncata* at natural CO_2 vents (2010)
R Rodolfo-Metalpa, C Lombardi, *et al.*
Marine Ecology 31 (3), 447-456

Volcanic carbon dioxide vents show ecosystem effects of ocean acidification (2008)
JM Hall-Spencer, R Rodolfo-Metalpa, *et al.*
Nature 454 (7200), 96

Effects of naturally acidified seawater on seagrass calcareous epibionts (2008)
S Martin, R Rodolfo-Metalpa, E Ransome, *et al*.
Biology letters 4 (6), 689-692

Salvatrice Vizzini.-

Plant and sediment properties in seagrass meadows from two Mediterranean CO_2 vents: Implications for carbon storage capacity of acidified oceans (2019)
S Vizzini, ET Apostolaki, E Ricevuto
Marine Environmental Research, Available online 18 March 2019

The influence of high pCO_2 on otolith shape, chemical and carbon isotope composition of six coastal fish species in a Mediterranean shallow CO_2 vent (2017)
AM irasole · BM Gillanders · P Reis-Santos · F Grassa · S Vizzini
Marine Biology 164(9):191

Ocean acidification as a driver of community simplification via the collapse of higher-order and rise of lower-order consumers
S Vizzini, B Martínez-Crego *et al.*
Scientific Reports 7(1):4018

Altered epiphyte community and sea urchin diet in *Posidonia oceanica* meadows in the vicinity of submarine volcanic CO_2 vents (2017)
P Nogueira, MC Gambi, S Vizzini, *et al.*
Marine environmental research 127

Ocean acidification effects on stable isotope signatures and trophic interactions of polychaete consumers and organic matter sources at a CO_2 shallow vent system (2015)
E Ricevuto, S Vizzini, *et al.*
Journal of Experimental Marine Biology and Ecology 468

Samuel Rastrick.-

Using natural analogues to investigate the effects of climate change and ocean acidification on Northern ecosystems (2018)
S Rastrick, H Graham, *et al.*
ICES Journal of Marine Science 75(7)

Feeding plasticity more than metabolic rate drives the productivity of economically important filter feeders in response to elevated CO_2 and reduced salinity (2018)
S Rastrick, V Collier, *et al.*
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Natural acidification changes the timing and rate of succession, alters community structure, and increases homogeneity in marine biofouling communities (2017)
NE Brown, M Milazzo, S Rastrick, *et al.*
Global Change Biology 24(1)

The impact of ocean acidification and warming on the skeletal mechanical properties of the sea urchin *Paracentrotus lividus* from laboratory and field observations (2016)
M Collard, S Rastrick, *et al.*
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Individual and population-level responses to ocean acidification (2016)
BP Harvey, NJ Mckeown, S Rastrick, *et al*.
Scientific Reports 6, 20194.

Sylvain Agostini.-

Geochemistry of two shallow CO_2 seeps in Shikine Island (Japan) and their potential for ocean acidification research (2015)
S Agostini, S Wada, *et al.*
Regional Studies in Marine Science 2, 45-53

Bacterial enhancement of bleaching and physiological impacts on the coral *Montipora digitata* (2013)
T Higuchi, S Agostini, BE Casareto, K Yoshinaga, T Suzuki, Y Nakano, *et al*.
Journal of experimental marine biology and ecology 440, 54-60

The effects of thermal and high-CO_2 stresses on the metabolism and surrounding microenvironment of the coral *Galaxea fascicularis* (2013)
S Agostini, H Fujimura, *et al.*
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S Agostini, H Fujimura, *et al*.
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Biological and chemical characteristics of the coral gastric cavity (2012)
S Agostini, Y Suzuki, *et al*.
Coral Reefs 31 (1), 147-156

Vanessa Yepes-Narvaez.-

Habitat-forming bryozoans in the Colombian Caribbean Sea: a possible hotspot of biodiversity? (2016)
P Flórez, E Montoya-Cadavid, V Yepes-Narváez, A Polanco, A Gracia. International Bryozoology Association 44 p.

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V Yepes-Narvaez, L Chasqui-Velasco, et al.
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V Yepes-Narvaez, K Carreño, M Santos-Acevedo, C Puentes, J Gómez- León.
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V Yepes-Narvaez, P Florez, *et al*.
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MarCCR: Mapping climate change refugia for marine conservation

1. Summary

Climate change is causing rapid, major, alterations to marine ecosystems and their biodiversity, with extreme events increasingly driving mass mortalities at multiple scales. Climate-driven stressors also interact with other human pressures, posing a significant challenge to marine conservation. Marine Protected Areas (MPAs) are key tools in marine conservation intended to preserve or recover native species and communities. Knowing where to place MPAs that limit, or are adaptive to, the effects of climate change – i.e., **climate change refugia (CCR)** - remains a critical challenge. Existing approaches by-in-large ignore the fact that climate *vulnerability* combines *exposure* (deviation from historic physico-chemical variability) and *sensitivity* of organisms and communities to such deviations. CCRs emerge because many climate-driven stressors exhibit wide spatiotemporal variability. Their identification and utilization toward climate-ready MPAs thus requires knowledge of how multiple climate-driven stressors are distributed, and how species respond to their patterns. Overcoming the challenges of CCR identification and implementation in marine conservation necessitates truly international collaborative networks of scientists, working across scales and representative of diverse sustainability contexts relevant to MPA implementation; these are generally not supported through traditional funding. The planned **MarCCR** SCOR working group builds on previously limited-funded collaborations of several of its members aimed at developing the criteria and tools for defining and mapping CCR, to be used in MPA-network planning. Our extended international group will significantly improve the ability to tackle CCR challenges, and will deliver global CCR maps and detailed case-study regional maps to support international climate-adaptive marine spatial planning and conservation strategies.

2. Scientific Background and Rationale

2.1 Why identifying climate change refugia is important for marine conservation

Climate change (CC) reshapes marine ecosystems at accelerating rates [1, 2]. This emerging threat poses a fast-moving challenge to both resource exploitation [3] and marine conservation, which until now was mostly designed to deal with direct human pressures like fishing or pollution [4]. Tackling the CC challenge requires adaptive management based on quantitative environmental information, extensive biological knowledge [5], and development of strategies to incorporate environmental change into marine spatial planning (MSP) [6-9]. How species experience CC is highly variable in space and time, but this has rarely been explored for management solutions [10]. Increasingly-detailed remote-sensing data and expanding arrays of ocean sensors, as well as better biological data and modelling (improved species distribution maps and knowledge of physiological sensitivity), should enable us to tap on this variability to identify areas that can serve as **climate change refugia (CCR)** for key marine species and threatened communities. Including CCR in conservation and spatial plans [6, 11, 12] is a promising approach [13, 14], especially when refugia are assembled as well-connected networks [15] at multiple spatial scales.

Although a conservation priority, the theoretical framework for identifying current and future CCR is in its infancy. The notion of environmental refugia is based on the observation that smooth, biogeographical-scale gradients are rare, and become increasingly less evident at smaller spatial scales. Instead, environmental conditions consist of highly heterogeneous geographic mosaics at the scales relevant to most organisms [16, 17], creating areas (or periods) that can provide physiological relief from stress during extreme events [18], or by allowing species to persist amidst long-term changes [19]. Yet, while high frequency spatial [20] and temporal [21] environmental variability may drive long-term ecological responses, these scales are often overlooked by studies focusing only on long-term climatic trends [22]. Moreover, approaches to identifying CCR based solely on ***exposure*** to CC, ignore variation in the mechanisms by which affected individuals, populations, species, and communities respond to CC and other pressures, i.e. their ***sensitivity***. Combining knowledge of exposure and sensitivity yields a much-improved measure of ***vulnerability,*** which is the critical metric to detect CCR.

2.2 The challenge

In MPA research, site vulnerability to future climate is sometimes analyzed, but few real-life examples exist where such information is implemented in management [12]. Furthermore, only a few studies have assessed ecosystem-level vulnerability of MPAs to CC [23]. To deliver on international commitments towards effective ocean sustainability under CC, embedded in broader commitments for climate smart MSP [8, 24], a step change is necessary to assess ocean life vulnerability and resilience to CC. Implementing MPAs is a complex process, requiring collaboration and coordination across governments, policy implementers and stakeholders. The identification of CCR is a necessary, yet challenging, step toward long-term sustainable and climate-smart planning, ensuring that the allocation of space to MPAs is justified and effective.

CCR can be defined by seascape features as experienced by organisms, acknowledging that local environmental dynamics can be distinct from long-term regional-level change [10]. The history of a specific population within a seascape determines its vulnerability to environmental change, conditioned by adaptive plasticity, gene flow and other processes [25]. The first building block of a CCR is therefore environmental ***stability,*** defined by the area's historical environmental variability. A CCR **can** then be an area of high temporal variability (e.g., intermittent upwelling regions), where dynamics continue to reflect historical variability patterns into the future. Conversely, no change in average site conditions, does not confer stability under situations where variability increases, e.g. through exposure to new or more frequent extreme events [26]. Within-area stability can be assessed using statistical analysis to determine if the dynamics of relevant physical/biogeochemical metrics change over time, [e.g., significant shifts in seasonal weather patterns 27].

Previous attempts to identify CCR frequently considered only ***exposure***, focusing on change of the central tendency of environmental variables. This concept of CCR based on environmental "status quo" ignores whether current conditions are optimal for organisms and communities that MPAs strive to preserve. Such approaches are potentially problematic because we do not always know what aspects of environmental stability are most critical to specific organisms. To respond to environmental stress, organisms allocate energy to stress-response pathways (physiological, biochemical or behavioral), which are metabolically expensive. A site where average conditions remain constant but incidence of extreme events increases, thus represents a poor CCR. Therefore, several environmental metrics, including site heterogeneity, variability and extremes, are required to identify what may constitute current and future CCR. Equally, conditions are optimal only over some portion of a species' range. Stable but suboptimal conditions at a site, may simply indicate that organisms will remain viable, although sustaining a suboptimal physiological state. For instance, while cold edges of species distributions often represent such conditions [28], suboptimal conditions can also occur away from range edges. Considering the interaction between local- and regional-scale variability in both exposure and sensitivity is thus critical for CCR identification [29-31].

Marine spatiotemporal variability in vulnerability to climate exists at almost any spatial scale [32, 33]. For instance, variation in intertidal thermal regimes over the scale of cm can exceed that observed over thousands of km [34], and variation in thermal tolerance among individuals can exceed differences between species [35]. Such variation can lead us to question how much predictive power we gain from considering increasingly higher resolution of variability in exposure and sensitivity [33], and how can they contribute to produce a CCR or its opposite, a CC hotspot [6, 36]. While data availability limits testing this globally, it can be assessed using case-studies where the seascape and its organisms are known in detail. Practically, physiological sensitivity of individuals can be estimated directly by quantifying performance curves along environmental gradients in the laboratory [37], and the sensitivity frequency distribution of individuals within a population can then be combined with variation in exposure to estimate vulnerability of entire populations [33, 35]. At the species level, it is also possible to integrate local factors that influence species occurrences by extracting the species' thermal distribution across its geographic range (its realized niche), called the species thermal index (STI) [38]. This measure can be integrated at the community level by taking the average STI across all species present, yielding the community thermal index (CTI) [38]. CTI has now been incorporated as a global biodiversity indicator (*https://www.bipindicators.net/indicators/reef-fish-thermal-index*).

Our **MarCCR** SCOR group will build on these approaches to develop both the conceptual framework and the metrics to identify ***multiple-driver CCR***, and produce global CCR maps, as well as focus on regional/local-scale case-studies. These products will be used to promote ocean CC literacy among practitioners, and the uptake of CCR into real-life MSP approaches, through group members' involvement in international committees and initiatives (e.g., ICES WGMPCZM, UNFCCC COP, SDG14 process).

2.3. Why a SCOR Working Group

A SCOR Working Group is an ideal platform to develop a framework for creating global CCR maps. Initial marine CCR concepts were developed within the EU COST-ACTION project MARCONS (http://www.marcons-cost.eu/), which only funded European members and ended in April 2020. Rilov and Helmuth received support from the a joint US NSF - Israel-USA Binational Science Foundation grant during 2016-2019 to develop tools to explore small-scale refugia. We made important progress in resolving some initial challenges related to CCR identification - a strong starting point for this Working Group. But progress has stalled due to the lack of a truly international funding platform. Climate-smart marine conservation and spatial planning are driven by global aspirations, but realized through highly diverse regional and local-scale implementation. A diverse SCOR Working Group would allow capitalizing on progress made, accelerating it by leveraging global expertise, delivering tangible products to improve global marine conservation planning.

3. Terms of Reference

Objective 1 (O1) - Develop a conceptual framework for defining and identifying marine CCR at different spatiotemporal scales and for multiple drivers.

Objective 2 (O2) – Develop empirical approaches to identify marine CCR at different scales, and quantify how their different physicochemical- biological properties are linked.

Objective 3 (O3) – Produce global CCR maps at relatively coarse scales applicable for broad scale transboundary planning.

Objective 4 (O4) - Produce high-resolution maps for several regional and local case studies in different regions and marine ecosystems, that can be applicable at local to regional scales.

Objective 5 (O5) – Produce materials for conservation and planning practitioners to use CCR identification tools and maps to inform real-life planning applications.

Objective 6 (O6) – Create opportunities for training and learn-by-doing for early-career and developing country researchers.

4. Working plan

The MarCCR working group will progress the Terms of Reference by addressing the objectives 1 to 6 according to the following program of activities (by years):

Year 1. To address O1 and O2, we will build on initial efforts of some members of the group and continue to develop and refine the building blocks for identification of CCR. Specifically, we will focus on more accurately defining *stability* and its metrics, as well as measures of *sensitivity* of populations, species and communities, and how these two measures can be combined to calculate *vulnerability*. To develop the required tools, we will first build on our initial progress in identifying temperature refugia, given that temperature plays a major role in determining the distribution, fitness and survival of species, and is readily measurable both locally and at global scales using remote sensing and the increasing array of sensors, such onshore loggers and oceanic deployments (e.g. ARGOS). We will then assess refugia using other climate-change related stressors including ocean acidification [39] and deoxygenation [40], thus more accurately representing the impacts of climate change on marine ecosystems [2]. Stability in temperatures at large scales can build for example on calculations of climate velocity and/or be assessed using different statistical metrics quantifying change in means, fluctuations, extremes and state changes. The latter can also be used at small scales. Tools for assessing stability in other climate-driven stressors require the same principles, and the added challenges of techniques to synthesize this information across geographical scales (relying less on remote-sensing data), to assess ecosystem level vulnerabilities. We will examine ways to assess sensitivity using both single species data (such as performance curves and species distributions), and community metrics (including CTI and others) by expanding principles to a multiple-drivers (stressors) context towards the delivery of equivalent tools that can be applied to identify CCR. Using first case studies on a local or regional scale, we will create and test different refugia layers and their links based on metrics similar to what was developed for temperature, and then assess community level vulnerabilities based on the refinement of existing techniques [6, 23]. A MarCCR webpage or website and social media accounts (e.g. Twitter) will be used to promote WG activities with the wider community. We will also attempt to coordinate presentations by the group's members at international meetings (such as the International Temperate Reef Symposium in January 2022 in Hobart Tasmania, where we can introduce the topic and initial findings), including the proposal of special sessions, which will include student investigators.

Year 2. While different policy frameworks aim to protect large areas of the world's oceans, there is a paucity of information to support decisions on conservation priorities related to climate change. We will address this gap in year 2, by developing global (O3) maps of current multiple-driver CCR at multiple spatial scales, with a special focus on coastal regions, where most present and planned MPAs are concentrated. This will be based on existing environmental remote sensing and *in-situ* data and physiological sensitivity of key or model species, as well as species distributions for well-studied groups (e.g., fish, kelps, corals and intertidal organisms), analyzed via spatial-meta-analysis and other techniques [6]. This approach allows us to categorize regions by the emergent properties of refugia. High-resolution regional case studies (O4) will be explored in greater detail towards anticipated engagement with practitioners in years 3 and 4. We will also develop and use metrics based on circuit theory to assess connectivity among CCRs and identify climatic corridors minimizing exposure to climatically hostile areas as other key areas for conservation prioritization [41, 42]. Our case-studies will include: the eastern Mediterranean, the Portuguese coast, the Chilean coast, the Galapagos Islands, and the Hawaiian Islands, considering also other case-studies at the center of programs that can peripherally support this WG, including those used in the new EU H2020 program (FUTUREMares) co-led by members of this team (Rilov and Queiros), Vietnam's UNESCO Man and Biosphere Reserve (UKRI GCRF Blue Communities, Queiros and Tri), and others.

Years 3-4. To address O5-6, we will develop a framework to incorporate CCR in MSP and conservation practices. We will work in collaboration with our ongoing funded research programs and networks to develop guidelines to incorporate CCR theory and modelling tools at three levels: i) MSP processes at national and supra-national scales - including transboundary CCR (crossing territorial waters, EEZ, ABNJ); ii) the identification of representative networks of MPAs within regional MSP; and iii) MPA management at local scales, focusing mainly on the case-studies. To achieve these goals, we will develop specific guidelines on how to incorporate CCR into the MSP standard phases: assess, design, implement, monitor, evaluate, and adjust [24]. We will identify the knowledge gaps and potential sources of uncertainties regarding CCR that need to be addressed, in harmony with the precautionary principle in MSP. We will also define a series of recommendations (managing potential synergies and conflicts) for the identification and designation of CCR regarding multiple uses. The identification of a representative network of MPAs (level ii) will be addressed by identifying strategies to prioritize CCR within an MSP context. The proposed guidelines will focus on how the metrics developed and implemented in O1-4 will deliver climate-resilient criteria for the selection of climate-ready MPAs, that further consider Convention on Biological Diversity (CBD) criteria of "effectively and equitably managed, ecologically representative and well-connected" protected areas (Art. 11). We will organize a workshop with resource managers and planners to co-develop such guidelines and recommendations (using web-based tools, where needed) in tandem to the WG meetings and possibly other more local activities involving our early career members and, when needed, specifically targeting developing nations where our members reside (e.g., in Chile, Ecuador, Vietnam). Potential participants in the workshop include resource managers and heads of conservation networks, building on our professional circles to include for example, ICES Working Group on Marine Planning and Coastal Zone Management (Queiros), H2020 FutureMARES (Rilov, Queiros), MEDPAN and MSPMED (Gissi), and other initiatives and committees within which our members participate.

5. Deliverables

(1) **Published articles**. Workgroup papers will highlight and synthesize the knowledge gained, as well as summarize the approaches developed and introduce the main scientific products. We envision at least three high-impact peer-reviewed papers focusing on: a) theory and guiding principles of multi-driver marine CCR; b) global maps of current CCR highlighting several local case studies; c) incorporating CCR in ocean management at different spatial scales. We will strive to publish at least one of those papers as open access, depending on funding.
(2) **CCR maps**. These will include gridded raster layers with globally distributed CCR and associated metrics, as well as detailed maps of our case-study regions. These maps will be published in long-term open access data repositories such as *Pangaea* and made available at the project webpage/website. To maximize the utility and encourage the usage and further development of the products from this project, we will make our code available to any interested party through a GitHub repository and eventually compile it into an R package.
(3) **Policy briefing**. This briefing will include recommendations for conserving biodiversity given rapid climate change relevant to marine assessments (CBD, IPBES and IPCC), the United Nations Sustainable Development Goals and Aichi Targets, as well as the recent goals set by the Decade of the Ocean UN initiative https://en.unesco.org/ocean-decade, specifically: the need for "adaptation strategies and science-informed policy responses to global change".
(4) **Layman's report**. This report will be co-developed with resource and MPA managers and ocean planners on guidelines and recommendations to incorporate CCR in ocean management. It will be posted on our MarCCR webpage/website and disseminated via social media.

6. Capacity Building

Many senior workgroup members have extensive experience in capacity building (CB) activities. The purpose of this CB workplan is to create literacy development, mentoring and training opportunities related to CCR identification and incorporation in MSP and conservation, specifically targeting: i) Early Career Researchers (ECR); ii) Researchers in Developing Countries (RDC); and iii) practitioners involved in planning and management decisions related to MPA design around the world.
i) **Early career researchers (ECR)**. Throughout the group's activities, the workgroup will strive to provide an inclusive environment that presents opportunities for training and mentoring of ECR. This includes membership of the workgroup (six ECR members), as well as opportunities for involvement in workgroup activities by ECR within the professional networks, external to the group. ECR will be expected to contribute to, engage in, and benefit from, all research activities of the workgroup. ERC will be given authorship of group-related publications and reports commensurate with these activities, and are expected to participate and present in high level activities, such as that at the Ocean Conference side-event submission (see iii). Secondly, we aim that one of our meetings will be held in parallel to the Ocean Sciences Meeting 2022 (FEB 27-MAR 4, 2022 - Honolulu, HI, USA) conference of the Association for the Sciences of Limnology and Oceanography (ASLO), where we will submit a proposal for a session focused on this workgroup products. This will allow ECR from around the world, which represent the bulk of attendees at the conference, to be exposed to the workgroup research, and external contributions will be encouraged on the subject of CCR. Participation in workgroup activities by ECR will be encouraged through workgroup members' research networks, UKRI GCRF programs, Blue Communities and SOLSTICE (which focus on capacity

development of sustainable marine management in developing states in the Western Indian Ocean and SE Asia), and the MBON Pole to Pole initiative, a Community of Practice across the Americas (https://marinebon.org/p2p/index.html). The workgroup will put in place several activities specifically targeted to PhD and graduate students on the topics and methodology developed.
To enlarge the potential targets of the training activities, the MarCCR working group will explore the possibility of preparing an *e-learning* training workshop in the form of a Massive Open Online Course (MOOC), a free online course available for anyone to enroll. The MOOC learning objectives are targeted to introduce the theoretical and modelling problems of establishing CCR, as well as the implications for ocean management. The MOOC will follow a problem-based approach, building on specific case studies developed in the first two years of the project. The contents and the problem-based learning of the MOOC will be tested in a training workshop, which will be held in a third-year meeting. The MOOC will be issued at the end of the third year or early in the fourth year, and uploaded in the websites of one of the Institutes of the workgroup members, and open to anyone who has a specific interest in the topic.
ii) Researchers in Developing Countries (RDC). The workgroup will build on its professional network and ongoing activities to promote the representation and participation of RDC in all core group activities and engagement events in Years 1-4. This participation creates opportunities for learning-by-doing, as well as ensuring that developing state perspectives are given due consideration during analyses of data, tool development and workgroup recommendation development. As well as contributing to CB, this focus ensures that the outputs of this workgroup have real potential for global applications, in all sustainability contexts.
Participation of RDC includes membership in the workgroup (four RDC members), opportunities to contribute to, engage in, and benefit from, all research activities of the workgroup; and an encouragement to present in high level engagement activities, such as that at the Ocean Conference side-event submission (please see iii).
Participation of at least some of the RDC in workgroup activities will be supported and funded via existing ongoing networks and projects that workgroup members are active in, including:
1) UKRI GCRF programme Blue Communities (which focuses on capacity development of sustainable marine planning in developing states in SE Asia)
2) UKRI GCRF programme SOLSTICE (which focuses on capacity development of sustainable marine management in developing states in the Western Indian Ocean)
iii) Practitioners. During the activities of this workgroup, we will draw on our professional networks to promote CCR literacy and increase awareness of MSP, Integrated Coastal Zone Management and MPA practitioners around the world. Specifically, we will build on the activities of existing expert groups (e.g. ICES WGMPCZM), research programs (H2020 FutureMARES, UKRI GCRF Blue Communities), and policy advisory committees (e.g., MSPMED) where workgroup members and associate members are active in, and that already involve practitioners. We aim to hold at least one targeted demonstration workshop in Year 3, organized in tandem with the activities of those groups, where the aims and outputs of the workgroup are presented and explored within the context of real-life MPA or MSP programs. We will also consider applying for a workshop as an event at the United Nations Ocean Conference, targeting the participation of decisionmakers and ocean managers interested in the sustainable management of ocean resources worldwide. This workshop will build on workgroup members' experience within the UNFCCC processes and community. During such a workshop, the results of the workgroup will be presented to conveners, which typically include representatives of policy, industry, business, research, and civil society interested in sustainability and ocean management. Guidelines and recommendations for the incorporation of CCR in ocean management will be disseminated as a short layman's report at the event, as well as being the focus of a Q&A session around the theme of operationalizing a CCR approach in decision making processes related to ocean management. The report will also be disseminated through marine managers networks previously described, and others such as the Marine Ecosystems and

Management (MEAM) network serving over 10,000 members of the global resource management community.

Working Group composition

Full Members

The sign * indicates early career member

Name	Gender	Place of work	Expertise relevant to proposal
1 Gil Rilov (Chair)	M	Israel Oceanographic and Limnological Research, Haifa, **Israel**	Marine community ecology, conservation biology, climate change impacts
2 Ana Queirós (Co-chair) *	F	Plymouth Marine Laboratory, Plymouth, **UK**	Climate modelling solutions for sustainable management of marine ecosystems under climate change. Science-policy.
3 Amanda Bates	F	Memorial University of Newfoundland, **Canada**	Physiological ecology, macroecology, conservation biology
4 Elena Gissi	F	University Iuav of Venice, **Italy**	MSP, ecosystem-based approach, conservation planning
5 Brian Helmuth	M	Northeastern University, Boston, MA, **USA**	Ecological forecasting, Physiological ecology, Science communication
6 Fernando Lima *	M	CIBIO, University of Porto, Porto, **Portugal**	Environmental monitoring, Biodiversity, Thermal stress, Macroecology, Climate change impacts
7 Yunwei Dong	M	Ocean University of China, Qingdao, **China**	Physiological ecology, marine spatial planning
8 Michael Burrows	M	Scottish Association for Marine Science, Oban, Scotland, **UK**	Predicting Responses of marine species and communities to climate change
9 Catriona Hurd	F	University of Tasmania, **Australia**	Macroalgal physiology, ocean acidification
10 Catarina Frazão Santos *	F	University of Lisbon, MARE–Marine and Environmental Sciences Centre, **Portugal**	MSP, ocean policy, climate change adaptation, sustainable ocean management

Associate Members

Name	Gender	Place of work	Expertise relevant to proposal

1 Mary O'connor	F	University of British Columbia, **Canada**	Adaptive capacity of biodiversity and ecosystem function in changing environments
2 Larry Crowder	M	Stanford Woods Institute for the Environment, Stanford University, **USA**	Marine ecology and conservation, sea turtle ecology, fisheries
3 Nicolas Moity *	M	Charles Darwin Foundation, Galapagos, **Ecuador**	Marine ecology, GIS, MSP, fisheries, anthropic impacts, conservation research, mangroves
4 Bernardo R. Broitman	M	Departamento de Ciencias, Facultad Artes Liberales, Universidad Adolfo Ibáñez, **Chile**	Marine ecology, coastal oceanography, ecophysiology, ocean remote sensing
5 Anthony Richardson	M	University of Queensland, **Australia**	Zooplankton, deep ocean, fishing, conservation prioritization
6 Jorge García Molinos *	M	University of Hokkaido, Sapporo, **Japan**	Coastal ocean connectivity, climate responses and conservation
7 David Schoeman	M	University of the Sunshine Coast, **Australia**	Ensemble climate forecasting for response modelling
8 Nguyen Hoang Tri	M	UNESCO Man and Biosphere Program; **Vietnam**	Integrated coastal zone management; marine conservation; equitable marine management
9 Laura Antao *	F	Research Centre for Ecological Change, University of Helsinki, **Finland**	Macroecology, climate change, global patterns in biodiversity change, biodiversity synthesis
10 Greg Asner	M	Center for Global Discovery and Conservation Science, Arizona State University, **USA**	Coastal and marine mapping; Marine geospatial analysis and A.I.; Coral reef ecology

Working Group contributions (full members)

Rilov’s research focuses on marine community ecology and how marine biodiversity and ecosystem functions are affected by human (fishing) and global (climate change and bioinvasions) stressors, from the species to the ecosystem. He also applies this knowledge to developing ways for adaptive conservation planning strategies to deal with climate change impacts.

Queirós develops ocean climate modelling and modelling analyses methods for dynamic ocean management and sustainability of marine policies under CC. She co-leads the ICES WGMPCZM ToR on CC and MSP, and works at science-policy interface. She recently led a CC assessment for the Irish government MSP framework; was engaged in various sustainable development initiatives (UKRI GCRF).

Bates’ research quantifies biodiversity in time and space with relevant environmental data and the physiological tolerances of species. Her group transforms physiological data into predictive tools incorporating both exposure and species’ sensitivities to global change drivers. In doing so, Bates generates novel theory and approaches for managing and conserving marine resources.

Gissi’s research incorporates ecosystem-based approach in ocean management, and in MSP processes, by understanding the uncertainties in assessing cumulative effects assessments from multiple stressors. She also addresses transboundary conservation challenges in marine spatial prioritization for systematic conservation planning. Her work also supports EU Member States in MSP implementation in the Mediterranean.

Helmuth's research centers on predicting the likely impacts of CC on coastal ecosystems using coupled biophysical and ecophysiological approaches, including the development of novel sensors. His lab also develops decision support tool design and testing, as well as novel methods for public engagement such as visualizations and citizen science.

Lima works on intertidal biogeography, studying the processes and mechanisms driving species distributions. He studies the mechanistic links between climate, thermal stress, physiology and macro-ecological processes. His research brings together climatology, biogeography, electronics, experimental ecology, behavior, physiology and modelling.

Dong's research focuses on developing an integrated understanding of the impacts of CC and human activity on biogeographic patterns of intertidal species. Mechanistic studies provide critical insights into the physiological and biochemical adaptations of intertidal invertebrates to environmental stresses, providing cause-effect frameworks for the mechanisms driving species range shifts.

Burrows's research addresses species and community responses to CC using long-term and spatially-extensive datasets to detect the effects of changing patterns of abundance and distributions in response to warming and other climatic change, comparing observed changes to expectations based on spatiotemporal metrics of CC (e.g. rates of shifting isotherms) and anticipated species responses to temperature.

Hurd examines the environmental regulation of seaweed primary production by light, nutrients, temperature, CO_2/pH and water motion. She takes a mechanistic physiological and biochemical approach to understand how seaweeds, and the communities that they support, will respond to CC - ocean acidification, temperature and marine heatwaves, and local stressors, focusing on the role that seaweeds play in creating refugia for coastal calcifiers from ocean acidification.

Frazão Santos's research focuses on the links among MSP, sustainable ocean governance, and CC effects in the ocean. She develops interdisciplinary research, investigating how human dimensions and political aspects influence sustainable use and ocean conservation. She is currently leading a R&D project on how MSP can be affected by and adapt to CC, and she supports UNESCO and the European Commission in MSP-related events.

Relationship to other international programs and SCOR Working groups

MarCCR will work in parallel with a new EU Horizon2020 project, FUTUREMares, co-led by members of this team (Rilov and Queiros), that is focused on climate change impacts and nature-based solutions in the marine environment that will start in September 2020. The results of **MarCCR** could naturally translate into implementations and recommendations for application within FUTUREMares. FUTUREMares might also be able to provide some support for personnel to help with data analysis for MarCCR, and students and postdocs from the EU project could benefit from capacity building through **MarCCR** activities. Queiros co-leads the ICES WGMPCZM (Working Group for Marine Planning and Coastal Zone Management) terms of reference on climate change and MSP, and the results from both groups present natural synergies that benefit the development of climate-adaptive MSP practices in Europe and elsewhere. Queiros is a Co-I in two UKRI Global Challenges Research Fund programmes (GCRF) focused on the development of capability in climate-adaptive approaches for ocean sustainability that support resilience of vulnerable communities in the developing world, with activities focused in the Western Indian Ocean and SE Asia, with **MarCCR** associate member Tri being part of the latter. Synergies will be explored with those projects, towards the delivery of: training activities led by this SCOR group with students, researchers and practitioners involved in those projects; synergies with the ICZM work delivered by PEMSEA in SE Asian partner countries involved in GCRF, including the Vietnam UNESCO Man andBiosphere Reserve (Tri); and the representation of developing country perspectives within this SCOR workgroup through engagement activities and contribution towards the publications of this workgroup. Gissi has been awarded a Marie Sklodowska Curie Global Fellowship for the project MEDIX "Marine

Environmental DynamIcs and seX-based analysis for climate change adaptation in MSP" in collaboration with Stanford University. The 3-year project will start by March 2021. Frazão Santos is the coordinator (PI) of project OceanPlan (*www.oceanplan-project.com*), a 3-year R&D project on how marine spatial planning can both be affected by and adapt to global climate change (2018-2021). The project is funded by the Portuguese National Science Foundation (FCT) and carried by an international team of scientists (including L. Crowder, T. Agardy, C. Ehler, H.O. Portner). OceanPlan outputs will provide support to **MarCCR**, namely regarding conceptual links between MSP-climate change (Frazão Santos et al. 2020), vulnerability assessments (preliminary work awarded at ICES ASC 2018), and MSP adaptation approaches. Catriona Hurd is an associate member of SCOR WG149 "Changing Ocean Biological Systems" (*https://scor149-ocean.com*) whose focus was to develop an online "Best Practice Guide" for designing and implementing laboratory multiple-stressor experiments (*https://scor149-ocean.com/decision-support-tool*). The team also runs training workshops to enable students and scientists with the skills to undertake multiple stressor experiments. We received a support letter for this **MarCCR** proposal from Prof. Philip Boyd, chair of WG149, stating that "the proposal is very timely, and I support it very strongly. It would be exciting for SCOR WG149 (COBS) to interact with MarCCR, in particular around the identification of suitable refugia to offset complex multi-faceted ocean change."

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Appendix

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

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ReMO: Respiration in the Mesopelagic Ocean: Reconciling ecological, biogeochemical and model estimates

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Summary

Together with organic matter export from the surface ocean, microbial respiration in the mesopelagic realm (~200m – 1000m) determines the long-term storage of carbon in the ocean, the extent of mesopelagic deoxygenation and, ultimately, the levels of carbon dioxide in the atmosphere. Yet, microbial respiration remains one of the least constrained metabolic rates in the Earth System, with mismatches between inverse model predictions, in situ budgets and in vitro observations of an order of magnitude. These mismatches stem from the difficulties in quantifying microbial respiration rates in the dark ocean. However, with the dawn of novel in situ technologies such as optodes, in situ incubators, gliders, and floats, we are now able to determine mesopelagic microbial respiration with unprecedented spatial and temporal coverage. However, whilst technologies have advanced substantially, efforts to bring all the data together across depth-, size-, and time-scales are still lacking.

This working group will bring together experts in observation, experimentation, data analyses, and modelling to systematically compile and compare data sets of mesopelagic microbial respiration in order to constrain respiration uncertainties and improve quantifications of organic matter flux and remineralisation rates. A final outcome will be to improve projections of the effects of global change on the decline of oxygen in the world's oceans, with implications for fisheries and food security. The outputs of ReMO will have a high impact on future ocean research as they will enable efficient use of the wealth of data currently collected by autonomous instruments in the oceans.

Scientific background and rationale

The relevance of mesopelagic respiration

Microbial respiration in the mesopelagic ocean is a major contributor to the vital ecosystem service of climate mitigation, determining the balance between the storage of organic carbon in the sea or its remineralisation to, and ultimately evasion of, carbon dioxide to the atmosphere. Yet it is one of the least constrained metabolic processes in the marine system, with large mismatches between predictions and observations. This severely compromises our ability to predict future decreases in oxygen and resultant changes to fisheries and global food supply. It is vital to fully understand the functioning of the mesopelagic ocean as soon as possible, prior to the imminent risk of commercial exploitation for fisheries and mineral extraction (Martin et al., 2020).

The challenge

Reasons for the paucity of mesopelagic data and the mismatch between ecological and biogeochemical measurements include the relative inaccessibility of the deep sea, and that despite being such a vast region of the ocean, through which all sinking material must pass, remineralisation rates are sufficiently slow that many direct methods struggle to make reliable measurements. A range of exciting new techniques means that the time is right to compare estimates made through a combination of ecological, biogeochemical and modelling approaches which integrate across different temporal and spatial scales.

Mesopelagic microbial respiration rates can be estimated from the consumption of oxygen or production of carbon dioxide in an incubated water sample; from the maximum activity of the enzymes associated with the electron transport system (ETS) of the plankton in a filtered water sample; from the time resolved estimate of the amount of oxygen consumed or carbon dioxide produced in a defined water body (transient tracer models), or from budgets of oxygen, nutrients or carbon in a given volume (box) of the ocean. In the case of transient tracer models, the oxygen utilisation rate (OUR) is based on the apparent age of the water estimated from tracers such as sulphur hexafluoride, while in box models, the time scale is the renewal time of water in the box. Microbial respiration can also be estimated from prokaryotic production (assuming a growth efficiency); determined from oxygen consumption rates estimated from quasi-Lagrangian autonomous platforms; inferred from the depth distribution of particle flux; or reconstructed from microbial metaproteomics.

Some recent developments of these approaches include :

the ability to incubate samples, including suspended and sinking particles, in situ, thereby avoiding pressure and sample manipulation effects,
the use of pyridine nucleotide concentrations and an enzyme kinetic model alongside the ETS technique to measure actual rather than maximum activity,
the use of a proxy for respiration derived from the in vivo reduction of the 2-para (iodophenyl)-3(nitrophenyl)-5(phenyl) tetrazolium (INT) salt by the cellular ETS,
the increase in in situ oxygen measurements from autonomous instrumentation such as gliders and Biogeochemical (BGC) Argo floats,
the development of fluorescent redox probes enabling the linkage between respiratory activity and microbial community structure,
the improved spatial and temporal coverage of estimates of particle flux attenuation derived from optical instruments on ship-deployed or autonomous platforms, and
the improved representation of particle sinking and decay in global models based on size spectra and age-dependency of remineralisation.

Before widespread use in the mesopelagic, each new technique requires comparison and intercalibration with traditional methods, and may have particular advantages, limitations or even be unfeasible in certain contexts. An ideal approach would be one which derived respiration from a combination of measurements covering the range of temporal and spatial scales from cellular metabolism to water column oxygen and nutrient budgets. Unfortunately, up until now, the small number of such comparative studies which have taken place, are only loosely constrained.

Calibrations of marine biogeochemical models with observed distributions of dissolved nutrients and oxygen are most sensitive to the parameters describing export and remineralisation of organic matter. Different models apply different parameterisations of particle flux attenuation in the mesopelagic ocean, with consequences for the simulation of oxygen minimum zones and atmospheric carbon dioxide. Observational constraints available so far have been insufficient to converge on appropriate parameterisations that are globally applicable and can be reliably used in climate change projections. Hence, coupled physical-biogeochemical models can currently only account for 50% of the observed decline in mesopelagic dissolved oxygen.

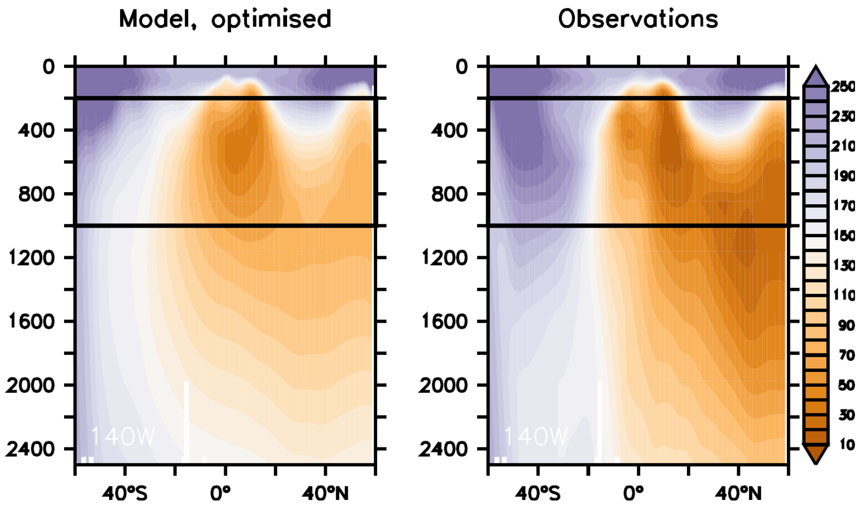

Figure 1. Dissolved oxygen (mmol m^{-3}) along 140^{o}W in a global biogeochemical model optimised against observed nutrients and oxygen after simulation over 3000 years (left: Kriest et al., 2020) and climatological observations (right: Garcia et al., 2006). Horizontal lines denote the mesopelagic between 200 and 1000m.

There is therefore a clear need to include the recently developed techniques in a comparative approach across the breadth of temporal and spatial scales, in order to constrain estimates of mesopelagic microbial respiration, and identify and parameterise factors which control variability in mesopelagic respiration, allowing accurate implementation into global models.

Such reconciliation requires progress through the following steps:

A need to review and improve methodologies for more accurate and precise ecological measurements of respiration considering the effects of pressure, temperature, in situ

oxygen and carbon dioxide concentrations, and the formation, transformation and mineralisation of particles
A need to understand what is required to build better, more reliable models and how these can be validated
A need to constrain the variability in the conversion factors used to estimate respiration from indirect ecological measurements, for example I) the ratio between dissolved oxygen consumption, single cell proxies of respiration and the ETS activity of cells in the water column, II) the respiratory quotient used to convert between oxygen consumption and carbon dioxide production, and III) prokaryotic growth efficiencies used to convert prokaryotic heterotrophic production into prokaryotic respiration
A need to reconcile ecological and biogeochemical estimates measured over a range of scales, for example oxygen utilization rates (OUR) derived from profiling sensors on buoys and gliders with oxygen consumption rates and rates of ETS activity
A need to compare and confront coupled physical-biogeochemical models, ranging from regional to increasingly high-resolution global climate models, with data, and undertake model sensitivity studies informed by observations and their uncertainties to understand processes and help constrain drivers of change

Why a SCOR working group ?

The work that we propose requires a multidisciplinary team involving ecologists, biogeochemists, physical oceanographers and ecosystem modellers who work across scales from cells to ocean basins. The expertise in these fields does not reside within a single nation, and national research funding rarely covers the type of method intercomparison and data collation exercises that are required to move the field forward. As new methods and approaches are being developed and tested, there is a need for an internationally recognised best practice manual and a network of experienced scientists able to increase the global extent of research groups studying mesopelagic respiration through training and mentorship. The scientific breadth, reputation and international perspective of SCOR, along with a key focus on capacity building, provides the ideal framework in which to undertake the activities proposed here.

In the 10 years since the last review of mesopelagic respiration (Arístegui et al. 2009), there have been significant developments in technologies, including enzyme kinetics, sensors on moorings, floats and gliders and in situ incubators. This has enabled greatly increased temporal and spatial data coverage alongside the growing consensus that the open ocean is losing oxygen overall, with the volume of the ocean's oxygen minimum zones projected to grow by 7.0 $\pm$ 5.6 % by 2100. There is therefore an urgent requirement to derive reliable estimates of respiration to resolve the dissolved oxygen consumption in the contemporary world ocean and to support and validate Earth System Models predicting the impacts of climate change.

Terms of Reference (ToR)

This working group will focus on quantification of mesopelagic microbial respiration in order to constrain mismatches between predictions and observations. It aims to:

ToR# 1 Identify, quantify and prioritise gaps in our knowledge, and prepare an action plan to reduce these gaps by reviewing available information on mesopelagic respiration

ToR# 2 Develop a global dataset of mesopelagic respiration estimates, derived from the range of ecological and biogeochemical techniques available, in order to create a resource for validation of biogeochemical models including Earth System Models used for climate projection

ToR# 3 Produce a new synthesis of open ocean mesopelagic respiration

ToR# 4 Produce a best practice manual of techniques and approaches to determine mesopelagic respiration, and make recommendations as to which is the most appropriate method or combination of methods for a particular application, including best practice on how to reconcile approaches across time and space scales

ToR# 5 Build capacity, share knowledge and transfer technical skills, particularly to scientists in developing nations

Work Plan

To deliver ToR# 1
We will collate publications on mesopelagic respiration, quantify the differences between estimates, and identify the gaps in our knowledge which are hindering progress. We will then prepare an action plan proposing how to address these gaps (Deliverable #1).

We will design studies to compare ecological, biogeochemical and model approaches, and to intercompare models, to address the identified uncertainties. The action plan and designs for comparative studies will form the basis of a position paper (Deliverable #2) on the importance of mesopelagic respiration, the identified knowledge gaps and the way forward. We will initiate the designed model intercomparison study, focussed on organic matter supply and mesopelagic respiration, and produce an open access publication (Deliverable #3).

To deliver ToR# 2
We will create a dataset of global mesopelagic respiration estimates, and, using a simple spreadsheet format on an open access platform such as Google docs encourage international colleagues to contribute. We will register this dataset for a Digital Object Identifier (DOI) through the British Oceanographic Data Centre (BODC) Published Data Library *https://www.bodc.ac.uk/submit_data/data_citations/* thus ensuring that it remains accessible and useable as a long term product (Deliverable #4). We will launch the dataset at an international conference, and submit a data paper to the journal *Earth System Science Data* https://www.earth-system-science-data.net/ (Deliverable #5).

To deliver ToR# 3
We will undertake a case study comparing approaches for determining mesopelagic respiration using published and our own unpublished data. We will identify suitable regions, such as the North Atlantic and Eastern Equatorial Pacific, where mesopelagic respiration can

be derived from available data such as OUR, ETS activity, and particle flux attenuation from sediment trap data and in situ optics profiling. We will also review the literature and interrogate the collated database from ToR#2 to assess the controls on mesopelagic respiration including organic matter input, microbial community composition, temperature, decreasing oxygen and increasing carbon dioxide. This case study will form the basis of a synthesis paper which we will present at a major international conference (Deliverable #6).

To deliver ToR# 4

We will collate information on the ecological, biogeochemical and modelling techniques used to determine mesopelagic respiration, identify the advantages and limitations, and wherever possible, quantify the errors, of each technique in order to recommend the ideal combination of approaches for a particular context. We will use this information to write a best practice manual linked to the Ocean Best Practices (OBP) *https://www.oceanbestpractices.net/platform* platform (Deliverable #7), and launch it at a suitable international conference.

We will organise a method intercomparison workshop at the University of Las Palmas de Gran Canaria in order to compare and contrast a range of ecological and biogeochemical methods. The data and interpretations obtained during the workshop will be submitted as a comparative paper and dataset (Deliverable #8).

To deliver ToR# 5

We will create and deliver a training course on mesopelagic respiration to be held immediately after the method intercomparison workshop (Deliverable #9). We will also create a series of online lectures and practical demonstrations of respiration techniques and modelling exercises (Deliverable #10). These materials will maximise the accessibility of the training while reducing the carbon footprint of the working group. We will submit a manuscript on mesopelagic respiration aimed at children to *Frontiers for Young Minds* (Deliverable #11).

Timeline

Year 1 - 2021

An initial workshop will be held during Spring/Summer 2021, possibly associated with the Gordon Research Conference on Biogeochemistry. The activities undertaken during the workshop will be to discuss, compare and evaluate approaches to determine respiration in order to begin to structure the action plan and design an observational and modelling intercomparison exercise, to discuss and design the format of the dataset and the best practice manual, and to plan the method intercomparison workshop and training course. We will allocate tasks amongst ReMO members to create a subgroup and lead members for each ToR, and hold virtual meetings every 2 months during the year in order to ensure timely progress of these.

By the end of year 1 we expect to have completed the action plan (Deliverable #1) and position paper (Deliverable #2) and have made progress with the dataset and best practice manual.

Year 2 - 2022

During year 2 we will continue with bimonthly virtual meetings in order to progress several of our deliverables. In particular, we will focus on planning and preparation for the intercomparison workshop and training course, undertaking the model intercomparison and drafting the respiration synthesis paper and the paper for school children.

By the end of year 2 we aim to have completed a first version of the dataset and the model intercomparison paper (Deliverable #3), and to have progressed with the best practice manual and data paper.

Year 3 - 2023

We will hold a second working group meeting alongside the method intercomparison workshop and training course (Deliverable #9). Due to the logistics, cost and associated airmiles, we feel these two activities are best achieved consecutively. The University of Las Palmas is the preferred venue for these activities based on easy access to deep water, suitable laboratory facilities, in-kind support and access for students from developing nations. During the workshops we will create the series of training podcasts.

By the end of year 3 we aim to have completed the best practice manual (Deliverable #7), the dataset (Deliverable #4) and data paper (Deliverable #5) and progressed with the synthesis paper.

Year 4 - 2024

We will hold a final working group meeting alongside an appropriate international conference such as Ocean Sciences to progress the remaining ToRs. We will launch the best practice manual and the dataset at a Town Hall meeting at the conference, chair a special session on mesopelagic respiration and present the synthesis paper.

By the end of year 4 we will have published the data and interpretations arising from the method intercomparison workshop (Deliverable #8), the synthesis paper (Deliverable #6), the paper for children (Deliverable #11) and made the training podcasts available online (Deliverable #10).

Deliverables

<u>From ToR# 1 :</u>

An action plan to identify gaps in knowledge and propose ways to address those gaps
A position paper, based on the plan, highlighting the importance of reliable estimates of mesopelagic respiration, and suggesting priority research questions
A model intercomparison / data sensitivity paper

<u>From ToR# 2 :</u>

A global dataset, linked to international marine data hubs, for use by modellers, launched at a Town Hall meeting at an international conference such as Ocean Sciences
A data paper in *Earth System Science Data* https://www.earth-system-science-data.net/

<u>From ToR# 3 :</u>

A synthesis paper on a model/observational case study, and presentations at appropriate international conferences

From ToR# 4 :
A best practice manual for ecological and biogeochemical methods used to derive mesopelagic respiration
A method intercomparison paper and dataset

From ToR# 5 :
A training course on model and observational approaches to derive mesopelagic respiration for early career and experienced researchers, particularly aimed at scientists from developing nations
Online training materials such as lectures and practical demonstrations of analytical techniques, budgeting exercises and modelling approaches
A manuscript for children on mesopelagic microbial respiration in *Frontiers for Young Minds* https://kids.frontiersin.org/

Capacity Building

Deep-sea biogeochemistry, microbiology and numerical modelling have historically been led by a small number of developed nations, yet marine ecosystem services such as climate mitigation and the potential for climate change effects such as ocean deoxygenation and acidification are worldwide challenges, potentially disproportionately affecting developing regions dependent on coastal fisheries. Therefore, one of the key aims of this working group is to provide materials, training and mentorship to extend access to the measurement, interpretation and understanding of mesopelagic microbial respiration, including how it affects climate and is itself influenced by climate change.

In order to do this, we will first interact with the SCOR Committee on Capacity Building, in order to benefit from their expertise in developing and implementing capacity building activities, including contacting their existing networks and mentoring programmes.

We have developed the deliverables of this working group specifically to contribute to this key capacity building aim. The action plan and position paper within ToR#1 aim to motivate the international community to incorporate studies on mesopelagic respiration into ecological and biogeochemical investigations of the deep ocean. This will require training and mentorship of experienced and early career scientists from developing nations. To this end, we will produce a best practice manual available through the Ocean Best Practices (OBP) *https://www.oceanbestpractices.net/platform* platform, an open access, permanent digital repository of community best practices in ocean-related sciences maintained by the International Oceanographic Data and Information Exchange (IODE) of the UNESCO-IOC.

We will also organise a dedicated training course for scientists from around the world, with priority given to scientists from developing nations, focussed on gaining experience in a range of ecological, biogeochemical and modelling approaches used to estimate mesopelagic respiration. We will take advantage of video streaming and recording technology to broaden participation in this training course, and we will produce a series of online lectures and practical demonstration podcasts detailing the relevant analytical techniques and modelling approaches. These will be posted online, through the Integrated Marine Biosphere Research (IMBeR) project's YouTube and YouKu channels https://www.youtube.com/channel/UCinzjRz7_TKHESn6uggCKlw/featured and *http://i.youku.com/imberipo*. We will also create a teaching 'module' on measuring and modelling respiration which can be used to contribute to the schedule of already established international summer schools, for example the IMBeR project's Climate and Ecosystems (ClimEco) series (http://www.imber.info/en/events/climeco-imber-summer-schools).

We will create a dataset of mesopelagic respiration which can be used in undergraduate and postgraduate teaching to understand the variability in respiration, in addition to being used to validate Earth System Models. The dataset will be hosted at the British Oceanographic Data Centre (BODC), assigned a Digital Object Identifier (DOI) linked to DataCite *https://datacite.org/mission.html*, thus ensuring adherence to FAIR Guiding Principles for scientific data management and stewardship (i.e. the capacity to **F**ind, **A**ccess, **I**nteroperate and **R**euse data with none or minimal human intervention), and it will also be linked to relevant international data hubs such as IMBeR's Marine Data Hub *https://ccdatahub.ipsl.fr/*, the Joint Exploration of the Twilight Zone Ocean Network (JETZON) data sharing and method intercomparison site *http://jetzon.org/* and the Simons Foundation's Collaborative Marine Atlas Project (CMAP) *https://cmap.readthedocs.io/en/latest/index.html*. The dataset and metadata will also be preserved through an open access publication in a specialist journal such as *Earth System Science Data*. We will aim to release a first version DOI of the dataset during year two so it can be used for case studies during the training course and within the model intercomparison paper, with the final DOI version launched in year four with the best practice manual.

Where possible, ReMO meetings will be held alongside conferences such as IMBeR's Western Pacific Symposia so associate members, early career researchers and scientists from developing nations can attend the sessions, and we will work with the scientific community to leverage additional funding for such participation. Progress towards ReMO Terms of Reference will be monitored and achieved through virtual meetings held at two monthly intervals. We envisage that some of these meetings will be open to the scientific community and targeted to scientists from developing nations to include webinar presentations and discussions of data.

We aim to initiate a mentoring scheme, whereby each ReMO member is paired with and subsequently mentors an early career scientist from a developing nation. This mechanism has been used successfully by organisations such as IMBeR, the American Geophysical Union (AGU) and the Association for the Sciences of Limnology and Oceanography (ASLO), over short time periods (i.e. a few months) leading up to major international conferences. We would hope to extend such a scheme to cover the full time period of ReMO. The opportunity to be a mentee on such a scheme would be advertised through the network afforded by the SCOR sponsored global projects, the SCOR capacity building committee and early career researcher networks such as the Young Earth System Scientists (YESS) community, the Interdisciplinary Marine Early Career Network (IMECaN), the IOC-UNESCO

Ocean Decade's network of Early Career Ocean Professionals, and the Association of Polar Early Career Scientists (APECS). We would evaluate the success of the scheme in order to know whether this could be a useful capacity building tool for future groups.

The action plan, position paper and design of comparative studies, undertaken within ToR#1, would also be the basis for a number of research proposals to be submitted to our national funding agencies in order to gain research ship time to undertake a more extensive biogeochemical, ecological and modelling intercomparison exercise at an established oceanographic time series station. Within these research proposals, berths will be made available and funding requested for early career scientists from developing nations to take part as shipboard trainees in mesopelagic respiration measurements. We would also apply to the Nippon Foundation - Partnership for Observation of the Global Ocean (NF-POGO) fellowship scheme to increase the number of early career scientists from developing nations able to take part, following the successful model used on the Atlantic Meridional Transect (AMT; https://www.amt-uk.org/) programme.

We will set up a webpage within the SCOR and our institutional websites linked to a twitter account, in order to advertise the plans, activities and achievements of the working group.

The activities of ReMO will contribute to two of the United Nation's sustainable development goals : SDG14 (Life below water) and SDG13 (Climate Action), and to three of the societal goals outlined in the Implementation Plan for the UN Decade of Ocean Science for Sustainable Development to define the '**ocean we want**' including a *healthy and resilient ocean* that will ensure continuing delivery of marine ecosystem services to society, a *predicted ocean* allowing confident predictions of the future state of the ocean to support business and policy decisions, and a *transparent and accessible ocean* whereby all nations, stakeholders and citizens have access to ocean data and information.

Composition of the Working Group

ReMO includes 10 Full Members with the range of expertise needed to address the Terms of Reference, including biochemistry, analytical chemistry, microbial ecology, biogeochemistry, particle flux and coupled ocean-atmosphere modelling, and experience in data collation, method development, public engagement and capacity building. They represent a broad geographic spread including from Europe, Australasia, South America and Asia. The gender balance is 4:6 female:male and the members include 3 early career researchers who gained their PhD within the last 10 years. The early career members are each recognised as expert in a particular new technique or approach, and will contribute this expertise in particular to the evaluation and comparison of mesopelagic respiration techniques using new datasets. ReMO will be co-ordinated by 3 co-chairs (Robinson, Arístegui and Kriest) who have substantial experience in the ecological, biogeochemical and modelling approaches to be used here.

Full members

Name	Gender	Place of Work	Expertise relevant to proposal

Carol Robinson (co-chair)	F	University of East Anglia, **UK**	Microbial oxygen consumption and carbon dioxide production
Iris Kriest (co-chair)	F	GEOMAR Helmholtz Centre for Ocean Research, **Germany**	Global biogeochemical models
Gerhard Herndl	M	University of Vienna, **Austria** & Netherlands Institute for Sea Research (NIOZ) **The Netherlands**	Single cell respiration measurements using fluorescing redox dyes linking to phylogeny, in situ microbial activity, pressure effects, metaproteomics and metagenomics
Natalia Osma (early career)	F	University of Concepcion, **Chile**	Electron transport system activity and enzyme kinetic models
Javier Arístegui (co-chair)	M	University of Las Palmas de Gran Canaria, **Spain**	Microbial oxygen consumption and growth efficiency, ETS activity, box models
Matthieu Bressac (early career)	M	University of Tasmania, **Australia**	Oxygen consumption of particle attached bacteria
Ying Wu	F	East China Normal University, **China**	Geochemical cycles, oxygen consumption and dissolved organic matter degradation
Hyung Jeek Kim (early career)	M	Korea Institute of Ocean Science and Technology (KIOST) **Korea**	Sinking particle flux derived from sediment traps
Morten Iversen	M	Alfred Wegener Institute, **Germany**	Aggregate-associated microbial respiration, organic matter export and turnover using traps and in situ optics in profiles and on moorings
Jack Middelburg	M	Utrecht University, **The Netherlands**	Biogeochemistry, organic geochemistry, stable isotopes, modelling, degradation kinetics

The Associate Members provide additional expertise and experience, including in modelling, microbial ecology, oxygen optodes within in situ respirometers, use of BGC Argo data to derive oxygen and carbon fluxes, and the effects of pressure on microbial metabolic rates.

Associate members

Name	Gender	Place of Work	Expertise relevant to proposal
Christian Tamburini	M	Mediterranean Institute of Oceanography (MIO), **France**	Pressure effects, particle degradation, sinking particles simulation, prokaryotic diversity
Sara Ferrón	F	University of Hawaii, **USA**	Oxygen and carbon dioxide fluxes, in situ optodes, in vivo ETS, gliders, membrane inlet mass spectrometry
Yao Zhang	F	University of Xiamen, **China**	Mesopelagic microbial community structure and activity, budgets of carbon flux
Giorgio Dall'Olmo	M	Plymouth Marine Laboratory, **UK**	Estimates of particle fluxes and oxygen consumption from BGC Argo data
Toshi Nagata	M	University of Tokyo, **Japan**	Microbial control of particle coagulation and disintegration
Dominique Lefevre	M	Mediterranean Institute of Oceanography (MIO), **France**	Optode calibration, in situ oxygen dynamic auto-sampler (IODA), CO_2, ETS
Katja Fennel	F	Dalhousie University, **Canada**	BGC Argo, regional biogeochemical models
Xose Antón Álvarez-Salgado	M	CSIC Institute of Marine Research, **Spain**	Geochemical determination of OUR and stoichiometric ratios, water mass mixing and mass balance
Haimanti Biswas	F	National Institute of Oceanography, **India**	Microbial oxygen consumption and degradation of dissolved organic carbon

Working group contributions

Carol Robinson studies the role of marine bacteria, phytoplankton and zooplankton in the global cycling of carbon and oxygen, with a particular focus on determining the magnitude and variability of microbial respiration using a combination of ecological and enzymatic techniques. She has extensive experience in leading international multidisciplinary research programmes including the Atlantic Meridional Transect (https://www.amt-uk.org/Home) and IMBeR, and a passion for outreach, mentoring and engagement.

Iris Kriest's research foci are the description of biogeochemical processes in large-scale ocean models, assessment of model skill, and calibration of biogeochemical model parameters (constants) on a global scale. This also involves analysis and synthesis of observations, as well as development and tests of metrics for global model optimisation.

Gerhard Herndl is working on mesopelagic microbial activity at the bulk and single-cell level as well as on the effects of hydrostatic pressure on microbial activity in meso- and bathypelagic waters. His group also uses metaproteomics and metagenomics to characterize the microbial activity of distinct microbial populations in mesopelagic waters.

Natalia Osma contributes her experience in measuring ETS activity in a wide range of ecosystems. She developed the methodology to measure pyridine nucleotides and applied an enzyme kinetic model to estimate respiration rates in marine organisms for the first time, and recently adapted this to water column work.

Javier Arístegui has extensive experience working on mesopelagic respiration, combining ecological (microbial oxygen consumption and growth efficiency), enzymatic (microbial ETS activity) and biogeochemical (particulate and dissolved organic carbon box model) approaches. He led the first published review on respiration in the dark ocean.

Matthieu Bressac (co-)developed the novel *in situ* incubators, RESPIRE and TM-RESPIRE, which allow the non-intrusive interception and incubation of settling particles at in situ pressure and temperature. RESPIRE determines oxygen consumption of particle-attached bacteria, while TM-RESPIRE allows the quantification of bacterial regeneration of nutrients and trace elements.

Ying Wu uses organic geochemical proxies to study the depth-dependence of remineralization of dissolved organic material and its interaction with microbial community structure and functioning. Building on her capacity building experience, she will identify regional capacity needs and help align activities across regional projects and programs.

Hyung Jeek Kim contributes his experience in using time-series sediment traps to determine particulate organic carbon flux and variability in the efficiency of the biological carbon pump, including seasonal variability and the influence on fluxes of the El Niño-Southern Oscillation (ENSO).

Morten Iversen is working on how upper ocean food web composition spanning from prokaryotes to zooplankton impacts on particle export dynamics, specifically how particle size and composition determine sinking velocity and remineralization. His group is developing several novel methods and instrumentations to measure in situ rates of settling, turnover, and export as well as collecting intact marine aggregates for detailed composition and rate measurements at high temporal resolution during year-long deployments in different regions.

Jack Middelburg contributes his extensive experience in organic matter degradation and how it links to the identity of the organisms involved. He pioneered the use of reactive continuum modelling and integrates organic geochemical, biogeochemical and ecological approaches.

Relationship to other international programmes and SCOR working groups

IMBeR, SOLAS, GO2NE, JETZON, BioGeoSCAPES

The ToRs of ReMO will strongly enhance the Integrated Marine Biosphere Research (**IMBeR**) project's science goal, contributing specifically to Grand Challenge 1 (*Understanding and quantifying the state and variability of marine ecosystems*) and 2 (*Improving scenarios, predictions and projections of future ocean-human systems at multiple scales*) of the IMBeR Science Plan. However, the topic lies outside IMBeR's interdisciplinary focus and so IMBeR funds are not available to progress this endeavour. The working group membership includes several current and previous members of IMBeR's scientific steering committee (i.e. Robinson [SSC Chair 2016-2021], Arístegui, Wu and Herndl) which will ensure effective interaction between ReMO and IMBeR. The importance of mesopelagic respiration to deoxygenation, acidification and the production of carbon dioxide, means that the work within ReMO will also be of relevance to Core Theme 1: *Greenhouse gases and the oceans* of the Surface Ocean Lower Atmosphere Study (**SOLAS**) which aims to understand and quantify greenhouse gas sources and sinks. ReMO also includes several participants of the Joint Exploration of the Twilight Zone Ocean Network (**JETZON**), (i.e. Robinson, Arístegui, Iversen, Tamburini, Dall'Olmo, Kriest, Álvarez-Salgado) which will ensure data sharing and intercomparisons of ReMO microbial respiration estimates with those of mesozooplankton respiration and quantification of the biological and particle pumps in the mesopelagic zone. We are in contact with Andreas Oschlies, the Chair of the Global Ocean Oxygen Network (**GO2NE**; https://en.unesco.org/go2ne), to ensure interaction between ReMO and the network in terms of capacity building and research in understanding the distribution and changes in the distribution of dissolved oxygen in the mesopelagic zone. Herndl and Robinson were involved in the development of the BioGEOTRACES component of GEOTRACES and are in contact with Alessandro Tagliabue to ensure interaction between ReMO and the emerging BioGeoSCAPES programme.

Other SCOR working groups

ReMO will build on some of the work started and ongoing by Robinson, Herndl, Álvarez-Salgado and Nianzhi Jiao on respiration of recalcitrant dissolved organic carbon as part of WG 134 The Microbial Carbon Pump, and incorporate and progress the recommendations made by Arne Körtzinger and colleagues in WG 142 Quality control procedures for oxygen sensors on floats and gliders. Through JETZON and ReMO member Iversen, we will interact with members of WG 150 on Optical measurements for particle content and flux (TOMCAT) led by Sari Giering. We will investigate opportunities to work with WG 159 Deep sea biology (DeepSeaDecade) led by Kerry Howell and Ana Hilario on capacity building activities and linkages with the Deep Ocean Observing Strategy (DOOS), and in assessing the impact of decreasing dissolved oxygen and increasing carbon dioxide on microbial respiration, through Biswas, ReMO will interact with WG 149 Changing ocean biological systems (COBS): how will biota respond to a changing ocean ? led by Philip Boyd. Although not specifically working in oxygen minimum zones, our work on microbial respiration and deoxygenation will be of relevance to WG 155 Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change.

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Appendix : Five key publications for each full member

Carol Robinson

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CONCENSUS: Are global indicators of COastal and Nearshore benthic fish assemblage status in agreement if derived from disparate visual CENSUS techniques?

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Summary
Fish are essential components of coastal and nearshore benthic ecosystems, and provide nutrition and livelihoods for millions of people. Yet, they are threatened by climate change and anthropogenic impacts that compromise ecosystem functioning and undermine service provision. To improve our understanding of the role fish play in ecosystems and the impacts of current threats, global scale datasets are required as they can distinguish local and regional phenomena from the global context. Research on coastal and nearshore benthic fish is common, but typically carried out in isolation with limited standardisation in sampling methods and approaches among projects and organisations. Due to methodological bias, the lack of standardisation compromises the ability to merge datasets and investigate regional or global scales questions. To identify the extent of this problem, we propose a SCOR Working Group that will determine the interoperability of data collected by different methods and investigate solutions to mitigate the effects of sampling method on our understanding of the status of coastal and nearshore benthic fish assemblages and the processes structuring them. To overcome this problem, we will establish standardised best practice guidelines, and provide recommendations on how best to utilise data to address scientific questions of local and global importance. Furthermore, the Working Group will develop workflows for the management, publication and visualisation of open-access data. In achieving this, we will lay the foundation for relevant and sustained research that encourages capacity development, furthers our fundamental understanding of coastal benthic ecosystems and provides essential support for policy and decision makers.

Scientific background and rationale

Research history and methods

The proximity of coastal and nearshore ecosystems to land has facilitated extensive research on benthic fish assemblages. This has advanced our understanding of their functioning (1-3), value (4, 5), vulnerability (6-8) and resilience (9, 10). Many of the recent advances have come from the use of global scale datasets, as they allow unprecedented opportunities to distinguish local and regional phenomena from the global context. However, the bulk of the research in these ecosystems has taken place in isolation with limited standardisation among different studies or locations.

A variety of methods has been used to census benthic fishes (11). This includes destructive techniques, such as trawling and line-fishing, with data obtained either from fisheries or independently through research organisations. Nowadays, non-destructive techniques are preferred, due partly to availability of technology (such as SCUBA, remotely operated video cameras and environmental DNA) and reduced costs (12-13), but also greater awareness of research impacts, and the need to limit further damage to severely degraded areas and maintain conditions in protected areas (14). The ecosystem-based approaches to biodiversity and fisheries management have increased the need for ecosystem-level knowledge (15), rather than only species or component level, and this has favoured methods that can sample multiple components of an ecosystem simultaneously. The most widely applied methods that meet these requirements are SCUBA based underwater visual census (UVC), diver operated video (DOV) and baited remote underwater video systems (BRUVs). With technological advances, these methods have become affordable and available throughout the world. The techniques are fundamentally different, but all rely on visual census (either *in situ* or from videos) to measure fish diversity, abundance and size structure, and collect ancillary data on habitat characteristics. Decisions on which method and sampling approach to use are typically based on equipment availability and research expertise, both of which vary among organisations (16). Consequently, there is large variability in the methods chosen, and sampling approaches followed among research programmes. It is widely accepted that data collected with different methods and sampling approaches are not always directly comparable, due to differences in the species detected, areas covered and methods for estimating species abundance and biomass (11). This jeopardises the potential to combine data from different programmes to address larger scale research questions (16).

There are, however, several examples of well-coordinated global research programmes collecting comparable data (e.g. Reef Life Survey, Global FinPrint) that have led to significant high-profile research outputs (e.g. 17-20). There are also examples at the regional level in the Long-Term Ecological Research and Marine Protected Area Networks. The global Marine Biodiversity Observation Network (MBON) and the Global Ocean Observing System Biology and Ecosystem Panel (GOOS BioEco) work through broad global partnerships to ensure relevant research and observations inform sustainable use and protection of marine resources. Such centrally coordinated research programmes lay the ideal foundation to address global scale research questions. However, due to their scale, they are typically not replicated frequently though time. This reduces their ability to provide up-to-date data to address research or management challenges (21).

Global programmes only constitute a small fraction of the data collected in nearshore and coastal environments. Greater levels of standardisation among the many diverse local research programmes could drastically increase the spatial coverage, volume and frequency of data being contributed to a global observation network. To achieve this, we need to better understand the synergies and scope of data, identify and agree on minimum levels of methodological standardisation and develop data schema and vocabularies that ensure synergistic aggregation, availability and persistence of data. In achieving this, we will significantly improve the spatial and temporal resolution of the data and frequency at which it can be used for global science questions and reporting.

Indicators and the need for standardised global networks

Across all continental margins, the important services provided by coastal and nearshore benthic fish and their ecosystems are being compromised by anthropogenic disturbances (6). Global initiatives, such as the Convention on Biological Diversity strategic plan for Biodiversity, and the United Nations Sustainable Development Goals, Decade of Ocean Science for Sustainable Development and Decade of Ecosystem Restoration, provide opportunities to improve management and reduce impacts on ecosystem functioning. However, the success of these global initiatives hinges on identifying essential variables that are standardised, scalable and indicative of ecosystem or population state (21-23).

Many indicators have been used to report the status and vulnerability of fish populations and diversity (24, 25). However, indicators of ecosystem and assemblage status that are applicable at a global scale have typically been developed from data collected by a specific method. For example, the Large Reef Fish Indicator and Reef Fish Thermal Index (*https://www.bipindicators.net/*) are indicators specific to the UVC method (26). Their precision and sensitivity if calculated using other methods are unknown. Due to inherent biases and strengths associated with a particular method (11), our understanding of the information that the indicator conveys may not be valid when using different methods. More general indicators, based on diversity, total abundance or biomass data, may be possible to report on for a larger range of methods, but may not respond as predictably or sensitively to pressures, and the responses may still heavily depend on the method and spatial scale of sampling. Thus, targeted research is required to investigate the trade-offs between the sensitivity and information content provided by the most promising indicators and their applicability to data collected using different methods, over different spatial scales.

The challenge

To advance our ability to address scientific hypotheses on the dynamics and status of coastal benthic fish assemblages, we need to determine the extent to which datasets collected with a consistent method, but inconsistent sampling approaches, can be merged to expand the spatial and temporal coverage. Furthermore, to accommodate the use of different methods, there is a need to determine which indicators of population, assemblage or ecosystem state are robust to differences in sampling equipment or can be used in metadata analyses to address broader questions.

The goals of the CoNCENSUS Working Group (WG) are thus to build a community that addresses this challenge and advances standardisation within the different sampling techniques, provides direction on how to collectively use data from the different methods to enable scientifically robust research over various spatial scales, and develops infrastructure and workflows for the management and publication of open-access data.

In achieving these goals, we will lay the foundation for relevant and sustained research that encourages capacity development, furthers our fundamental understanding of coastal benthic ecosystems and provides essential support for policy and decision makers.

Why is SCOR the appropriate platform?

The CoNCENSUS WG will be an international collaboration focussed on solving methodological and conceptual problems that hinder research in an area of critical importance to marine biodiversity and the blue economy. A constraint on the degree to which biological data are used to address global scale questions, or report progress against agreed international goals, is a lack of consistency in data collection and limited publication of open-access data onto platforms, such as the Ocean Biogeographic Information System (OBIS). The CoNCENSUS WG will establish standardised best practice guidelines, determine the scope and interoperability of data and provide guidance on how best to utilise data from the UVC, BRUV and DOV sampling methods to address scientific questions of local and global importance. Furthermore, the WG will develop workflows for the management, publication and visualisation of open-access data. In doing this, CoNCENSUS will contribute significantly to capacity development and contribute towards other projects and initiatives implemented by the United Nations, GOOS, Partnership for Observation of the Global Ocean and Group on Earth Observation, including MBON and Blue Planet.

Terms of Reference

1: Determine the extent to which data obtained from different methods (UVC, DOV and BRUVs) and sampling approaches can be used in conjunction to measure and report on the status of coastal and nearshore benthic fish assemblages at a global scale. This will be achieved by identifying and analysing appropriate data sources to compare trends in indicators against known drivers of ecological condition, and by exploring solutions to mitigate the effects of sampling method and approach.

2: Endorse and, where necessary, publish best practice guidelines for ethics (including CARE principals for indigenous data governance), survey design, sampling techniques, data analysis and archival, and agree on a common base level of data and metadata collection required to enable data to be comparable, useful for reporting on key indicators and reusable in the future.

3: Develop data schema and vocabularies relevant to the visual census techniques, establish and implement data management protocols aligned with FAIR (Findable, Accessible, Interoperable, Reusable) and open-access principles, and establish infrastructure and workflows for open-access data to be published on OBIS and dedicated web-based platforms.

4: Determine priority areas and methods for engagement, capacity development and research to enhance coverage and strengthen the global network by carrying out a gap analysis on the appropriate data sources and peer-reviewed published literature.
5: Establish a global community of practice willing to employ the agreed minimum methods in programmes with demonstrated sustainability, and who are willing to share data through the agreed workflow and web-based platforms.

Working plan
TOR 1: Determining the extent of interoperability for data from different methods.
TOR 1 forms the basis of the WG and will underpin the strong and sustained collaboration. The WG is comprised of key members that can provide data and have expertise in data management, analysis, ecological theory and global policy requirements. To achieve this TOR, the following activities will be undertaken:
Identify suitable datasets and merge into a data framework permitting preliminary exploratory analyses. Work on the development of data schema and common vocabularies for the data, based on Darwin Core Standards to feed into TOR 3.
Agree on detailed scope of research questions based on properties of available data. Additional research questions may emerge from this process and will be explored.
Identify a suite of indicators that measure the status of the fish assemblages and, where applicable develop new indicators that best accommodate variable data sources and sampling methods.
Run analyses and draft manuscripts for peer-reviewed publication.
TOR 2: Development of minimum data standards and best practice guidelines for measuring indicators.
Fundamental to the WG is agreement on the most appropriate methods and sampling approaches, as well as the minimum resolution of biodiversity data and metadata, required to meaningfully report on indicators of assemblage status. Considerations relating to ethics and indigenous data co-management will be incorporated into the best practices. The required activities are to:
Agree on the optimal and minimum requirements for sampling.
Identify and/or develop best practice guidelines for the methods to carry out visual census research, and analyse and report on the findings.
Distribute guidelines for external review by the broader research community.
Publish the endorsed guidelines on the Oceans Best Practices website.
TOR 3: Establish and implement a data management policy.
Agree on the minimum standards, data schema and vocabularies for metadata and biodiversity data in accordance with Darwin Core standard and FAIR principals to ensure interoperability and persistence of data.
Engage with OBIS staff and relevant national-level biodiversity information managers to develop workflows that enable the seamless publication of data into OBIS via integrated publishing toolkits, to create an enabling environment for data discovery and access.
Identify and utilise established web-based applications (e.g. Reef Life Survey), and/or enable the expansion of existing systems (e.g. Global Archive) that allow discovery and automatic modelling and visualisation of the data to maximise the value for scientists, managers and policymakers.
TOR 4: Develop a roadmap to address the gaps in the coverage of methods and data.
Mapping a way forward to expand the potential global coverage and relevance of data collected is critical to advancing a coordinated and global approach to the visual census of benthic ecosystems. Here we will:
Determine the spatial extent of data coverage and identify priority gaps where capacity development can be implemented, and identify programmes that with minor changes to protocols could contribute data.

Provide direction for future research by producing a systematic review of peer-reviewed literature demonstrating the broader research coverage within the field, primary research questions and priority research gaps.
Draft a strategic plan to strengthen the global network and tackle priority areas for engagement, capacity development and research.
TOR 5: Establish a global community of practice.
The formation of the WG with the proposed TOR and capacity development will represent the foundation of the community of practice. Through the provision of best practice resources, capacity development and open-access data, the network will create an open, productive and enabling environment that encourages participation. This will assist in generating sustainability and long-term participation in and benefits from the WG after the completion of this project.

Timeline
The project will run over three years with a WG meeting held each year. The first two meetings will coincide with international or regional conferences (e.g. North Pacific Marine Science Meetings Western Indian Ocean Marine Science Symposium, Temperate Reef Symposium, GEO Blue Planet Symposium). The third WG meeting will take place at a location identified as critical for capacity development, and will be followed by a training workshop. Regular online meetings will be held to review progress and identify areas that need additional capacity.

Months 1-6: Key members to identify and prepare datasets to be used for TOR 1, to streamline the initial activities at the kick-off meeting.
Month 6: *Kick-off meeting* – Review TOR and further develop activities required to meet TOR; Assign leads and subgroups for each TOR. Assign co-leads (either early-career or post-graduate students) for each TOR to facilitate capacity development within the WG. Determine the detailed scope and questions that can be achieved under TOR 1 and determine a way forward to prepare the datasets for analysis. WG will agree on the optimal and minimum standards for sampling and data management required for TOR 2 and 3 and establish workplans.
Months 6-18: Subgroups for TOR 1 and 3 to work together on completing the dataset, run preliminary analyses and drafting a data schema and workflow. Subgroup working on TOR 3 to engage with OBIS and local biodiversity information managers. Subgroup working on TOR 2 to identify existing best practices and draft a framework for further guideline development.
Month 18: *2nd WG meeting* – Subgroups to report on progress and plans, with discussions on the best way forward. The conceptual structure of the roadmap document (TOR 4) and the community of practice (TOR 5) to be decided.
Months 19-30: Subgroup working on TOR 1 to complete analysis and produce a draft manuscript for WG review. Subgroup working on TOR 2 and 3 to have completed the work required to meet the TORs prior to the 3rd WG meeting. Subgroup working on TOR 4 to determine the data spatial coverage and produce a draft systematic review for review by WG.
Month 30: *3rd WG meeting* – Discuss draft manuscript (TOR 1) and the completed products for TOR 2 and 3. Subgroup working on TOR 4 to present progress with the systematic review and roadmap. WG to critically review the outcomes of all TOR and identify areas of success, shortcoming and future opportunities. Determine a plan to engage the broader community within the community of practice (TOR 5) and work towards continuation.
Months 31-36: Manuscript from TOR 1 and 4 submitted for peer-review, endorsed best-practice guidelines available on the Ocean Best Practice (OBPS) website and data published on OBIS and visible on selected web-based applications. Subgroup working on TOR 4 to complete roadmap document.
Month 36: All products to be complete.

Deliverables

Open-access peer-reviewed paper testing the level of agreement in trends of key ecological indicators when calculated using data from different sampling methods.
Endorsed best practice guidelines for methods (including standardized vocabularies) and data management published on the Ocean Best Practices (OBPS) website.
Open-access data available on OBIS, and RLS and Global Archive.
An open-access peer-reviewed global systematic-review of the status and trends of coastal benthic fish assemblages, identifying priority research gaps and future directions.
Roadmap document on the vision and priority areas for capacity development and research within coastal and nearshore benthic environments.

Capacity Building

Capacity building will be coordinated through three key areas: internal capacity building will focus on skills transfer within the WG; focussed training activities will be provided to researchers outside the WG; and open-access resources will be published to enable independent learning and self-development.
The WG is a mixture of established and emerging researchers from diverse backgrounds and disciplines. As far as possible, the established researchers leading the TORs will be paired with emerging researchers to facilitate knowledge transfer. Where possible, group members will allow senior post-graduate students (PhD or post-docs) to participate in the WG activities, and provisions will be made to allow students to incorporate components of the WG TOR into their research theses and lead resulting publications.
The WG will develop training materials (including video and printed tutorials) and host them on open-access web-based platforms. We will work with the Ocean Teacher Global Academy (OTGA) of the International Oceanographic Data and Information Exchange (IODE) to formalise the training materials, and get support to provide training at regional training centres; we will also explore opportunities to co-locate trainings with MBON regional workshops towards integration of these approaches in global MBON, and at Blue Planet meetings and symposia. The third WG meeting is planned to take place at a location identified as critical for capacity development, and a focussed training course will be provided to relevant stakeholders at this site. In addition, the WG will actively apply for funding from national (e.g. Knowledge Interchange and Collaboration grants, South Africa), regional (e.g. WIOMSA MASMA Grants for Workshops and Training Courses) and international (e.g. SCOR visiting scholar) bodies to provide training to advance capacity and grow the global network.
WG members include researchers actively engaged with the GOOS Biology and Ecosystems Panel, the POGO Biological Observations Working Group, GEOBON MBON, MarineGEO and the IOC Ocean Best Practice portal. Standards and procedures developed as part of this WG inform these groups and become part of their ongoing research and monitoring infrastructure.
Finally, the establishment of a community of practice, agreement and publication of best-practice guidelines, development of on-line training materials, open-access data and web-based applications to visualise the data will all enable independent learning and research.

Working group composition

Our working group includes ten full members (5 female, 5 male) covering a range of careers stages and representing eight countries. All members have appropriate experience in the study of benthic fishes using UVC, DOV and BRUVs. In addition, the member have expertise in method development, data management, global indicators, data analysis, management, policy and education. The diverse range of stills and experiences will ensure the WG achieve its OR.
Full members

Name	**Gender**	**Place of work**	**Expertise**
Anthony Bernard (co-chair)	M	South African Institute for Aquatic Biodiversity, *South Africa*	Marine ecology and conservation, stereo-BRUVs

Rick Stuart-Smith (co-chair)	M	University of Tasmania, *Australia*	UVC, Reef Life Survey, global indicators
Rene Abesamis	M	Silliman University, *Philippines*	Coral reef ecology and conservation
Emily Darling	F	Wildlife Conservation Society, *United States of America*	Coral Reefs, Conservation, Climate Refuges, Social-Ecological Systems
Jordan Goetze	M	Department of Biodiversity Conservation and Attractions (DBCA), Western Australia, *Australia*	Field surveys with Stereo-BRUVs/DOVs, UVC; Global FinPrint, Global Archive
Aaron MacNeil	M	Dalhousie University, *Canada*	Bayesian data analysis, reef ecology, fisheries
Eva Maire	F	Lancaster University, *England*	Socio-ecology, conservation, functional ecology
Ana Carolina Mazzuco	F	Universidade Federal do Espiritu Santo, *Brazil*	Biodiversity data management and marine ecology
Christy Pattengill-Semmens	F	REEF, *USA*	Marine biology, citizen science, education
Melita Samoilys	F	CORDIO East Africa, *Kenya*	Coral reef ecology, management and fisheries

Associate members

Name	**Gender**	**Place of work**	**Expertise**
Rusty Brainard	M	King Abdullah University of Science and Technology (KAUST), *Saudi Arabia*	Coral Reef Ecosystems, Climate Change, Ocean Acidification, Fisheries, Biodiversity
Pascale Chabanet	F	French Institute of Research for sustainable Development (IRD), *Reunion Island*	Coral reef ecology, extensive field experience with UVC and video for fish census
Emmett Duffy	M	Smithsonian Institution, *USA*	Marine ecology and Biodiversity, Co-lead on C-GRASS SCOR working group
Reiji Masuda	M	Maizuru Fisheries Research Station of Kyoto University, *Japan*	Subtidal fish ecology, fish behaviour, UVC long term-monitoring
Peter Mitchel	M	Centre for Environment Fisheries and Aquaculture Science, *England*	Marine ecologist, specialising in mapping benthic habitats and fish assemblages.
David Obura	M	CORDIO East Africa, *Kenya*	Coral reef resilience, biogeography, management and policy.
Alejandro Perez-Matus	M	Pontificia Universidad Católica de Chile, *Chile*	Fish and kelp ecology. Field experience in UVC and BRUVS.

Fernanda Rolim	F	São Paulo State University, *Brazil*	Marine ecology and management
Peter Walsh	M	University of Tasmania, *Australia*	Marine and terrestrial biodiversity data management and information systems.

Working group contributions
Rene Abesamis is a marine biologist with more than 20 years experience in coral reef ecology and conservation. He is part of a wide network of UVC practitioners in the Philippines – the global epicentre of fish biodiversity. He advocates for more extensive use of BRUV in this network.
Anthony Bernard is a marine biologist focussing on the ecology and conservation of rocky and coral reef ecosystems in the Western Indian Ocean (WIO). He manages the stereo-BRUVs Platform at SAIAB, which supports research projects in the WIO, and is a member of the GOOS Biology and Ecosystems panel.
Emily Darling is a Conservation Scientist with the Wildlife Conservation Society, where she leads a global coral reef monitoring program to investigate how tropical coral reefs are changing in the face of our climate crisis. She is passionate about collaborative big data to reveal new solutions for coral reef conservation.
Jordan Goetze is an early career researcher, with experience describing and comparing the methods proposed here, as well as storing and synthesising such data over global/continental scales. He has assisted in the development of GlobalArchive and worked across nine countries as a part of the Global FinPrint project.
Aaron MacNeil is a marine biologist with interests in integrating datasets to address fisheries conservation and management problems, from small to global scales. He is Associate Professor and Canada Research Chair in Fisheries Ecology, leading a 10-person team in the Integrated Fisheries Lab at Dalhousie University, with research covering sharks, coral reefs, and small-scale fisheries around the world.
Eva Maire is a marine ecologist exploring how humans affect the dynamics of coral reef systems and the structure of fish communities using both ecological and social-ecological approaches in the Indian Ocean and globally. She is experienced in using data from both UVC and BRUVs from across the world.
Ana Carolina Mazzuco is an early career researcher at the Universidade Federal of Espírito Santo, who is leading the ILTER data acquisition, curation, and scientific outputs. She has experience in biological oceanography, data science, and research management. She also collaborates as Data Manager for the Ocean Biogeographic Information System Brazil Node and is a member of the MBON Pole to Pole.
Christy Pattengill-Semmens is a marine biologist whose work as Executive Director of Reef Environmental Education Foundation (REEF) intersects citizen science, data management, education, and conservation. She oversees all aspects of REEF's Volunteer Fish Survey Project, one of the longest-running and largest marine life sightings programs.
Melita Samoilys is a co-Director of CORDIO East Africa. She has worked in coral reef and fisheries research, management and conservation in East Africa, elsewhere in the Indian Ocean and also in the Pacific and Red Sea. She is a member of three IUCN Species Specialist Groups - Groupers and Wrasses, Shark, Snapper Seabream and Grunt.
Rick Stuart-Smith is a field ecologist with interests that include identifying the most informative biodiversity indicators for reporting on ecological state of reefs at global scales. He is co-founder and president of Reef Life Survey, which uses standardised visual census methods on tropical coral and temperate reefs, with open-access data.

Relationship to other international programmes and SCOR working groups
Other SCOR working groups

The TOR proposed for the CoNCENSUS WG align and can contribute to TOR proposed for the DeepSeaDecade WG (WG 159). We have already initiated contact with WG member (Dr Kerry Sink) begin this process. The work developing best-practices and data management systems done by the C-GRASS WG (WG 158) can provide a starting point for the CoNCENSUS WG to address TORs 2 and 3. The co-lead of the C-GRASS WG, Emmett Duffy, is an associate member of the CoNCENSUS WG will provide support, in this regard.

GOOS, POGO and MBON

The GOOS Biology and Ecosystem panel, the MBON and the POGO Biological Observation task force operate synergistically within the space of global biodiversity observing systems, and aim to strengthen coordination and monitoring of essential variables for reporting on the status of biodiversity and ecosystems by defining appropriate indicators, and developing tools and capacity to measure and report on the indicators. The proposed TOR for this WG will directly benefit these programmes and advance their high-level objectives. Members of the CoNCENSUS WG, Anthony Bernard, Rick Stuart-Smith, David Obura and Emmett Duffy, work closely with these programmes and will ensure the WG activities are embedded in their goals.

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OASIS: Developing an Observing Air-Sea Interactions Strategy

SUMMARY

This SCOR Working Group (WG) will harmonize observational strategies of several dozen OceanObs'19 community papers to create a unified vision for an Observing Air-Sea Interaction Strategy (OASIS). While OceanObs'19 led to consensus recommendations within communities, this effort will bring previously siloed communities together, under the umbrella of SCOR, to work towards the larger *UN Decade of Ocean Science for Sustainable Development* outcomes: "a predicted ocean, predicted marine weather & predicted climate"; "a safe ocean"; "a healthy & resilient ocean"; and "a sustainable & productive ocean". The strategy will follow the Framework for Ocean Observing for designing networks to meet stakeholder requirements for ocean information. Likewise, the strategy will identify where short-duration process studies are needed to advance understanding, parameterizations, and modelled and satellite representation of Essential Ocean and Climate Variables used for estimating air-sea fluxes. Focusing on air-sea fluxes of heat, momentum, moisture, important greenhouse gasses, and biogenic trace gases, and their boundary layers, the strategy will identify gaps in the current observation network and opportunities for leveraging multidisciplinary activities. Capacity will also be built through inclusion of developing countries, by identifying leveraged opportunities that connect local scales to regional scale networks. OASIS will consider air-sea-biosphere coupled processes holistically to integrate the observing system. At the strategy's core will be community building, training, and promotion of standardized methods to ensure Findable-Accessible-Interoperable- and-Reusable (FAIR) observational best practices. Ultimately, the WG will develop a practical, integrated approach to observing air-sea interactions that will allow near-realtime quantification of air-sea exchanges, with breakthrough accuracy, throughout the global ocean.

SCIENTIFIC BACKGROUND AND RATIONALE

The surface of the ocean is the portion of the ocean felt by the atmosphere, viewed from space, and experienced most directly by people and most other life on Earth. The ocean modulates the Earth's weather and climate through exchanges of heat, moisture, momentum, greenhouse gasses, aerosol precursor gases, and aerosols at the air-sea interface. Air-sea exchange can even influence the stratosphere; e.g., N_2O is now considered a major threat to the ozone layer and approximately a third of the N_2O source to the atmosphere is from the ocean. The influence of air-sea fluxes on the Earth's water cycle, carbon cycle, and energy cycle is a critical element of the support of life on Earth.

It is therefore imperative that the air-sea exchanges of heat, moisture, momentum, important greenhouse gasses, and biogenic trace gasses be monitored globally. Furthermore, because air-sea fluxes can depend upon feedbacks and interactions across disciplines and scales, to understand these air-sea exchanges and how they couple the atmosphere, ocean and biosphere, it is vital to also observe the oceanic and atmospheric boundary layer's chemical, biological, physical and geological components. These do not need to have independent observational networks. Because these different types of air-sea fluxes depend upon many of the same variables (e.g. winds, sea surface temperature,...), and upon similar turbulent and radiative processes, there is potential for considerable leveraging of observations through integration of the observing system.

The surface of the ocean is observed by satellites and a set of regional and thematic *in situ* ocean observing networks that provide essential data for addressing critical scientific, societal, policy, and economic issues. Despite many successes, the need for this oceanic and atmospheric surface and boundary layer information, across different temporal and spatial scales for different disciplines, has outstripped the capabilities of these individual networks. Making matters worse, in some regions, observations are seasonal (e.g., summer bias in polar regions), and/or have minimal integration of sensors for monitoring relevant feedbacks, and have severe funding difficulties. Indeed, whole swaths of the world's oceans do not have any *in situ* surface observations.

This WG will build on the work leading up to and following the OceanObs'19 Conference, which assembled more than 1,500 ocean scientists, engineers, and users of ocean observing technologies from 74 countries and across many disciplines. The ocean observing community submitted 140 community white papers (CWPs) with over 2500 contributing authors to OceanObs'19. More than three dozen CWPs addressed concepts associated with surface observing (see **KEY REFERENCES**), but were largely siloed by discipline, region, network, Essential Ocean Variable of interest, or stakeholder need. The proposed OASIS Working Group will integrate these recommendations into a unified vision for a multifunctional, multidiscipline, integrated observing system that allows near-realtime quantification of the air-sea exchanges, with breakthrough accuracy, throughout the global ice-free ocean.

The initial core drivers for the strategy include:

(1) **monitoring and predicting the ocean's influence on global weather and climate on timescales of days-seasons-decades** [This addresses the *UN Decade of Ocean Science for Sustainable Development* outcomes of "a safe ocean", "a predictable ocean"]. This requires improved coupled ocean-atmosphere models and sustained observations to constrain and validate their forecasts, including observations of the heat, freshwater, and momentum exchange between the ocean and atmosphere, and boundary layer processes affecting these fluxes. Model development may also require short-duration, intensive observations of processes, such the impacts of currents and waves on the turbulent fluxes and feedbacks between phytoplankton blooms, biogenic aerosol fluxes and radiative fluxes.

(2) **monitoring and predicting marine weather in the ocean and atmosphere** [*Decade* outcomes: "a safe ocean", "a predicted ocean","a clean ocean", "a sustainable productive ocean"]. This requires a subset of the same EOVs, but observed and studied at higher frequency and resolution. Improved marine weather information, including better ocean eddy, surface wave, and atmospheric boundary layer characterization would lead to improved monitoring of fisheries, open ocean biodiversity, debris (e.g., microplastics) and other pollutants; as well as better tracking for search and recovery, and protection of nearshore Marine Protected Areas.

(3) **tracking ocean uptake of carbon dioxide and oceanic deoxygenation and denitrification** [*Decade* outcomes: "a healthy & resilient ocean", "a sustainable productive ocean"]. This effort will provide insights on the ocean's uptake potential of atmospheric CO_2, as well as the potential of oceanic deoxygenation and denitrification over the next decade. These processes, together with consequent ocean acidification (OA), depend upon not only on the physics and chemistry of the ocean, but also interact with the biology, ecosystem and biodiversity in the ocean. Thus a core driver also includes collocating multidiscipline measurements that consider the full suite of interactions that feedback on OA and influence the development of oxygen minimum zones.

(4) **studying how biology, biodiversity, and the surface ecosystems relate to changes in surface concentrations and fluxes of CO_2, DMS, and N_2O** [*Decade* outcomes: "a healthy & resilient ocean", "a sustainable productive ocean"]. The goal will be to provide information needed to better understand air-sea exchanges of properties and how those properties influence phytoplankton community structure and propagate throughout the marine food web. As food web models and process understanding become more sophisticated the propagation of physical feedbacks into food web interactions will need to be parameterized and accounted for. Improved predictions in this domain influence stakeholder products for harmful algal blooms, pathogens, ocean acidification, hypoxia, and fisheries impacts. This effort will be a step toward the ultimate goal of sound management of human activities to maximize societal benefits, including a robust blue economy, improved human health, protection of property, and the wise conservation of marine resources.

A system-as-a-whole approach is called for. We envision a multi-scale integrated observing system, with satellites that are optimized for marine boundary layer observations, tuned and validated against a global network of regional *in situ* platforms. Global coverage of air-sea fluxes will be achieved through consolidation and expansion of the existing networks and introduction of new sustainable ocean technologies, such as autonomous surface vehicles and a new generation of chemical, biological and physical sensors. Gridded fields at the desired spatial and temporal resolution, and required accuracy will be achieved by constraining coupled models with these observations.

This would result in a sea-change increase of surface and boundary layer data that would lead to revolutionary improvement in understanding of air-sea interactions and its representations in forecast models and would be used to constrain these improved numerical models for ocean, weather, and climate prediction. To realize the value of this "Big Data", the OASIS must also build the community for making and using these data via new techniques, such as machine learning or community-based data processing software packages. The OASIS thus must also include strategies for training data providers and data users, promoting standardized methods, and ensuring Findable-Accessible-Interoperable-and-Reusable (FAIR) observational best practices.

OceanObs'19 provided an opportunity for scientists to come together to form strategy papers that would propel their communities forward over the next decade. We now want to take this a step further. Through this SCOR Working Group, we want to bring these previously siloed communities together, under the umbrella of SCOR, and as a unified ocean community, work towards *UN Decade of Ocean Science for Sustainable Development* outcomes of "a predictable ocean, predictable marine weather, and predictable climate", "a safe ocean", "a clean ocean", "a healthy and resilient ocean", "a sustainably harvested ocean", and "a transparent ocean". This can only be done by a diverse, international, multidisciplinary group of scientists, working together. We believe that this SCOR Working Group is the ideal way, and maybe the only way, to achieve this long-term legacy.

TERMS OF REFERENCE

Harmonize the recommendations from the OceanObs'19 CWPs into a unified Observing Air-Sea Interaction Strategy (OASIS) by identifying and ranking overlaps and resolving apparent contradictions, focusing on global air-sea exchanges of heat, moisture, momentum, important greenhouse gasses, biogenic trace gasses, and the multidisciplinary boundary layer variables associated with these air-sea exchanges.

Produce a capacity building strategy that enables developing nations (including least developed nations and island nations) to actively participate in and benefit from local-to-global air-sea interaction observations. This will involve a training strategy, as well as identification of opportunities for leveraging contributions by new partners.

Develop and assess network designs that optimize air-sea interaction observations, following the Framework for Ocean Observations, in coordination with OceanPredict, and other working groups focused on optimizing network design.

Develop a strategy for air-sea interaction process studies to address knowledge gaps; to improve model and satellite representation of Essential Ocean Variables (EOVs), Essential Climate Variables (ECVs), and Essential Biological Variables (EBVs) associated with air-sea interaction processes; and to develop parameterizations to relate variables that are difficult to measure with variables that can be broadly observed.

Develop a strategy for assessing interoperability of surface observing platforms. This will include intercomparisons of EOV, ECV, and EBVs observed from different platforms; development of best practices; and development of procedures to increase Technical Readiness Levels and expand technology solutions.

Build community and capacity for using, operating, and developing air-sea interaction observational platforms that allow collaborative partnerships with existing national and international air-sea interaction working groups and observational coordination groups.

WORKPLAN & 3-YEAR TIMELINE

Review of ongoing activities and OceanObs19 community recommendations (desk studies, 3-12 months): Consolidate, summarise and rank air-sea flux related recommendations delivered from the OceanObs19 CWPs. Recommendations will be grouped by topic in order to highlight commonalities. Rankings made within each CWP will be preserved and contribute to the overall ranking of the synthesized recommendation. Prioritization and rankings of recommendations requires understanding the science behind the recommendation and can only be done successfully by a diverse working group of scientists, such as we have proposed here.

Curriculum development for Capacity Building Institutes (3-36 months): Our members have extensive experience with capacity building activities, and one WG member will be organizing SOLAS Summer Institutes in the 2021-2023 timeframe. Thus the WG will develop a curriculum for these, that will include background science lessons, data handling and engineering training and information/training needed for participation in air-sea interaction fieldwork. In particular, the WG will develop software toolboxes and "How To" manuals for making air-sea flux observations, for calculating fluxes, and for using the fluxes. For more detail on this, see the **CAPACITY BUILDING** section below.

Assessment of recommendations addressing gaps in knowledge requiring process study research (6-24 months): This will synthesize recommendations from OceanObs19 publications, from ongoing regional and global research activities, and from gaps identified by the WG. High-resolution (e.g. hourly, <10 km), global air-sea fluxes with breakthrough accuracy will only be possible by using numerical models that combine remotely-sensed and in situ surface observations. Thus it is not sufficient to just improve the in situ observing network. We must also improve the satellite observations of surface ocean and atmospheric boundary layer variables. Likewise, we must improve numerical models. Coordinated experiments are needed to understand air-sea interactions and feedbacks, across scales and disciplines, that are currently not well resolved in numerical models. These experiments are also needed to relate remotely sensed variables to in situ environmental conditions. These 'Big Science' challenges can only be undertaken through broad community interaction, consensus and sharing of resources.

Assessment of interoperability of different observing platforms (12-24 months): There are a wide range of *in situ*, upward-looking remote sensing and downward-looking satellite platforms for measuring EOVs, and even within each type of platform, the technologies can be diverse. Assessments of platform intercomparisons are needed to ensure specification of their measurement uncertainty, a key factor when determining appropriate platforms for a given sampling strategy. These assessments are likely to be ongoing, but are required for developing the OASIS implementation plan. Development of Best Practices will be done in coordination with the IOC's Ocean Best Practices System (OBPS).

Assessment of existing air-sea flux observing systems (12-18 months): Before implementing the OASIS, the existing regional and global initiatives must be assessed to identify existing capability gaps. As a SCOR Working Group, our primary focus will be to identify areas for potential collaboration, and opportunities for leveraging new partners, including early career scientists, scientists from developing nations, and citizen scientists. This assessment of existing air-sea interaction observations will extend throughout the global ocean (including at ice margins and coastal zones), and include the ability of developing nations' weather, climate, and ocean services to provide and access air-sea exchange information.

Assessment of network designs (12-24 months): Following the Framework for Ocean Observing, array designs will begin by first assessing stakeholder needs for ocean information. This will then set the baseline requirements for prioritizations of phenomena needing monitoring and evaluation of the network's ability to (1) measure key phenomena, (2) constrain uncertainties in budgets, (3) have appropriate scales and accuracy for calibration/validation of satellite measurements. Other array design methods may also be used to optimize the OASIS both regionally and globally, including Observing System Simulation Experiments/Observing System Experiments to assess the impact of observations. This effort will work with existing regional groups (e.g. TPOS-2020, CLIVAR basin panels, SOCCOM, SOOS and SOFLUX) to provide recommendations that take into consideration unique conditions for each region, and different requirements for applications with different objectives.

Strategy Document (24 - 36 months): Develop a unified vision for the global, integrated air-sea interaction observations that identifies gaps in the present system, activities required for implementation, and potential leveraging opportunities that would accelerate implementation, and enable participation from developing countries. The strategy will also explain how these data will be Findable-Accessible-Interoperable-and-Reusable (FAIR). To the extent possible, the strategy will include costs and prioritizations for implementing recommendations.

Virtual WG meetings (monthly or bi-monthly) and Face-to-Face Workshops (6 months, 24 months, and 36 months): The WG will have regular virtual meetings focused on specific deliverables (see DELIVERABLES). These will be supplemented with three larger workshops that will consider the full workplan, and showcase deliverables as they become finalized. WG workshops will be open meetings and scientific and resource manager representatives from different air-sea interaction communities, including from private, public and academic sectors, will be encouraged to participate. Funds will be sought to support early career scientists and scientists from developing nations.

Some travel will be supported through the Consortium for Ocean Leadership (COL) as an OceanObs'19 Research Coordination Network (RCN) activity. Further support by the US Interagency Ocean Observation Committee (IOOC) is under consideration. We may consider holding one of the workshops in conjunction with an OceanObs RCN annual meeting, as these are generally coordinated with a large international science meeting, and many of our invited guests and CWP original authors, would likely already be planning to attend this meeting.

Communications (Ongoing, pending COL support): With web-support from COL, the WG could develop an independent OASIS website that will highlight the OASIS recommendation rankings and rationale; will maintain a calendar of relevant workshops, meetings, and other activities; will act as a portal to the air-sea flux toolbox and curriculum; and will host an electronic newsletter that will solicit engagement, promote coordination activities, highlight scientific results, and new publications.

DELIVERABLES

Consolidated recommendation report (TOR #1; 6-months): This synthesis report, based upon more than three dozen OceanObs19 CWP (see **KEY REFERENCES**) will be made publicly available and will guide all activities undertaken by the WG.
OASIS publication (TOR #1-6; 36-months): The OASIS will be published as an open-access peer-reviewed publication.

Best practice papers (TOR #2-5; 18-36-months) for ocean surface flux measurements, platforms, standards, analysis, array design for publication as part of the special Section Ocean Best Practices of Frontiers in Marine Sciences.

Air-sea flux toolbox (TOR #2, 4-6; 12-36-months) will be made available as open source code through github and published in code-themed journals (where needed) that includes well-documented, easy-to-use bulk flux algorithms, asset mapping, direct covariance flux code for physical fluxes with the possibility to extend to trace gas fluxes (especially CO_2 and DMS), and numerical 1-D (vertical) model codes.

Air-sea flux curriculum (TOR #2, 4-6; 12-36-months), including a library of How-To manuals relevant to air-sea fluxes, will be geared towards early career scientists and Summer Institute students in developing nations.

Website, webinars and newsletter (TOR #1-6; Ongoing): Focused webinars (1-2 per year) will allow the community to 'meet' and discuss WG's deliverables. Pending COL support, an OASIS website will be launched that will host an electronic newsletter, sent out to email subscribers, that will highlight OASIS news (e.g., flux-related publications, upcoming meetings and training opportunities, new observational capabilities and career opportunities). The newsletter format has proven very popular and valuable in other flux initiatives (e.g. SOFLUX).

CAPACITY DEVELOPMENT & COMMUNITY BUILDING

To promote the practice and understanding of air-sea interactions over the next decade or even longer, the OASIS working group will also dedicate itself to long-lasting capacity development in this field (explicitly stated in TOR 2 and 6). Our main capacity development tools will be a curriculum that will include background science lessons, Best Practice guides and "How To" manuals for making air-sea flux observations and calculating fluxes from either state variables using a bulk algorithm, and an open-source (e.g via GitHub) well-documented air-sea flux toolbox. Capacity development will also be achieved by shifting the observing system culture towards partnerships, collaboration and mentorships by identifying leveraged observing opportunities.

The "How To" manuals will include Best Practice guides for making air-sea flux observations (from ships, buoys, autonomous surface vehicles and drifting platforms) and for calculating fluxes from either state variables using a bulk algorithm, or directly using covariance techniques. Air-sea flux toolboxes, provided openly (e.g. via GitHub), will allow for easier access to scripts to process level 1 data in order to derive 'science-ready' flux estimates for a variety of applications (from research to operations). The curriculum will also include some examples of how these fluxes could be used within the context of large general circulation models as well as simple 1-d models that show how different surface physical and biogeochemical fluxes can result in different water column physical and biochemical tracers and processes (mixed layer, primary and secondary production).

This curriculum and tool-box development activity is well suited for a SCOR WG, which can facilitate interactions between members who are experts in the model and parameterization development, members who are experts in the methodological handling of field data, members who can implement these methods into new and well documented (via well-explained code and publications in code-themed journals) processing language and packages (e.g. Python) to be made openly available, and members familiar with the broad spectrum of potential users of this toolbox, including ECS and scientists and students in developing countries. <u>We wish to emphasize that these tools will make it significantly easier for all users (students to established researchers, current operators to developing nations, etc) to make and work with air-sea flux observations</u>. The tools will include modules that enhance data standardization easing downstream data storage and discoverability. Its community-driven approach ensures these tools remain up-to-date and all-encompassing. Such tools will work in parallel with best practice guidelines and papers.

Our first opportunity to test the curriculum will be at the 2021 SOLAS summer school, which is directed by one of our group members. While the development of the toolboxes and guides will have just started, background concepts and early versions of lesson plans could be implemented by the program as early as 2021. The participants are asked at the end of every SOLAS summer school to evaluate the content and it can be retested at the next school (either 2022 or 2023). This feedback will be integral in shaping the final version of OASIS curriculum. In addition, the 2021 school will be held in Cape Verde, with the potential to return there for subsequent schools. The location is ideal to bolster capacity to early career scientists in Africa, especially on the Cape Verde Islands and in coastal nations, who are primarily interested in fisheries and biodiversity, but must understand how surface fluxes in a changing ocean will impact their research and their community.

Air-sea fluxes are challenging to compute as they rely upon many co-located, high resolution, high quality surface EOV and ECV. Air-sea heat fluxes, as an example, require more than 8 EOV/ECV: surface winds, surface currents, surface humidity and air temperature, sea surface skin temperature, downwelling solar and longwave radiation, and surface albedo and emissivity estimates. Modern bulk air-sea heat flux algorithms also depend upon sea state. Several of these variables are also needed for other air-sea fluxes, such as for carbon dioxide fluxes. This complexity means that partnerships are often needed to make air-sea flux observations, with one partner being responsible for the platform and a subset of EOV/ECV measurements, and other partners being responsible for other EOV/ECV. This provides a leveraging opportunity for new partners. New partners may join an observing team to help with a single EOV without needing to be responsible for engineering and operating the entire platform. New sensors, of course, must be carefully tested and integrated into platforms to ensure interoperability and non-interference with other measurements. However by developing best practices, and technical readiness level advancement procedures, and by developing a culture of mentorship and partnership, the capacity of the observing system could be significantly expanded. Developing such a culture requires a diverse working group, such as we have formed here, and terms of reference that mandate this. The result of this cultural shift would be a broader base of users, operators, and technological solutions.

MEMBERSHIP & REPRESENTATION

Full Members (*co-chairs)

Name	Gender	Place of work	Expertise
1 Meghan Cronin*	F	NOAA Pacific Marine Environmental Laboratory, **US**	Heat, momentum, moisture fluxes; Operating longterm surface observing platforms; emerging technologies; Optimizing observing systems (TPOS2020, OOPC)
2 Sebastiaan Swart *	M	University of Gothenburg, **Sweden**	Heat, momentum and CO2 fluxes; Mixed layer physics; Operating autonomous surface platforms; Southern Ocean fluxes (SOFLUX)

3 Nadia Pinardi	F	University of Bologna, **Italy**	Numerical ocean forecasting systems, surface air-sea fluxes in the Mediterranean Sea for coupling with atmospheric forecasts
4 R. Venkatesan	M	National Institute of Ocean Technology, **India**	Physics, Operational met, Capacity Building
5 Phil Browne	M/ECS	ECMWF, **UK**	Operational, Coupled DA
6 Warren Joubert	M/ECS	South African Weather Service, **South Africa**	BGC, Capacity Building, Operational
7 Ute Schuster	F	University of Exeter, **UK**	Ocean carbon cycle variability and biogeochemical drivers; operating long-term observational platforms; member of European ICOS observational infrastructure, SOCONET, AtlantOS programme; past memeber of SCOR WG 133, CARBOOCEAN, CARBOCHANGE; co-author of OceanObs19 papers of Steinhoff et al., Wanninkhof et al., Smith et al.
8 Christa Marandino	F	GEOMAR, **Germany**	Climate-relevant trace gas air-sea exchange and surface ocean cycling, short-lived biogenic trace gases (e.g. DMS), SOLAS
9 Shuangling Chen	F/ECS	Second Institute of Oceanography, **China**	BGC, satellite estimation of air-sea CO2 flux, Chen et al.
10 Clarissa Anderson	F	Scripps Institution of Oceanography, **US**	Biological oceanography, integrated ocean observing, stakeholder capacity building

Associate Member

Name	**Gender**	**Place of work**	**Expertise**
1 Jim Edson	M	Woods Hole Oceanographic Institution, **US**	Physics, direct flux measurement & parameterization, novel technology & observing systems

2 Zhaohui Chen	M	Ocean University of China, **China**	ECVs/EOVs and Heat fluxes using surface fixed/mobile observing platforms, Centurioni et al.
3 Juliet Hermes	F	South African Environmental Observation Network, **South Africa**	Physics, observing systems, modelling, IORP, GOOS OCG, IOC/GOOS Ocean Best Practices steering group, Capacity Building
4 Fabrice Ardhuin	M	University Brest, CNRS, IRD, Ifremer, Laboratoire d'Ocèanographie Physique et Spatiale (LOPS), IUEM, **France**	Physics, Satellite observations of winds, waves, and surface currents
5 Oscar Alves	M	Bureau of Meteorology, **Australia**	Coupled modelling, coupled DA, sub-seasonal to seasonal prediction, WGNE Member
6 Hiroyuki Tomita	M	Institute for Space-Earth Environmental Research (ISEE), Nagoya University, **Japan**	J-OFURO satellite-based flux products

WORKING GROUP CONTRIBUTIONS

Meghan Cronin was lead author of the OceanObs19 paper “Air-Sea Fluxes with a Focus on Heat and Momentum”, and co-author on four other CWP. With her system’s experience as co-chair of the Tropical Pacific Observing System (TPOS)-2020 Planetary Boundary Layer Task Team and member of Ocean Observations for Physics and Climate (OOPC) panel, and experience maintaining reference station moorings and using novel surface observing technologies, she will act here as Co-Chair.
Sebastiaan Swart was lead author of the OceanObs19 strategy paper “Constraining Southern Ocean air-sea-ice fluxes through enhanced observations”. He brings expertise in air-sea flux field observations with a focus on the Southern Ocean (former Co-Chair of SOOS) and will act here as Co-Chair.
Nadia Pinardi was the lead author for the OceanObs19 review paper “The Joint IOC (of UNESCO) and WMO Collaborative Effort for Met-Ocean Services” and she was leading the design and the implementation of the Mediterranean Forecasting System from the operational observing system to the numerical modelling and data assimilation. She now serves as vice-president of the WMO Infrastructure Commission.
R Venkatesan has designed, developed, installed, and established Indian moored buoy systems in the Indian Ocean (OMNI), contributes to the RAMA network and global OceanSITES network, and is responsible for Indian Arctic Observatory; with particular expertise in flux data measurements and validation. He serves as a Chair of GOOS Regional Alliances of IOC UNESCO
Phil Browne is the lead developer of coupled ocean-atmosphere data assimilation for numerical weather prediction at the European Centre for Medium-Range Weather Forecasts (ECMWF). He brings expertise in the operational use of surface observations and the pathways to impact through weather forecasting.
Warren Joubert, an ECS, has expertise in air-sea CO_2 fluxes through field observations in the Southern Ocean. He is currently responsible for a Global Atmosphere Watch long term atmospheric observations station in South Africa.
Ute Schuster has expertise in ocean carbon cycle variability, including air-sea CO_2 flux and interior ocean anthropogenic carbon transport and storage, including underlying biogeochemical and

physical drivers of variability, from seasonal through multi-decadal time scales. She is executive group member of the European ICOS OTC (https://otc.icos-cp.eu/), leading the North Atlantic section of the global Surface Ocean CO2 ATlas (SOCAT; www.socat.info), and co-author of three OceanObs'19 papers.

Christa Marandino uses eddy covariance to measure trace gas air-sea exchange. She is active within SOLAS (German national rep, summer school director, science and society co-lead).

Shuangling Chen, an ECS, brings expertise in air-sea CO2 flux, especially its remote estimation from satellites. She is passionate about the future potential of the ocean in absorbing anthropogenic CO2.

Clarissa Anderson was lead author of the OO'19 CWP, "Scaling up from regional case studies to a global harmful algal bloom observing system" and a newly elected member to the IOC-SCOR GlobalHAB Scientific Steering Committee, the U.S. National HAB Committee (NHC), the OO'19 RCN "Impacts and Applications" Working Group, and the OO'19 Ecosystem Health and Biodiversity Planning Team. She brings expertise in biological oceanography, harmful algal blooms, and integrated ocean observing systems.

RELATIONSHIP TO OTHER INTERNATIONAL PROGRAMS AND SCOR WORKING GROUPS

1. Other SCOR Working Groups

OASIS has synergies with SCOR Working Group 153 FLOTSAM. In developing a strategy for FAIR data, with automated quality control, OASIS will benefit from SCOR Working Group 148 IQuOD. OASIS will also benefit from SCOR Working Group 133 OceanScope for ship-based observations, and from SCOR Working Group 143 on dissolved N_2O and CH_4 measurement. Their OceanObs'19 paper will contribute to OASIS's synthesis recommendations. SCOR Working Group 152 ECV-Ice standardized protocol for gas exchange measurements over sea ice are relevant to OASIS goals for open waters. Finally, SCOR Working Group 154 global plankton observations will inform the OASIS for EBVs.

2. Global and regional networks

OASIS will help integrate the air-sea interaction observations across the patchwork of GOOS Regional Alliances (**GRAs**), and from emerging systems, such as the Southern Ocean Observing System (**SOOS**), to mature systems, such as Tropical Pacific Observing System (**TPOS-2020**). OASIS will take work with their surface flux task teams (e.g. SCOR/SCAR's **SOOS SOFLUX)**.

The Observations Coordination Group (**OCG**) is charged to review, advise on, and coordinate across the global ocean observing networks to strengthen the effective implementation of a global ocean observing system (**GOOS**). OASIS will provide a vision for integrating air-sea interaction observations across networks, and disciplines. OASIS will also consider leveraging opportunities for multidisciplinary observations that could bring new partners, including early career scientists, scientists from developing countries, and citizen scientists.

Several **GOOS OCG** networks observe air-sea interaction (e.g. **OceanSITES**, **DBCP network** (Centurioni et al. 2019), etc.). In addition, there are several discipline-specific flux networks, e.g. **Integrated Carbon Observation System** (ICOS -OTC; https://otc.icos-cp.eu/), **Surface Ocean CO2 NETwork** (SOCONET; Wanninkhof et al., 2019). OASIS will identify common ground across discipline, where leveraged observations could contribute to an integrated observing system.

OASIS will also develop community endorsed best practices which can be shared, with support of the **Ocean Best Practices** steering group.

3. UN Decade of Ocean Science for Sustainable Development

It is hoped that OASIS will be embraced as a Decade Project and in this way have its strategy implemented.

4. OceanObs Research Coordination Network (RCN)

OASIS is a community effort, resulting from OceanObs19 and therefore has close affinity with the **OceanObs RCN**.

5. International programs

The **WCRP**, **CLIVAR, SOLAS,** and **IMBER** programs will benefit from OASIS. For example, Core Theme 2 of SOLAS focuses on surface fluxes and each of the remaining four Core Themes contain important

elements related to air-sea exchange. The International Ocean Carbon Coordination Project (**IOCCP**), promotes the development of a global network of ocean carbon observations; http://www.ioccp.org/. OASIS WG members are closely linked to **IOCCP** activities.
OASIS will be informed by **OceanPredict**'s array design studies.
Working Group on Numerical Experimentation (**WGNE**) is expanding its remit, from a focus on atmospheric/weather models to a focus on coupled models of the earth system, and therefore has a priority to improve air-sea fluxes in coupled models of the earth system for weather and climate studies and prediction. **WGNE** is currently undertaking a surface flux intercomparison project, that involves collecting and evaluation surface fluxes from operational weather forecast models.

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AEROS: Atmospheric aerosol deposition as forcing factor for microbial ecology and biogeochemistry in the ocean

1. Summary

Mineral dust, sea spray, combustion black carbon rich and volcano ash particles are among the major global primary aerosols. Their role in climate forcing, e.g. by reducing albedo, or as nuclei for cloud condensation, is well recognized. Aerosols are constantly deposited into the ocean, where they release nutrients and toxins that can significantly influence microbial physiology, diversity and ecology. Aerosols can also increase the density of particles (ballasting), enhancing aggregation and absorbing organic matter, thereby influencing the carbon export into the deep sea. The impact of atmospheric deposition on biogeochemical cycles, and the response of the marine microbial community depend on the trophic status of the system and on the aerosol sources and deposition rates. The AEROS working group initiative strives to: 1) Develop a database of the chemical composition of different aerosol types and their deposition rates to better identify knowledge gaps, and better constrain data for different ocean basins, 2) Establish a best practice booklet on sampling strategies and experiments with aerosols in order to improve the comparability of data, 3) Summarize data on the effects of aerosols on the microbial ecology and biogeochemistry of the ocean and 4) Use the expertise of participants of the WG to move beyond the current focus on specific types of aerosols, and attempt a more holistic approach to understand the effects of aerosols on the microbial ecology and biogeochemistry in the ocean.

2. Scientific Background and Rationale

2.1 Aerosols

The atmosphere contains aerosols (i.e. airborne solid particles and liquid droplets in suspension) of different sources and compositions. Aerosols are significant players in the global climate system, e.g. by affecting the heat budget, increasing albedo and acting as nuclei for cloud formation. Mineral dust aerosols (MDA), volcano ash aerosols (VAA), black carbon rich aerosols (BCA) and sea spray aerosols (SSA) are among the major aerosol components in the atmosphere.

Aerosols can be transported and spread over great distances (http://gmao.gsfc.nasa.gov/animations/aerosols_geos5.mov). The deposited aerosols release abiotic and biotic components into the water column, including material adsorbed during atmospheric transport, thereby affecting the chemistry and biology of the water column. This influences ocean productivity, microbial diversity, biogeochemistry (e.g. carbon and nitrogen uptake and regeneration), toxicity, aggregation and export of organic matter (ballasting). Current data suggest that atmospheric deposition may supply significant loads of bioactive elements and airborne microorganisms to oceanic surface waters (Mayol et al. 2017). The exposure to acidic conditions during gas-aerosol interactions and in clouds and to solar radiation during atmospheric transport increases the solubility of aerosols and exerts selection on airborne microbes (Archer et al. 2019, Caliz et al. 2018, Dien et al. 2017).

It is estimated that between 5 and 50 percent of the mineral aerosols are of anthropogenic origin (Hamilton et al. 2018). Organic and black carbon emissions occur in large amounts in developing regions where extensive biomass and fossil fuel burning occurs seasonally. In some regions, climate change tends to increase wildfires, but land-use and human activity tend to decrease fires, so that there are likely regional changes in BCA in the future (Andela et al. 2017, Hamilton et al. 2010). Hence it is timely to assess the various roles by which aerosols affect ocean processes.

2.2 Aerosol–microbe interactions: known and potential roles

Microorganisms, i.e. viruses, bacteria, phytoplankton and other single-celled organisms, make up the largest fraction of total marine biomass (Whitman et al. 1998). They are the key biological factors involved in element cycling in the ocean (Moore et al. 2013), playing a crucial role in controlling biogeochemical cycles, ecosystem functions, and climate change (Kirchman 2000; Kirchman 2010; Gasol and Kirchman 2018). Aerosol deposition can impact the microbial food web and biogeochemical cycles in various ways, by releasing nutrients, toxins, airborne microbes, viruses, or through ballasting of organic particles.
There are large physical and chemical differences within and between each type of aerosol. Sea-borne organic material and microorganisms are horizontally transported with SSA, whereas with MDA, VAA and BCA, organic matter and microorganisms either from terrestrial origin or absorbed during horizontal transport in the atmosphere are deposited in the ocean. Aerosol deposition varies strongly with seasonal and geographical scales, which can potentially result in complex responses of planktonic microbial communities.
Since iron is associated with MDA, BCA and VAA (Myriokefalitakis et al. 2018, Ito et al. 2019), aerosol deposition is linked to the iron hypothesis, i.e. that phytoplankton growth and many microbial processes are limited by iron in large so-called high-nutrient low-chlorophyll (HNLC) areas (Boyd et al. 2007; Smetacek and Naqvi 2008). It is assumed that release and total deposition rates of bioavailable iron from VAA are possibly of similar importance compared to MDA (Olgun et al. 2011, Weinbauer et al. 2017). VAA deposition from volcanic eruptions can induce anomalously large blooms of diatoms and increase bacterial diversity and activity in HNLC regions (Hamme et al 2010, Zhang et al. 2017). Manganese, phosphorus and ammonia deposition by aerosols could also be important in some oceanic areas especially in low-nutrient low-chlorophyll (LNLC) regions for which such a nutrient addition could be of crucial importance. Such an area is the ultra-oligotrophic Mediterranean Sea which receives high quantities of MDA from the adjacent Sahara desert (Guerzoni et al. 1999). Large scale mesocosm experiments have shown the importance of atmospheric deposition for the vulnerable Mediterranean ecosystem (Guieu et al. 2014; Pitta et al. 2017). Basin scale correlation approaches also show an influence of aerosol deposition on chlorophyll in the Mediterranean (Gallisai et al. 2014; Gallisai et al. 2016).
Aerosols may also contain toxic metals and toxic organic compounds which can potentially influence phytoplankton. Furthermore, freshly produced sea-spray aerosol contains bacterial enzymes active in cleaving proteins, sugars, lipids and phosphorus rich compounds further coupling the oceanic and atmospheric biogeochemistry. Changes in organic matter quality and quantity due to phytoplankton blooms followed by bacterial enzymatic degradation influences chemical properties of SSA and therefore the process of cloud formation, which can be considered as a feedback process of aerosol deposition in the ocean.
MDA and BCA deposition are sources of bioavailable organic carbon (absorbed during atmospheric transport), and it has been shown both *in situ* and in the lab that this organic matter can stimulate bacterial abundance and respiration (Romero et al. 2011, Marín-Beltrán et al. 2017, 2019).
Observation and experiments suggest that marine organic matter such as transparent exopolymeric particles (TEP) and microorganisms can become rapidly associated to MDA, VAA and BCA. This aggregation enhances bacterial production. In studies with MDA and VAA, the role of aerosols as particles is typically neglected, i.e. only release rates are considered, although particles and particle associated processes are crucial for the understanding of the ecology and biogeochemistry of the ocean. Previous studies suggest that aerosol deposition causes shifts in biodiversity (e.g. Hamme et al 2010, Zhan et al. 2017). The matrix and material of aerosols could, for example, provide niches for microorganisms, hence sustaining overall diversity. Larger particles sink faster than smaller ones, hence the role of particles will strongly depend on particle size distributions.
Owing to their high density, aerosols deposited into the ocean and aerosols attached to organic particles can sink out of the euphotic zone and transport organic matter and attached microorganisms into the deep sea (ballasting). This could affect the fate of organic matter. Export

into the deep ocean represents an aerosol link to the biological pump (lithogenic pump, for MDA and VAA; black pump for BCA).
The stimulation of massive phytoplankton blooms by VAA deposition events causes the production (P) to respiration (R) ratio to be shifted towards autotrophy (P:R > 1). Current knowledge suggests that BCA deposition stimulates bacterial production, but not primary production (citation). Therefore, the findings suggest a shift toward autotrophy by VAA (P:R > 1), and shifts toward heterotrophy by BCA (P:R < 1). For MDA, the most thoroughly studied aerosol, the response depends on the degree of oligotrophy (Marañón et al. 2010), and for VAA a concentration effect was observed (Weinbauer et al. in preparation).
Anthropogenic material in the atmosphere such as metals, organic compounds, nano-particles and plastic particles (Kuznetsova et al. 2005; Thompson et al. 2009), and SSA, a significant, marine-borne aerosol, can interact with MDA, VAA and BCA. The effects of these aerosols on microbial plankton communities are poorly studied, and represent an additional future avenue for the study of aerosol–microbe interactions. Sea-borne organic material and microorganisms are horizontally transported with SSA, whereas with MDA, VAA and BCA, organic matter and microorganisms either from terrestrial origin or absorbed during horizontal transport in the atmosphere are deposited in the ocean.

2.3 Why a SCOR Working Group?

Although there are initiatives to address ocean-atmosphere studies such as SOLAS or GESAMP, here are not many (in space or in time) direct deposition measurements, and besides some cruise samples, none over the ocean, and especially time series are missing (e.g. Baker et al. 2007). Some time series exit from islands, which always also include local sources. Extensive data can be calculated from air quality measurements but variability in actual settling velocities (needed to get the deposition measurements) are a challenge (not only for wet vs. dry deposition) and again only coastal or island data are available. There is also the issue that the local sources are typically not resolved, although they can sometimes be filtered out using wind direction. Satellite data can give the concentration in the air column, but again obtaining actual deposition from it remains challenging.

Since atmosphere and ocean sciences are different disciplines, and there is very little interdisciplinary overlap, we lack a combined approach to this research and consensus in the methods used. This prevents us from reaching a holistic understanding of the impact of aerosols on marine microbial communities and marine primary production, which is responsible for about 50% of global primary production. The main goal of AEROS is to compile data to enable the comparison of the effects of different types of aerosols on marine microbial ecology and biogeochemistry, and prepare guidelines for future research, thus linking atmosphere with ocean sciences, and (bio)geochemistry with microbiology. Such an endeavor transgresses typical national projects, and calls for an international collaboration. As global change intensifies aerosol production (potentially even for VAA; (Brothers et al. 2013)), a comparative assessment of the effects of aerosol deposition is imperative for understanding the future ocean.

3. Terms of Reference

ToR1. To establish a database on deposition rates of different types of aerosols.

ToR2. To evaluate sampling strategies and experimental approaches for aerosols.

ToR3. To evaluate the role of different types of aerosols in the marine food web, and their potential impact on biogeochemical cycles.

ToR4. To assess the impact of aerosols along trophic gradients and along gradients of aerosol deposition rates.

ToR5. To come up with a global assessment of the combined role of aerosols on the ocean.

The ToR will be met by:

ToR1 will be realized establish a long-lasting data base e.g. to the BCO DMO in the USA.

* ToR2 will be realized by writing a best practice paper (for example an L&O eBook or SCOR booklet) on sampling, experiments and specific analyses. This will include solids and soluble fractions analyses as well as microorganisms.

ToR3 and ToR4 will be realized by writing a review paper comparing the role of different aerosols in the food web, and evaluating their potential impact on biogeochemical cycles along with guidelines for future needs.

* ToR5: The AEROS WG will also try to come up with a global assessment of the combined role of the effect of different aerosols. If this is not possible, e.g. due to the lack of comprehensive data, we will strive to define the knowledge gaps needed to be overcome in order to allow for such an assessment.

4. Working plan

We will convene annual meetings over the next three years (upon funding by SCOR), together with regular email exchange and online meetings to achieve the goals listed above.

The main activities for the work plan are

A data base will be developed on the variability of deposition rates of aerosols to better identify knowledge gaps and better constrain data for different ocean basins. This is a necessary step to evaluate the combined effects of aerosols on the microbial ecology and biogeochemistry of the ocean.
In addition, aerosols are also subject to strong temporal and spatial variations. We will try to constrain this variability or at least define knowledge gaps.
In order to improve the comparability of data, we will publish a best practice eBook.
The expertise of the participants of the WG AEROS is needed for a holistic approach. A first brief attempt has been made (Weinbauer et al. 2017) but needs to be extended and expanded.

Timeline

Year 1:
First WG meeting (e.g. during the Aquatic Sciences Meeting in 2021)

Details on the data base will be discussed and the tasks will be distributed.

The general structure of the paper on best practices will be discussed, and writing tasks will be assigned.
The general structure of the review paper will be discussed and writing tasks will be assigned.

Year 2:
Second WG meeting (e.g. During the EGU meeting 2022)

Progress reports on the database and the publications will be discussed within the WG.
This year is mainly devoted to paper writing.

Year 3:
Third WG meeting (e.g. During the Aquatic Sciences Meeting 2023)

In this meeting, we will submit a special open session on the effect of aerosols deposition on microbial ecology and biogeochemistry in the ocean. We envision a special issue that will include the presentations of this session.
* The discussions of WG meetings and compilation of different parts already written will be synthesized to obtain a first draft of the review paper.
* Future collaborative proposals will be discussed

5. Deliverables **(Max 250 words)**

A database with information on aerosol' impact on ocean processes will be established.
A best practices eBook with open access will be compiled.
A review paper will be published in an open access journal reviewing the effects of aerosols on marine microbial ecology and biogeochemistry and their combined impact for the future ocean.

Organize short meetings during large meetings such as AGU, EGU, ASLO. In addition, full meetings will be organized before or after these meetings to allow a stronger representation by associate members and other participants of these larger meetings. The meetings will in part be restricted to AEROS WG members and in part open to others.

To expose the AEROS WG and SCOR in general to a larger audience, social media will be used, and the review paper will be adapted to a more general audience.

6. Capacity Building

The SCOR WG is balanced with respect to gender (11 females, 9 males) and career stage, and diverse in terms of geographic representation (two full members and one associate member from Africa and South America). Its members are experts in atmospheric chemistry, biogeochemistry, viral and microbial oceanography, allowing for an interdisciplinary scientific dialogue.

The SCOR Working Group will actively help building capacity by funding participants from developing nations as well as early-career scientists to attend workshops and working with the community to leverage further funding from other sources.

7. Working Group Composition

Full members

Name	Gender	Place of work	Expertise
Markus G. Weinbauer (Co-chair)	M	Laboratoire d'Océanographie de Villefranche (LOV), France	Effect of black carbon on viral microbial diversity and food web dynamics; viral and microbial oceanography
Koji Hamasaki (Co-chair)	M	Atmosphere and Ocean Research Institute (AORI), Univ. Tokyo, Japan	Microbial oceanography; bacterial diversity and functions in relation to biogeochemical cycles
Renato Carreira	M	Pontifical Catholic University of Rio de Janeiro (PUC-Rio), Brasil	Lipid biomarkers and isotopic composition in marine organic biogeochemistry and paleoceanography
Linn Hoffmann	F	University of Otago, Dunedin, New Zealand	Marine phytoplankton eco-physiology, effect of trace metals on phytoplankton production and community composition
Maria Kanakidou	F	Environmental Chemical Processes Laboratory, Department of Chemistry, University of Crete, Heraklion, Greece	Atmospheric deposition of aerosols, nutrients and trace gases and their variability driven by emissions, climate and atmospheric chemistry
Hongbin Liu	M	Department of Ocean Science, Hong Kong University of Science and Technology, Hong Kong	Effect of dust of different sources on the microbial food web dynamics, with particular focus on community and functional changes using molecular approaches
Francesca Malfatti	F	Department of Life Science, University of Trieste, Italy	Marine microbial ecology, marine aerosol microbiology, marine microscale biogeochemistry, marine organic matter cycling
Adina Paytan	F	University of California Santa Cruz, USA	Biogeochemistry, effect of atmospheric deposition on ocean biogeochemistry
Paraskevi Pitta	F	Institute of Oceanography, Hellenic Centre for Marine Research, Heraklion, Crete, Greece	Structure and function of pelagic microbial food webs in oligotrophic environments: from viruses to ciliates, effects of atmospheric deposition on the ultra-oligotrophic Mediterranean, ciliate mixotrophy, field work, mesocosm experiments

Miri Trainic	F	Weizmann Institute of Science, Department of Earth and Planetary Sciences, Israel	Sea spray aerosol and cloud properties as a function of phytoplankton ecology and anthropogenic pollution in the ocean

Associate Members

Name	Gender	Place of work	Expertise
Zanna Chase	F	Institute for Marine and Antarctic Studies, University of Tasmania, Tasmania	Marine biogeochemistry; quantification of dust deposition to the modern and paleo ocean
Benjamin Guinot	M	Laboratoire d'Aérologie, CNRS, Université Toulouse III, France	Aerosol collection, aerosol sources and aging, black carbon, bioaerosols
Cui Guo	F	Ocean University of China, Qingdao, China	Effect of east Asian aerosols on diversity and function of bacteria and phytoplankton; biological oceanography and microbial ecology
Yoko Iwamoto	F	Graduate School of Integrated Sciences for Life, Hiroshima University, Japan	Physical and chemical measurement of atmospheric aerosol, atmosphere-ocean link of biogeochemical cycles between the atmosphere and the oceans, interaction between atmospheric aerosols, clouds, and precipitation.
Sekou Keita	M	University Peleforo Gon Coulibaly, Korhogo, Ivory Coast	Measurements of atmospheric compounds, emission factor and emission inventory development, modelling of atmospheric pollution and its impacts
Natalie Mahowald	F	Department of Earth and Atmospheric Sciences. Reducing Climate Risk Working Group co-leader for the Cornell Atkinson Center for Sustainability, Cornell University, Ithaca, NY, USA	Atmospheric inputs of nutrients into the ocean

Jutta Niggemann	F	Research Group for Marine Geochemistry (ICBM-MPI Bridging Group) of the Institute for Chemistry and Biology of the Marine Environment (ICBM) at the University of Oldenburg, Germany	Sources and fate of dissolved black carbon in aquatic environments; chemical analytics and biogeochemistry of dissolved organic matter, interactions of microorganisms and organic matter
Francesc Peters	M	Institute of Marine Sciences (ICM, CSIC), Barcelona, Catalunya, Spain	Atmospheric deposition measurements, effects of natural and anthropogenic aerosols on algal and bacterial production and community composition, marine microbial ecology
Véronique Yoboué	F	Félix Houphouët Boigny University of Abidjan (UFHB), Ivory Coast	Atmospheric physics and chemistry: measurements of deposits (dry and wet) and emissions of atmospheric compounds - Study of urban pollution and its impact on health and climate change.
Rui Zhang	M	Key State Laboratory of Environmental Marine Science, University of Xiamen, China	Marine viral ecology, volcano ash aerosols

8. Working Group contributions

Renato Careira works on lipid biomarkers and isotopic composition in marine organic biogeochemistry and paleoceanography.

Koji Hamasaki is an expert in marine microbial ecology, especially focusing on bacterial diversity and functions in the process of ocean biogeochemical cycles.

Linn Hoffmann is an expert in marine phytoplankton eco-physiology with a focus on the effect of trace metal additions on phytoplankton growth and community composition.

Maria Kanakidou is an atmospheric chemist with expertise on atmospheric aerosols and deposition of nutrients to the ecosystems and subsequently on climate with emphasis on understanding the impact of human activities.

Francesca Malfatti is a marine microbial ecologist, focusing on small scale biogeochemical processes mediated by bacteria in the ocean and in sea-spray aerosol.

Adina Paytan is a marine biogeochemist with ample experience on the effects of atmospheric deposition on marine phytoplankton with emphasis on in-situ experimental data collection and observations.

Francesc Peters is interested in marine microbes and plankton, especially from dynamic and biogeochemical perspectives. He has worked on temperature effects, turbulence, protistan grazing, nutrients in coastal areas and atmospheric deposition in marine systems. Now getting also interested in polllution, climate change, marine production and planetary and human health.

Paraskevi Pitta is a marine microbial ecologist with an extended experience on the effect of Saharan dust deposition on oligotrophic microbial plankton communities as studied by means of large-scale mesocosm experiments.

Miri Trainic is an expert in aerosol chemistry and optical properties, specializing in sea spray aerosol properties and link to the oceans' microbiological as well as anthropogenic components.

Markus G. Weinbauer is expert in viral ecology and in the effect of black carbon rich aerosols on viral and microbial ecology and diversity.

9. Relationship to other international programs and SCOR working groups

Related work is done in GESAMP WG38, Atmospheric Input of Chemicals to the Ocean http://www.gesamp.org/work/groups/38 and Surface Ocean Lower Atmosphere Studies (SOLAS), especially Theme 3: Atmospheric deposition and ocean biogeochemistry.
However, the proposed work will be complementary to GESAMP WG38 or SOLAS theme 3, since it will provide a review the aerosol types impact on the microbial ecology and biogeochemistry of the ocean while GESAMP WG38 until recently was more focused on the impact of atmospheric deposition (gases and aerosols) on the GHG sink/ emissions to/from the ocean and did not get into much details on microbial ecology. The same holds for SOLAS where microorganisms are rather restricted to their role in biogeochemistry and not in microbial, ecology and diversity.

AEROS is also related to the TARA Oceans expeditions studying marine biodiversity and the Malaspina circumnavigation expedition, an interdisciplinary research project to assess the impact of global change on the oceans and explore their biodiversity. These expeditions did not assess aerosols input as suggested by AEROS.

AEROS will also benefit from previous working groups such as WG 141: Sea-Surface Microlayers, WG 134: The Microbial Carbon Pump in the Ocean, WG 126: Role of Viruses in Marine Ecosystems and WG 120: Marine Phytoplankton and Global Climate Regulation: The *Phaeocystis* spp. Cluster as a Model.

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11. Appendix

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APPENDIX 4. WORKING GROUP REPORTS

WG 143. Dissolved N2O and CH4 measurements: a global network of ocean time series measurements

1. Name of group

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

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

- Overview poster presented by Sam Wilson, co-chair of SCOR WG#143, at the Ocean Obs'19 conference in Honolulu, Hawaii, 16-20 September 2019.
- An OCB workshop in 1-3 October 2019 discussed potential activities of US scientists relevant to the Surface Ocean Lower Atmosphere Study (SOLAS) program. Sam Wilson attended this workshop and reported on the outcomes of the SCOR WG#143 and the 2018 Lake Arrowhead workshop.
- WG lunchtime meeting with 25 participants organized by Sam Wilson on 18 Feb 2020 during the AGU Ocean Sciences Meeting, San Diego, CA.

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

In April 2019 a movie about the Lake Arrowhead workshop in October 2018 was released on 'YouTube': https://www.youtube.com/watch?v=0DyMyIVs4Qs .

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

1. Conduct an intercalibration exercise between the time series programs (for methane and nitrous oxide)
This is completed and published (Wilson et al., 2018).

2. Establish the appropriate standards to be used by the scientific community
This is completed and the Technical Report has been published on the SCOR website (Bullister, J.L., D.P. Wisegarver and S.T. Wilson (2016) Technical Report: The production of methane and nitrous oxide gas standards for Scientific Committee on Ocean Research (SCOR) Working Group #143. pp 1-9)

3. Recommend the analytical reporting procedures to be used for N_2O and CH_4
All members of SCOR WG#143 publish their own respective research on methane and nitrous oxide, and are therefore very familiar with their own analytical procedures. However, as a community of trace gas analysts there is no published consensus about the most appropriate methods and we have not yet agreed on the reporting procedures. In response to this, we are currently writing the Standard Operating Protocols (SOPs) for methane and nitrous oxide. See also '5. WG activities planned for the upcoming year'.

4. Establish framework for an N_2O/CH_4 ocean time series network and write a global oceanic N_2O/CH_4 summary paper for publication in an open access journal.
This is completed and published (Bange et al., 2019).

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

On the basis of the discussions and recommendation of the Lake Arrowhead workshop we are about to write a perspective article for Biogeosciences:
Wilson, S. T., Al-Haj, A. N., Bourbonnais, A., Frey, C., Fulweiler, R. W., Kessler, J. D., Marchant, H. K., Milucka, J., Ray, N. R., Suntharalingam, P., Thornton, B. F., Upstill-Goddard, R. C., Weber, T. S., Bange, H. W., Benway, H. M., Bianchi, D., Borges, A. V., Chang, B. X., Crill, P. M., del Valle, D. A., Farías, L., Kock, A., Labidi, J., Manning, C. C., W., P. J., Rehder, G., Sparrow, K. J., Tortell, P. D., Treude, T., Valentine, D. L., Ward, B. B., Yang, S., and Yurganov, L. N.: Ideas and perspectives: A strategic assessment of methane and nitrous oxide measurements in the marine environment, Biogeosciences, in preparation, 2020.

Moreover, we are about to finish writing the Standard Operating Protocols (SOP)
SOP1 - Gas Sampling, SOP2 - Calibration, SOP3 - Internal controls, SOP4 - Purge&Trap method, SOP5 - Headspace method, SOP6 - Underway, SOP7 - N_2O process measurements, SOP8 - CH_4 process measurements, and SOP9 - Data. All participants from the WG intercomparison studies and the 2018 Lake Arrowhead workshop were invited to contribute the SOPs. The SOPs will be submitted to the IODE/IOC Ocean Best Practices Repository (www.oceanbestpractices.org). The individual SOPs are citable as they receive a DOI when uploaded to the repository. In addition, a summary paper about all the SOPs will be written and submitted to the ongoing Frontiers special issue on ‘Best Practices for Ocean Observing’. Frontiers will explicitly have a link to the SOPs repository.

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

No difficulties to report.

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

None at this time. Thank you to Ed Urban, Patricia Miloslavich and SCOR for supporting the activity of WG#143 during the past years. It has been extremely helpful to the progress of methane and nitrous oxide measurements in the ocean.

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

WG 145. Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC)

1. Name of group

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

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

WG meeting

- The Working Group met in San Diego on 16 February 2020. The meeting report is available at *http://marchemspec.org/wp-content/uploads/2020/03/SCOR-WG145-Report-4th-Meeting-2020.pdf*

NSFGEO-NERC project *A Thermodynamic Chemical Speciation Model for the Oceans, Seas, and Estuaries*

This project (PI's Clegg, Dickson and Benway) was initiated to support the WG aims, and provides funding for thermodynamic measurements, and speciation model and software development. The first prototype software for chemical speciation modelling, including uncertainty estimates, has been completed and was presented at a lunchtime session and at the SCOR exhibition booth at the 2020 Ocean Sciences meeting in San Diego.

Experimental measurements

- Collaboration between Dickson's laboratory at Scripps and the national standards laboratories in France, Germany, Japan and USA has continued, with a focus on intercalibration of Harned cell measurements.
- Pablo Lodeiro, working in Achterberg's laboratory at GEOMAR has extended the Tris solubility measurements to include the solubilities of Tris in TrisHCl and $(Tris)_2SO_4$ at different concentrations and temperatures.
- Martha Gledhill has characterised the acid-base properties of natural organic matter concentrated from seawater, and has developed a preliminary chemical speciation model for this material using the NICA-Donnan approach.

Collaborations

- SCOR/IAPSO/ICPWS Joint Committee on the Properties of Seawater: WG members Frank Bastkowski, Simon Clegg, Andrew Dickson, Frank Millero and Daniela Stoica are members of this committee, which has a particular interest in establishing SI-traceability for seawater pH: the modelling developments of WG145 will contribute to this goal.
- Andrew Dickson leads a newly established IAPSO Best Practice Study Group on seawater "pH" measurement, which will complement the work of WG145 on modelling seawater pH buffers.
- Collaborators at the University of Bristol, UK, have made measurements of the osmotic coefficients of Tris in water, complementing the solubility measurements made by Pablo Lodeiro (above).

Conference presentations

- Matthew Humphreys, Andrew Dickson, David Turner and Simon Clegg: Modelling Chemical Speciation in Seawater pH Buffers, Standard Seawater and Other Natural Waters: Applications and Uncertainties. eLightning presentation at Ocean Sciences 2020.

- Pablo Lodeiro, David Turner, Simon Clegg, Lucia González and Eric Achterberg: Determining the Pitzer interaction coefficients of TRIS in aqueous solutions of NaCl, TrisHCl and $(TrisH)_2SO_4$ by solubility measurements. A new experimental contribution towards the development of a traceable chemical speciation model of pH buffers used for applications involving seawater and other natural waters. Poster at Ocean Sciences 2020.

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

The prototype chemical speciation modelling software demonstrated at the 2020 Ocean Sciences Meeting has been published at the web address *www.aim.env.uea.ac.uk/osm/main_page.html*

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

1) *To document the current status, and basis in laboratory measurements, of Pitzer models of seawater and estuarine water focusing on the chemistry of ocean acidification and micronutrient trace metals (including, but not limited to, Fe, Cu, Mn, Cd, and Zn). Current capabilities and limitations for oceanographic and biogeochemical calculations will be defined, and future needs established. Important gaps in knowledge, which should have high priority for new measurements, will be identified. The components to be covered will include the seawater electrolytes, the selected trace metals, and buffer solutions and key organic ligands such as those used in CLE-CSV titrations.*

Documentation is complete for Tris buffers in artificial seawater, and for the seawater electrolyte.

2) *To publish the results of the first term of reference in the refereed scientific literature, and to introduce the conclusions and recommendations to the oceanographic community at a "town hall" event or special session at an international ocean sciences meeting.*

The WG hosted a Town Hall at the 2016 Ocean Sciences meeting, and a lunch session at the 2020 Ocean Sciences meeting presenting the prototype chemical speciation modelling software. The prototype software was made available at the SCOR exhibition booth at the 2020 meeting. The WG's progress is reported as updates to the website *http://marchemspec.org*

3) *To specify the functions and capability for a web-based modelling tool that will make chemical speciation calculations easily accessible for a wide range of applications in oceanography research and teaching, and thus improve understanding and spread best practice in modelling*.

The results of the web survey of potential users is guiding the software development, and will be described in a paper planned for the Research Topic "Best Practices in Ocean Observing" in the journal Frontiers in Marine Science.

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*.

Prototype software, including the estimation of uncertainties, was presented at the 2020 Ocean Sciences meeting.

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

We have identified four activities that will be required in order to fulfil our Terms of Reference:

- Extend the modelling to the trace metals identified in the ToR, together with key organic ligands: *trace metals to be completed in the coming year; key organic ligands in 2021/22*
- Document key knowledge gaps*: most to be completed in the coming year; key organic ligands in 2021/22*
- Complete the "Best Practice" paper: *to be done in the coming year*
- General release of the chemical speciation modelling software, supported by webinars and other forms of community engagement such as the working group website (marchemspec.org) and communications to relevant international networks (e.g., OCB, SCOR, GEOTRACES, etc.) - *early 2022*

Additional activities, beyond the Terms of Reference, for the coming year:

- Publish the Tris solubility work
- Publish the work on estimation of uncertainties
- Continue with our collaborators to make Harned cell measurements relevant to artificial seawater buffers and begin writing up this work
- Further work on modelling the chemistry of natural organic matter, and integration of the NICA-Donnan approach with a Pitzer model.
- WG145 has been invited to contribute to a proposed GESAMP Working Group on the effect of climate change on contaminants in marine systems, although this initiative is expected to be delayed due to the Coronavirus pandemic

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

The WG proposal noted that completion of the Terms of Reference would require significant additional funding, and that obtaining this funding could result in a delay. A large grant from the prestigious NERC/NSF joint programme was awarded in 2017, which provided necessary core funding for analyses and speciation model development. As noted above, we have also developed extensive collaborations with other institutions and national metrology laboratories that have made substantial in-kind contributions to our experimental programme. The NERC/NSF project will end in early 2022. We plan to complete the Terms of Reference with a software release at that time. As such, we respectfully request an extension of WG145 to April 2022, which we anticipate will be mutually beneficial, since the new chemical speciation software would be clearly seen as a product of a SCOR activity, which would in turn enhance the status and visibility of the software and encourage its use in the broader oceanographic community.

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

This WG has been effective in building a research community focused on chemical speciation in marine waters. Participants in the WG meeting in 2020 expressed interest in continued collaboration beyond the life of the WG, which will continue to enrich the experiments and model development that is underway. Furthermore, speciation model survey respondents and participants of the 2016 and 2020 Ocean Sciences events have requested regular communication via an email list (currently ~100 members) to remain informed of new developments on the project.

Coronavirus pandemic: The WG members working on the remaining tasks in the Terms of Reference are currently working from home due to government restrictions. While future developments are hard to predict, we do not currently expect the pandemic to significantly affect the timetable for ToR completion. Planned experimental work outside the ToR that is supporting further model development will, however, be delayed

WG 148. International Quality Controlled Ocean Database: Subsurface temperature profiles (IQuOD)

1. Name of group

Working Group 148: International Quality controlled Ocean Database (IQuOD)

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

IQuOD in-person meetings:

- The 6th IQuOD workshop took place at Ifremer, Brest, France during 29-31 October 2019. The workshop focused on developing a "roadmap" for the v1.0 data release. The workshop report is available here http://www.iquod.org/documents.html

IQuOD Intersessional meetings (virtual):

- 28 February, 2020. The next planned release of the IQuOD product was reviewed, task team goals for the release were reviewed.
- 31 March, 2020. Focus on Expert QC and Intelligent Metadata task teams. Website was reviewed.
- 20 April, 2020. Discussion about future funding for the IQuOD Project.
- 28 April, 2020. Uncertainties themed discussion.

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

Updates to the webpages: www.iquod.org.
New Google Scholar publication list:

https://scholar.google.com/citations?hl=en&user=qYD_0r8AAAAJ&view_op=list_works&authuser=1

Journal Articles:

Casteleo, G., 2020. A Framework to Quality Control Oceanographic Data. https://doi.org/10.21105/joss.02063

Matthew Palmer, Paul Durack, Maria Chidichimo, John Church, Sophie Cravatte, et al.. Adequacy of the Ocean Observation System for Quantifying Regional Heat and Freshwater Storage and Change. *Frontiers in Marine Science*, Frontiers Media, 2019, 6, pp.416. ⟨10.3389/fmars.2019.00416⟩. ⟨hal-02286221⟩

Ponte, Rui M.; Carson, Mark; Cirano, Mauro; Domingues, Catia M.; Ezer, Tal; and Zhang, Xuebin, "Towards Comprehensive Observing and Modeling Systems for Monitoring and Predicting

Regional to Coastal Sea Level" (2019). *CCPO Publications*. 309. https://digitalcommons.odu.edu/ccpo_pubs/309

Meyssignac B, Boyer T, Zhao Z, Hakuba MZ, Landerer FW, Stammer D, Köhl A, Kato S, L'Ecuyer T, Ablain M, Abraham JP, Blazquez A, Cazenave A, Church JA, Cowley R, Cheng L, Domingues CM, Giglio D, Gouretski V, Ishii M, Johnson GC, Killick RE, Legler D, Llovel W, Lyman J, Palmer MD, Piotrowicz S, Purkey SG, Roemmich D, Roca R, Savita A, von Schuckmann K, Speich S, Stephens G, Wang G, Wijffels SE and Zilberman N (2019) Measuring Global Ocean Heat Content to Estimate the Earth Energy Imbalance. Front. Mar. Sci. 6:432. doi: 10.3389/fmars.2019.00432

Engagement with user communities:

Goni Gustavo J., Sprintall Janet, Bringas Francis, Cheng Lijing, Cirano Mauro, Dong Shenfu, Domingues Ricardo, Goes Marlos, Lopez Hosmay, Morrow Rosemary, Rivero Ulises, Rossby Thomas, Todd Robert E., Trinanes Joaquin, Zilberman Nathalie, Baringer Molly, Boyer Tim, Cowley Rebecca, Domingues Catia M., Hutchinson Katherine, Kramp Martin, Mata Mauricio M., Reseghetti Franco, Sun Charles, Bhaskar TVS Udaya, Volkov Denis, 2019: More Than 50 Years of Successful Continuous Temperature Section Measurements by the Global Expendable Bathythermograph Network, Its Integrability, Societal Benefits, and Future. Front. Mar. Sci. 6:452. doi:10.3389/fmars.2019.00452

Storto Andrea, Alvera-Azcárate Aida, Balmaseda Magdalena A., Barth Alexander, Chevallier Matthieu, Counillon Francois, Domingues Catia M., Drevillon Marie, Drillet Yann, Forget Gaël, Garric Gilles, Haines Keith, Hernandez Fabrice, Iovino Doroteaciro, Jackson Laura C., Lellouche Jean-Michel, Masina Simona, Mayer Michael, Oke Peter R., Penny Stephen G., Peterson K. Andrew, Yang Chunxue, Zuo Hao, 2019: Ocean Reanalyses: Recent Advances and Unsolved Challenges. Front. Mar. Sci. 6:418. doi: 10.3389/fmars.2019.00418

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

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.

- Work is being led by Stephen Haddad at the Met Office to implement a Machine Learning ensemble approach. This is being funded through an internal secondment. All the code is open source (Python) and freely available at https://github.com/Fracappo87/XBTs_classification

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.

- The manuscript "Benchmarking of automatic quality control checks for ocean temperature profiles and recommendations for optimum sets" by Good, Mills et al. is currently in preparation for Frontiers in Marine Science. We expect to submit the paper in the next month or two (June or July 2020).

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.

- The optimal set of automated QC checks are documented in Good, Mills et al (in prep). All code is freely available at https://github.com/IQuOD/AutoQC

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.

- Work is ongoing and testing of an expert QC interface with a machine learning engine is underway. The machine learning toolbox is described in Castelao (2020) “A Framework to Quality Control Oceanographic Data” in Journal of Open Source Software

- Guilherme Casteleo provided a demonstration of the expert QC interface at the Ocean Sciences Meeting 2019 which was well received.

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

- A manuscript for journal publication of the uncertainty values applied to the v0.1 IQuOD release is currently underway. Publication expected by end of 2020.
- Improving the uncertainties for future IQuOD releases is an ongoing task and we aim to publish details of enhancements and improvements with each release.

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.

- The main task for this year has been working towards a first full-release of the IQuOD v1.0 dataset. This will be the first product to include an internationally-coordinated optimised automated QC flags. The main purpose of the IQuOD workshop in Brest during Oct/Nov 2019 was agreeing on a “roadmap” to deliver this data product. While we had a target for October 2020 for completion, this now is subject to delay associated with COVID-19 lockdown in IQuOD member countries.

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.

- The IQuOD 6th workshop and intersessional meetings are the primary means by which this ToR has been addressed in the last 12 months.

- The last workshop had attendees from over 10 countries from many areas of expertise including data collection and management, quality control experts, and end users from the modelling community.

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

- Publication of the IQuOD v1.0 product
- Publication of Auto QC paper associated with the v1.0 product
- Publication of Uncertainties paper associated with the v0.1 product
- Seeking endorsement from UN Decade of Ocean Science for Sustainable Development
- Seeking funding for FTE to continue the IQuOD project work (potentially NERC UK)
- Completion and delivery of Machine Learning-based intelligent metadata for XBT observations, including probabilistic information to inform Monte Carlo studies for future XBT bias corrections.
- Duplicate checking routines built and shared via github
- Measuring progress by testing the IQuOD releases by end-users.
- Hosting of the IQuOD products on the NCEI World Ocean Database platform will continue as the platform moves into a cloud-based storage environment.

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

IQuOD currently has no long-term funding for its participants and relies on engagement and in-kind funding from the participants' home institutions. We continue to achieve what we can under limited funding conditions. Additionally, Covid-19 has impacted on everyone's ability to contribute to the project.
We will continue to actively source funding for IQuOD into the future and have regular online contact within the group.

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

Many thanks to the SCOR committee for their support over the last 3 years. IQuOD would like to continue as a SCOR WG if possible, and we request a one-year extension to our 3-year term to allow us to finalize one of our planned activities for the upcoming year.

If appropriate, we may request a letter of support for funding proposals in the future. We also request thoughts on how we can maintain a relationship with SCOR and related relevant SCOR WGs for mutual benefit.

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

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

1. Name of group

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

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

Special issue

Our Research Topic (special issue) in Frontiers in Marine Sciences called "We Shed Light: Optical Insights into the Biological Carbon Pump" following on from the session at the Ocean Science Meeting is closed now and has 7 accepted publications.

Literature Review

Our literature review has been published this year. Title: "Particles in the ocean - what can we learn from optical devices?" The review provides a practical overview of the challenges and potential of using optical instruments for estimating carbon fluxes. It gives plenty of recommendations and a useful guide for improving the application of optical devices as well as allowing intercomparisons. Since its publcation in Feb 2020, it has had over 3500 views and has already been cited in *Science*.

Data sharing platform

Several of the TOMCAT members have been involved in starting the Joint Exploration of the Twilight Zone Ocean Network (JETZON; *http://jetzon.org/*). JETZON hosts a dedicated website for data and method sharing, which we have identified as the perfect platform for TOMCAT methods to be broadcasted. We are now in the process of contributing to the JETZON website.

Capacity building – Postgraduate training

In an effort to bring TOMCAT methods to South Africa, Sari Giering is currently supervising a PhD student based at the Nelson Mandela University (NMU), South Africa. In Jan-Feb 2020 she worked at NMU where she advised and trained the PhD student and staff in collecting flux data using traditional methods and optical methods and assisted in the data analysis and interpretation.

Capacity building – SUMMER school

Members of TOMCAT are preparing a 1-week summer school in Cape Town, South Africa. The summer school was originally planned for October 2020, but due to COVID-19 we are now anticipating hosting it in early 2021. The focus of the school is capacity building, so the teaching material will be accessible and hands-on with a focus on optical instruments that are affordable (< US$ 2,000). For example, we will introduce the affordable "PlanktoScope" (<US$400 in parts), which is of comparable quality to more costly commercial instruments. Therefore, this instrument is a potential chance to allow a low-cost approach to extend imaging approaches in oceanography as well as citizen sciences projects. The anticipated number of students is 20. SCOR has already kindly approved US$ 5,000 for travel support of developing country scientist to attend the summer school.

Group meeting

A social group meeting was held during the Ocean Sciences meeting in San Diego bringing together TOMCAT scientists and related researchers from the imaging and biological carbon pump community to exchange ideas, and discuss potential project and collaboration activities.

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

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

Publications:

Lombard et al. (2019) Globally Consistent Quantitative Observations of Planktonic Ecosystems. Frontiers in Marine Science. doi: 10.3389/fmars.2019.00196

Giering et al. (2020) Review: Sinking organic particles in the ocean - Flux estimates from in situ optical devices. Frontiers in Marine Science. Doi: 10.3389/fmars.2019.00834

Giering et al. (2020) The interpretation of particle size, shape and carbon flux of marine particle images is strongly affected by the choice of particle detection algorithm. Frontiers in Marine Science. doi: 10.3389/fmars.2020.00564

Website pages:

Details on optical methods via the JETZON data sharing platform. (www.jetzon.org)

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

TOF:

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

2. **Make vocabularies more transparent and interoperable using international standards.**
   Some of these have been defined as part of the literature review. Darroch and Giering will apply for funding to build official recommendations and specifications for the optical community for describing individual images and the overall fluxes. The specifications will include all the necessary metadata (e.g. threshold, focus, etc.) and guides on formatting the information in a consistent, interoperable format. It would also define controlled vocabularies and supply digital notebooks such as Jupyter notebooks for documenting data workflows.

3. **Define key parameters for interpretation of optical information, and recommend which optical measurements are useful for characterizing particle type, interactions and export.**
   Partly achieved as part of the literature review and recent publication (Giering et al. 2020). More will follow via TOF2 and method distribution via jetzon.org.

4. **Evaluate various techniques and algorithms for the conversion of optical observation into particle type, size, concentration, mass, composition, and fluxes, and recommend ways of improving our understanding of the relationships between these properties.** Achieved. We have addressed this issue as part of the literature review as well as a separate paper submitted to the TOMCAT research topic.

5. **Promote sharing of software examples and codes, placed on a public repository.** We have started using digital notebooks to document data analysis workflows (e.g. for one of the Research Topic papers exploring the effect of thresholding on particle size estimates). We will further promote method sharing and provide templates via the JETZON portal.

6. **Improve the visibility and usage of data by hosting an inventory of published datasets.** We have discussed options with different platforms and came to the conclusion that EcoTaxa is currently the best platform for sharing. EcoTaxa is a web application dedicated to the visual exploration and the taxonomic annotation of plankton images, and it has the potential to be extended or used as a template for marine snow images.

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

Capacity building

We will continue our capacity building efforts in South Africa by supervising and training students and staff at NMU. One goal is to introduce the PlanktoScope to the community as a low cost camera system, and increase the general usage of imaging devices in the framework of oceanography.

More transparent and interoperable vocabulary. Giering will apply for a fellowship to follow-up the TOFs that have not been achieved owing to lack of time and resources. The aim is to extend the work started with TOMCAT, building a global data sharing and analysis framework that will eventually allow us to compute global POC process maps.

Example codes

First example codes have been published as part of the papers submitted to the Research Topic (Giering et al. 2020). We have identified the JETZON website as a great tool for sharing data and methods and will publish examples here.

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

We are pleased with the overall progress we have made. This working group has opened the dialogue between many different research groups and – as hoped - has brought researchers from the different fields together. We are looking forward to the summer school and to sharing data and methods via JETZON.

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

We thank SCOR for the generous contribution of $5,000 to the summer school. Any additional support (incl. advertisement) is – as always – highly appreciated.

WG 151. Iron Model Intercomparison Project (FeMIP)

1. Name of group

Iron Model intercomparison project (FeMIP), SCOR WG 151

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

Ocean Science session convened by Al Tagliabue and Andy Ridgwell. Titled 'The role of micronutrient cycles in global scale dynamics' it showcased 8 oral presentations and a set of posters, bringing together observations and modelling of iron and other micronutrients over different space and time scales.

The second working group meeting was held in conjunction with Ocean Sciences, San Diego on 16 Feb 2020. This meeting was attended by 23 people (2 remotely), including most of the working group and several guests. We had several talks covering four specific topics:

Iron inputs and internal cycling; iron model evaluation; role of dust in ocean iron cycle; role of biology in ocean iron cycle.

We also had several discussions based on the WG objectives:

Obj 1: Best practices in ocean iron cycle modelling
Obj 2: New tools in ocean iron model evaluation
Obj 3: Constraining the supply of iron by dust

The meeting was very productive and we feel led to significant process towards the goals of the working group.

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

None yet

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

Objective 1: Iron inputs and internal cycling.
The working group has put together the materials and finalized a table on the complexity used in various models. An open access article was being drafted by Tagliabue, but given the uncertainties about what closures are optimal, it was not thought it useful to lay out a definitive view. The WG agreed that is premature to share code, but that sharing inputs fields would be a very useful step forward for data sharing.

Objective 2: New tools for ocean iron model evaluation.
Marcello Vichi has taken the lead of this objective, and it is near completion. A new tool for standardized model evaluation was demonstrated at the WG meeting. He will distribute his package of model evaluation matlab code via github and potentially a FeMIP specific website (see point 7 below).

Objective 3: Role of dust in ocean iron cycle.
Andy Ridgwell has undertaken several experiment with GENIE making different assumptions on the solubility, natural versus anthropogenic, depth of deposition, and scavenging particles. Unfortunately, Andy was unable to attend the Feb meeting.

Objective 4: Role of biology in the ocean iron cycle.
Phil Boyd and Stephanie Dutkiewicz have provided a table with the main physiological process that need to be captured in models that are important for iron cycling. Ben Twining has compiled a synthesis of iron quota in a range of marine microbes. Discussions have focused on hierarchal approaches to modelling the iron cycling through the ocean biota.

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

Objection1: We will compile and share on publicly available website (to be determined) fields for the following iron inputs: Dust, cosmic dust, glaciers, sea-ice and iceberg supplies, hydrothermal, and rivers. At the February meeting a person volunteered to move forward with each of the above fields. Additionally, we plan to make a FeMIP multi-model mean iron concentration field available in a FeMIP specific website (see point 7 below) which can then be used as a standard model initialization for any OMIPs.

Objective 2: We believe the scope of this objective planned by the working group has been achieved. However, as continuation, we plan to exploring translating Vichi's matlab code to other languages (e.g. python). Additionally, several working group members offered Vichi more modelled iron fields to evaluation and add to the synthesis. Vichi is near to completing a publication on this work.

Objective 3: We plan a video-conference with a subset of the WG plus several guests to discuss Andy Ridgwells results, and those from several other studies currently underway. At the February meeting we did discuss the difficulty constraining model parameterization given the large uncertainties in atmospheric deposition, and we discussed writing a paper review paper on this issue.

Objective 4: We plan a future meeting(s) to push forward with this topic. We will focus on synthesizing on what is known about iron uptake (by diverse organisms), iron limitation and recycling. We plan a video meeting in the near future, but given the scope of this topic, we believe and additional meeting in the 2021 timeframe would be good.

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

Good progress and energy during meeting in February. Unfortunately, subsequent events regarding the pandemic and shut down of institutions and changes in home/work/schooling life has reduced much of the momentum on immediate plans. As the situations improve, the co-chairs will attempt to revitalize this plans.

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

We now have code and fields (forcing and initial conditions) that we would like to make publicly available. Some of these are already on local sites, but we believe that a FeMIP specific website would be beneficial to be able to group these all together, and that would have longevity. Is there any feasibility of SCOR hosting such a website?

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

WG 152. Measuring Essential Climate Variables in Sea Ice (ECV-Ice)

1.Name of group

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

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

In-person meeting

#1: CO_2 flux compilation meeting at Alfred Wegener Institute, Germany, 18 Mar. 2019. Present: D. Nomura, B. Delille.

#2: CO_2 flux compilation meeting at Hokkaido University, Sapporo, Japan, 23 Apr. 2019. Present: D. Nomura, L. A. Miller.

#3: Planning meeting for Inter-comparison experiment for primary production and CO_2 flux at Cambridge Bay, Canada, 3 Jul. 2019. Present: D. Nomura, B. Else.

#4: 2019 ECV-Ice annual Meeting with BEPSII, Winnipeg, Canada, 16-18 Aug. 2019. Present: D. Nomura, F. Fripiat, B. Else, B. Delille, L. Miller, J. Bowman, A. Fransson, D. Lannuzel, K. Meiners, and J.-L. Tison.

#5: CO_2 flux compilation meeting at Tromsø, Norway, 19 Aug. 2019. Present: D. Nomura, B. Delille, S. Moreau.

#6: Planning meeting for Inter-comparison experiment for primary production at Toyama, Japan during SCOR annual meeting, 24 Aug. 2019. Present: D. Nomura, L. A. Miller, I. Peeken.

#7: CO_2 flux compilation meeting at California, USA during CATCH annual meeting, 7 Dec. 2019. Present: D. Nomura, B. Delille.

#8: Planning meeting for sea ice storage for sea ice tank experiment at University of East Anglia, UK, 20 Jan. 2020. Present: B. Delille, O. Crabeck, D. Nomura.

#9: Planning meeting for Inter-comparison experiment for primary production in Cambridge Bay, Canada at University of East Anglia, UK, 29 Jan. 2020: B. Delille, D. Nomura (skype: L. Miller, B. Else, F. Fripiat).

Inter-comparison Experiment

#1: Sea ice inter- comparison experiment for light measurement in Saroma-ko Lagoon, Hokkaido Japan, 23-28 Feb. 2019. Present: D. Nomura, P. Wongpan, T. Toyota, T. Tanikawa, Y. Kawaguchi, T. Ono, T. Ishino, M. Tozawa, T. P. Tamura, I. Yabe, E. Y. Son, F. Vivier, A. Lourenco, M. Lebrun, Y. Nosaka, and M. Vancoppenolle.

#2: Inter-comparison experiment for sea ice storage and gas flux in UEA ice-tank facility, UK, 18-29 Jan. 2020. Present: B. Delille, O. Crabeck, D. Nomura, Kyle Simpson.

#3: Inter-comparison experiment for eddy covariance CO_2 flux measurement in Tsukuba, Japan. 25-29 Feb. 2020. Present: D. Nomura, H. Ikawa, K. Ono, F. Kondo.

Virtual meeting

#1: CO_2 flux compilation meeting with skype, 25 Jan. 2019. Present: D. Nomura, S. Moreau.

#2: ECV-Ice co-chair meeting with skype, 19 Apr. 2019. Present: D. Nomura, F. Fripiat.

#3: ECV-Ice co-chair and full member meeting with skype, 24 Jan. 2020. Present: B. Else, D. Nomura, F. Fripiat, B. Delille, L. A. Miller, O. Crabeck.

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

Peer-reviewed journal articles

#1: Roukaerts, A., Nomura, D., Deman, F., Hattori, H., Dehairs, F., Fripiat, F.: The effect of melting treatments on the assessment of biomass and nutrients in sea ice (Saroma-ko lagoon, Hokkaido, Japan), Polar Biology, 42, 347–356, 2019.

#2: Campbell, K., Mundy, C. J., Juhl, A. R., Dalman, L. A., Michel, C., Galley, R. J., Else, B. E., Geilfus, N. X., and Rysgaard, S.: Melt Procedure Affects the Photosynthetic Response of Sea Ice Algae. Front. Earth Sci. 7:21. doi: 10.3389/feart.2019.00021, 2019.

#3: Nomura D, Wongpan P, Toyota T, Tanikawa T, Kawaguchi Y, Ono T, Ishino T, Tozawa M, Tamura T. P, Yabe I. S, Son E. Y, Vivier F, Lourenco A, Lebrun M, Nosaka Y, Hirawake T, Ooki A, Aoki S, Else B, Fripiat F, Inoue J, Vancoppenolle M. Saroma-ko Lagoon Observations for sea ice Physico-chemistry and Ecosystems 2019 (SLOPE2019). Bulletin of Glaciological Research, 38, 1-12, doi:10.5331/bgr.19R02, 2020.

Web pages: Updated by Daiki Nomura (*https://sites.google.com/view/ecv-ice/*).

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

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

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

We compiled published and unpublished datasets (raw data, methodologies and associated protocols for data correction, instruments, and sampling design) on sea ice-air CO_2 flux and *in situ* primary production from the sea-ice research communities.

(1) Published and unpublished datasets, using various methodologies, have been collated for primary production both in the Arctic and Antarctic sea ice: incubations (^{13}C, O_2, ^{14}C), under-ice microelectrode, and biomass accumulation rates (F. Fripiat, C. J. Mundy, F. Deman, and K. Campbell). The different methods will be compared, and a mechanistic understanding of the

observed discrepancies will be elaborated. Together, this dataset represents the largest compilation of primary production rates so far in sea ice.

(2) Published and unpublished datasets have been collated to compare gas flux measurements over sea ice using chamber techniques (D. Nomura, B. Else, F. Fripiat et al.). A preliminary draft of this paper has been almost completed, and it was discussed at the ECV-Ice annual meeting in Winnipeg, MB, Canada.

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

Completed Inter-calibration Experiments:

(1) Sea ice light measurement: Saroma-Ko Lagoon, February 2019

Participants: D. Nomura, P. Wongpan, T. Toyota, T. Tanikawa, Y. Kawaguchi, T. Ono, T. Ishino, M. Tozawa, T. P. Tamura, I. Yabe, E. Y. Son, F. Vivier, A. Lourenco, M. Lebrun, Y. Nosaka, and M. Vancoppenolle.

Summary: An intercalibration experiment (one week; Lead: D. Nomura) was carried out at Saroma-ko lagoon (Japan) in February 2019 to evaluate different methodologies (sensors) assessing sea-ice over/under ice light measurement. The experiment was successful and a peer reviewed paper (Nomura et al., 2020) was published.

(2) Gases in sea ice and sea ice-air gas flux: Roland Von Glasgow Air-Sea-Ice Chamber (University of East Anglia), January 2020

Participants: B. Delille, D. Nomura, A. K. Simpson, O. Crabeck

Summary: Sea ice freezing experiments were carried out at Roland von Glasgow air-sea-ice chamber (University of East Anglia) for the sea ice storage inter-comparison experiments. We obtained warm and cold sea ice and stored them in the different kinds of bags over different time periods to inter-compare the storage of sea ice samples.

(3) Eddy covariance (EC) drying air comparison for air-sea ice CO_2 flux measurement: Tsukuba, Japan, February 2020

Participant: D. Nomura, H. Ikawa, K. Ono, F. Kondo

Summary: In order to check the moisture effect on the EC CO_2 flux on sea ice (very small magnitude of CO_2 flux), we have examined the drying air experiments in the National Agriculture and Food Research Organization, Tsukuba, Japan. We prepared two CO_2/H_2O analyzers (enclosed, LI-7200) and compared with/without air drying systems (Drierite, Magnesium perchlorate, Perma pure dryer) for CO_2 signals to calculate the CO_2 flux. This EC system will be used for inter-comparison experiment in the Cambridge Bay, Canada, 2021 to compare with the other EC system and enclosure CO_2 chamber system for air-sea ice CO_2 flux.

Planned Inter-calibration Experiments:

Primary Production and Gas Fluxes: The Canadian High Arctic Research Station (CHARS), Cambridge Bay, Canada

Participants: B. Else (lead), F. Fripiat (co-lead), D. Nomura (co-lead), Bowman, C.J. Mundy, N. Kanna, B. Delille, L. Tedesco, N. Geilfus, N. Steiner, L.A. Miller etc.

Summary: We will attempt to do this experiment in 2021 (late April-middle of May), in order to target the sea-ice algal bloom in an ascending phase. During the Canada-Japan workshop 2019 at CHARS (July 2019), we discussed (science, logistics, funding) the possibility to perform a large-scale intercalibration experiment in Cambridge Bay. At the ECV-Ice meeting in Winnipeg (August 2019), we also discussed with ECV-Ice and BEPSII members.

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

We have tried to merge as much as possible the inter-calibration experiments (e.g. Roland Von Glasgow Air-Sea-Ice Chamber in University of East Anglia and eddy covariance experiment in Tsukuba) with emerging technologies.

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

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

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

Virtual meetings: Expect to meet 2-3 times to discuss updates and working plans for the different TR. F. Fripiat, B. Else, and D. Nomura and other members. 2-3 meetings expected to discuss about each data collation related to TR1 (primary production and sea ice-air CO_2 exchange).

In-person meeting: We planned Aug. 2020, ECV-Ice annual meeting with BEPSII, Hobart, Australia. However, due to Covid-19, we have decided that we will cancel this meeting. Alternatively, we will discuss as virtual meetings for review progress on the Terms of reference (present the data-collations (TR2), pursue the elaboration of intercalibration experiments (TR #1 and #3)), including reviewing results of UEA sea ice tank experiment and eddy covariance method in Tsukuba. For 2021 ECV-Ice annual meeting, we are planning at the Canadian High Arctic Research Station (CHARS), Cambridge Bay, Canada during following Inter-calibration experiment.

Inter-calibration experiment: We will attempt to do this experiment in 2021 (late April-middle of May) at CHARS, Cambridge Bay, Canada in order to target the sea-ice algal bloom in an ascending phase. Expected participants: B. Else (lead), F. Fripiat (co-lead), D. Nomura (co-lead), J. Bowman, C.J. Mundy, N. Kanna, B. Delille, L. Tedesco, N. Geilfus, N. Steiner, L.A. Miller etc.

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

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

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

We would like to express heartfelt thanks for financial and technical supports. Due to Covid-19, we have decided that we will cancel 2020 ECV-Ice annual meeting, Hobart, Australia. Therefore, we would like to use 8,000 USD for 2021 ECV-Ice annual meeting.

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

Please see attached minutes (Appendix A) from the 2019 ECV-Ice annual meeting in Winnipeg, Canada on August 2019.

WG 153. Floating Litter and its Oceanic TranSport Analysis and Modelling (FLOTSAM)

1.Name of group

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

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

The second official WG153 meeting was held in Utrecht (NL) on May 6-9th 2019. The program of the meeting and information have been provided in the First Year Annual Report.
In this report we describe activities from May 2019 to May 2020.
After meeting in Utrecht we discussed the necessary actions to:

- Revisiting the current state of knowledge on the dynamics and ocean phenomena that control the dispersion of floating marine debris;
- Identifying key knowledge gaps in this dispersion.
- Writing a review paper on the findings of the workshop.

WG 153 is a global and geographically widely distributed SCOR group and regular videoconference are heavily affected by time zone related problems, therefore we decided to use email as the regular media for the exchange of information. There was no scheduled email exchange or newsletter but the chairs of the WG exchanged emails within the group and outside of the group, according to needs. A shared space on Google Drive was used to write papers or to exchange large files.
Many WG group partners regularly met at major Meetings and Congresses and the updates and exchange of information was prompt and complete.

A list of meeting where the FLOTSAM topics had been addressed is reported.

Atlantic from Space workshop 2019, Southampton (UK), 23-25 January 2019
ESA organised workshop to gather community requirements to stablish a regional research funding call for the Atlantic area. Marine plastic community interests were represented there by Victor Martinez-Vicente, from SCOR-FLOTSAM, and other members of the community. This resulted on the inclusion of marine plastic debris in the description of the call for proposals in 2020.

2019 Living Planet Symposium Milan (ITA) 13-17 May 2019
Dedicated sessions: LPS2019 Session A4.01 Current and Potential Multisensor Approaches to Marine Litter Detection, May 14, 2019. Convener: Victor Martinez-Vicente. Co-convenors: Shungu Garaba, Emmanuele Organelli, Laia Romero, Julia Reisser, Guillaume Bonnery, Vagelis Spyrakos, Paolo Corradi, Manuel Arias Ballesteros . Chair Stefano Aliani and Paolo Corradi. The session was about multisensor approaches to marine litter detection and included 13 contributions.

27 IUGG Conference, Montreal (CAN) 8-18 July 2019
Keynote talk by Erik Van Sebille at session U01c - Achieving Sustainable Development: The Role for Earth Sciences. Title: Our Plastic Oceans: Sources, Fate and Risk of Marine Litter Presentation number: IUGG19-0518
The keynote highlighted that ocean currents and eddies carry floating plastic from coastlines into the infamous garbage patches in the centres of the gyres with time scales and pathways still unknown. To assess impact, it is key to know where plastics get carried through vulnerable ecosystems. Earth scientists, making observations, gathering data and developing models of the

'behaviour' of plastic in our oceans, not only help solve the plastic problem, but also learn how our ocean works.

Dedicated Session P10 - Role of ocean processes in the transport and fate of floating plastic litter in the ocean and shelf-seas: theory, modelling and observations http://iugg2019montreal.com/p.html Convener: Erik van Sebille, Co-Conveners: Kara Lavender Law, Stefano Aliani, Nikolai Maximenko. The session marine debris is transported by the ocean on a large range of scales. The way that these different phenomena affect the dispersion of marine debris, and how this leads to the emergence of patchy accumulation regions and 'hotspots', is a major knowledge gap. Presentations on advances in the theory and modelling, supported by observations, of marine plastic debris of all sizes had been addressed. Topics included but were not limited to:

- The stirring of buoyant debris due to turbulence, particularly in the mixed layer.
- The transport of plastic in coastal seas, from surf zone to open ocean.
- The effects of Stokes drift, Langmuir circulation, and other (nonlinear) wind effects on the transport of debris.
- The effects of fragmentation, degradation, bio-aggregation and biofouling on the evolution of the buoyancy of debris particles.
- Development of and comparison between tools and software to simulate the dispersion of debris.

These dedicated sessions concentrated on some of the knowledge gaps that have been addressed during FLOTSAM Meetings #1 and #2.

ESA User Consultation Meeting, Cambridge UK 16–17 July 2019
The Earth observation scientific community invited us to participate in a European Space Agency (ESA) User Consultation Meeting at the Robinson College, University of Cambridge. This consultation was a critical input to the decision-making process to the selection of ESA's ninth Earth Explorer mission. Two candidate Earth Explorer fast-track missions – FORUM and SKIM – have been undergoing feasibility studies. Erik Van Sebille and Stefano Aliani represented FLOTSAM.

Hawaii Marine Debris Action Plan Research Workshop, July 25-26, 2019, Hawaii Pacific University, Waimanalo, HI (USA)
Presenter: Maximenko. FloatEco: Study of Physical and Biological Processes Maintaining a Unique Floating Ecosystem of the North Pacific Garbage Patch.

OceanObs'19 in Honolulu 16-20 September 2019
A session has been organised and dedicated to the idea of a Global Observing system for marine debris Leading (IMDOS). Chair was Nikolai Maximenko. The outcome was a white paper published in Frontiers in Marine Science. https://doi.org/10.3389/fmars.2019.00447. Some contacts have been taken with GOOS to implement IMDOS. Also, Maximenko participated in the OceanObs Research Collaboration Network meeting February 16 2020 and discussed practical steps for building IMDOS.

SCOR Annual meeting, Toyama (Japan) 22 Sept. Invited talk presentation: Victor Martinez-Vicente. Can satellites, drones and other remote sensing platforms help us solve the marine plastic litter problem? This presentation was followed up with an invited talk in Tokyo in the Saskawa Peace Foundation.

Ocean Surface Topography Science Team Meeting, October 21-25, 2019, Chicago (USA)
Preliminary results of FloatEco: experimental study of physical and biological processes maintaining the floating ecosystem. Presenter: Maximenko.

The Science of Microplastics in the World Ocean, Woods Hole, MA October 2019
Morss Colloquium (public event): Kara Lavender Law, keynote speaker. "Microplastics in the Ocean: Emergency or Exaggeration?"
Presentation: Kara Lavender Law, "Plastics as tracers to understand physical ocean processes"

French-American Workshop: Responding to Plastic Pollution through Science: from research to action, Le Mans, FRA, December 12 – 13, 2019.
Maximenko, N., Effects of ocean circulation on long-range debris drift and biological rafting.

Ocean Science Meeting in S. Diego USA. 16 21. February 2020
Plenary keynote on 18 February 2020. The connected ocean: the global-scale transports of heat, nutrients, plankton and plastic by ocean currents by Erik van Sebille.
Dedicated sessions:

- OM41A - Lagrangian Methods for Understanding Ocean Circulation and Tracer Transport I eLightning
- OM42A - Lagrangian Methods for Understanding Ocean Circulation and Tracer Transport II eLightning
- OM44A Lagrangian Methods for Understanding Ocean Circulation and Tracer Transport III Posters
- OM41A-03 Antarctic Biological Invasions Driven by Stokes Drift and Mesoscale Variability
- CP52B-08 Photochemical dissolution of buoyant microplastics to dissolved organic carbon: Rates and microbial impacts.

Sessions co-chaired by Stefano Aliani and Kara Lavender Law (with Tracy Mandel and Nimish Pujara), and moderated by Stefano Aliani, Kara Lavender Law and Erik van Sebille (with others):

- PS31A - Physical Processes Governing the Distribution and Transport of Dispersed Particles in the Ocean I
- PS33A - Physical Processes Governing the Distribution and Transport of Dispersed Particles in the Ocean II
- PS34D - Physical Processes Governing the Distribution and Transport of Dispersed Particles in the Ocean III Posters
- PS44C - Physical Processes Governing the Distribution and Transport of Dispersed Particles in the Ocean IV Posters

US CLIVAR Workshop on Surface Currents in the coupled ocean-atmosphere system February 22-23, 2020 at Scripps Institution of Oceanography (USA).
Van Sebille and Maximenko discussed effects of ocean currents on transport of debris and debris as a Lagrangian tool to measure ocean currents.

93rd Meeting of the Ocean Studies Board of the National Academies of Sciences, Engineering and Medicine (March 10, 2020, Washington, DC), Kara Lavender Law gave a presentation on FLOTSAM. In a public roundtable session that followed, she served on a panel discussing, "Path to a Plastic-Free Ocean".

Virtual Presentation to International Ocean Colour Coordinating Group (IOCCG) Executive members. 28 April 2020. Victor Martinez-Vicente, Paolo Corradi, Shunghu Garaba, Manuel Arias with comments from Nikolai Maximenko, presented the progress from ESA projects to the IOCCG group including SCOR-FLOTSAM discussions. The aim is to try to set up a dedicated Task force group in IOCCG dedicated to marine litter problem detection from ocean colour, to which ToR3 of FLOTSAM has been a seminal activity.

A virtual meeting was held on April 29 among Chairs and Patricia Miloslavich (SCOR), who fostered discussion about the feasibility to detect if reduction in human activities due to COVID has led to any changes in the amount and/or distribution of marine floating plastics since the beginning of the pandemic and if any subsequent impact can be measured / forecasted. Topic is still under discussion.

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

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

The following FLOTSAM publications included the outcome of the WG153 workshops:

Van Sebille et al. The physical oceanography of the transport of floating marine debris.
This paper was the result of a very successful global scientific collaborative effort. A first draft coming from Utrecht's meeting discussions was first made available online on Google Drive for editing by partners and then by a selection of relevant invited external experts. Then, it was pre-published in an online repository to get more comments and suggestions from the all scientific community interested in the topic. After some stimulating inputs from the community through the web, which we included in the text, the ms was submitted to *Environmental Research Letters* Topical Review for peer review and published on 17 February 2020 as Open Access free available article. The paper has been **downloaded 5247 times** on 1 June 2020. **Citation**: van Sebille et al 2020 Environ. Res. Lett. 15 023003. https://iopscience.iop.org/article/10.1088/1748-9326/ab6d7d

Maximenko et al Towards the Integrated Marine Debris Observing System (IMDOS). Frontiers in Marine Science Community White Paper
This paper aims to stimulate the establishment of a best-practice-guide as well as optimization and expansion of the existing observational network to the Integrated Marine Debris Observing System (IMDOS). It's a relevant wide effort, coordinated by SCOR co-chair Nikolai Maximenko, to prepare a global observing system for plastic at sea. A network of in situ observations, including reports from volunteers, citizen scientists and ships of opportunity, will be developed to provide data for calibration/validation of remote sensors and to monitor the spread of plastic pollution and other marine debris. IMDOS will interact with other observing systems in the ocean and on shorelines.
The paper has been **downloaded 1731 times** on 1 June 2020
Citation: Maximenko et al. 2019 Front. Mar. Sci. | https://doi.org/10.3389/fmars.2019.00447.

Martinez-Vicente et al. Towards marine plastic debris detection from satellite remote sensing. Remote Sensing .
The initial steps towards the potential design of remote sensing system for marine debris were described by: identifying the properties of marine plastic debris amenable to remote sensing methods and highlighting the oceanic processes relevant to marine plastic debris. Remote sensing approaches were reviewed and matched to the optical properties of marine plastic debris and the relevant scales of observation to identify challenges and opportunities.
Citation: Martinez-Vicente et al. Remote Sensing Volume 11 Issue 20 10.3390/rs11202443 The paper has been **downloaded 3066 times** on 1 June 2020 https://www.mdpi.com/2072-4292/11/20/2443/htm

Biermann, et al., Finding Plastic Patches in Coastal Waters using Optical Satellite Data. Scientific Reports

Satellites collecting optical data offer a unique perspective to observe plastic litter in the marine environment. For the first time, we show that patches of floating macroplastics are detectable in optical data acquired by the European Space Agency (ESA) Sentinel-2 satellites and are distinguishable from naturally occurring materials such as seaweed.
Citation: Biermann et al. 2020, Sci Rep volume 10, Article number:5364
https://www.nature.com/articles/s41598-020-62298-z

I. Chubarenko, et al. From macro to micro, from patchy to uniform: Analyzing plastic contamination along and across a sandy tide-less coast. Marine Pollution Bulletin, Volume 156, 2020,
The abundance of small-microplastics (0.5–2 mm) at the beach face is similar for all the locations and replicates. Swash-zone mixing, water percolation, importance of sediment pore size (rather than grain size), natural sorting of plastic particles at the beach face are considered.

Wichmann et al, Influence of near-surface currents on the global dispersal of marine microplastic. Journal of Geophysical Research
Buoyant microplastic in the ocean can be submerged to deeper layers through biofouling with consequent loss of buoyancy or by wind-induced turbulent mixing at the ocean surface. Particles in deeper layers are transported by currents that are different from those at the.
References https://doi.org/10.1029/2019JC015328. This paper was chosen as Research Spotlight by JGR editors

Haram et al. A Plasticene Lexicon. Marine Pollution Bulletin. 150 (2020), 110714, https://doi.org/10.1016/j.marpolbul.2019.110714
The paper brings together disparate neologisms into a single lexicon to encourage use of a unified vocabulary to describe the new reality of ecological, chemical, and geological systems in the age of plastics.

Murray, Therriault, Maki, and Wallace [Eds.] 2019. The Effects of Marine Debris Caused by the Great Japan Tsunami of 2011, PICES Special Publication 6, 278 pp.
The report includes 17 chapters, summarizing physical studies of tsunami debris dispersal from Japan and biological research on the debris impact on and interaction with the marine ecosystem.

Murray, Therriault, Maki, and Wallace [Eds.] 2019. The Effects of Marine Debris Caused by the Great Japan Tsunami of 2011, PICES Special Publication 6, 278 pp.
The report includes 17 chapters, summarizing physical studies of tsunami debris dispersal from Japan and biological research on the debris impact on and interaction with the marine ecosystem.

Ryan P et al. 2020 The transport and fate of marine plastics in South Africa and adjacent oceans.
South African Journal of Science Vol 116, N5/6 https://doi.org/10.17159/sajs.2020/7677.
Local condition of transport and fate of marine plastic litter in South Africa are presented.

Ryan et al 2020. Monitoring marine plastics – will we know if we are making a difference? South African Journal of Science: Vol 116 No 5/6. https://doi.org/10.17159/sajs.2020/7678
Monitoring is required to assess whether mitigation measures to reduce waste plastics at sea are making a difference.

Van Gennip *et al.* In search for the sources of plastic marine litter that contaminates the Easter Island Ecoregion. *Sci Rep* **9,** 19662 (2019). https://doi.org/10.1038/s41598-019-56012-x

High-resolution ocean circulation models are used with a Lagrangian particle-tracking tool to identify the connectivity patterns of the EIE with industrial fishing areas and coastline regions of the Pacific basin

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

The WG made relevant progresses toward objective through meeting, sessions at scientific congresses, email exchanges and Skype calls.

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

The paper VanSebille et al. (2020) identifies relevant oceanographic processes affecting marine litter distribution and transport and the gaps in the present state of knowledge have been ranked according to their relevance for marine debris studies. In the paper sections relevant to ToR2 have been included.

TOR 2 - Improve future marine litter modelling capabilities

The current state of modelling of marine debris has been discussed in different occasions and summarised in several conference dedicated sessions. In the review paper some chapters relevant to ToR2 have been included.

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

The community white paper published by Maximenko et al. (2019) summarises the outcomes of this WG relevant to ToR 3. It has been considered in 2 ESA funded projects related to remote sensing of marine debris. In the review paper by VanSebille et al., some chapters relevant to ToR 3 have been included. Other papers published by WG partners on remote sensing took advantage of discussion at our meetings and precedent meetings and discussions organised by ESA in 2017 to gather users requirements. The ESA consultation meeting in Cambridge was a critical input to the decision-making process to the selection of ESA's ninth Earth Explorer mission.

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

FLOTSAM website has been regularly updated with news.

Participants of WG153 chaired sessions at several conferences and in many institutions. Communication with media and interviews with newspapers has been regularly performed.

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

The 3rd FLOTSAM meeting was planned to be held in Japan in September 2020. The meeting would be hosted by Dr. Isobe (Kyushu Univ.) and Dr Chiba (JAMSTEK) and co-sponsored by the Lounsbery Foundation through awarded grant (PI: Dr. Law). Due to COVID 19 this meeting is postponed.

The Chairs of FLOTSAM have considered a number of options and contingencies to address the rapidly evolving situation of COVID19 but, given the situation, we have decided to postpone the 3rd meeting of our Working group that was planned for Fall 2020 in Japan. This has not been an easy decision. However, due to various countries' travel restrictions that have been put in place in response to COVID-19, many partners might be unable to attend meetings in Fall 2020. It will therefore not be possible to deliver the inclusive and international knowledge-sharing conference that we are aiming for.

In the meantime, we are going to proceed with the expectation that people interested in our topics will join the web meetings or online conferences we might decide to organize. A dedicated poll will be sent to receive feedbacks.

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

We encountered fundamental problems in organizing the final meeting due to COVID19 pandemic and the resulting lockdown in many countries. The WG plans to reschedule the meeting in 2021 as soon as it becomes possible. Although some preliminary agreements have been reached, at the time of this report no reliable information can be provided.

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

We are grateful to SCOR, who graciously extended our working group terms to the end of 2021.

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

WG 154. Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)

1.Name of group

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

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

This is our 3rd SCOR report. Prior to OceanObs19 we finalized a draft report to be distributed in conjunction with the meeting. We had a meeting this year in conjunction with the OceanObs19 meeting the Saturday before where we discussed our report and future plans. On that Sunday we presented our to GO-SHIP report to the GO-SHIP steering committee. It was very well received. Our members participated in several SCOR relevant white paper associated with the meeting where plankton measurements were emphasized. Following the meeting GO-SHIP US asked us to organize a community proposal to make biological measurements on GO-SHIP. Collaborating with OCB a call to scientists (particularly early scientists) went out and a team was formed. That team (headed by Adam Martiny) submitted a proposal to NSF that is currently waiting decision. Following a period of public comments we published the GO-SHIP report to the Ocean Best Practice and obtain a DOI.

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

SCOR Working Group 154 (2020) Recommendations for plankton measurements on the GO-SHIP program with relevance to other sea-going expeditions. SCOR Working Group 154 GO-SHIP Report. Scientific Committee on Oceanic Research, 70pp. DOI: http://dx.doi.org/10.25607/OBP-718

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

Identify current technologies (sensors as well as water sample analyses) that can be integrated into existing observing infrastructure to provide input and guide studies of plankton for marine ecosystem and biogeochemistry studies -- *Finalized* Provide the necessary details associated with every technology/measurement proposed (e.g., power, cost, and human effort). -- *Finalized* Document potential applications, including science case studies and lists of publications, and document measurement protocols. Develop adequate protocols when these are not available. – *in progress* Identify synergies with specific measurements done from other observing programs (e.g., BGC-Argo, space-based measurements, Continuous Plankton Recorder surveys) to provide cross-calibration and a better representation of the 4-D distribution of the parameter measured. – *Finalized (in Lombard et al., 2019)*

Identify technological limitations and/or gaps, and identify areas of priority investments to develop and implement the required observation technologies and tools for specific needs. – *Finalized (in Lombard et al., 2019)*
Outreach activity – We see our involvement in the creation of a proposal to US GO-SHIP as a major outreach accomplishment. We are interested to do more.

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

In person meeting in Halifax in Sep. 2020 if possible. Draft a report for OCEAN-SITES by fall 2020 and finalize it after a period of public comments by the end of the year.

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

No difficulties at this time.

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

None

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

WG 155. Eastern boundary upwelling systems (EBUS)

1.Name of group

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

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

Activities previously to October 2019 were described in the October report:

E-Mail Discussion: Many emails of very active discussion on the Summer School organization, revision of applicants, budget and organization took place between December 2019 and March 2020.

Virtual Meeting Summer school: This meeting was held in 20 January 2020 and attended by the Summer School subgroup, along with Chairs of the SCOR WG and it was carried out to discuss the budget for the Summer School and SCOR WG annual meeting planned for May 2020 in Dakar, Senegal.

E-mail discussion took place between February and May 2020 by the Subgroup coordinating the Open Science Conference in Lima 2021.

An online meeting of the Summer School Subgroup took place on 29 May to discuss next steps related to the planned Summer School in Dakar in May 2020, as cancelled (postponed) due to Coronavirus pandemic.

Online Annual Meeting: This annual virtual meeting was held on 3, June 2020 and chaired by R. Escribano. Key issues were a review paper, coordination with CLIVAR EBUS, Lima Open Science Conference, and cancellation or postponing the Summer School for 2021.

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

Contributions from WG Members and with acknowledge to SCOR 155 EBUS WG:

Riascos, J.M., Gutiérrez, D.A., Escribano, R., Thadje, S. 2019. Editorial: El Niño-Southern Oscillation on a Changing Planet –Consequences for Coastal Ecosystems. Frontiers in Marine Sciences. Published in 20 December 2019. doi: 10.3389/fmars.2019.00774. 17, 455–473, 2020

Tutasi, P., Escribano, R. 2019. Zooplankton diel vertical migration and downward C flux into the Oxygen Minimum Zone in the highly productive upwelling region off Northern Chile. Biogeoscience. Published in January 2020. doi.org/10.5194/bg-17-455-2020.

Garçon,V. et al., 2019, Multidisciplinary Observing in the World Ocean's Oxygen Minimum Zone Regions: From Climate to Fish — The VOICE Initiative, Frontiers in Marine Science, https://doi.org/10.3389/fmars.2019.00722.

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

Our progress toward achieving the TORs include the following:

ToR #1. Synthesize available information on important EBUS processes, their time and space scales (i.e., diurnal, intraseasonal, interannual, decadal, multidecadal) and their implications on water column properties, biogeochemical cycles, biodiversity/ecosystem structure and functioning, and the ecosystem services they provide. Seek to identify key feedback mechanisms, establish similarities, differences and knowledge gaps across all EBUS. A scientific review paper and a summary for policy makers will be the key deliverables.

A review article entitled "Ecosystems services and climate change: a new paradigm - A case study in the EBUS" is being drafted as part of this TOR. Leader authors include most WG Members. The key focus and scope of the work have been defined and progress is being made on writing.

The SCOR WG 155 'EBUS' Summer school called '*Changes in coastal upwelling systems and their impact on marine resources*' was organized, in conjunction with TARA seminar 'Biodiversity to Ecosystems and Science to Policy in the High seas', from May 4 to 15, 2020 in Dakar – Senegal (https://sites.google.com/view/scor-wg-ebus-ss-2020/home?authuser=0). Baye Mbaye (Full Member) is the summer school main director, accompanied by Eric Machu (Associate Member), Xavier Capet (Associate Member), Ivonne Montes (co-chair), and Véronique Garçon (WG invited member). The scientific committee was listed in the program proposal. Nine WG 155 members accepted to participate as lecturers in the summer school. Discussion on potential new dates for 2021 is currently going on, although there is also discussion on the need to continue developing Webinars while plans for re-scheduling the summer school are underway.

ToR #2. Develop a Web portal for EBUS by creating a web-based platform to graphically query integrated information on published data, model outputs, as well as protocols for measuring key properties and indicators in EBUS.

We are currently discussing on availability of existing platforms (e.g., POMEO, EMODNET, CCLME ECO-GIS viewer) for data gathering and synthesis. However, new directions and advices from the recent work of Todd et al. (2019 Frontiers in Marine Science), in which several SCOR 155 WG are co-authors, are under consideration in the context of developing a global observational network of EBUS dynamics.

ToR #3. Determine the strengths and weaknesses of existing EBUS coupled physical-biological models. Such an analysis will have mostly a regional focus, but it will also attempt to address subregional scales building upon past and ongoing research programs on upwelling centers (e.g., Bay of Hann near Dakar (Senegal), Monterey Bay (USA), Bay of Concepcion (Chile)). This TOR will require interaction with the CLIVAR EBUS Research Focus. The key product will be a publication in a high-impact journal.

No recent progress has been made yet on this ToR. However, we have been discussing preliminary ideas where a comparison from existing EBUS regional models with a global regional simulation is proposed and we are aiming at this action in collaboration with CLIVAR EBUS Research Focus.

ToR #4. Recommend a framework for regional interdisciplinary (physics to biology) EBUS observing and modeling systems. This stems from TORs 1-3. The observation system will be designed to improve the performance and reliability of forecast models in these socio-economically relevant regions of the world ocean. Such a recommendation brief will also address needs for fostering interactions between the observational and modelling communities (e.g., coordinated experiments with common forcing; recommendations on resolution of specific processes or a specific scale, etc). The recommendations will be included in the summary for policy makers.

This ToR depends on completing ToRs 1, 2 and 3, so our efforts are focused on ToRs #1 and #2. The Open Science Conference is another proposed activity for this goal and organization is under-way, although now it is much depending on the Covid-19 pandemic during 2021.

Outreaching on WG actions for a wider community is also being developed through our webpage *https://scah.igp.gob.pe/scor-working-group-155*. Information on the SCOR WG 155 can be found, including ToRs, members, publications, activities, and special announcements, such as info about the summer school (*https://sites.google.com/view/scor-wg-ebus-ss-2020/home*) and the Open Science Conference (*https://scah.igp.gob.pe/sites/scah.igp.gob.pe/scor/OSC_SCORWG155.pdf*).

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

- During the recent online meeting (June 2020) the possibility of developing a Webinar on EBUS dynamics and socio-economical implications has been proposed. This idea came up after raised concern on how our WG can contribute to reduce the Carbon footprint by avoiding presential lectures and meetings. This activity may initiate during the second half 2020.
- Two online meetings are considered during July-September 2020. Main issues to be under discussion will be the Summer School next year, the Open Science Conference next year, and advances of the review paper.
- Potential activities and actions, such as participation and organization of Conferences, Workshops and Special Sessions in Congresses during second term 2020 and early 2021 are depending on the pandemic situation, and therefore these activities will be under continuous evaluation and discussion in next virtual meetings and e-mail interaction.

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

The current situation during the recent months have slowed down the work and actions, because of the COVID-19 pandemic. Most universities and research centers have been closed for more than 3 months making difficult to advance in science and collaboration and so reducing scientific products.
Lately, we are relying on virtual meetings and e-mail interactions to maintain activities of the WG. We are hoping the situation improves late this year as to resume main activities, but presential meetings, courses, Conferences or others will most likely be postponed until mid or second half 2021.

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

N/A

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

WG 156. Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity

1. Name of group

WG156: Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity

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

We held a major full two-day meeting of our WG just prior to the AGU/ASLO Ocean Sciences conference in San Diego. The large majority of the WG was able to attend in person, with additional attendees participating for some of the discussion (subject to time zone constraints) via video conferencing. The meeting was highly productive, building on the week-long discussions and laboratory inter-comparison held at UBC in June, 2019. Other activities focused on the analysis and compilation of the data obtained at the June 2019 workshop, as well as recovery of new literature data used to update meta-analyses of C:ETR ratios. Finally, a number of WG members conducted their own field research, employing approaches and methodologies that were shaped by the Vancouver discussions. As part of this, a number of WG members exchanged / shared FRRF instruments (e.g. Suggett lent Bermman-Frank an instrument for use on a South Pacific cruise).

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

We have created a new shared Wiki page to organize the content of our SCOR WG activities (http://scor156.com/). The site is currently password protected, but we will make parts of it public-facing as we develop more shared resources (e.g. SOP documents and open-source software packages). We are currently working on the first publication from our SCOR working group. It will be a based on the Frontiers in Marine Sciences paper outlining a prospectus for future FRRF measurements in oceanography. This article will be based on the example of Lomard et al. (2019) - https://doi.org/10.3389/fmars.2019.00196. We have also begun drafting a second high-profile perspective type publication on how fluorometry can transform understanding of marine primary productivity. New meta-data compiled for this publication may also contribute to other papers led by the WG ECR members.

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

i. To inter-compare active Chla induction measurements across instruments and approaches, identifying key aspects of instrument configuration, deployment and parameter acquisition that may introduce variability in retrieved data. • Significant Progress: Based on our results from the June, 2019 UBC workshop, we are now beginning to assemble a 'standard operating procedures' document as part of a best-

practices guide for end-users. This will identify key sources of error / uncertainty, and approaches to improve inter-comparability among users / instruments. We are also working on drafting a review article for Frontiers in Marine Sciences (see above) that also summarizes the key aspects associated with this document.

ii. To develop, implement and document internationally-agreed best practice for data acquisition, standardized output formats and archiving approaches.

- In progress. See above.

iii. *To develop, implement and document internationally-agreed best practice for processing raw fluorescence data to retrieve photosynthetic parameters and primary productivity estimates, taking into account taxonomic and environment factors driving diversity in chlorophyll fluorescence signals in the oceans. From this work we will develop freely available software and documentation to allow non-specialist users to process fluorescence data according to these best practices.*

- Significant Progress. One of our ERC members, Thomas Ryan-Keogh, has largely completed development work on Python scripts to process FRRF data from all major instrument manufacturers. At the San Diego meeting, Thomas had the opportunity to discuss the software with the manufacturers and resolve a few outstanding questions regarding data formats produced by different instruments.

iv. To produce a new synthesis of parallel 14C and active Chla induction measurements that can be used to examine the relationship between these two productivity metrics under a range of field conditions. We will also consider other metrics of Net Primary Production alongside 14C.

- Initiated and underway, but significantly slowed by limitations on summer field work associated with Covid-19. For example, several WG members had committed to attend the August 2020 Group for Aquatic Productivity Meeting (USA) to better resolve ETR-14C relationships for cyanobacterial dominated communities, but this has been postponed until 2021. However, we are currently analyzing preliminary data from the June, 2019 UBC workshop derived from a novel incubation technique ("simultaneous triple incubation" of 14C, O2 and ETR). ECR Dave Hughes is leading the charge on this analysis / publication. Also, we have conducted a significant literature analysis to update the global 14C – ETR data set presented by Lawrenz et al. (2013), adding a significant number of new data points (more than double) to the existing information, including substantial new geographic coverage of previously under-represented areas (e.g. Indo-Pacific; sub-polar). Based on this updated data set, we are currently drafting a manuscript examining global patterns in the electron requirements of carbon fixation as a means of understanding 'the reducing power of the oceans' (above).

v. To develop a global database structure for hosting quality-controlled active Chla induction measurements, creating standards for data and meta-data collection, submission and archiving.

- In progress. We had two representatives from NASA present for the full course of our San Diego meeting – Suzanne Craig (Project Scientist – PACE mission) and Zachary Johnson (PDF). Based on our discussions, the NASA team is now exploring options for hosting a global FRRF data base on their servers (most likely through SeaBass). We expect more definitive information on this by summer or fall of this year, but this seems like a good possibility at this point. Discussions are on-going about required meta-data and formats, and the need to archive raw data files. A sub-group of WG members (e.g. Silsbe, Simmis, Craig et al.) with significant experience in this area will convene further discussions.

vi. To build a framework through which in situ active Chla induction data can be used to validate and refine relevant remote sensing measurements (e.g. sun-induced fluorescence yields).

• Not yet started. To be initiated in years 3-4.

vii. To share knowledge and transfer skills in instrumentation, best practice, quality control and data stewardship with the rapidly expanding user community in developing nations.

• Our Working Group had a reasonably high profile at the Ocean Sciences meeting in San Diego, with a dedicated poster session (including submissions from non-WG members), and a well attended 30 min. tutorial presented by Suggett and Schuback (ECR).

Other on-going activities:

• Initiated a community voice of WG activities, outputs, interests and opportunities via Twitter (@SCOR_WG156)
• We are still standing by for the next call for proposals for ship-time on the Falkor.
• Discussed with key instrument manufacturers possibility of providing some visibility to the WG activities via their existing web sites (similarly, amongst all WG members).
• Begun working with WG member Aurea Ciotti and collaborator Osvaldo Ulloa to develop proposals for new training workshops in South America, through collaboration with the Universidade de Sao Paolo (Brazil) and the Millennium Institute of Oceanography (Chile).
• Developing a training workshop on fluorometry practice for central American institutes (students and ECRs) via Universidad Nacional Autónoma de México (UNAM). The first workshop, led by Suggett, is scheduled to run February 2021, international travel restrictions dependent.

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

We have a series of Zoom conference calls coming up in early July (with multiple days / times to accommodate a wide range of time zones). These will be used to build momentum in conversations and writing initiated at our San Diego meeting, and to discuss planning (including contingencies) for future meetings and field work. Summer field work will proceed in a more limited fashion than anticipated. Some laboratories have limited activity resuming, but many are not at full capacity, and field work plans are largely on hold for the summer. We are still evaluating our plans for another face to face meeting, and will commit a venue/date once international travel restrictions begin to resolve. We will similarly revisit whether the GAP 2021 workshop will proceed to resolve cyanobacterial fluorometry (ETR-14C) signatures. If travel limitations persist, we will likely continue with virtual meetings.

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

As with many programs, our summer field work activities have been significantly impacted by Covid-19. A number of our group members had planned to attend the summer GAP meeting, looking at primary productivity (resolve cyanobacterial fluorometry (ETR-14C) signatures) in the Lake Erie ecosystem. This activity has now been postponed until 2021. There have also been some delays in the call for proposals on the Schmidt Ocean Institute's vessel Falkor. In summer, 2019, we had an excellent conversation with SOI representatives, who seemed enthusiastic about our work. But there have been no updates on the next round of applications. We are thus planning smaller-scale more distributed field sampling opportunities, as part of other existing sea-going programs in our various member nations.

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

We note that one of our active Early Career members, Nina Schuback, has applied to join the SCOR Executive Committee. We wholly endorse this, and Tortell has written a support letter. If Dr. Schuback is selected to join the SCOR Executive, it will be a significant contribution of WG 156 to the broader mandate of the organization.

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

WG 157. Marine zooplankton biodiversity based on DNA (MetaZooGene)

1.Name of group

SCOR WG157 MetaZooGene: Toward a new global view of marine zooplankton biodiversity based on DNA metabarcoding and reference DNA sequence databases

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

Meetings:

2019 Annual Meeting of MetaZooGene SCOR WG157 was held at the Gothenburg Global Biodiversity Center (GGBC, Gothenburg, Sweden) on Saturday, September 14, 2019, in association with the Annual Science Conference of the International Council for the Exploration of the Sea (ICES). The first annual meeting of WG157 was attended by 15 members (including associate members) and 13 invited guests. WG157 members were encouraged to invite colleagues and collaborators with closely-related interests, with priority given to early career, postdoctoral fellows, and students. Björn Källström (GGBC) and Erik Selander (Dept. Marine Sciences, University of Gothenburg) were our local hosts, who encouraged participation by local researchers and provided outstanding meeting space. Participants presented overviews of their research interests and expertise, expected contributions to MetaZooGene, and summaries of ongoing and future activities.

SCOR Symposium: *Rediscovering pelagic biodiversity: Progress, promise, and challenges of metabarcoding of microbes to mammals*, was held at the Swedish Exhibition & Congress Centre (Gothenburg, Sweden) on September 13, 2019. The Symposium was co-sponsored by ICES, IOC, and other groups. The convenors were Ann Bucklin (University of Connecticut, USA) and Bengt Karlson (Swedish Meteorological and Hydrological Institute, Sweden). The Symposium was organized into three sessions: Diversity of the pelagic assemblage; Data and database resources; and Exploring the potential of metabarcoding. The talks were followed by a discussion session organized and led by Anders Andersson and Katja Peijnenburg. The SCOR Symposium was attended by 50 people (the maximum capacity allowed for the venue), with participants from 20 different countries.

2020 Annual Meeting of MetaZooGene SCOR WG157 was held in association with the Ocean Sciences Meeting (OSM 2020, San Diego, CA USA) on Sunday, February 16, 2020. In all, 14 people joined the meeting, plus one via SKYPE. All members and guests introduced themselves, briefly describing their interests. WG157 members were encouraged to invite guests to the meeting, especially students and early-career scientists with related interests. The meeting began with a review the Agenda (Appendix I) and overview of the MetaZooGene plan of work. SCOR overviews were provided by Ed Urban and Patricia Miloslavich, who summarized what SCOR expects of each WG. In response to questions about SCOR's goals for capacity building, Ed explained that SCOR seeks to reach out to students world-wide, has a committee on capacity building, and a website with suggested approaches (see https://scor-int.org/work/capacity/). Recognizing that funds are limited for capacity building, WGs are encouraged to seek additional funds for this effort.

Lunch Meeting at OSM 2020 for WG157 members and guests was held during the Ocean Sciences Meeting on February 20, 2020. Enrique Montes Herrera, new SCOR Reporter for WG157, joined the meeting and described his role as the SCOR Reporter and his research interests.

SCOR Exhibit Booth at OSM 2020 was staffed by WG157 member Todd O'Brien, who demonstrated the MetaZooGene DNA barcode database and atlas. There was considerable interest from visitors to the booth, which provided an opportunity to widen the reach of WG157 and obtain advice and feedback from interested researchers and managers.

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

Laakmann, Silke, Leocadio Blanco-Bercial, and Astrid Cornils (2020, In Press) The crossover from microscopy to genes in marine diversity - from species to assemblages in marine pelagic copepods. Philos. Trans. Royal Society B

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

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

The DNA barcode data and metadata have been assembled and posted to an open-access web portal, with deep links to the GenBank records and associated publications (see https://metazoogene.org/products). The goal is a comprehensive summary and analysis of COI barcodes available for holopelagic mesozooplankton taxa, organized by ocean region with explicit intent to achieve global coverage. The MetaZooGene barcode atlas now includes maps of global distributions for 20 zooplankton taxonomic groups. The MetaZooGene database (MZGdb) now includes ~186,000 barcodes, and is updated regularly from GenBank and BOLD. The DNA sequence data will be downloadable for use as a reference sequence database for species identification of marine zooplankton from metabarcoding analysis of environmental samples.

2) Design an optimal DNA barcoding pipeline for marine zooplankton

Progress is being made on preparing a best practices document describing an optimal pipeline for DNA barcoding marine zooplankton, including optimal protocols for collection and preservation of samples and specimens. WG157 member Leocadio Blanco-Bercial has searched for existing documents from museum collections and major research laboratories, but could not find any written guidelines for DNA barcoding of zooplankton. Given the lack of existing documents, this will indeed be a useful and worthwhile WG157 deliverable.

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

WG157 members are committed to advancing this topic, and are focusing on designing a metabarcoding inter-calibration experiment, with allocation of alternative laboratory and bioinformatics protocols and parameters to the laboratories of participating WG157 members. The inter-calibration analysis would then be able to determine which steps in the analytical pipeline have the biggest impacts on the results. The use of "standard samples" and "mock communities" was discussed. Next steps are to agree upon the logistical organization and coordination of the people and labs involved, and to design the experiment to ensure eventual publication. Ann agreed to prepare a draft list of the critical metabarcoding protocol steps and distribute to WG157 members to identify their interest, willingness, and ability to carry out testing of particular protocol steps.

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

Special journal issue in ICES Journal of Marine Science

Ann Bucklin, Katja Piejnenburg, Ksenia Kosobokova and Ryuji Machida are named as 'motivators" for a special issue on "Patterns of biodiversity of marine zooplankton based on molecular analysis" in the ICES Journal of Marine Science. Currently, 12 manuscripts have been promised from WG157 member authors. The call for papers is public and has attracted additional manuscripts that will increase attention for the subject and impact of the WG157 contributions. See https://academic.oup.com/icesjms/pages/themed_sets

Review paper: DNA Barcoding of Marine Zooplankton (Ann Bucklin, Katja Peijnenburg, et al.)

Work is ongoing for a manuscript for submission to Marine Biology Reviews: *Toward a global reference database of COI barcodes for marine zooplankton*. The WG157 co-authors have agreed to provide sections either by taxonomic group or ocean regions. A primary goal of the review paper is to answer the question of completeness of the barcode database for zooplankton. Next step is for authors to submit any unpublished barcode data; these will be added to the MZGdb and included in the review paper.

Planning for Capacity Building Workshops

- Hands-on 'DNA-to-data' training workshop, organized by Ryuji Machida, Academia Sinica (Taipei, Taiwan). A workshop is tentatively planned for Summer 2021. Funding will be requested from SCOR, PICES, and other sources.

- Online bioinformatics workshop for metabarcoding, organized by Ann Bucklin, University of Connecticut (USA). An online training session focused on statistical analysis and bioinformatics of DNA sequencing data for metabarcoding is being planned. UConn computing facilities and expert bioinformatics support staff will provide overviews; Todd O'Brien (NOAA NMFS, USA) will lead demonstrations on use of the MZGdb and atlas. Continue progress on Terms of Reference and Deliverables will continue online and via web resources, including project-specific web "work spaces" for WG157 members.

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

Work has slowed somewhat due to the challenges of COVID-19 pandemic. Research laboratories in most universities and institutes have been closed for ~2 months. Working from home reduced productivity and progress for many WG157 members, especially those with family responsibilities.

In response, private online work-areas were created for WG157 members, including one for all members and another for co-authors of the Review Paper. These areas are linked to the website for the group, https://metazoogene.org/, and are valuable tools for collaboration by allowing uploading and sharing of files, which is not possible for all WG157 using other web platforms.

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

N/A

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

WG 158. Coordinated Global Research Assessment of Seagrass System (C-GRASS)

1.Name of group

C-GRASS: Coordinated Global Research Assessment Of Seagrass Systems (Co-leads: Emmett Duffy, Lauren Weatherdon)

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

Virtual coordination meetings and working groups have been held to advance the core objectives of C-GRASS.

We successfully planned our first C-GRASS international workshop as a joint meeting, in collaboration with the MBON Pole-to-Pole group, to be held at INVEMAR in Santa Marta, Colombia in early May 2020. That meeting had to be cancelled in March due to COVID-19 restrictions.

Our major work since then has involved rebooting the plan to adapt to a completely virtual workshop process. We recently circulated an invitation to group members for the first virtual workshop, expected to be held in July-August 2020. We assigned members of C-GRASS as members of four core teams, with proposed coordinators as follows:

1. **Data analysis and synthesis:** This team will identify opportunities for collating and synthesizing seagrass data and corresponding metadata to fill gaps in knowledge. ***Coordinators:*** *Jon Lefcheck, Erin Satterthwaite, Sara Pruckner, Maria Potouroglou*
2. **Best practices**: This team is developing monitoring protocols for *in situ* and remote sensing monitoring of seagrasses. ***Coordinators:*** *Chris Roelfsema, Frank Muller-Karger, Len McKenzie, Fred Short, Richard Unsworth, Jon Lefcheck*
3. **Data schema:** This team is developing data schema templates to accommodate the 'seagrass cover and composition' Essential Ocean Variable and its corresponding sub-variables, while aligning with OBIS' DarwinCore schema (including controlled vocabulary and metadata structure). An initial draft was created by UNEP-WCMC, as the next evolution of the 'Global Distribution of Seagrasses' dataset, which will be further reviewed and expanded to reflect data collected across multiple scales. ***Coordinators****: Ward Appeltans, Michael Lonneman, Jon Lefcheck, Sara Pruckner, Lauren Weatherdon*
4. **Community of Practice group:** This team is identifying and illustrating partnerships, roles and responsibilities along the seagrass data supply chain, complementing the activities of the 'Data sources' group, and including discussion of how to incentivize data provision. ***Coordinators:*** *Erin Satterthwaite, Sara Pruckner*

These teams will be charged with developing draft procedures and templates, and with helping develop the specific agendas for their working groups during the project. These documents will be discussed during the plenary meetings of the first workshop. PIs Emmett Duffy and Lauren Weatherdon will contribute to each of these working groups.

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

A related activity than many members of the WG—including the co-PIs—participated in involved the production and launch of the *Out of the Blue* global seagrass synthesis report. While not a direct output of the C-GRASS WG, the report will form the basis of the WG's work moving forward. Further details and content can be found here: https://www.unenvironment.org/resources/report/out-blue-value-seagrasses-environment-and-people.

A further output linked to the WG is the first draft of the proposed **data schema** (aligning with the DarwinCore standard) to complement monitoring protocols and support data collation and integration into open access databases. This draft has not yet been formally published but will be used to inform discussions during the upcoming workshop.

Following the workshop, the resulting templates and procedures will be used to form the basis of a peer-reviewed journal article, with the aim to publish the updated dataset, methodology and schema in *Nature Scientific Data* (or equivalent).

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

Specific progress toward the group's terms of reference include:

1. Collate, synthesis and analyze seagrass data:

UNEP/GRID-Arendal released *Out of the Blue*, a global seagrass synthesis report, in June 2020 with contributions from several C-GRASS group members. Building on that report our working group has begun to identify seagrass data sources and build on known data gaps. We are also reviewing possible data licenses (e.g. Creative Commons), Data Contributor Agreements, and data schema (see #3) for use when collating appropriate data, which we expect to begin shortly.

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

A coordination team has been established to draft **common protocols and best practices** for *in situ* and remote sensing monitoring of seagrasses, building on their existing knowledge and practices.

For remote sensing, team member Heidi Dierssen is contributing to or leading two manuscripts resulting from international workshops and data comparisons sponsored by the Alliance for Coastal Technologies working group on hyperspectral remote sensing: "***Methodological Considerations for Hyperspectral Remote Sensing of Benthic Habitats***" and "***Best Practices for Use of Hyperspectral Imaging in Coastal Environments***."

3. Promote development of standardized vocabularies and data schemas:

Our working group is in the process of developing a shared **data schema** aligning with the DarwinCore standard, including corresponding controlled vocabulary for the 'seagrass cover and composition' Essential Ocean Variable's sub-variables. This will facilitate integration of data into the Ocean Biogeographic Information System (OBIS) and other open-access portals, such as UNEP-WCMC's Ocean+ initiative (e.g. Ocean Data Viewer). An initial draft has been compiled and is currently being reviewed by the core team, before being circulated to the broader C-GRASS network.

4. Organize an interdisciplinary community of practice:

Our group has established a community of practice, linking with existing networks (e.g. the International Seagrass Experts Network; the World Seagrass Association; SeagrassNet; SeagrassWatch; MarineGEO), and we are also reaching out to the newly formed Seagrass Community of Practice organized by the Coastal and Estuarine Research Federation. Our group is currently mapping **data flows** to facilitate integration of existing seagrass data into national and global inventories.

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

- Trial formatting of data for integration into the Ocean Biogeographic Information System (OBIS).
- Draft and publish seagrass *in situ* and remote sensing monitoring protocols, to be uploaded to the Ocean Data Standards and Best Practices Project of IODE.
- Complete map of data flows.
- Hold a virtual workshop (via Zoom) to advance C-GRASS' terms of reference and finalise products (e.g. data schema, monitoring protocols).
- Collate and curate an updated version of the 'Global Distribution of Seagrasses' dataset, aligning with the revised data schema.
- Draft a peer-reviewed journal article presenting a comprehensive global analysis of the SeagrassNet global dataset as a quantitative foundation for the group's continuing analysis.
- Draft a peer-reviewed journal article for *Nature Scientific Data,* to mark the re-launch of a global seagrass dataset based on IOC-UNESCO GOOS' 'Seagrass Cover and Composition' EOV.
- Hold the first in-person workshop, ideally in association with an international meeting that draws our community (date and location to be determined in light of the COVID-19 outbreak).

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

See above. The global pandemic, COVID-19, has made it necessary to adapt our approach and in-person meeting schedule for the coming months. We are currently planning to hold a virtual workshop, with breakout groups facilitated by the video conferencing software, Zoom. While this may affect our ability to work effectively as a group, we also envision that it will offer an opportunity to expand the participant group to include those who would otherwise be unable to travel due to costs or time commitments.

We will monitor the global situation and schedule an in-person workshop once feasible, ideally in conjunction with the MBON Pole-to-Pole group as we had planned in Colombia in May 2020. We will also explore scheduling one of our later workshops in association with the World Seagrass Conference and International Seagrass Biology Workshop, currently rescheduled to (northern) summer 2022.

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

We anticipate that COVID-19 restrictions will continue to influence our ability to implement the C-GRASS plan for many months, and perhaps years, to come. We are confident we can make progress beginning with virtual workshops as described above, but the path forward will surely evolve as we learn how to work effectively in the new world. This will require flexibility from all parties.

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

WG 159. Deep-Sea Biology for the Decade of Ocean Science for Sustainable Development (DeepSeaDecade)

1.Name of group

WG 159 DeepSeaDecade: Roadmap for a Standardised Global Approach to Deep-Sea Biology for the Decade of Ocean Science for Sustainable Development.

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

The group held its first meeting 22-24th Jan 2020. The group outlined two papers to be developed over the next 4 months. One outlining a blue print for the UN Decade and one focused on barriers to deep-sea science for developing nations. The last day of the meeting was given over to a public event discussing needs and plans for the Decade. Many students and early career researchers were invited to this meeting.

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

None yet

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

1. To develop a global plan for survey / sampling deep-sea ecosystems to underpin deep-sea research for the UN Decade of Ocean Science. – Plan has been discussed and agreed, abstract for paper and paper outline written.

2. To agree on methods and standards for the acquisition of biological data, including the role of existing and novel technologies. – not yet discussed

3. To develop habitat-specific approaches for survey / sampling the deep-sea ecosystem (following the Census of Marine Life model), that integrate the global approaches developed under ToRS 1 and 2, but allow greater specialisation. – Progress made on Seamount plans and outline issues to be highlighted in paper under TOR 1

4. To integrate ToRs 1-3 with wider efforts under the Global Ocean Observing System (GOOS) via the Deep Ocean Observing Strategy (DOOS). – Discussed and agreed how the two fit together and outline will be provided under TOR 1 paper.

5. To actively facilitate efforts to build capacity in developing nations for deep-sea science – outlined a paper to review the current barriers to deep-sea science for developing nations and what capacity building efforts have worked well / not so well in the past.

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

Second meeting to be held in Brazil in August – Coronavirus permitting.

Full draft paper for TOR 1 by June, for TOR 5 by end of year

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

Not yet

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

No

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

APPENDIX 5. RESEARCH PROJECT REPORTS

GEOTRACES – Trace elements and isotopes

GEOTRACES Scientific Steering Committee
Annual report to SCOR 2019/2020

April 1st, 2019 to March 31st, 2020

Table of contents

1. SCOR Scientific Steering Committee (SSC) for GEOTRACES

Co-Chairs
Andrew Bowie, Australia
Karen Casciotti, USA

Members
Eric Achterberg, Germany
Adrian Burd, USA
Zanna Chase, Australia
Jay T. Cullen, Canada
Susanne Fietz, South Africa
Tina van de Flierdt, UK
Marina Kravishina, Russia
Rob Middag, Netherlands
Hajime Obata, Japan
Haojia (Abby) Ren, China-Taipei
Yeala Shaked, Israel
Kazuyo Tachikawa, France
Rodrigo Torres, Chile
Antonio Tovar-Sanchez, Spain
Liping Zhou, China-Beijing

The SSC membership (listed above) contains representatives of 15 different countries, with diverse expertise, including marine biogeochemistry of carbon and nutrients; trace elements and isotopes as proxies for past climate conditions; land-sea fluxes of trace elements/sediment-water interactions; trace element effects on organisms; internal cycles of the elements in the oceans; hydrothermal fluxes of trace elements; tracers of ocean circulation; tracers of contaminant transport; controls on distribution and speciation of trace elements; and ocean modelling.

2. Progress on implementation of the project

Preparing the release of the third Intermediate Data Product, GEOTRACES sustains a very favourable implementation as shown in the following sections:

2.1 Status of GEOTRACES field programme

During the past year (April 1st, 2019 to March 31th, 2020), the GEOTRACES programme has progressed excellently. It is of particular importance that a new country, China, has successfully completed its first GEOTRACES section cruise (in the North West Pacific see map below, section in orange). Additionally, 4 process studies were also completed: 1 process study from USA (with 3 cruises), 2 process studies from Brazil and 1 from France. In total 7 new cruises were completed.

Overall 120 cruises have been completed, corresponding to 31 GEOTRACES sections (with 41 cruises), 38 process studies (with 59 cruises) and 9 compliant data sets, as well as, 11 cruises completed as a GEOTRACES contribution to the International Polar Year (IPY).

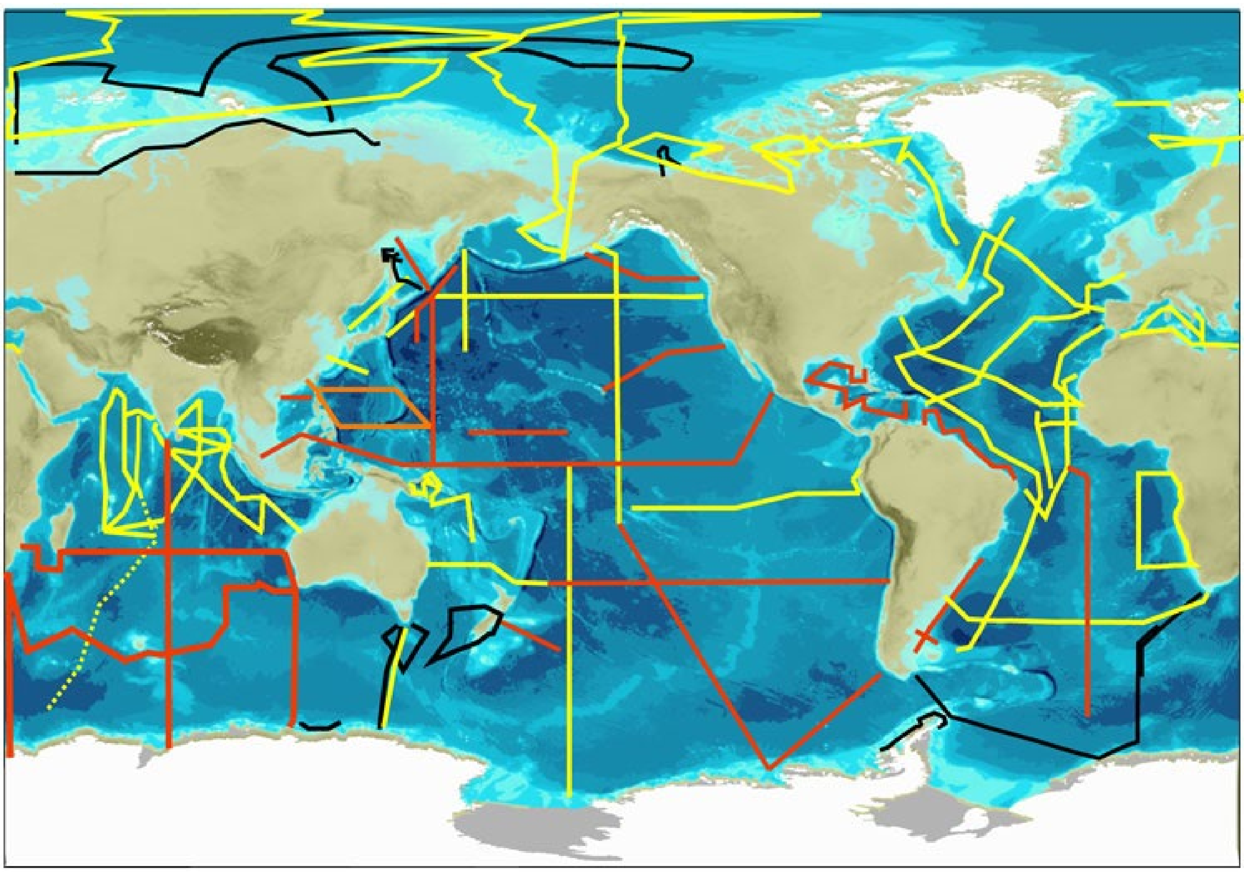


Figure 1: Status of GEOTRACES global survey of trace elements and their isotopes. In black: Sections completed as the GEOTRACES contribution to the International Polar Year. In yellow: Sections completed as part of the primary GEOTRACES global survey. In orange: Sections completed during the past year. In red: Planned Sections. An updated version of this map can be found on the GEOTRACES home page <http://www.geotraces.org>.

2.2 GEOTRACES Intermediate Data Products

Planned release of Intermediate Data Product 2021
Following from the release of two Intermediate Data Products in 2014 and 2017 GEOTRACES announced, in December 2019, the release of the third intermediate data product in July 2021 (IDP2021). To ensure timely release of the IDP2021, two deadlines for data submission have been established: one deadline that guarantees data inclusion on April 1, 2019 (extended to May 15, 2020 due to the COVID-19 situation) and a final deadline in December 15, 2020 (see data management section in this report for further details).

Assistance to researchers in registering data in IDP
In order to help researchers in submitting data to the IDP, several actions have been planned or completed during the reporting period:

Completing the GEOTRACES Data for Oceanic Research portal (DOoR) which is a new interface where researchers can register and submit their data sets for intercalibration and potential inclusion in IDP2021 as well as obtain all templates for submission of their data (see GEOTRACES International Project Office section in this report for further details). This has been a huge task that involved the coordinated work of all components of the GEOTRACES programme. The portal it is available at: https://geotraces-portal.sedoo.fr/pi/

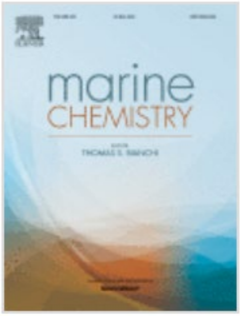
Providing guides to researchers on how to use the DOoR and submit data to the IDP including:
- a *how to document* available at:
http://www.geotraces.org/images/GEOTRACES_DOoR_User_Guide.pdf
- *a video guide* available at:
https://youtu.be/KZHZ8MffV98 and,
- *improved interactive guides and flowcharts* for researchers available at:
https://www.geotraces.org/how-to-ensure-that-your-data-are-in-idp-flow-chart/

Organising several drop-in events at various conferences and workshops in 2020 to demonstrate the use of the DOoR portal and to register datasets with PIs if desired. The first of these occurred at the SCOR booth during the Ocean Sciences Meeting in February 2020 where GEOTRACES committee members and Mohamed Adjou, the leader of the GEOTRACES Data Assembly Centre (GDAC) provided demonstrations of the DOoR Portal.
Thanks to those committee members and Mohamed Adjou for all their assistance and to SCOR for the opportunity to participate in the booth.

Fair Use Agreement
An important change with IDP2021 is that GEOTRACES moves away from the formal registration step (the "Download Agreement") towards adherence to a fair use agreement (available at: https://www.geotraces.org/idp2021-fair-use-document/), to cover appropriate recognition of data generators in the subsequent usage of IDP2021. All data in IDP2017 will be rolled over to IDP2021 under this fair use agreement. Researchers who do not wish their data to be rolled over from IDP2017 to IDP2021, should inform the GEOTRACES International Project Office.

2.3 GEOTRACES publications

During the reporting period, 123 new peer-reviewed papers have been published. This includes the publication of one special issue (two more are currently in preparation):



ASIAN GEOTRACES: Interaction between the North Pacific and its marginal seas
Editors: Greg Cutter, Jing Zhang and Pinghe Cai
Marine Chemistry
April 2019
https://www.sciencedirect.com/journal/marine-chemistry/special-issue/10ZN2NDLMVP

It also includes the publication of a comprehensive review of the GEOTRACES international programme published at the *Annual Review of Marine Sciences* by Bob Anderson (see the GEOTRACES Science Highlight section in this report for further details):
Anderson, R. F. (2020). GEOTRACES: Accelerating Research on the Marine Biogeochemical Cycles of Trace Elements and Their Isotopes. *Annual Review of Marine Science*, *12*(1), annurev-marine-010318-095123. DOI : https://doi.org/10.1146/annurev-marine-010318-095123
In total, the GEOTRACES peer-reviewed paper database includes 1,353 publications.

Publicity documents: It is important to mention that in addition to the peer-reviewed publications, publicity articles to promote GEOTRACES are continuously published nationally and internationally. These publications are not included in the GEOTRACES publication database, but have a dedicated web page on the GEOTRACES site.

For complete information about GEOTRACES publications please check the following web pages:
GEOTRACES peer-reviewed papers database: https://www.geotraces.org/geotraces-publications-database/
GEOTRACES special issues: https://www.geotraces.org/category/scientific-publications/geotraces-special-issues/
List of GEOTRACES promotional articles: https://www.geotraces.org/category/library/publicity/

2.4 GEOTRACES science highlights

The GEOTRACES International Project Office regularly generates science highlights of notable published articles, which are posted on the GEOTRACES website (https://www.geotraces.org/category/science/newsflash/). So far, about 217 highlights have been published. Among the numerous highlights published since last year's report, we selected the following seven:

A review constituting the half-way mark of GEOTRACES
After a brief reminder on the motivation and foundation processes of the international and ambitious programme GEOTRACES, Bob Anderson (2020, see reference below) proposes an overview of many results of GEOTRACES activities related to the three guiding themes of the programme: (1) fluxes and processes at ocean interfaces (2) internal cycling of TEIs, and 3) the

development of proxies for past change. It is beyond the scope of a highlight to summarise the main results obtained with the programme so far, knowing that most of them are already covered as highlights in this website!

Thus your favourite International Project Office (IPO) encourages colleagues, teachers and students who wish to discover how fruitful modern marine geochemistry is to open this review. As an example we propose the illustration below: the contrasting distributions of phosphate (PO_4), aluminium (Al), iron (Fe), cobalt (Co) and zinc (Zn) along a meridional Atlantic section. These data illustrate how the acquisition of clean and reliable data at high resolution questions established paradigms. Although each is a micronutrient, Fe, Zn and Co fates appear to be governed by different processes. Similarly, while both Al and Fe have lithogenic origins, their distributions are quite different, due to their different chemistries, residence times, and additional boundary sources. Among these brief examples, there are many new questions to explore!

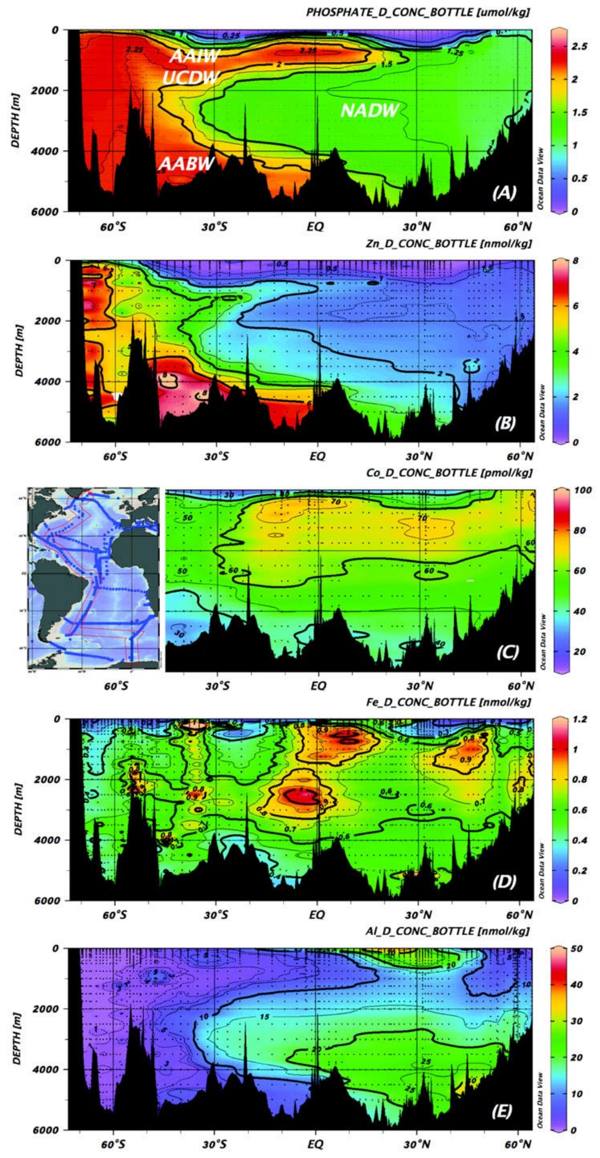


Figure 2: *Meridional sections down the length of the Atlantic Ocean created by splicing data from multiple GEOTRACES sections (see inset in panel C). Data are available in the [GEOTRACES Intermediate Data Product IDP2017](). A) Phosphate data from IDP2017. B) Dissolved Zn (Middag et al 2019) and unpublished data from P. Croot, available in IDP2017. C) Dissolved Co (Dulaquais et al 2014a, Dulaquais et al 2014b) and unpublished data from M. Boye available in IDP2017. D) Dissolved Fe (Klunder et al 2011, Rijkenberg et al 2014). E) Dissolved Al (Middag et al 2015, Middag et al 2011) and unpublished data from Peter Croot available in IDP2017. Figure produced using Ocean Data View <http://odv.awi.de>.*

References:

Anderson, R. F. (2020). GEOTRACES: Accelerating Research on the Marine Biogeochemical Cycles of Trace Elements and Their Isotopes. Annual Review of Marine Science, 12(1), DOI: https://doi.org/10.1146/annurev-marine-010318-095123

Dulaquais G, Boye M, Middag R, Owens S, Puigcorbe V, et al. (2014a). Contrasting biogeochemical cycles of cobalt in the surface western Atlantic Ocean. Glob. Biogeochem. Cycles 28:2014GB004903

Dulaquais G, Boye M, Rijkenberg MJA, Carton X. (2014b). Physical and remineralization processes govern the cobalt distribution in the deep western Atlantic Ocean. Biogeosciences 11:1561–80

Klunder MB, Laan P, Middag R, de Baar HJW, Ooijen JV. (2011). Dissolved iron in the Southern Ocean (Atlantic sector). Deep-Sea Res. II 58:2678–94

Middag R, van Hulten MMP, Van Aken HM, Rijkenberg MJA, Gerringa LJA, et al. (2015). Dissolved aluminium in the ocean conveyor of the West Atlantic Ocean: effects of the biological cycle, scavenging, sediment resuspension and hydrography. Mar. Chem. 177:69–86
Middag R, van Slooten C, de Baar HJW, Laan P. (2011). Dissolved aluminium in the Southern Ocean. Deep-Sea Res. II 58:2647–60
Rijkenberg MJA, Middag R, Laan P, Gerringa LJA, van Aken HM, et al. (2014). The distribution of dissolved iron in the West Atlantic Ocean. PLOS ONE 9:e101323

Neural network as tools to replace oceanic data deficiencies

The importance of the cycle and speciation of nitrate and its isotopes (δ15N) in the ocean does not have to be demonstrated anymore. In an attempt to overcome the difficulty to compare the results of N/δ15N cycle models to a sparse set of data, Rafter and co-workers propose an original approach, based on artificial intelligence (AI) methods.

They use a compilation of 12,277 published δ15N measurements together with climatological maps of physical and biogeochemical tracers to create a surface to-seafloor map of δ15N using an ensemble of artificial neural networks (EANN). In other words, they train the seawater parameters to deduce a δ15N value at a given location and depth taking into accounts the climatological values. The strong correlation ($R2 > 0.87$) and small mean difference (< 0:05 ‰) between EANN-estimated and observed nitrate δ15N indicate that the EANN provides a good estimate of climatological nitrate δ15N without a significant bias. This climatology reveals large-scale spatial patterns in nitrate δ15N and allows the quantification of regional and basin-average oceanic values of nitrate δ15N. This work demonstrates how AI tools could help to address the unavoidable deficiency of data inherent to oceanic studies, keeping in mind that they require ab initio reasonable data coverage and mostly a good understanding of the parameter fate.

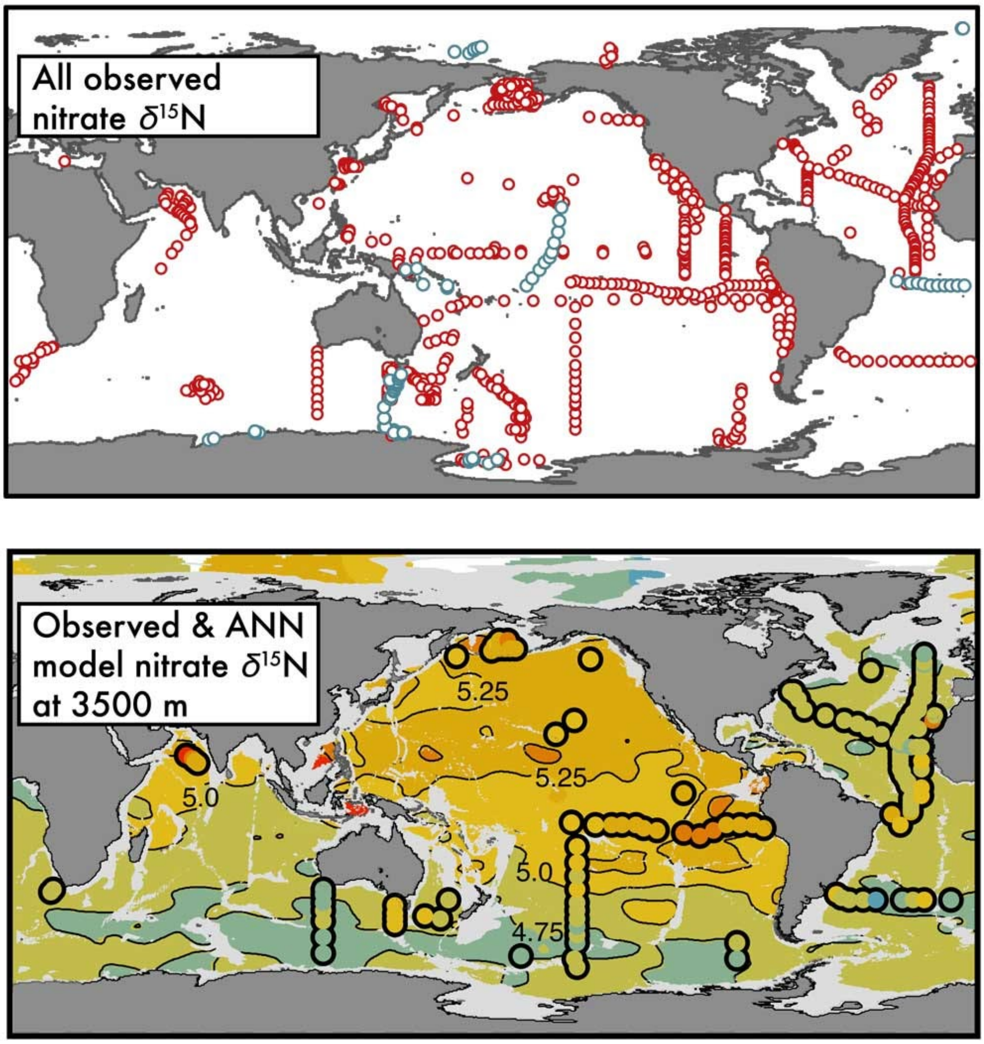


Figure 3: *(Top) Available nitrate δ15N (N isotopic composition) measurements at the time of publication. (Bottom) View of nitrate δ15N at 3500 m from two perspectives: the observed value (circles) and the model value (the contours).*

Reference:

Rafter, P. A., Bagnell, A., Marconi, D., & DeVries, T. (2019). Global trends in marine nitrate N isotopes from observations and a neural network-based climatology. Biogeosciences, 16(13), 2617–2633. https://doi.org/10.5194/bg-16-2617-2019

[Welcome to the first Korean participation in GEOTRACES]

Thanks to the newly launched research vessel (R/V) *Isabu* of the Korea Institute of Ocean Science and Technology (KIOST), and the acquisition of a contamination-free PRISTINE (NIOZ, NL) ultraclean seawater sampling system for trace elements, the Korean marine geochemists are pleased to published their first reliable trace metal (TM) results. Two cruises conducted in the Indian Ocean together with an intercalibration conducted at a GEOTRACES cross over station allowed them to assess their data quality. Thanks to these very positive results, researchers from KIOST and other academic institutes of Korea are currently conducting and planning *R/V Isabu*-based long-term research in offshore areas (Korean marginal seas) and the open ocean. Welcome to GEOTRACES!

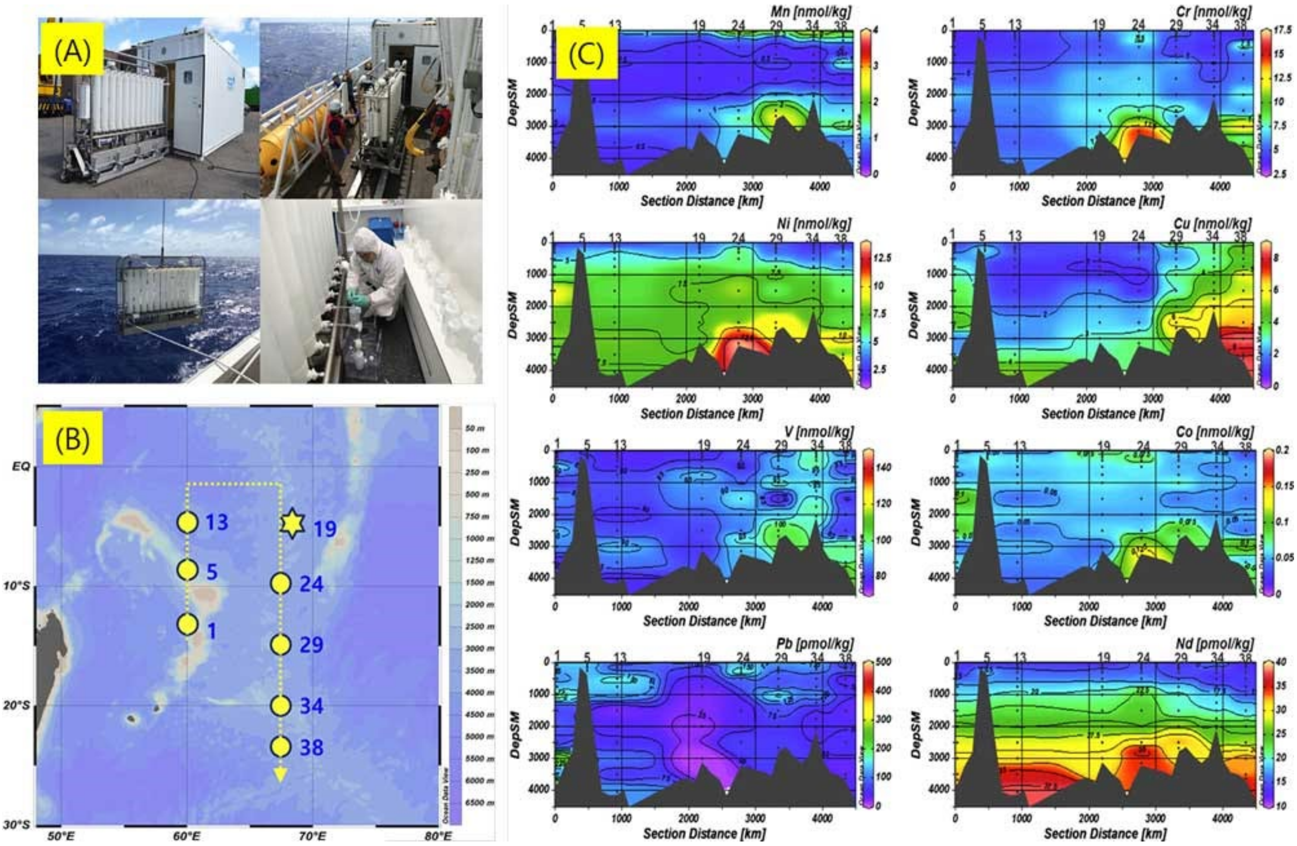


Figure 4: *A) Photographs of operating the PRISTINE ultra-clean sampler at sea and of subsampling (Upper left). B) Sampling station in the Indian Ocean in Apr. 2018 (yellow dots of lower left). Yellow star (station 19) indicates the GEOTRACES crossover station (69.54°E–5.16°S) where samples were also collected in 2017. Yellow dotted arrow line denotes the cruise track. C) Contour maps of some dissolved trace element along the western Indian Oceans (60°E and 68°S). The direction of contour (left to right) is the same as the cruise track in Fig. B. Modified from Ocean Science Journal.*

Reference:
Kim, S. H., Ra, K., Kim, K.-T., Jeong, H., Lee, J., Kang, D.-J., Rho, T., Kim, I. (2019). R/V Isabu-Based First Ultraclean Seawater Sampling for Ocean Trace Elements in Korea. Ocean Science Journal, 1–12. https://doi.org/10.1007/s12601-019-0030-x

[Upwelled hydrothermal iron stimulates massive phytoplankton blooms in the Southern Ocean]

Joint Science Highlight with US-Ocean Carbon & Biogeochemistry (US-OCB).

In a recent study, Ardyna et al (2019, see reference below) combined observations of profiling floats with historical trace element data and satellite altimetry and ocean color data from the Southern Ocean to reveal that dissolved iron (Fe) of hydrothermal origin can be upwelled to the surface.

Furthermore, the activity of deep hydrothermal sources can influence upper ocean biogeochemical cycles of the Southern Ocean, and in particular stimulate the biological carbon pump.

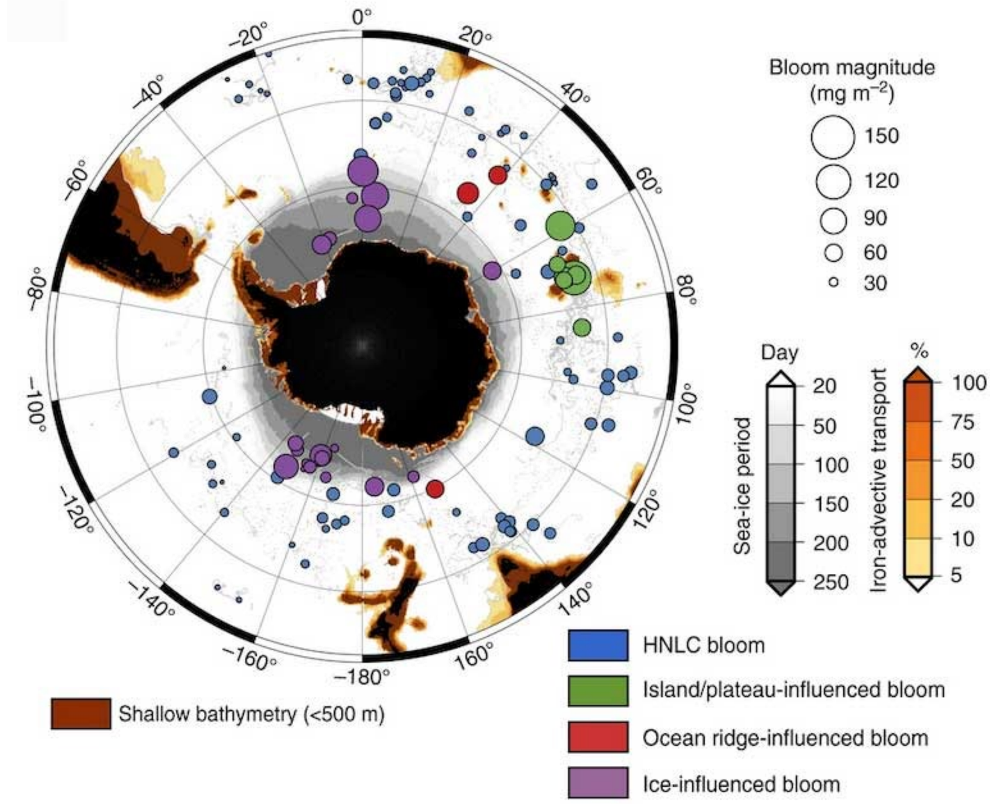


Figure 5: *Southern Ocean phytoplankton blooms showing distribution, biomass (circle size) and type (color key). Adapted from Ardyna, et al., 2019.*

Reference:

Ardyna, M., Lacour, L., Sergi, S., d'Ovidio, F., Sallée, J.-B., Rembauville, M., Blain, S., Tagliabue, A., Schlitzer, R., Jeandel, C., Arrigo, K.R., Claustre, H. (2019). Hydrothermal vents trigger massive phytoplankton blooms in the Southern Ocean. Nature Communications, 10(1), 2451.
DOI: https://doi.org/10.1038/s41467-019-09973-6

About the decoupled fates of aluminium, manganese, cobalt and lead in the North Pacific Ocean

Did you know that each of these tracers could follow its own marine story, quite decoupled from the others?

This is what is shown and discussed by Zheng and co-workers (2019, see reference below) after having analysed about 500 samples for aluminium (Al), manganese (Mn), lead (Pb) and cobalt (Co) along three sections in the North Pacific Ocean. They demonstrate that the distribution of each element is uniquely related to ocean circulation; that the subsurface Pb maximum has been sustained in the North Pacific Ocean through the growth of anthropogenic sources in Asia and Russia, contrasting with the decrease observed in the Atlantic Ocean (please also read the science highlight from Bridgestock et al., 2016 here: https://www.geotraces.org/testament-of-environmental-policies/); that the labile fraction of particulate Al is larger than that of particulate lead; and finally that while the Pb enrichment factor confirms its predominant atmospheric origin, those of Mn and Co clearly attest that sources other than the aerosol deposition are more significant contributors to the concentrations of these two tracers.

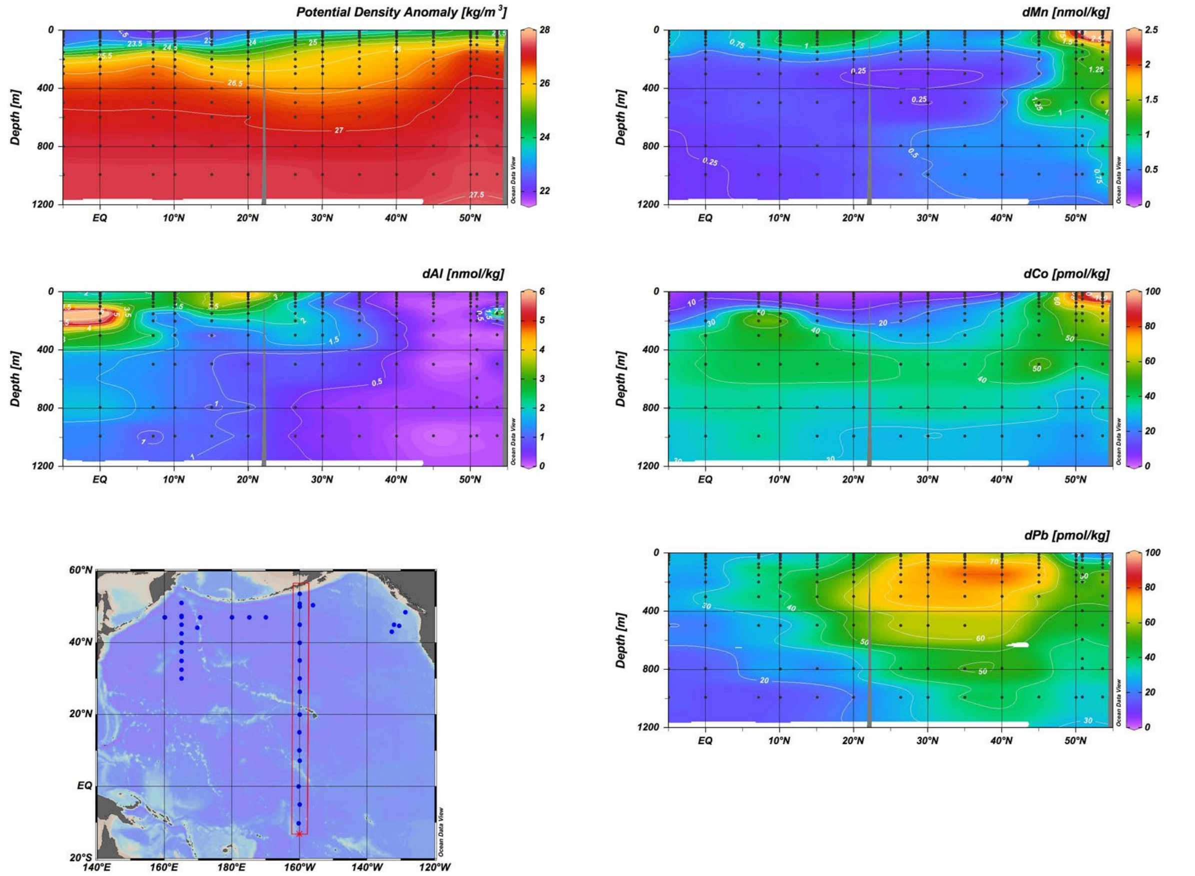


Figure 6: *Sectional distributions of dissolved metals (dM) and potential density anomaly at depths of 0–1200 m along 160°W (section highlighted in red in the map). Dissolved aluminium (dAl) is high in Equatorial Under Current (EQ, 175 m depth) and North Equatorial Current (20°N, surface). Although dissolved manganese (dMn) and dissolved cobalt (dCo) have a concurrent source at the continental shelf of the Aleutian Islands, dCo is more widely distributed via North Pacific Intermediate Water (NPIW, ~600 m). Dissolved lead (dPb) is concentrated in Subtropical Mode Water and Central Mode Water above the NPIW. Adapted from Zheng et al., 2019.*

References:

Zheng, L., Minami, T., Konagaya, W., Chan, C.-Y., Tsujisaka, M., Takano, S., Norisuye, K., Sohrin, Y. (2019). Distinct basin-scale-distributions of aluminum, manganese, cobalt, and lead in the North Pacific Ocean. Geochimica et Cosmochimica Acta, 254, 102–121. DOI: http://doi.org/10.1016/J.GCA.2019.03.038

Bridgestock, L., van de Flierdt, T., Rehkämper, M., Paul, M., Middag, R., Milne, A., Lohan, M.C., Baker, A.R., Chance, R.,, Khondoker, R., Strekopytov, S., Humphreys-Williams, E., Achterberg, E.P., Rijkenberg, M.J.A., Gerringa, L. J.A., de Baar, H. J. W. (2016). Return of naturally sourced Pb to Atlantic surface waters. Nature Communications, 7, 12921.
doi: http://doi.org/10.1038/ncomms12921

A treasure of geochemical data to trace ocean circulation, ventilation, mixing, biogeochemical and hydrothermal processes

This treasure is made of approximately 60,000 valid tritium measurements, 63,000 valid helium isotope determinations, 57,000 dissolved helium concentrations, and 34,000 dissolved neon concentrations, including their metadata (geographic location, date and sample depth). It was compiled by Bill Jenkins and co-workers (2019, see reference below) who describe the nature of the data, discuss their quality, list the contributors and pioneers, and of course are giving free access to this huge dataset (https://doi.org/10.25921/c1sn-9631). They also provide some figures illustrating how powerful this new tool is as for example the figure below.
Authors invite anyone with knowledge of additional tritium, helium, or neon data that has not been included, to please contact wjenkins@whoi.edu with details for inclusion in future versions of the data set.

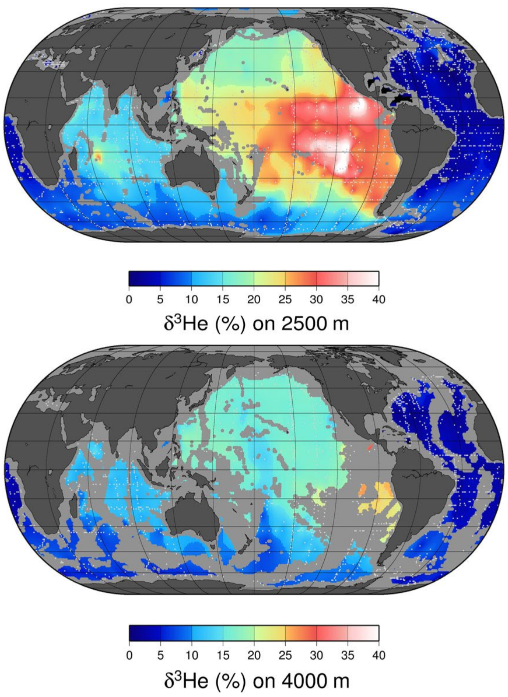


Figure 7: *(top) A map of helium values at approximately 2500 m depth. (bottom) A map of helium values at approximately 4000 m depth. The values plotted are simply an average of all measurements within a 1' square between 3750 and 4250 dbar. Depths shallower than 4000 m are masked in gray, and sampling locations are indicated by light gray dots. ^{3}He is an extremely rare isotope that is a sensitive tracer of hydrothermal processes. Since it is both stable and chemically inert, it is detectable over great distances in the ocean. The two maps shown above are of the distribution of δ^{3}He, a tracer of hydrothermal activity, at two levels in the deep ocean. The shallower one roughly corresponds to the depth of the mid-ocean ridge system, where the bulk of this hydrothermal injection takes place. One can see the dominant role of the fast-spreading ridges in the eastern Pacific, which drive two massive, westward reaching plumes north and south of the equator. The deeper horizon shows the spreading of δ^{3}He-impoverished bottom waters from the northern and southern polar regions into the deep ocean basins.*

Reference:
Jenkins, W. J., Doney, S. C., Fendrock, M., Fine, R., Gamo, T., Jean-Baptiste, P., Key, R., Klein, B., Lupton, J. E., Newton, R., Rhein, M., Roether, W., Sano, Y., Schlitzer, R., Schlosser, P. Swift, J. (2019). A comprehensive global oceanic dataset of helium isotope and tritium measurements. Earth System Science Data, 11(2), 441–454. DOI: http://doi.org/10.5194/essd-11-441-2019

South Pacific particulate organic carbon fate challenges Martin's Law

Joint Science Highlight with US-Ocean Carbon & Biogeochemistry (OCB).

Carbon storage in the ocean is sensitive to the depths at which particulate organic carbon (POC) is respired back to CO_2 within the twilight zone (100-1000m). For decades, it has been an oceanographic priority to determine the depth scale of this regeneration process. To investigate this, GEOTRACES scientists are deploying new isotopic tools that provide a high-resolution snapshot of POC flux and regeneration across steep biogeochemical gradients in the South Pacific Ocean.

A recent paper in *PNAS* reported on particulate organic carbon (POC) fluxes throughout the water column (focusing on the upper 1000 m) along the GP16 GEOTRACES section between Peru and Tahiti (Figure 1A). POC fluxes (Figure 1B) were derived by normalising concentrations of POC to ^{230}Th following analysis of samples collected by in situ filtration. This work builds on a research theme initiated at the GEOTRACES-OCB synthesis workshop held at Lamont-Doherty Earth Observatory in 2016.

The study results show that POC regeneration depth is shallower than anticipated, especially in warm stratified waters of the subtropical gyre. Regeneration depth—expressed in terms of the Martin-curve power-law exponent "b" (Figure 1C)—is shown to be greater than previous estimates (horizontal dashed lines), but similar to values obtained using neutrally buoyant sediment traps at the Hawaii Ocean Time-series Station Aloha. In contrast to the rapid regeneration of POC in warm stratified waters, POC regeneration within the oxygen deficient zone (ODZ) is below our detection limits. Models have shown that shallower regeneration of POC leads to less efficient carbon storage in the ocean, making the authors speculate that global warming, yielding expanded and more stratified gyres, may induce a reduction of the ocean's efficacy for carbon storage via the biological pump.

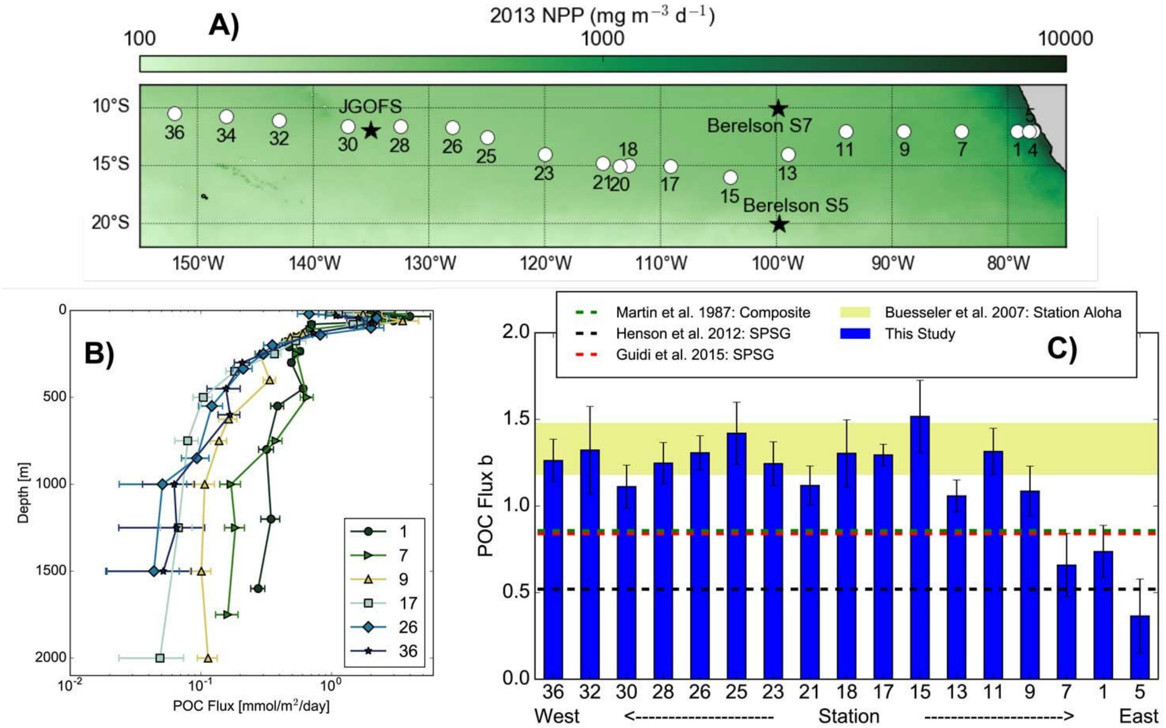


Figure 8: *Site map and POC flux characteristics from [GEOTRACES GP16 section](). Plot A) shows the GP16 station locations as white circles, with nearby sediment trap deployments as black stars, with 2013 MODIS satellite-derived net primary productivity in the background. Plot B) shows POC fluxes from particulate ^{230}Th-normalization from selected stations spanning the zonal extent of the GP16 section. Plot C) shows power law exponent b values for each GP16 station (blue), compared to estimates from bottom-moored sediment traps in the South Pacific (black and red dashed lines), a compilation of sediment traps in the North Pacific (green dashed line), and neutrally buoyant sediment traps in the subtropical North Pacific (yellow shaded band). GP16 regeneration length scales from ^{230}Th-normalization agree most closely with the estimates from neutrally buoyant sediment traps.*

Reference:

Pavia, F. J., Anderson, R. F., Lam, P. J., Cael, B. B., Vivancos, S. M., Fleisher, M. Q., Lu, Y., Zhang, P., Cheng, H., Edwards, R. L. (2019). Shallow particulate organic carbon regeneration in the South Pacific Ocean. Proceedings of the National Academy of Sciences of the United States of America, 116(20), 9753–9758. https://doi.org/10.1073/pnas.1901863116

2.4 GEOTRACES Statement of Values and Behaviours

In October 2019, GEOTRACES has released a Statement of Values and Behaviours which reflects GEOTRACES common understanding of respectful values, acceptable behaviour, and cooperative interaction as an international scientific programme. This document was prepared by Andrew Bowie and Phoebe Lam, co-chairs of the GEOTRACES Scientific Steering Committee.

The GEOTRACES Statement of Values and Behavious is available to download at: https://www.geotraces.org/statement-of-values-and-behaviours/

3. Activities

3.1 GEOTRACES intercalibration activities

The S&I Committee is currently composed of Ana Aguilar-Islas, Karen Casciotti, Tina van de Flierdt, Walter Geibert, Lars-Eric Heimbürger-Boavida, Yoshiko Kondo, Maeve Lohan, Hélène Planquette, Peter Sedwick and Alyson Santoro. Maeve Lohan and Walter Geibert serve as co-chairs. The committee met in person on 12th and 13th June 2019 in Norfolk, Virginia, hosted by Peter Sedwick.

The focus for the past reporting period was again on the preparation of our procedures for the upcoming intermediate data product (IDP2021), and on implementing improvements of the S&I report submission procedure. The focus of the meeting in Norfolk was on testing the new system for registering datasets and submitting intercalibration reports (DoOR).

With the new functionalities offered by the electronic system, it is possible to track individual criteria for intercalibration and reporting back to the submitting PIs is simplified. Supported by the well-structured parameter names, unique identifiers, and the portal software, PIs now select the parameters to be submitted and intercalibrated themselves, which is anticipated to greatly reduce the potential for discrepancies between intercalibration and data submission.

Since the release of the portal, the submission system has been used by a number of PIs, but in anticipation of the upcoming 1st deadline for the IDP2021, no meeting of the S&I committee has taken place as of 31st of March. An in-person meeting that had been scheduled for summer 2020 had to be canceled in March 2020 at the onset of the Covid-19 pandemic.

Laboratory intercomparisions & Consensus Materials

We also report the status and progress on initiatives to produce consensus materials and lab intercomparisons.

Seawater Consensus materials

Consensus values for a suite of trace elements in the GSP and GSC seawaters were established last year by Jim Moffett and made available on the GEOTRACES web page: https://www.geotraces.org/standards-and-reference-materials/

Mercury

About 800 bottles of offshore Mediterranean Sea water, 400m-depth, unfiltered seawater are left from the 2017 Hg intercalibration cruise, in precombusted 125mL glass bottles, teflon seal crimped, stored in a cold chamber at 4°C.
About 15kg Mediterranean Sea sediment, dried at 60°C, sieved at 300um, batch tested for Hg are available, on which so far no other trace metal has been measured.

Next Meeting

The date for the next meeting of the S&I committee is currently not set as the duration of the travel restrictions due to the Covid-19 is unclear.
3.2 Data management for GEOTRACES

The GEOTRACES Data Assembly Centre (GDAC) is hosted by the British Oceanography Data Centre Data management for GEOTRACES

The GEOTRACES Data Assembly Centre (GDAC) is hosted by the British Oceanography Data Centre (BODC), with the head office located in Liverpool; Dr Mohamed Adjou, the GEOTRACES Data Manager, is based at Liverpool BODC office. He is assisted by Donna Cockwell from the Southampton BODC office. GDAC benefits from additional BODC expertise when work cases require it.

GDAC is responsible for the entirety of the GEOTRACES data activities. This takes into account the following components:

Interaction between PIs and national data centres in order to encourage regular and timely data/ metadata submissions;
Maintaining and modifying GDAC web pages to include updated ocean basin maps (http://www.bodc.ac.uk/geotraces/cruises/section_maps/) and upcoming cruises on the programme page (http://www.bodc.ac.uk/geotraces/cruises/programme/);
Liaising with the Data Management Committee and Standards and Intercalibration Committee to answer issues/questions relating to GEOTRACES;
Input of metadata and data into the BODC database and compilation of documentation to include originator's methodology
Collation of data and metadata for the future IDP;
Answering requests from GEOTRACES community and assisting on IDP download.

This year, GDAC would like to highlight and report on the following tasks:

Cooperation with the IPO: The IPO is in regular contact with GDAC in order to have an up-to-date cruise inventory as displayed on the GDAC website. IPO is also assisting GDAC by sending reminders to respect time-scheduled tasks to project participants.

Contribution to DOoR portal design and release: Preparing and releasing DOoR portal by Sedoo colleague (Toulouse) was one of the main event in GEOTRACES during 2019. DOoR will ensure an efficient tracking of single data set submitted for intercalibration process. GDAC contributed actively in developing the specifications and the testing before the release. GDAC also adapted its data workflow to match this new change in data submission. This work comes in addition to GDAC delivering GEOTRACES' cruise metadata to the portal through a webservice (described in last year's report).

GDAC website updates: GDAC website update is planned on a bi-weekly basis to ensure up-to-date information.

DMC and SSC meetings: During DMC and SSC meetings (Hobart, September 2019), the accent was put on IDP2021 preparation and timeline was proposed with DMC.

Liaison with national data centres: Liaison with national marine data centres (BCO-DMO, CYBER-LEFE, NIOZ and SKLMES) was maintained during the whole 2019 and information on the new GEOTRACES data submission including DOoR portal edited templates was approved.
Data and cruise metadata overview New data submission are constantly received. Over 1500 data sets from 51 different cruises have been registered with about half of these data sets already submitted to GDAC on May 2020.

Deadlines for inclusion in IDP2021: The first deadline which guarantees inclusion in IDP2021, for the submission of datasets to GDAC or national data centres via DOoR and using DOoR templates and intercalibration reports was the 1st of April 2020. It was extended to 15th May 2020 as a response to the pandemic's potential impact on PIs' work conditions. GDAC also provided support by answering questions, in a relative record time, and assisted with the preparation of data and metadata submission.
Details of the data received before the first data submission deadline will be provided during the next DMC and SSC meetings expected in September 2020.

Summary of GEOTRACES cruises, which have taken place in the period April 2019-April 2020:

Cruise	Chief scientist(s)	GEOTRACES scientist(s)	Type	Period	Location
PROVOCCAR I (GApr15)	Borges Mendes Carlos Rafael	Hatje Vanessa	Process Study	20200202 20200308	South West Altantic- North Antarctic Peninsula
AE1930 (BAIT-IV, GApr13 Leg4)	Johnson Rod	Sedwick Peter	Process Study	20191114 20191120	Sargasso sea
TONGA (GPpr14)	Guieu Cecile & Bonnet Sophie	Sarthou Géraldine, Bressac Matthieu & Planquette Hélène	Process Study	20191031 20191206	Western Tropical South Pacific
Explorer AE1921 (BAIT-III, GApr13 Leg3)	Johnson Rod	Sedwick Peter	Process Study	20190816 20190822	Sargasso sea
SAMBAR_A2 (GApr14, SAM-18)	Campos Edmo	Hatje Vanessa	Process Study	20190615 20190701	South West Atlantic

AE1909 (BAIT-II, GApr13 Leg2)	Johnson Rod	Sedwick Peter	Process Study	20190511 20190517	Sargasso sea
KK1903 (GP09)	Cai Yihua & Zhou Kuanbo	Zhimian Cao, Minhan Dai & Liping Zhou	Section Cruise	20190425 20190610	North West Pacific

Other GDAC activities: During the last year Mohamed Adjou contributed to two key communication events:
1) GEOTRACES (Meta-) data management course provided to students during GEOTRACES summer school (Cadiz, September 2019).
2) SCOR booth in Ocean Sciences meeting (San Diego, February 2020) for a demonstration of new GEOTRACES procedure to register and submit data and Intercalibration reports using DOoR portal.

In summary
Preparing the data reception at GDAC under the new DOoR procedure was the most notable event this year in GDAC work. The achievement of this new procedure to efficiently track single data set submitted for intercalibration process, is the result of a synergetic collaboration between GEOTRACES working parties.

The collation and processing of data to be included in the IDP2021 will be the focus of GDAC's activities after the 1st data submission deadline has passed. GDAC continue to provide useful information on GDAC web pages for scientists and to answer questions related to data and metadata submission though our GDAC email (geotraces.dac@bodc.ac.uk). We encourage the GEOTRACES community to contact GDAC for any question about their data or metadata submission.

3.3 GEOTRACES International Project Office

The GEOTRACES International Project Office (IPO) is based at the Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS) in Toulouse, France. The IPO is staffed by Elena Masferrer Dodas, the IPO Executive Officer and it has very recently recruited Katherine Brownlie as part-time assistant although due to the COVID-19 situation she has not been able to start on her duties. She works under the scientific supervision of Catherine Jeandel (CNRS, LEGOS, France).

The IPO is responsible for:

assisting the Scientific Steering Committee (SSC) in implementing the GEOTRACES Science Plan and implementation plans of the programme;
organising and staffing meetings of the SSC, working groups and task teams;
liaising with the sponsors and other relevant organisations;
seeking and managing programme finances;
representing the project at international meetings;
maintaining the project website and Facebook and Twitter pages;
maintaining the project mailing lists;
preparing GEOTRACES science highlights and the bimonthly GEOTRACES eNewsletter;
maintaining the GEOTRACES publications database and the GEOTRACES Scientists Analytical Expertise Database;
assisting the GDAC in securing information about upcoming cruises; and
interacting with GEOTRACES national committees and groups, as well as other international projects.

This year, we want to highlight the following activities:

On-line GEOTRACES DOoR portal

The management of the development of the GEOTRACES Data for Oceanic Research (DoOR) on-line portal has been an important task conducted by the IPO during this reporting period. The portal was officially released on 22 December 2019, and it is available at the following link: https://geotraces-portal.sedoo.fr/pi/

The GEOTRACES IPO has guided and overseen the technical development of the portal - carried by François André, Arnaud Miere and Guillaume Brissebrat (in the earlier stages of the development) from the Observatory Midi-Pyrenées Data Center (SEDOO, Toulouse) - in close liaison with the GEOTRACES Executive Committee, the Standards Intercalibration Committee, the Data Management Committee, the Parameter Definition Committee and GDAC.

The DOoR portal has been designed to streamline the preparation of IDP2021, both for the PIs and those who work behind the scenes to assemble the data product. Indeed, following the success of the GEOTRACES Intermediate Data Products 2014 and 2017, the amount of data to be reviewed, managed and processed has increased considerably making necessary the development of an on-line management tool for the assessment of the IDP.

The DOoR portal consists of 4 on-line portals, so far: (1) one portal for GEOTRACES scientists, (2) one portal for the Standards and Intercalibration Committee, (3) one portal for the GDAC and (4) one portal for DOoR administrators.

The DOoR portal for GEOTRACES scientists is where principal investigators (PI) can: (1) register datasets for inclusion in GEOTRACES Data Products and track its status, (2) generate and download templates needed to submit intercalibration reports, submit the intercalibration reports to the S&I

Committee for processing and tracing their progress, (3) generate and download data templates to be used for data submission to the appropriate data centre and track the status of inclusion in IDP, (4) link publications that must be cited when using the data, (5) associate scientists (students, postdocs, etc.) with each dataset to ensure they are duly acknowledged and (6) give permission for the release in IDP2021 for each dataset registered.

The other 3 portals are management tools designed to facilitate the work for each specific group that works assembling the Intermediate Data Product.

GEOTRACES website (<http://www.geotraces.org>)

A major overhaul of the GEOTRACES website has been successfully undertaken. The redesign of the website was motivated by the need to: (1) move the website from Institut de la mer de Villefranche in France to a new host the SEDOO Data Centre where the GEOTRACES DOoR is hosted and (2) migrate the site to a new content management system, WordPress instead of Joomla!. About 85% of the migration process is completed this stage.

We want to thank Olivier Boebion (IT system administrator at Institut de la Mer de Villefranche, France) for all his technical assistance with the GEOTRACES website during the last 10 years and Pierre Vert (IT system administrator at SEDOO) for all this technical assistance in migrating the GEOTRACES website.

Assistance during the SCOR review of GEOTRACES

The IPO has compiled the necessary information and prepared the first draft of the GEOTRACES report requested by the SCOR review panel.

Logistics for meetings

The IPO has hosted the GEOTRACES DOoR Portal Meeting (January 2020) and organised multiple virtual meetings with committee's members during the preparation of the GEOTRACES DOoR. It has also provided assistance in the organisation of the GEOTRACES Data Management Meeting (7-8 September 2019, Hobart, Australia) and the GEOTRACES SSC Meeting (9-11 September 2019, Hobart, Australia), the GEOTRACES Summer School (23-28 September 2019, Cadiz, Spain).

Some statistics

26 new highlights published (217 in total)
6 eNewsletters published, including one special issue (bimonthly 39 in total)
123 new peer-reviewed papers included in the GEOTRACES Publication Database (1,353 in total)
104 new articles published on the GEOTRACES website
86 new announcements sent through the GEOTRACES mailing list
1,447 followers (top tweet reached 3.1K) and 647 followers in Facebook (top post reached 1.6K)
97 new subscribers on the GEOTRACES mailing list
Featured outreach activity: New educational materials for improving science literacy in students

Timothy Kenna and Margie Turrin from Columbia University, New York, have made available a new set of educational materials in English and Spanish for developing science literacy in students. They have produced three educational activities which all have a focus on understanding radioactivity in the environment.

The first is a lab designed to introduce the topic of radioactivity and dispel myths around its presence and impact. The second activity does not have an associated lab but works well as an introductory piece to analysing what is provided through news outlets. It can be used introducing a phenomena building into the longer lab around critical reading and article analysis. The third activity is a lab designed to introduce students to critically reading and analysing environmental articles to be able to discern what is real and what is hype.

These materials are available on the GEOTRACES website: https://www.geotraces.org/developing-science-literacy/

3.4 GEOTRACES workshops

A list of completed GEOTRACES Workshops is available below:

Second Russian GEOTRACES seminar, 7 February 2020, Moscow, Russia.

The 2nd Russian GEOTRACES seminar was held on February 7, 2020 in Moscow at the Shirshov Institute of Oceanology, Russian Academy of Sciences (https://ocean.ru). Prof. Dr. Eric Achterberg initiated the GEOTRACES seminar during his visit as part of the Helmholtz team. About 50 people attended the seminar in Moscow and some people listened to the presentation remotely in Sevastopol, Kaliningrad, and Arkhangelsk. The presentation aroused a great interest among the seminar participants.

The GEOTRACES seminar commenced with a short introduction and welcome by Prof. Dr. Piotr Zavyalov. Dr. Marina Kravchishina reported about GEOTRACES activity in Russia and highlighted the main purposes of the study of the marine biogeochemical cycles of trace elements and their isotopes (TEIs) and the need for international collaboration. Prof. Dr. Eric Achterberg gave the opening speech entitled 'International GEOTRACES Programme: Observations across ocean gradients provide insights into biogeochemical cycles'. This was followed by a round table discussion on the TEIs clean sampling systems and analyses organised by Prof. Dr. Eric Achterberg (GEOTRACES SSC member), Dr. Marina Kravchishina (GEOTRACES SSC member) and Dr. Ludmila Demina (Past GEOTRACES SSC member).

For further details about the 2nd Russian GEOTRACES Workshop are available on the GEOTRACES website: https://www.geotraces.org/2nd-russian-geotraces/

Southern Ocean Biogeochemistry Workshop, 12-13 September 2019, Hobart, Australia

A workshop on Southern Ocean Biogeochemistry was organised by Zanna Chase, Andy Bowie and Phil Boyd (University of Tasmania) from 12th to 13th of September at the Institute for Marine and Antarctic Studies (IMAS) in Hobart, Australia. The workshop was aimed at bringing together national and international scientists as well as local students and researchers in biogeochemical oceanography, modelling and paleoceanography focused on the Southern Ocean's response to climate change. During the workshop the development of collaborative projects including GEOTRACES process studies was also discussed.

The programme of the workshop is available here:
https://geotracesold.sedoo.fr/images/stories/documents/workshops/2019_SouthernOcean/Southern%20Ocean%20Biogeochemistry.pdf

Exploring GEOTRACES Data with Ocean Data View Workshop, 5-6 September 2019, Hobart, Australia

Reiner Schlitzer (AWI, Bremerhaven) gave a 2-day workshop on exploring GEOTRACES and other environmental data with Ocean Data View (ODV) in Hobart, Australia, in September 2019. This very successful hands-on workshop was attended by 40 participants.

Figure 9: Participants at the ODV Workshop at IMAS, University of Tasmania.

Fourth Asia GEOTRACES Workshop: Sources/sinks and internal cycling of mercury and other TEIs in the Northwest Pacific Ocean, 8-10 December 2019, Qingdao, Shandong, China

The Asia GEOTRACES Workshop: Sources/sinks and internal cycling of mercury and other TEIs in the Northwest Pacific Ocean, organized by Ocean University of China (OUC), was held during December 8-10, 2019, Qingdao, China. More than 50 participants from 9 countries, including China, Japan, Korea, India, Singapore, Canada, Germany, United States, and France (remote) attended the workshop. The aim of the workshop is to evaluate a full picture of the current status of the studies on the major sources/sinks and internal cycling processes of mercury and other TEIs in seawater in the Northwest Pacific Ocean (NWPO), and to generate a future regional collaboration and action plan for Asia GEOTRACES. During the workshop, two major topics were focused: 1) The distribution, speciation, sources, and internal cycling of mercury and its isotope in the NWPO; 2) TEIs fluxes and processes at ocean interfaces, e.g. atmospheric deposition, sediment-water boundary, continental run-off as well as interaction between marginal seas and Kuroshio water. In addition to normal sessions, a student session was co-chaired by Profs. Greg Cutter and Eric Achterberg, 6 graduate students gave oral presentations. Moreover, the international inter-calibration for TEIs, particularly Hg were addressed, the discussed details include sample collection, storage, intercalibration, and data management. The capability of marine Hg analysis and study in the Asia is expected to be strengthened by the scientific exchange and communication during the workshop. Furthermore, some participants visited the new R/V "Dongfanghong III" (5,000 tons) and discussed the possible crossover stations with other international cruises (e.g. Germany and Japan) and the potential contribution for the international GEOTRACES collaboration, e.g., sharing cruise and performing inter-calibration in its near future cruise. Finally, per discussion, bio-GEOTRACES was considered one of the potential research fields. The future collaboration in research and possible joint grant applications were discussed and preliminary agreements were reached. The importance and possibility of regional collaboration to study marine pollution, e.g. Hg and Pb were also emphasized.

For further information please check the GEOTRACES website:
https://www.geotraces.org/event/asia-geotraces-workshop-sources-sinks-and-internal-cycling-of-mercury-and-other-teis-in-the-northwest-pacific-ocean/

3.5 GEOTRACES summer school

The second GEOTRACES Summer School was held from 23 to 28 September 2019 in Cadiz, Spain and it was hosted by the International Campus of Excellence of the Sea (CEI-Mar) on board the Spanish school vessel *'Intermares'*.

The summer school aimed at teaching the skills and knowledge necessary for a good understanding of the biogeochemical cycles of trace metals and it brought together 39 students from 15 different countries and 10 world-leading international scientists, including: Bob Anderson (LDEO, Columbia University – USA); Catherine Jeandel (LEGOS, France); Reiner Schlitzer, Alfred Wegener Institut (AWI), Germany; Susanne Fietz (Stellenbosch University, South Africa); Eric Achterberg (GEOMAR, Germany); Maite Maldonado (British Columbia, Canada); Mohamed Adjou (Brtish Oceanographic Data Center,UK); Géraldine Sarthou (CNRS – France); Rob Middag (NIOZ, The Netherlands); José Antonio López (Universidad de Cádiz); and Antonio Tovar (ICMAN/CSIC Spain).

Particular objectives of the summer school were:
Gaining knowledge and experience on oceanographic sampling campaigns for collection of samples for the analysis of trace metals.
Students should be capable to properly select and conduct analytical strategies for the study of trace metals in marine samples.
Gaining knowledge on bio-geochemical cycles of metals in the ocean and their speciation.
Data management to analyse the role of trace metals in the ocean.

Among the most exciting experiences of the summer school were the field sampling workshops on board of the 'Intermares' vessel. Every morning, after the master lecture, the vessel was heading to a point away from the Bay of Cádiz looking for 100 meters deep to submerge a rosette including eight bottles from which seawater samples were extracted. Each pair of students took a bottle and brought it to the laboratory installed on the 'Intermares' school vessel. In there they continued learning how to follow the strict GEOTRACES protocols that allows getting uncontaminated seawater samples. Trace metals are available in very low concentrations in the ocean so any accidental addition may ruin the entire process. First, and dressed for the occasion, they entered in the "bubble"; a clean environment of particles and metals for a first extraction. Next, they went to the laminar flow hood, where the air was filtered in order that the samples were not contaminated with other particles when it is manipulated. From there, to the laboratory where marine students usually work whatever the place of the world in which his/her research institution is located.

Despite the intensity of the summer school, the strength of these young scientists made it possible to achieve the second objective of the course: establishing a working network that will last and become strong over time.. The ‘International Summer School GEOTRACES Spain’ has been a great and very successful experience!

GEOTRACES greatly acknowldege the work done by all co-organisers: the University of Cádiz (UCA), the Andalusian Institute of Marine Sciences of the Spanish National Research Council (ICMAN-CSIC), the Ministry of Agriculture and Fisheries, the Ministry of Defense, the International Campus of Excellence of the Sea (CEI·MAR). As well as the funding provided by the Scientific Committee on Oceanic Research (SCOR)/GEOTRACES, the General CSIC Foundation, the International Doctorate School of Marine Studies (EIDEMAR), and the CEI·MAR.

For further information please visit the Summer School website: https://geotraces.uca.es/

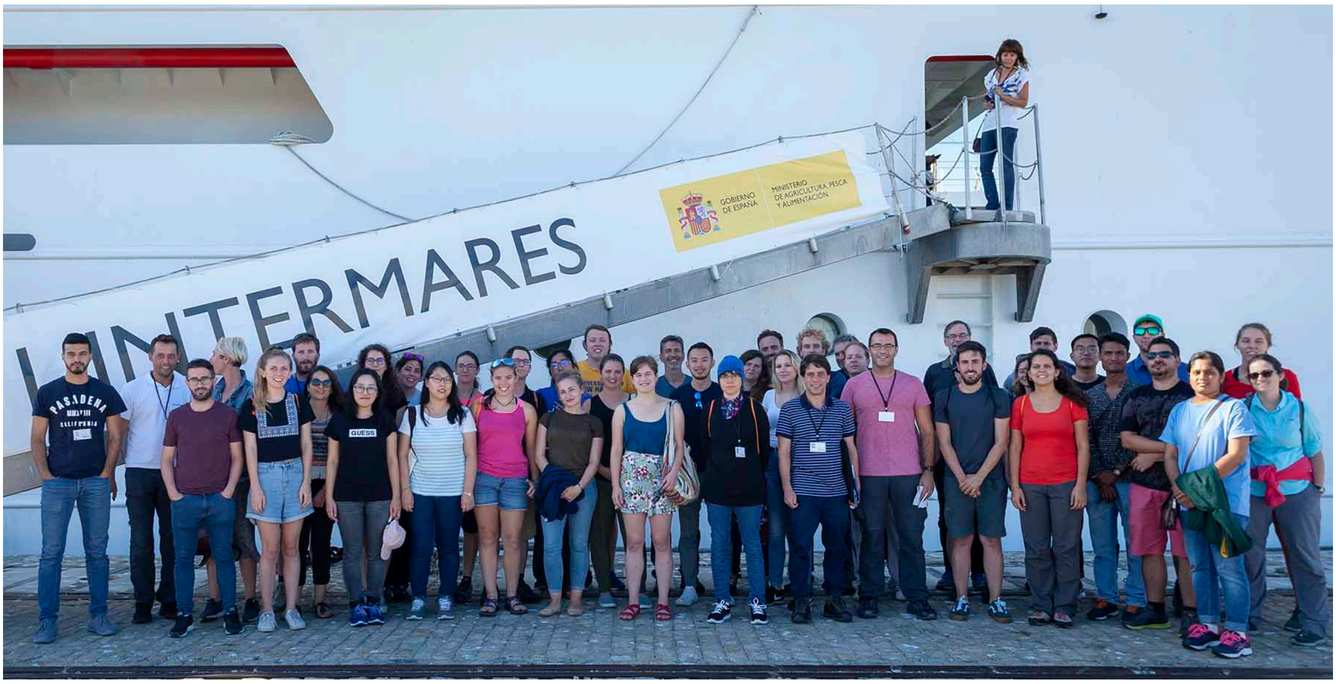


Figure 10: 2019 GEOTRACES Summer School participants

3.6 Special sessions at international conferences featuring GEOTRACES findings

Several GEOTRACES special sessions were held or are planned in major international conferences including:

SOLAS Open Science Conference, 21-25 April 2019, Sapporo, Japan
For further information: https://www.confmanager.com/main.cfm?cid=2778

GEOTRACES session:

*Atmospheric deposition of iron, ocean biogeochemistry and marine emission of biological aerosols
Conveners: Akinori Ito (JAMSTEC), William M. Landing (Florida State University) and Douglas S. Hamilton (Cornell University)

27th IUGG General Assembly, 8-18 July, 2019, Palais des Congrès in Montréal, Québec, Canada

GEOTRACES relevant sessions:

*P02 Physics and biogeochemistry of semi-enclosed, shelf seas and coastal zones
Conveners: Peter Zavialov, Jianping Gan, Osmar Moller Jr, Katrin Schroeder

*P09 Marine biogeochemistry through time: nutrient, trace metal, oxygen, and carbon cycling in the past, present and future
Conveners: Kate Hendry, Zanna Chase, Katja Fennel and Patrick Rafter

Goldschmidt 2019, 18-23 August 2019, Barcelona
For further information: https://goldschmidt.info/2019/
GEOTRACES or GEOTRACES-related sessions:

*10c: Arctic and sub-Arctic Large Scale Ocean Processes: What can We Learn from Tracers?
Conveners: Núria Casacuberta, Michael Karcher

*10j: Biogeochemical Cycles of Low Oxygen Zones and their Response to Ocean Deoxygenation
Conveners: Nicole Bale, Darci Rush, Ruifang Xie, Tim Conway, Insa Rapp, Laura Bristow

*10k: Trace Metal Cycling and Radioisotope Tracers of Ocean Biogeochemistry (GEOTRACES)
Conveners: Aridane G. González, Hannah Whitby, Amber Annett, Emilie Le Roy

*08m: Wally Broecker: A Scientific Celebration of a Life in Geochemistry
Conveners: Sidney Hemming, Edouard Bard, Sigurdur Gislason, Roberta L. Rudnick

It included the GEOTRACES talk:
GEOTRACES: Inspired by GEOSECS to Investigate Trace Elements and their Isotopes in the Ocean, Anderson R, Francois R, Frank M, Henderson G, Jeandel C & Sharma M

*08f: The Role of Carbon in Regulating Climate States: Lessons from Earth's Past
Conveners: Kate Littler, Gerhard Kuhn, Norbert Frank, Thomas Chalk, William Gray

Keynotes: Jessica Tierney (University of Arizona), Robert (Bob) Anderson (LDEO - Columbia Univ.)

*10a: Linking Marine Silicate Alteration to Carbon Cycle and Trace Elements Budgets in the Ocean and Sediment
Conveners: Wei-Li Hong, Jianghui Du, Antoine Crémière
Keynote: Catherine Jeandel

*10h: The Oceanic Particle Flux and its Cycling within the Deep Water Column
Conveners: Maureen Conte, Rut Pedrosa Pamies, Phoebe Lam, Henry Ruhl

*12a: Hydrobiogeochemical Processes at the Sediment-Water Interface: Wetlands, River Corridors and Coastal Zones
Conveners: Dipankar Dwivedi, Xingyuan Chen, Joseph Tamborski, Valentí Rodellas, Edward O'Loughlin, Yamin Deng, Virginie Sanial
Keynote: Christof Meile

*13e: Radionuclides in the Environment: Modeling, Experimental, Scaling, Controlling Chemical/Microbial/Hydrological Processes
Conveners: Peter H. Santschi, Daniel Kaplan

*13f: Trace Elements Speciation: Novel Methodologies and Insights into Transformations Influencing their Global Biogeochemical Cycle
Conveners: Sylvain Bouchet, Adrien Mestrot

2020 Ocean Sciences, 16-21 February 2020, San Diego, California, USA.
For further information: https://www.agu.org/Ocean-Sciences-Meeting
GEOTRACES or GEOTRACES-related sessions:

*Revealing Biogeochemical Processes on Basin Scales through Ocean Transects
Primary Chair: Gregory A Cutter, Old Dominion University.
Co-chairs: Phoebe J Lam, University of California Santa Cruz; Karen L Casciotti, Stanford University; Rob Middag, Royal Netherlands Institute for Sea Research.

*Linking the biology, geochemistry, and circulation of the Gulf of Mexico
Primary Chair: Angela N Knapp, Florida State University.
Co-chairs: Alan M Shiller, University of Southern Mississippi; Heather M Benway, Woods Hole Oceanographic Inst.; Juan Carlos Herguera, Center for Scientific Research and Higher Education at Ensenada.

*Controls on trace metal biogeochemistry and physicochemical speciation in seawater
Primary Chair: Hannah Whitby, IUEM Institut Universitaire Européen de la Mer.
Co-chairs: Randelle M Bundy, University of Washington; Jessica N Fitzsimmons, Texas A & M University College Station; Andrea Koschinsky, Jacobs University Bremen.

*Biogeochemical cycles in oxygen minimum zones: mechanisms, drivers, and change
Primary Chair: David Janssen, University of Bern.
Co-chairs: Daniele Bianchi, University of California Los Angeles; Thomas S Weber, University of Rochester.

*Autonomous observing systems for macronutrients and bioactive trace metals in coastal and open ocean settings: present status, challenges and emerging technologies
Primary Chair: Maxime Grand, Moss Landing Marine Laboratories.
Co-chairs: Andrew R Bowie, University of Tasmania; Agathe Laes-Huon, IFREMER; Alexander Beaton, National Oceanography Center, Soton.

*Towards BioGeoSCAPES: Exploring molecular drivers of ocean metabolism and biogeochemistry
Primary Chair: Benjamin S Twining, Bigelow Lab for Ocean Sciences.
Co-chairs: Erin Marie Bertrand, Dalhousie University; Martha Gledhill, GEOMAR Helmholtz Centre for Ocean Research; Naomi Marcil Levine, University of Southern California.

*The role of micronutrient cycles in global-scale dynamics
Primary Chair: Andy Ridgwell, University of California Riverside.
Co-Chair: Alessandro Tagliabue, University of Liverpool

*Understanding Rare Earth Element (REE) distributions and isotopic ratios and the mechanisms behind their use as tracers of (paleo)oceanic processes
Primary Chair: Brian A Haley, Oregon State University
Co-chairs: Torben Stichel, Alfred Wegener Institute Helmholtz-Center for Polar and Marine Research Bremerhaven; Johan Schijf, University of Maryland Center for Environmental Science; Vanessa Hatje, Universidade Federal da Bahia.

Forthcoming:

Virtual Goldschmidt 2020, 21-26 June 2020
For further information: https://goldschmidt.info/2020/

GEOTRACES session:

*14m: Biogeochemical Cycling of Trace Elements and their Isotopes in the Oceans (GEOTRACES)
Conveners: Tim Conway, Mariko Hatta, Nick Hawco
Keynote: Brandy Toner
Invited Speakers: Jun Nishioka, Sam Wilson

3.7 Capacity building

Activities GEOTRACES continues to apply its strategy to organise training workshops the day or the two-days immediately before or after a SSC meeting in order to increase the local impact of these meetings. During the reporting period, two of such worhsops have been organised: the Worshop Exploring GEOTRACES Data with ODV and the Southern Biogeochemistry Workshop, see GEOTRACES Workshops above for further details). Note that SSC meetings are also an occasion for a fruitful exchange with local scientists and often-parallel scientific meetings are organised during the breaks all along the SSC meeting.

Travel Grants GEOTRACES has requested support from SCOR to enable scientists from developing countries and countries with economies in transition to participate in the second GEOTRACES Summer School. GEOTRACES is thankful to SCOR for the funding received.

Sampling Systems   It is a goal of GEOTRACES that every nation carrying out oceanographic research should have access to a trace metal-clean sampling system. GEOTRACES offers guidance based on past experience in the design and construction of sampling systems, as well as advice in operating these systems as shared facilities. At the time of writing this review, a document "Recommendations for nations developing a trace metal-clean sampling system" is being prepared by Greg Cutter (Old Dominion University, past S&I co-chair). This document will summarise the lessons learned during past guidance experiences and it will be of great resource for other countries wishing to develop trace metal-clean sampling. This document will be available on the GEOTRACES Capacity Building web page http://www.geotraces.org/science/geotraces-activities.

An updated status of trace metal-clean sampling systems to support GEOTRACES research is provided in the table below (in blue new additions since last reporting period). Scientists interested in developing one of these systems for their own use are encouraged to contact the GEOTRACES IPO or any member of the SSC, who will arrange for contact with an appropriate person to provide technical information about the design, construction and cost of a system.

Nation	Status	System/ Carousel	Bottles	Depth
Australia (Australia National University)	Complete	Powder coated aluminium, autonomous 1018 intelligent rosette system (General Oceanics)	12 x 10-L Teflon-lined Niskin-1010X (General Oceanics)	6000 m; 6 mm Dynex rope
Australia (Marine National Facility)	Complete	Polyurethane powder-coated aluminium autonomous Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 12-L Teflon-lined OTE external-spring Niskin-style bottles	1750 m 9mm Dyneema rope or 200 m 6 mm Dyneema rope wth coupling to 6000 m CTD wire
Australia (Marine National Facility)	Complete (backup system)	Polyurethane powder-coated aluminium autonomous Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 12-L Teflon-lined OTE external-spring Niskin-style bottles	1750 m 9mm Dyneema rope or 200 m 6 mm Dyneema rope wth coupling to 6000 m CTD wire
Brazil	Complete	GEOTRACES WATER SAMPLER - 24-bottle sampler for use with modem equipped 911plus CTD	24 X 12-L GO-Flo	3000 m; Kevlar cable
Canada	Complete	Powder coated aluminium with titanium CTD housing, Seabird Rosette	24 X 12-L GO-Flo	5000 m conducting Vectran
China - Beijing	Complete	Seabird Rosette. Powder coated aluminium with titanium pressure housings and fittings	24 x 12-L OTE GO-Flo; 24 X 12-L Teflon-lined Niskin-X	8000 m; conducting Kevlar
China - Taipei	Complete	Teflon coated rosette	Multi- size GO-Flo	3000 m; Kevlar line

France	Complete	Powder coated aluminium with titanium pressure housing for CTD	24 X 12-L GO-Flo	8000 m; conducting Kevlar
Germany	Complete	Powder coated aluminium with titanium pressure housings and fittings	27 x 12-L OTE GO-Flo	8000 m; conducting Kevlar
India	Complete	Powder coated aluminum with titanium pressure housings and fittings	24 X 12-L Niskin-X	8000 m; conducting Kevlar
Israel	Complete	Powder coated aluminium, SeaBird Rosette	12 X 12-L Niskin; 8 X 12-L GO-Flo (Teflon coated)	2000 m, steel conducting cable
Italy	Complete	Go-Flo bottles on Kevlar line	5 x 20-L Go-Flos	Kevlar
Japan	Complete	Powder coated aluminium	12-L Niskin-X	7000 m; Vectran conducting Cable
Netherlands	Complete	Titanium frame	24 X 24-liter ultraclean polypropylene	10000 m; conducting Kevlar* *There is only one cable for the two systems*
Netherlands	Complete	Titanium frame	24 X 24-liter ultraclean PVDF	10000 m; conducting Kevlar* *There is only one cable for the two systems*
New Zealand	Complete	Powder coated aluminium	13 X 5-L Teflon-lined Niskin-X; 13 X 5GO-Flo	4000 m; 8 mm Kevlar line
Norway	In development	Standard 12 positions CTD Rosette GO	Six 5-L Niskin-X	1000m steel conducting cable
Poland	Complete* (although the steel cable)	Powder coated aluminum, SeaBird Rosette	8x 10L GoFlo	3000m, steel conducting cable
Poland	Complete	Single bottle	10l G-FLO X Teflon coated	300m Kevlar
Poland	Complete	Teflon pump on-line	Surface water pump	1.5m fixed
Poland	In development	Pump CTD	Teflon hose 10mm	Up to 200m
Republic of Korea	Complete	Titanium frame PRISTINE	24 × 12L PVDF	10,000 m; conducting Kevlar
Russia	Complete* (although the steel cable)	Powder coated aluminium, SeaBird Rosette SBE9p occupied CTD SBE 9+	24 × 12-L Niskin bottles	4000 m, steel conducting cable

Russia	In development (by 2021–2024)	Powder coated aluminium, SeaBird Rosette and all titanium housings and fittings	GO-FLO, Niskin-X, 24 × 12-L	10000 m, conducting Kevlar
South Africa	Complete	Powder coated aluminium, titanium housing/fittings	24 X 12-liter GO-Flo	6500 m; Kevlar cable
South Korea	Complete	Titanium frame	24 × 12L PVDF	10,000 m; conducting Kevlar
UK	Complete	2 x Titanium frame, Ti pressure housings	24 10-L OTE 24 10-L OTE	2 x 8000m conducting Kevlar
USA - CLIVAR	Complete	Sea-Bird GEOTRACES Powder-coated aluminium	12 X 12-L GO-FLO	1500 m; conducting Vectran cable
USA - GEOTRACES	Complete	Seabird GEOTRACES Powder-coated aluminium with titanium pressure housings and fittings	24 X 12-L GO-FLO	7000 m conducting Vectran cable
USA- University of Alaska Fairbanks	Complete	Sea-Bird GEOTRACES Powder-coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	No Kevlar line available yet.
USA – University of South Florida	Complete	Sea-Bird GEOTRACES Powder-coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 12-L OTE Niskin-X	3000 m 0.25” Amsteel wire
USA- Old Dominion University	Complete	Sea-Bird GEOTRACES Rosette. SBE-19plusV2 CTD unit. Powder coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	2000 m 0.5-inch Kevlar wire
USA – Polar Programs	Complete	Sea-Bird GEOTRACES Powder-coated aluminium with titanium pressure housings and fittings	12 X 12-L Niskin-X	3500 m; conducting Vectran cable
USA – Scripps Institution of Oceanography	Complete	Sea-Bird painted aluminium with stainless pressure housing (standard system). Fires at pre-programmable depths	12 X 10-L Niskin-X 12 X 5-L Niskin-X	2000 m Amsteel cable and 2000 m Space-Lay coated metal cable
USA – Woods Hole Oceanographic Institution	Complete	Sea-Bird painted aluminium with stainless pressure housing (standard system). Fires at pre-programmable depths	12 X 8-L Niskin-X	4000 m Amsteel cable

4. Plans for the coming year

Towards Intermediate Data Product 2021
Major GEOTRACES effort will be devoted to the release of the third GEOTRACES IDP in July 2021. In parallel, the GEOTRACES DOoR interface will continue to evolve to add new services for the GEOTRACES community.
Also, GEOTRACES plans to continue advancing the GEOTRACES field programme, although the COVID-19 pandemic that has perturbed cruise plans for the coming reporting period. In this sense, all the cruises scheduled for 2020 that had to be cancelled have been or will be re-scheduled to another date in 2021 or 2022.

Capacity building through GEOTRACES Summer Schools
Following the successful GEOTRACES Summer Schools organised in 2017 and 2019, GEOTRACES plans to pursuit its two-year strategy and hold its third summer school in 2021 (tentatively in 28 June – 2 July 2021) in Bremerhaven, Germany, organised by Walter Geibert (AWI-Bremerhaven). The preliminary estimate is that this summer school could host about 50-60 participants.

Scientific workshops
GEOTRACES plans to continue its synthesis efforts initiated by the suite of three synthesis workshops (in 2015, 2016 and 2018, http://www.geotraces.org/science/synthesis-of-results) by organising a synthesis workshop on sensitivity to trace elements and isotopes cycles to global change to be held in 2021 at Hanse-Wissenschaftskolleg Institute for Advanced Study (HWK) in Delmenhorst, Germany. This workshop will be driven by Walter Geibert, and it will combine new knowledge gained from GEOTRACES with the latest models of TEIs. The workshop should also continue the efforts in bringing together the observational and modelling communities fostered by the three Data-Model Synergy Workshops that GEOTRACES organised in 2007, 2009 and 2011. In any case, the synthesis will continue to respond to the expectation that GEOTRACES results benefit other oceanographic disciplines.

BioGeoSCAPES effort
GEOTRACES investigators continue to provide advice and recommendations, as appropriate, to help launch this new programme. A complete report on the activities completed by the BioGeoSCAPES is available in the annex of this report.

Acknowledgements

Once more, we wish to express our immense gratitude to SCOR, and very especially to Ed Urban on his role of Executive Director during the past years. His continuous support and valuable advice generously given has been essential for the successful implementation of the GEOTRACES programme. At the same time, GEOTRACES warmly welcomes Patricia Miloslavich as new SCOR Executive Director and greatly thanks her for the SCOR continuous support. We wish Patricia plenty of success in this new position.

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Alessandro Tagliabue and Bill Landing (Co-Chairs of the GEOTRACES DMC Committee)
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SOLAS – Ocean/atmosphere interactions

SOLAS Annual Report to SCOR

Reporting period: May 2019 - May 2020
Version of 07 June 2020 by Jessica Gier

I. SOLAS Mission and Organisation

The SOLAS mission is:
To achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and the atmosphere, and of how this coupled system affects and is affected by climate and environmental change.

The 2015-2025: Science Plan and Organisation organised this mission around five core themes:
Core Theme 1: Greenhouse gases and the oceans
Core Theme 2: Air-sea interface and fluxes of mass and energy
Core Theme 3: Atmospheric deposition and ocean biogeochemistry
Core Theme 4: Interconnections between aerosols, clouds, and marine ecosystems
Core Theme 5: Ocean biogeochemical control on atmospheric chemistry
In addition, the study of these themes are integrated in efforts to understand key environments, e.g. upwelling systems, polar oceans, and the Indian Ocean, as well as to evaluate the environmental efficacy and impacts of climate intervention proposals, policy decisions, and societal developments. The SOLAS 2015-2025: Science Plan and Organisation (SPO) is available to download from the SOLAS website (https://www.solas-int.org/science/science-plan.html), and hardcopies are available upon request from the IPO.

With the launch of the new science plan in 2015, SOLAS chose to use a pragmatic approach to the implementation strategy with a continually-evolving live document developing plans at least 2 years into the future. This approach means that the document is a moving target that is regularly updated. The implementation strategy is intended to be a live web-based document only and a new version will be available for download from the SOLAS website soon at: https://www.solas-int.org/science/implementation-strategy.html

The latest iteration of the Implementation Strategy was released online in April 2018 and the update for 2020 is in progress.

Upcoming SOLAS activities include:
Future Earth Summit 2020, virtual, 15-17 June, 2020
Workshop to organise global scientific oversight community on climate intervention, summer 2020
6th International Marine Conservation Congress, virtual, 22-28 August, 2020
BEPSII annual meeting, virtual, 24-28 August, 2020
Annual SOLAS Scientific Steering Committee meeting 2020, virtual or face-to-face, Sept., Oct., or Nov. 2020
AGU, San Francisco, USA, 7-11 December, 2020
XMAS-V Symposium on Multidisciplinary Sciences Can Serve a Sustainable and Healthy Ocean, Xiamen, China, 11-14 January, 2021
BEPSII & ECV-Ice annual meetings, in conjunction with Gordon Research Conference - Polar Marine Science, Ventura, CA, USA, May 2021
ECV-Ice intercalibration experiment, Cambridge Bay, Canada, April 2021
BEPSII Winter School, Cambridge Bay, Canada, May 2021

8th International Symposium on Gas Transfer at Water Surfaces, Plymouth, UK, **18-21** May, 2021
8th international SOLAS Summer School, Cape Verde, 7-18 June, 2021
Sustainability Research and Innovation Congress (SRI2021), Brisbane, Australia, **12-15 June, 2021**
GEOTRACES - SOLAS workshop on Iron at the Air-Sea Interface, Ashville, North Carolina, USA, July 26-29 or August 2-6 2021
16th IGAC Science Conference, Manchester, UK, 12-16 September, 2021
SCOR Working Group 155, EBUS summer school, Dakar, Senegal, 2021
GESAMP Working Group 38 workshop on Atmospheric Input of Chemicals to the Ocean – Management Implications, Port Elizabeth, South Africa, 2021
International Indian Ocean Science Conference (IIOSC), Goa, India, 2021
South American SOLAS symposium, 2021
Workshop connecting the Southern Ocean Projects, 2021
Open workshop on How Can SOLAS Science Best Inform on Climate Intervention Proposals, 2021
Synthesis workshop on pan-Arctic expeditions, 2021
SOLAS Open Science Conference, Cape Town, South Africa, 2022

II. Progress on implementation of project science

II.a. Integrated activities across all SOLAS science

SOLAS Summer School
The first SOLAS summer school took place in July 2003 in Cargèse, France. The success of this first school was such that the SOLAS summer school became a regular, highly successful, and productive event. SOLAS is proud to have offered 7 schools between 2003 and 2018, training more than 500 students. The 2021 edition of the school will take place at the Ocean Science Centre Mindelo, Mindelo, Cabo Verde (https://www.oscm.cv/), from 7-18 June 2021. It will bring together 70 early career scientists from diverse countries with about 20 world-leading international scientists, for a mix of plenary lectures and hands-on practical workshops. Christa Marandino from GEOMAR, Kiel, Germany will again be the director of the summer school.

SOLAS Network of Integrated Atmosphere-Ocean time-series stations
Numerous efforts are underway around the globe to integrate atmospheric and oceanic time series stations to better understand ocean-atmosphere interactions. To better facilitate collaboration and capacity building between these air-sea observatories, SOLAS has launched an initiative to form a network of scientists running and building such stations. A discussion session at the 2019 SOLAS Open Science Conference brainstormed ways the community should work together (see SOLAS Event Report, Issue 14), and SOLAS just implemented a formal endorsement process for integrated air-sea time series programs. In addition, an international collaborative proposal is being prepared, with SOLAS support, to upgrade the observatories at Cape Verde to include a dedicated air-sea interaction spar, providing direct information on fluxes and the sea-surface microlayer.

Collaboration with the European Space Agency (ESA)
The long-standing and fruitful collaboration between ESA and SOLAS is continuing on a number of fronts. An ESA-SOLAS session on "***Remote Sensing of the Ocean Surface and Lower Atmosphere - a SOLAS Session"*** was held at the ESA Living Planet Symposium ***at the ESA Living Planet Symposium, Milan, Italy,*** 12-16 May, 2019. Following that session, a Special Issue in the journal Remote Sensing on 'Remote Sensing of Air-Sea Fluxes' is being planned, with deadline on 31 August 2020. An ESA-SOLAS satellite-focused discussion session will be held at the ***8th International Symposium on Gas Transfer at Water Surfaces, Plymouth, UK, 18-21*** May 2021. Topics of particular joint interest

between SOLAS and ESA include the physical and chemical dynamics of upwelling regions and air-sea interactions in polar oceans and coastal waters.

Ocean Carbon & Biogeochemistry (OCB) Ocean-Atmosphere Interaction Subcommittee
https://www.us-ocb.org/about/ocb-subcommittees/subcommittee-on-ocean-atmosphere-interactions/
The Ocean Atmosphere Interaction Committee (OAIC) was formed by OCB to coordinate research on ocean-atmosphere interactions and their role in marine biogeochemical cycles. The subcommittee held a workshop on "Ocean-Atmosphere Interactions: Scoping directions for U.S. research", in October 2019 in Sterling, VA, USA (https://web.whoi.edu/air-sea-workshop/). The goal of this workshop was to bring together members of the U.S. air-sea research community to facilitate new collaborations and identify knowledge gaps and high-priority science questions to motivate innovative research and contribute to international SOLAS efforts. The workshop included 59 members of the air-sea research community and representation from NSF, NASA, and the US Carbon Cycle Science Program. The OAIC will assemble a grassroots document to help coalesce the U.S. air-sea interaction research community around a common set of science goals and research priorities. The workshop and its outcomes are expected to strengthen ties between the ocean and atmosphere research communities and foster a more cohesive U.S. contribution to international SOLAS.

II.b. Progress on Core Themes

SOLAS/IMBER Ocean Acidification Working Group (SIOA)
https://www.solas-int.org/science/sponsored-science.html
The SOLAS/IMBER Ocean Acidification (SIOA) working group provides a key advisory role to the Ocean Acidification International Coordination Centre (OA-ICC) at the International Atomic Energy Agency in Monaco. In 2019, the SIOA/IAEA OA-ICC continued to act as an international coordination platform for ocean acidification research and collaboration by
Ensuring that scientists have access to recently updated, state-of-the-art software to calculate ocean acidification parameters, and that ocean acidification data collected across the globe are properly archived, accessible, and comparable. This is particularly relevant in the context of reporting from countries on the UN SDG 14.3.
Acting as a hub for global stakeholders interested in ocean acidification, providing unique resources such as a comprehensive bibliographic database and a news stream updated daily with info on ocean acidification scientific articles, media coverage, jobs, and meetings.
Providing increased awareness about ocean acidification with contributions to major reports and working groups, highly visible international events and meetings, training courses, the OA-ICC web site, news stream, and communication products.
Contributing to the development of international and regional coordination activities and networks, such as GOA-ON, LAOCA, and OA-AFRICA.
Contributing to methodology development for UN SDG14.3 on Ocean Acidification and helping countries to get ready to report towards that target.
The largest OA community meeting, "The Ocean in a High CO_2 World", has been postponed to 2021. The 2019 SIOA and OA-ICC annual meeting took place in Monaco on 27-28 May. The 2020 annual meeting has been postponed and will take place in conjunction with "The Ocean in a High CO_2 World" in 2021.

Integrated Ocean Carbon Research (IOC-R)
https://www.solas-int.org/science/sponsored-science.html
The Working Group on Integrated Ocean Carbon Research (IOC-R) was initiated in 2018, and is coordinated by the Intergovernmental Oceanographic Commission (IOC), with involvement of the

carbon cycle and ocean science expert community. The first in-person workshop of IOC-R, took place at IOC-UNESCO in Paris, France, in October 2019. This expert workshop aimed to:
Identify critical knowledge gaps in the ocean carbon cycle;
Identify research activities in order to close this gap;
Bridge science and policy through contributions to The United Nations Decade of Ocean Science for Sustainable Development (2021-2030), the United Nations Framework Convention on Climate Change and its Paris agreement, and the Intergovernmental Panel on Climate Change 6th Assessment Report.
A high-level white paper is being written that will contribute to the Ocean and Climate Dialogue under the UN Framework Convention on Climate Change's scientific body (SBSTA). The white paper will outline an IOC-R science plan, and will focus on a range of issues to include: (i) priority research questions and their linkages; (ii) synergies with other initiatives; and (iii) societal and policy implications and applications. A summary of the white paper will be a submitted to the UNFCCC call (cf. UNFCCC 1/CP.25 decision, paras. 31, 33, and 34).

Collaborations with GEOTRACES
A discussion session on 'Atmospheric deposition of iron, ocean biogeochemistry and marine emission of biological aerosols' was held at the SOLAS Open Science Conference in April 2019 in Sapporo, Japan. Following this session, a GEOTRACES - SOLAS workshop was planned for summer 2020 on Iron at the Air-Sea Interface, in Ashville, North Carolina, USA. This workshop has been postponed to July 26-29 or August 2-6, 2021.

Collaboration with PICES
A SOLAS session on 'Atmospheric nutrient deposition and microbial community responses, and predictions for the future in the North Pacific Ocean' has been organised as part of the PICES annual meetings. A virtual session of scientific presentations is planned for the 2020 virtual meeting, to be followed by a face-to-face meeting at the 2021 PICES meeting, to foster collaborations among the Asian and North American communities.

New Initiatives in Atmospheric Chemistry
In collaboration with the International Global Atmospheric Chemistry (IGAC) program, SOLAS has launched a scoping exercise to identify critical science on which our two organisations should collaborate. Although the discussions are on-going, initial proposals include tropospheric halogen-ozone interactions, atmospheric processing of nutrients and pollutants deposited to the ocean, interactions between marine and anthropogenic aerosols, and photochemical production of climatically-active materials in the surface ocean.

II.c. Progress on Cross-cutting Themes

Biogeochemical Exchange Processes at Sea Ice Interfaces (BEPSII)
http://www.bepsii.org
Biogeochemical Exchange Processes at Sea-Ice Interfaces (BEPSII) started in 2011 with a focus on sea-ice biogeochemistry, was a SCOR working group from 2012 until September 2016, and has since been endorsed as a SOLAS-CliC Activity (from 2016) and as a SCAR Action Group (from 2017). Following a workshop in Switzerland in 2018, the BEPSII community submitted a Position Analysis on 'Arctic sea-ice biogeochemical responses to climate change' to Nature Communications. A targeted 3-day workshop was held in Paris, France, in May 2019 with participants in the intercomparison of 1-D sea-ice biogeochemical models project (8 scientists present). In 2019, 2 early-career scientists (ECSs) were appointed to the SSC. The annual BEPSII meeting took place in Winnipeg, Canada, 16-18 August 2019 (SOLAS Event Report, Issue 16). A BEPSII winter school is being planned for 27 graduate students to be held in May 2021 in Cambridge Bay, Canada. The annual BEPSII meeting for 2020 has

been moved on-line, but SOLAS will support the 2021 annual meeting, which is planned in conjunction with the Gordon Research Conference on Polar Marine Science, in Ventura, CA, USA in May 2021.

Cryosphere and Atmospheric Chemistry (CATCH)
https://sites.google.com/view/catchscience/home
Cryosphere and Atmospheric Chemistry (CATCH), cosponsored by SOLAS and the International Global Atmospheric Chemistry (IGAC) program, facilitates atmospheric chemistry research within the international community, with a focus on natural processes specific to cold regions of the Earth. CATCH defined and sharpened its mission and scope during the past year, which resulted in a peer-reviewed commentary (Thomas et al., 2019). A 2-day CATCH science workshop prior to AGU in December 2019 was organised with 44 scientists (SOLAS Event Report, Issue 17). The CATCH SSC holds monthly tele-conferences to discuss updates and planning of activities, and held their first annual physical meeting right after the CATCH December 2019 workshop. A CATCH working group structure has been developed and will be implemented in 2020 in order to push CATCH actions and science forward. The six working groups are on Data, Models, Lab Approaches, Field Campaigns, Outreach, and Community Building.

Climate Intervention
Following our successful workshop in Sapporo, Japan, in spring, 2019, SOLAS is building a coalition of global research programmes to form a scientific oversight community on geoengineering. The intent is to provide a forum through which the efficacy and potential side effects of climate intervention proposals can be evaluated, as well as to explore governance concerns. An initial workshop with leaders of key programs is being planned for summer 2020.

Capacity building in Ocean Deoxygenation
In collaboration with the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organisation (UNESCO), SOLAS co-sponsored the 1st International Global Ocean Oxygen Network (GO_2NE) Summer School, held in Xiamen, China, 2-8 September 2019 (see SOLAS Event Report, Issue 15). The summer school was designed to connect young researchers with leading scientists in different components of GO_2NE research, and scientists from small and medium-sized enterprises not only in a theoretical framework, but also through practical exercises, laboratory experiments and special sessions. Altogether, brought together 37 PhD students and early career scientists from 19 countries and 14 world-leading international scientists from 12 countries participated.

The Indian Ocean
A joint SOLAS-IIOE-2 workshop was planned for the International Indian Ocean Science Conference (IIOSC-2020) in Goa, India. The intent was to both discuss SOLAS science being conducted in the Indian Ocean and to revitalise the SOLAS community in India. With the IIOSC postponed to 2021, we are now organising an online event.

Contributions to the UN Ocean Decade

SOLAS participated in the First Global Planning Meeting of the Preparatory Phase of the UN Decade of Ocean Science for Sustainable Development, Copenhagen, Denmark, 13-15 May 2019. In addition, SOLAS SSC members attended the webinar on ‘Introduction to the Draft Implementation Plan for the Ocean Decade’ in March 2020. SOLAS provided feedback to the UN Decade Implementation Plan (Zero Draft) and the organising committee of SOLAS summer school plans to apply for formal UN Ocean Decade endorsement for the event.

III. Summary of 2019-2020 SOLAS activities

III.a. SOLAS events:

Journée Future Earth, Paris, France, 9 May 2019
First Global Planning Meeting of the Preparatory Phase of the UN Decade of Ocean Science for Sustainable Development, Copenhagen, Denmark, 13-15 May 2019
Ocean KAN meeting, Copenhagen, Denmark, 16 May 2019
iCACGP annual meeting, Montreal, Canada, 6-8 July, 2019
BEPSII annual meeting at the IGS Sea Ice Symposium, Winnipeg, Canada, 16-18 August, 2019
Global Ocean Oxygen Network (GO_2NE) summer school, Xiamen, China, 2-7 September 2019
Shipping & the Environment II, Gothenburg, Sweden, 4-6 September, 2019
OceanObs'19, Hawai'i, USA, 16-20 September 2019
SCOR annual meeting, Toyama, Japan, 23-25 September 2019
IGAC SSC meeting, Mexico City, Mexico, 29-30 October 2019
CATCH annual meeting at the AGU, San Francisco, USA, 9-13 December 2019
CATCH Open Science workshop, Berkeley, USA, 7-8 December 2019
SCOR China annual meeting, Sanya, Hainan, China, 19-20 December 2019
Ocean Science Meeting, San Diego, USA, 16-21 February 2020
EGU, GESAMP / iCACGP / SOLAS session on "Air-sea Chemical Fluxes : Impacts on Biogeochemistry and Climate", virtual, 4-8 May 2020
WCRP JSC meeting, virtual, 18-20 May, 2020
SOLAS SSC discussions on SSC membership, virtual, 27 May and 3-4 June 2020

III.b. SOLAS communications

Website, http://www.solas-int.org/
The SOLAS website has been redeveloped and updated, with a new design and structure.
Newsletter: 12 SOLAS newsletters have been sent to over 1000 SOLAS scientists since the last SCOR report. The monthly newsletter releases compile scientific highlights, news from SOLAS, opportunities for meetings, abstract submission deadlines, recent publications, vacancies, and news from relevant partner projects and collaborators. Past issues of the e-news can be viewed on the SOLAS website: https://www.solas-int.org/news/newsletter-archive.html

Event Report series: Reports on SOLAS sponsored or co-sponsored events are published after each SOLAS-sponsored event. These reports are sent to the SOLAS sponsors and other interested parties and are released in combination with the monthly Newsletters.
https://www.solas-int.org/publications/event-reports.html
Issue 17, March 2020. Cryosphere and Atmospheric Chemistry (CATCH) Open Science Workshop, Berkeley, California, USA, 7-8 December 2019.
Issue 16, November 2019. Biogeochemical Exchange Processes at Sea-Ice Interfaces (BEPSII) annual meeting, Winnipeg, Canada, 16-18 August 2019.
Issue 15, November 2019. Global Ocean Oxygen Network (GO2NE) International Summer School, Xiamen, China, 2-8 September 2019.
Issue 14 July 2019. SOLAS Open Science Conference, Sapporo, Japan, 21-25 April 2019.

Twitter: Regular posts (currently 8020) are being sent out and the number of followers is steadily increasing (currently 786). Twitter: *@SOLAS_IPO*

ResearchGate: Connects the SOLAS research network and includes more than 360 SOLAS-related publications with 147 followers and 822 reads.
https://www.researchgate.net/project/Surface-Ocean-Lower-Atmosphere-Study-SOLAS-2

Flickr: SOLAS public photo stream shows pictures (currently 52) of the most recent SOLAS events and SOLAS related research. In addition, SOLAS distributes event pictures (currently 369) among participants via private links.
https://www.flickr.com/photos/182357030@N02

Outreach: SOLAS figures, conceptual diagrams, 3-fold SOLAS flyer, and logos are available for download from the SOLAS website
https://www.solas-int.org/publications/downloads.html

Presentation: A SOLAS presentation for workshop organisers is available upon request from the IPO.

III.c. SOLAS publications

Please see the SOLAS project on ResearchGate for an extensive list of relevant publications from the community: https://www.researchgate.net/project/Surface-Ocean-Lower-Atmosphere-Study-SOLAS-2

Key integrative SOLAS publications from 2019 and early 2020 are listed below and summarised on the SOLAS website: https://www.solas-int.org/publications/publications.html
Paper resulting from the SOLAS Science and Society kick-off meeting, which took place in October 2016 in Brussels, Belgium: Marandino, C., van Doorn, E., McDonald, N., Johnson, M., Açma, B., Brévière, E. & Thomas, H. (**2020**). From Monodisciplinary via Multidisciplinary to an Interdisciplinary Approach Investigating Air-Sea Interactions – a SOLAS Initiative, *Coastal Management*, DOI: 10.1080/08920753.2020.1773208
ESA Support to Science Element (STSE) initiative, collection of publications (2019 and 2020) (https://www.solas-int.org/publications/publicatios-reader/publications-from-esa-support-to-science-element-initiative.html)
Special issue: NETCARE (Network on Aerosols and Climate: Addressing Key Uncertainties in Remote Canadian Environments) (2019). Overview paper: Abbatt, J. P. D., Leaitch, W. R., Aliabadi, A. A., Bertram, A. K., Blanchet, J.-P., Boivin-Rioux, A. … & Yakobi-Hancock, J. D., New insights into aerosol and climate in the Arctic. Editor(s): L. Bopp, K. S. Carslaw, D. J. Cziczo, and L. M. Russell Special issue jointly organised between Atmospheric Chemistry and Physics, Atmospheric Measurement Techniques, and Biogeosciences, 19, 2527–2560. DOI: 10.5194/acp-19-2527-2019
Gruber, N., Clement, D., Carter, B. R., Feely, R. A., van Heuven, S., Hoppema, M. … & Wanninkhof, R. (2019). The oceanic sink for anthropogenic CO2 from 1994 to 2007, Science, 363(6432), 1193-1199. DOI: 10.1126/science.aau5153
Thomas, J. L., Stutz, J., Frey, M. M., Bartels-Rausch, T., Altieri, K., Baladima, F. … & Gier, J. (2019). Fostering multidisciplinary research on interactions between chemistry, biology, and physics within the coupled cryosphere-atmosphere system. Elementa Science of the Anthropocene, 7:58. DOI: 10.1525/elementa.396

III.d. SOLAS national networks

SOLAS has National Representatives in 30 countries around the globe. The national representatives are asked to report annually on SOLAS activities in their countries. To facilitate the reporting effort, a template form is provided. In June 2020, 11 reports from 2019 had been received and are posted on the SOLAS website. The information contained in the reports is a valuable source of information for the IPO to report to sponsors but also to facilitate coordination and dissemination of results and progress from national projects to the rest of the SOLAS community. Information provided through the reports is also used by the Scientific Steering Committee to develop the implementation strategy.
All reports received during the reporting period are available in an Addendum to this document.
Current national networks:

Australia: Sarah Lawson and Andrew Bowie *
Belgium: Nathalie Gypens *
Brazil: Leticia Cotrim Da Cunha
Canada: Martine Lizotte *
Chile: Laura Farias
China (Beijing): Minhan Dai *
China (Taipei): Chonlin Lee *
Denmark: Lise Lotte Soerensen and Mikael Sejr
Finland: Lauri Laakso *
France: Rémi Losno
Germany: Christa Marandino and Hartmut Herrmann *
India: VVSS Sarma
Israel: Yoav Lehahn *
Ireland: Peter Croot *
Italy: Chiara Santinelli
Japan: Yuzo Miyazaki *
Korea: Kitack Lee
Mexico: Jose Martin Hernandez Ayon
Netherlands: Jan-Berend Stuut
New Zealand: Cliff Law
Norway: Siv Lauvset
Peru: Michelle Graco
Poland: Timo Zielinski
Russia: Sergey Gulev
South Africa: Sarah Fawcett
Spain: Alfonso Saiz-Lopez
Sweden: Katarina Abrahamsson
Turkey: Baris Saglihoglu, Mustafa Koçak, Nazli Olgun
UK: Tom Bell
USA: Rachel Stanley *

* SOLAS has received the 2019 report

III.e. Current endorsed projects and time series
April 2020: Shipping Emissions in the Arctic and North Atlantic Atmosphere (SEANA), www.birmingham.ac.uk/seana
December 2019: Are marine microorganisms influencing clouds? (Sea2Cloud), **https://www.europeandissemination.eu/sea2cloud-by-karine-sellegri-2/2704**
November 2019: Atmospheric Composition and Radiative forcing changes due to UN International Ship Emissions regulations (ACRUISE), https://www.pml.ac.uk/Research/Projects/ACRUISE
October 2019: Atlantic Meridional Transect Ocean Flux from Satellite Campaign (AMT4oceanSatFlux), https://amt4oceansatflux.org/
September 2019: Role of Eddies in the Carbon Pump of Eastern Boundary Upwelling Systems (REEBUS), **https://www.ebus-climate-change.de/reebus**
March 2019: Impact of atmospheric multi-stressors to coastal marine systems in a changing climate scenario (AMBIEnCE), **https://projectambience.wordpress.com/**
October 2017: Processes Influencing Carbon Cycling: Observations of the Lower limb of the Antarctic Overturning (PICCOLO), ***https://roses.ac.uk/piccolo/***
September 2016: The Great Barrier Reef as a significant source of climatically relevant aerosol particles

June 2016: Tudor Hill Marine-Atmospheric Observatory,
http://www.bios.edu/research/projects/tudor-hill-marine-atmospheric-observatory/
November 2015: North Atlantic Aerosols and Marine Ecosystems Study (NAAMES),
http://naames.larc.nasa.gov/
October 2013: Network on Climate and Aerosols: Addressing Key Uncertainties in Remote Canadian Environments (NETCARE), **http://www.netcare-project.ca/**
August 2011: Marine ecosystems response in the Mediterranean experiment (MERMEX),
https://mermex.mio.univ-amu.fr/

SOLAS has launched a formal process to endorse integrated atmosphere-ocean time series stations. Information on all endorsements and the formal application processes is available on the SOLAS website: http://www.solas-int.org/activities/project-endorsement.html.

III.f. SOLAS metadata portal

The SOLAS metadata portal was set up by the SOLAS project integration initiative (2007-2013) with the intention to help SOLAS scientists identify what data exist, where they are stored, and the data originators. The portal is hosted by the BODC, and the metadata files are stored on the international standard Global Change Master Directory (GCMD). The resource is freely available at
https://www.bodc.ac.uk/solas_integration/research_objectives/metadata_portal/
The SOLAS metadata portal is an ongoing effort. Scientists can help expanding the SOLAS metadata base by completing a simple template available at
https://www.bodc.ac.uk/solas_integration/implementation_products/data_submission/

IV. Income and expenses for the past year and budget for the coming year, including funding from all sources (not only SCOR funding)

Executive director salary, office space and in kind provided by GEOMAR until December 2020, 50% salary in 2021.
Project officer salary, office space and in kind provided by NSF funding/GEOMAR via SCOR/GEOMAR until December 2021.
Project officer salary, office space and in kind provided by MEL until September 2020, maybe extended until September 2021.
US-NSF via SCOR annual grant of 32-35kUSD until September 2021. About half to cover the cost of the SSC meetings.
Future Earth annual block grant of 15kEUR contributing to the costs of the SSC meetings.

Income, expenses and budget for 2019-2020:

INCOMES		Credit (EUR)	Debit (EUR)
	Funds and in kind from GEOMAR Helmholtz Center for Ocean Research Kiel	90.000	
	Funds from NSF via SCOR for PO salary	51.000	
	Funds from MEL for PO salary	50.600	
	SCOR-NSF Travel (year 2 and 3)	32.000	
	SCOR-NSF Subsistence (year 2 and 3)	16.000	
	SCOR-NSF Publication (year 2 and 3)	5.200	
	SCOR-NSF Other (year 2 and 3)	3.600	
	NSF grant: For SOLAS Capacity building OSC2019	6.600	
	Hokkaido University for SSC meeting 2019	5.000	
	OSC 2019 - Registration	67.000	
	OSC 2019 - Various sources	12.600	
	Future Earth block grants for SSC meeting 2019 and 2020	30.000	
	IUGG fund via iCACGP for South America capacity building	1.400	
Total Income		371.000	
EXPENSES		**Credit (EUR)**	**Debit (EUR)**
IPO	Salaries		191.600
	Consumables		500
Representational travel			15.000
Capacity building	NSF grant: For SOLAS Capacity building SOLAS OSC - SCOR		6.600
Events	SSC meeting 2019		28.500
	SOLAS OSC, Apr 2019		72.000
	SIOA annual meeting, May 2019		4.300
	GO2NE Summer School, Sep 2019		3.100
	Shipping and the Environment II, Sep 2019		2.600
	BEPSII annual meeting, Aug 2019		4.400
	IOC-R annual meeting, Oct 2019		1.000
	CATCH annual meeting, Dec 2019		4.000
	SSC meeting 2020 - cancelled		5.800
Publications	SOLAS Website subscription 2019 and 2020		160
	SCOR business 2019 and 2020		2.500
	SOLAS Website update		4.800
Total Expenses			346.860
Balance			24.140
Note:			
Many SOLAS events and SOLAS co-sponsored events are postponed to 2021. Thus, funds couldn't be used in 2020 but are committed for 2021.			
This does not include the following items:			
In kind from GEOMAR and MEL with office space/computer/printing/administration etc.			

V. Update on the Scientific Steering Committee and International Project Office status since the last report

IV.a. SOLAS Scientific Steering Committee

Lisa Miller (F, Canada) is the 5th SOLAS SSC Chair, acting for 3 years, from January 2018 through December 2020.
In late 2019, a chair search committee was established, which consists of Katye Altieri, Maurice Levasseur, Phil Boyd, and Jessica Gier. Based on suggestions from the community, the committee compiled a shortlist of chair candidates and requested vision statements from them. The SSC gave their feedback on the statements and the chair search committee will make a decision by mid-June.
SOLAS has an Executive Committee composed of the Chair Lisa Miller (F, Canada), Katye Altieri (F, South Africa), Maurice Levasseur (M, Canada), and Jun Nishioka (M, Japan).
The following SSC members rotated off at the end of 2019:
Phil Boyd (M, Australia)
In January 2020, one new SSC member was appointed:
Andrew Lenton (M, Australia)

Cristina Facchini (F, Italy) and Maurice Levasseur (M, Canada) will complete their second term at the end of 2019. In addition, Laura Gallardo, whose first term will be ending at the end of 2019, has indicated a desire to rotate off the committee. We are currently searching for replacements with relevant expertise.

Arne Körtzinger (M, Germany), Katye Altieri (F, South Africa), Santiago Gassó (F, USA), and Talib Mohd Latif (M, Malaysia) will also finish their first terms at the end of 2019, and we are currently discussing their renewal for a second term.

The current membership of the SOLAS SSC is 17 members including the chair:

Last name	First name	Country of employ-ment	Gender	Scientific expertise	SOLAS expertise	Term	End
Sunthara-lingam	Parvadha	UK	F	Numerical modelling / C, N, S bgc cycles	Theme 1 and 3	2	2021
Körtzinger	Arne	Germany	M	Carbon cycle, Ocean observation	Theme 1, Upwelling	1	2020
Zhang	Guiling	China	F	Bgc of trace gases	Theme 1, Coastal ocean	2	2022
Minnett	Peter	USA	M	Remote sensing, physical air-sea exchange	Theme 2	2	2021
Rutgersson	Anna	Sweden	F	Air-sea physical interaction	Theme 2, Coastal ocean, Science & society, WCRP rep	2	2022
Latif	Mohd Talib	Malaysia	M	Microlayer, atmosph. aerosols	Theme 2 and 5	1	2020
Altieri	Katye	South Africa	F	Atmospheric molecules, climate policy	Theme 3 and 5, Polar oceans, Science & society	1	2020
Lenton	Andrew	Australia	M	Marine bgc	Theme 3, geoengineering	1	2022
Gassó	Santiago	USA	M	Remote sensing, aerosols, dust transport	Theme 3 and 4, NASA connection	1	2020
Levasseur	Maurice	Canada	M	Ocean bgc, dimethylsulfide, Arctic, ice algae	Theme 3 and 4, Polar oceans	2	2020
Gallardo	Laura	Chile	F	Atmospheric modeling, pollutants	Theme 4 and 5, Upwelling, Coastal ocean, Science & society, IGAC	1	2020
Facchini	Cristina	Italy	F	Physical and chemical processes in multiphase atm. systems	Themes 4 and 5, Coastal ocean	2	2020
Ovadnevaite	Jurgita	Ireland	F	Aerosol chem, physics and cloud processes	Themes 4 and 5	1	2021
Mahajan	Anoop	India	M	Atm chemistry, halogens, climate modelling	Theme 5, Indian Ocean	1	2021

Miller	Lisa	Canada	F	Sea-ice bgc and marine inorganic bgc	Theme 2, Polar oceans, PICES connection	1	2020
Nishioka	Jun	Japan	M	Oc. trace metal bgc cycle, Polar oceanography and sea-ice bgc	Theme 3, Polar oceans , Coastal ocean	2	2022
Van Doorn	Erik	Germany	M	Law of the Sea	Science and Society	2	2022

The current gender and country balance of the SSC for 17 members including the chair:
8 female members and 9 male members
4 members from developing countries and 13 from developed countries

IV.b. SOLAS International Project Office

IPO at GEOMAR in Kiel, Germany
The SOLAS IPO is hosted at the GEOMAR Helmholtz Centre for Ocean Research Kiel in Kiel, Germany. Jessica Gier was appointed the Executive Director in April 2018. The salary of the Executive Director and office space for the IPO, are supported by GEOMAR. However, our current sponsorship agreement with GEOMAR ends this coming December, and they have decided that they cannot continue to host the IPO. In order to facilitate a smooth transition, GEOMAR agreed to allow the office to remain in Kiel for one more year (to the end of 2021), but only at half funding. Therefore, we need to find a new host for the IPO by January 1, 2022, and find half of the executive directors salary for 2021.

A proposal to NSF to maintain a Project Officer position at GEOMAR was approved in September 2018, and Esther Rickert was appointed on a half-time basis until December 2021. Every three months, GEOMAR sends an invoice to SCOR, and Esther submits a job description to SCOR. In order to maintain the project officer position, we will apply for it again in the next NSF proposal in spring 2021.
Nodal Office at MEL in Xiamen, China
Minhan Dai (past SSC member) from MEL, Xiamen University supports a SOLAS regional office and an additional Project Officer, Li Li, until September 2020. There is a high chance to extend the contract until Sept. 2021, but this is still in progress.

Possibilities for a new IPO host
Minhan Dai submitted a proposal for hosting the IPO at MEL, Xiamen, China. He agreed also to the possibility of hosting a 'dual IPO'.
Jurgita Ovadnevaite, who is at NUIG in Galway, Ireland, has the possibility to host the IPO, which would include the salary for 1 executive director. It would be connected to developing and administering a 1-year international SOLAS master’s program. The students would spend 3 months at NUIG and then go abroad for a research project. The international SOLAS network would provide hosts for the students.
The SOLAS community in UK (at PML and UEA) is investigating possibilities with NERC.
The SOLAS-OCB subcommittee in the US is investigating possibilities with NASA.
Anna Rutgersson in Sweden is checking options with FORMAS (the national funding agency) and Uppsala University.

IMBeR – Marine biosphere research

IMBeR
Integrated Marine Biosphere Research

Annual Report to SCOR
2019 – 2020

Ocean Sustainability under Global Change
for the Benefit of Society

Table of contents

Introduction

Integrated Marine Biosphere Research (IMBeR) is a marine global change research project co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and Future Earth.

The IMBeR Science Plan and Implementation Strategy (2016-2025) is underpinned by the vision, "*Ocean sustainability under global change for the benefit of society*", which recognises that marine ecosystems (including human systems) are influenced by natural and anthropogenic drivers and stressors, and leads to the IMBeR research goal to "*Understand, quantify and compare historic and present structure and functioning of linked ocean and human systems to predict and project changes including developing scenarios and options for securing or transitioning towards ocean sustainability*".

To implement its vision and goal, IMBeR's mission is to "*Promote integrated marine research and enable capabilities for developing and implementing ocean sustainability options within and across the natural and social sciences, and communicate relevant information and knowledge needed by society to secure sustainable, productive and healthy oceans*".

IMBeR science aims to foster collaborative, interdisciplinary and integrated research that addresses important ocean and social science issues and provides the understanding needed to propose innovative societal responses to changing marine systems. Implementation of the IMBeR Science Plan is underpinned by the two IMBeR International Project Offices. IPO-Canada in Halifax, Canada is sponsored by Dalhousie University, the Ocean Frontier Institute (OFI), the Marine Environmental Observations, Prediction and Response Network (MEOPAR) and the Ocean Tracking Network (OTN). IPO-China is based at the East China Normal University (ECNU) in Shanghai, China supported by the State Key Laboratory of Estuarine and Coastal Research (SKLEC). The IMBeR research goal is progressed through the activities of regional programmes, working groups and endorsed projects, and is facilitated through focussed workshops (IMBIZOs), conferences and symposia, and the training of early career researchers at biennial Climate-Ecosystem (ClimEco) summer schools and other

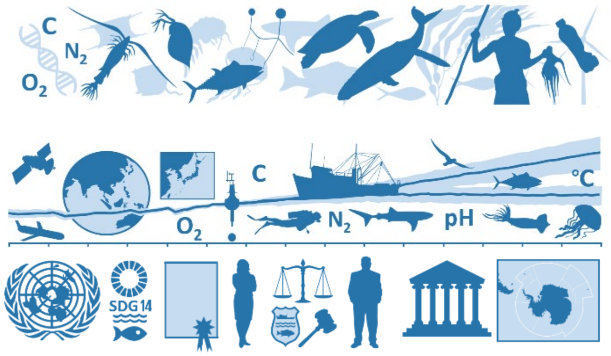
training courses organised by the Interdisciplinary Marine Early Career Network (IMECaN). [Further details at http://www.imber.info]
IMBeR Science Plan and Implementation Strategy (2016-2025)
http://www.imber.info/resources/images/prosjekter/imber/IMBeR-Science-Plan-and-Implementation-Strategy-2017.pdf

The IMBeR Science Plan and Implementation Strategy (SPIS) provides a 10-year (2016-2025) marine research agenda. The SPIS is built around three Grand Challenges (GC) that focus on climate variability, global change and drivers and stressors.

Grand Challenge I:
Understanding and quantifying the state and variability of marine ecosystems

Grand Challenge II:
Improving scenarios, predictions and projections of future ocean-human systems at multiple scales

Grand Challenge III:
Improving and achieving sustainable ocean governance.



The qualitative and quantitative understanding of historic and present ocean variability and change (GCI) is the basis for scenarios, projections and predictions of the future (GCII). These are linked in GCIII - to understand how humans are causing the variability and changes, and how they in turn are impacted by these changes, including feedbacks between the human and ocean systems. Priority research areas with overarching and specific research questions are identified.

Supplementing the GCs are four Innovation Challenges (IC) that focus on new topics for IMBeR where research is needed and where it is believed that major achievements can be made within three to five years. These Innovation Challenges also enable IMBeR to adjust focus as major science discoveries are made and new priorities arise. The science outlined in the Science Plan is progressed through the IMBeR Regional Programmes, Working Groups, Endorsed Projects, conferences and other activities (Fig. 1).

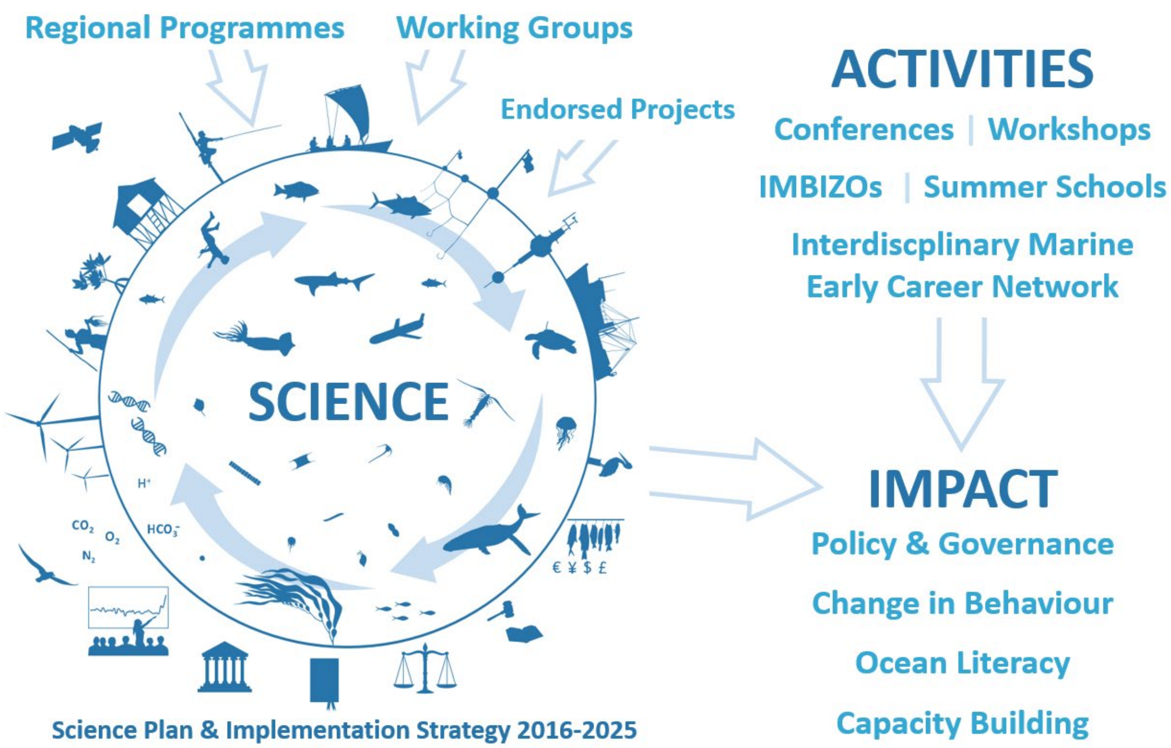


Figure 1. Contribution of the Regional Programmes, Working Groups, Endorsed Projects and IMBeR activities towards addressing the Grand Challenges and Innovation Challenges

Selected science highlights in 2019-2020

Ecosystem Studies of Subarctic and Arctic Seas (ESSAS)

One of the major scientific stories in marine systems of both the Pacific Arctic and the Atlantic Arctic has been the increasing ‘Borealization’ of the Arctic, as evidenced in the northward expansion of boreal species from zooplankton to fish and mammals. This is well documented for the Barents Sea, but has more recently unfolded in the northern Bering Sea and Bering Strait region. An unexpected and, based on the historical record, unprecedented lack of sea ice in recent winters has, among other changes, led to the disappearance of the cold pool of water on the Bering Sea shelf, which typically formed during winter and remained on parts of the shelf throughout summer. The cold pool was completely absent in 2018, and this absence was associated with a northward shift in the distribution of some of the large commercially important stocks such as walleye pollock and Pacific cod. For example, over half of the biomass of Pacific cod occurred in the northern Bering Sea in the summer of 2018. These changes have had profound effects on local communities who rely on subsistence hunting and fishing and are struggling to adapt. These shifts were particularly stark in the Pacific Arctic, where a key Arctic fish species, the polar cod (*Boreogadus saida*) has retreated northward (Marsh and Mueter 2019) as larger, commercial species such as Pacific cod (*Gadus macrocephalus*) and walleye pollock (*G. theragrammus*) have shifted the center of their distribution into the northern Bering Sea.

Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER)

As part of the Second International Indian Ocean Expedition (IIOE-2), "A coupled biophysical, ecosystem-scale, examination of Australia's International Indian Ocean Expedition line" voyage of the RV Investigator in the south-eastern Indian Ocean was successfully completed in June 2019. The scientific team was led by SIBER SSC member Lynnath Beckley (Murdoch University). Michael Landry and Raleigh Hood (SIBER SSC) participated in the voyage. The voyage encompassed 20 stations along the 110°E meridian from 39.5°S to 11.5°S revisiting many historical sampling stations last examined in 1962/63 during the first International Indian Ocean Expedition. In view of documented warming of the surface waters off Western Australia, the aim was to assess change in the physical, chemical and biological properties of the water column at these locations. In addition, using an array of modern techniques, other important aspects such as the distribution of microbes, microbial gene expression, biogeochemistry (especially related to nitrogen and sulphur cycling), pelagic food webs (including meso-pelagic fishes) and bio-optics related to satellite-based ocean colour radiometry of the south-east Indian Ocean were investigated for the first time. The voyage provided an opportunity to train post-graduate students, deploy autonomous Argo floats (Integrated Marine Observing System - IMOS and Japan Agency for Marine-Earth Science and Technology - JAMSTEC) and drifting weather buoys (National Oceanic and Atmospheric Administration - NOAA and Bureau of Meteorology - BOM), measure underwater sound and examine eastward flows feeding into the anomalous Leeuwin Current that flows along the west coast of Australia.

Integrated Climate and Ecosystem Dynamics (ICED)

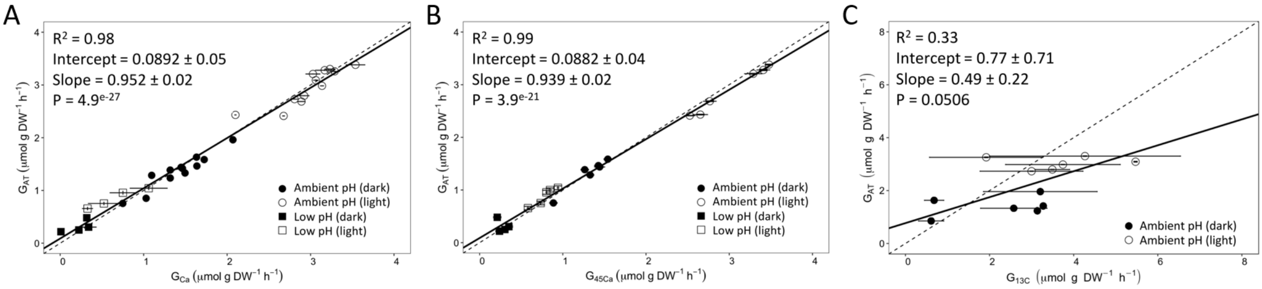
A major objective of the ICED regional programme has been to develop understanding of the role of biological processes in biogeochemical cycles in the Southern Ocean. Cavan et al. (2019) synthesized understanding of the role of Antarctic krill (*Euphausia superba*) in biogeochemical cycles. *E. superba* are swarming, oceanic crustaceans, up to two inches long, and are best known as prey for whales and penguins. Due to their large size, high biomass and daily vertical migrations, they transport and transform essential nutrients, stimulate primary productivity and influence the carbon sink. Antarctic krill are also fished by the Southern Ocean's largest fishery. However, how krill fishing impacts nutrient fertilisation and the carbon sink in the Southern Ocean is poorly understood. This synthesis suggests that this role in biogeochemical cycling needs to be explicitly considered in fisheries management.

Climate Impacts on Top Oceanic Predators (CLIOTOP)

Central place foragers, such as the little penguin (*Eudyptula minor*) rely on areas within a small range of their breeding grounds for chick provisioning (Evans et al., 2019). Consequently, there is a tight coupling between their breeding success and local bio-physical conditions. The effects of fine-scale variability in environmental parameters and resource distribution on the foraging behaviour of marine predators was studied in a region of rapid environmental change. Little penguin habitat preference during two years of varying environmental conditions was used to investigate the interactions between environmental variables, resource distribution and penguin habitat preference. Penguins were tagged with GPS devices during a marine heatwave event in 2016 and again in 2018 during comparatively cooler conditions. Penguin distribution was found to be highly correlated with a fine-scale horizontal sea surface temperature (SST) gradient feature, which appeared on the shelf in 2016 as a result of tropical water from the East Australian Current (EAC) interacting with cooler temperate water from southern Tasmania. Spatially, warmer SST anomalies corresponded to a lower probability of little penguins utilizing an area in both years, despite the much more uniform SSTs that were present during 2018. By modelling little penguin habitat preferences using two biological predictors, zooplankton community abundance as an indication of general resource distribution, and krill abundance - a prey species of little penguins - habitat preference was shown to be only slightly more strongly driven by prey type, than by general resource distribution. The correlation between little penguin habitat preference and both zooplankton and krill abundance could indicate a plasticity in foraging behaviour which might be beneficial if lower-trophic level structure continues to change due to warming. In light of the continued warming predicted for this region, and the preference shown for cooler SSTs, this plasticity might be important under future resource climates.

SOLAS-IMBeR Ocean Acidification (SIOA) Working Group

As part of the Ocean Acidification International Coordination Centre's (OA-ICC) intercomparison activities, a study was conducted to compare different methods for quantifying coral calcification rates. This is an important parameter to study coral response to ocean acidification and other stressors. As more studies on coral calcification rates are conducted, it is increasingly important to compare the various methods being used. An intercomparison study on this subject was conducted at the IAEA Environment Laboratories in Monaco in collaboration with colleagues at Laboratoire d'Océanographie de Villefranche, the Monaco Scientific Centre, and the Cienfuegos Environmental Studies Centre in Cuba. The resulting paper was recently published in the journal Biogeosciences (Gómez Batista et al., 2020).



Calcification rates estimated based on the alkalinity anomaly technique (G_{AT}) as a function of calcification rates estimated based on (A) the calcium anomaly technique (G_{Ca}), (B) the ^{45}Ca incorporation technique (G_{45Ca}), and (C) the ^{13}C incorporation technique (G_{13C}).

Regional Programmes

Brief descriptions of the Regional Programmes and their major activities during the past year are presented below. Further details on their activities can be found in Section *G. Implementation of the IMBeR Science Plan*.

Ecosystem Studies of Subarctic and Arctic Seas (ESSAS)

https://essas.arc.hokudai.ac.jp

ESSAS objectives are to understand how climate variability and change affect the marine ecosystems and sustainability of the Subarctic and Arctic seas, and in turn, how these changes affect humans.

ESSAS has four working groups:

The comparative marine ecological working group - **Paleoecology of Subarctic Seas (PESAS)**, which brings together paleoclimate, paleoecology, archaeology and history to investigate similarities and differences in the human-environmental co-evolution of the subarctic North Pacific and North Atlantic since the Last Glacial Maximum. Plans are underway to convene a congress in Seattle in 2021 or 2022.

The **Analogues of an Arctic in Rapid Transition (AnalogueART)** working group aims to provide a platform to develop methodologies and accelerate the establishment of natural analogues to investigate the effects of climate change and ocean acidification in Subarctic and Arctic ecosystems.

The **Bioenergetics Working Group** has broadened its focus to examine early life dynamics of Subarctic and Arctic fishes (primarily gadids) and has submitted several papers to the Special Issue arising from the Fairbanks, Alaska ESSAS Annual Science Meeting in 2018.

The **Human Dimensions Working Group** is actively contributing to the development of socio-economic scenarios for high-latitude marine ecosystems particularly with regard to the response of human systems to past regime shifts such as the observed transitions between gadid and crustacean dominated systems in the Northeast Pacific and the Northwest Atlantic. These scenarios would be used in model projections (equivalent to the emissions scenarios widely used in projections but considering possible socio-economic pathways).

Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED)

www.iced.ac.uk/index.htm

The ICED regional programme aims to better understand climate interactions in the Southern Ocean, the implications for ecosystem dynamics, the impacts on biogeochemical cycles, and the development of sustainable management procedures. ICED is co-sponsored by SCAR (Scientific Committee on Antarctic Research).

ICED continues to provide input to the Antarctic Treaty System via SCAR and build on collaborations with several treaty agreements, particularly the Committee for Environmental Protection (CEP) and

Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR.) The Antarctic Treaty System has recognised the role that ICED can play in providing external and valuable input on climate change impacts on Southern Ocean ecosystems.

Following the ICED session convened at the IMBeR *Future Oceans2* Open Science Conference in 2019 that reflected on the past decade of ICED science to improve future research on understanding and projecting changes in Southern Ocean ecosystems so that it is relevant to conservation and management decisions, three ICED Task Teams were established to take ICED's three priority research areas forward. These are:
Modelling Southern Ocean species and ecosystems
Projections of ecological change
Policy implications and decision-making (with a focus on integrated understanding of natural and human systems interactions).

ICED convened a session at AGU Oceans 2020 on *Complexity, connectivity and change in Southern Ocean food webs*. It focussed on foodwebs, as a result of changes in ice, ocean and ecosystem dynamics in the Southern Ocean which are affecting biodiversity at all trophic levels, from plankton to whales.

There is also ongoing collaboration between ICED and the Southern Ocean Observing System (SOOS). Andrew Constable (Co-Vice Chair Biology) is leading the development of ecosystem Essential Ocean Variables and is co-ordinating field activities in different sectors of the Southern Ocean, co-ordinated delivery of data and field planning products, and assessments of change. There are also joint activities to deliver a benchmarking of Southern Ocean ecosystems in 2022, following the successful Census of Antarctic Marine Life a decade ago.

CLimate Impacts on Oceanic TOp Predators (CLIOTOP)
http://imber.info/science/regional-programmes/cliotop

CLIOTOP organises large-scale comparative studies to elucidate key processes involved in the interaction between climate variability and change and human use of the ocean on the structure of pelagic ecosystems and large marine species.

CLIOTOP task teams:
Operational Oceanography in Support of Sustainable Top Predators (OOSTOP) is working on the inclusion of environmental variability in the International Commission for the Conservation of Atlantic Tunas (ICCAT) ecosystem report card.
Modelling Animal Behaviour in a Changing Climate is developing robust predictions of marine predator at-sea distributions under current and future climate scenarios. This work is premised on using individual-based movement data from satellite telemetry devices combined with state-of-the-art statistical modelling tools for inference of animal movement patterns, associated behaviour and habitat preference.

Most of the manuscripts submitted to CLIOTOP's special issue in Deep-Sea Research II (arising from the 4th CLIOTOP Symposium in October 2018) are now published online. Thus far 17 papers have been published (see Section L), and four more are expected soon.

Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER)
https://incois.gov.in/portal/siber/index.jsp)

The SIBER regional programme is co-sponsored by the Indian Ocean GOOS (IOGOOS) Programme with close ties to CLIVAR's Indian Ocean Panel (IOP). It focuses on understanding climate change and anthropogenic forcing on biogeochemical cycles and ecosystems in the Indian Ocean, to predict the impacts of climate change, eutrophication and harvesting. The 2nd International Indian Ocean Expedition (IIOE-2) is now the main scientific focus of SIBER.

Numerous Indian Ocean research cruises, many involving SIBER-related science and participation by SIBER SSC members, have taken place in the last year (see https://iioe-2.incois.gov.in/IIOE-2/Expedition.jsp). More cruises are scheduled for later in 2020 and beyond, as part of the extended IIOE-2.

Working Groups

Brief descriptions of the Working Groups are presented below. Further details on their activities can be found below in Section *G. Implementation of the IMBeR Science Plan*.

IMBeR-Future Earth Coasts Continental Margins Working Group (CMWG)

http://www.imber.info/en/projects/imber/science/working-groups-1/cmwg

The CMWG is a collaboration between IMBeR and Future Earth Coasts which aims to compare a sparsely populated northern Arctic shelf region with a shelf in a heavily populated south-east Asian region.

The Chinese Marginal Seas case study group met at a workshop in Qingdao, China in November 2019 to develop a strategy framework to study ocean health and sustainability in the Chinese marginal seas. It was decided that priority research areas will include studying the environmental, ecosystem and economic changes of the marginal seas to understand the impact of human activities on the ecological environment and the interrelationship with management policies.

Human Dimensions Working Group (HDWG)

http://www.imber.info/en/projects/imber/science/working-groups-1/human-dimensions-working-group-hdwg

The HDWG has continued to develop systems understanding of the human dimensions of marine resource use and interactions with global oceans. Work by members of the group is pivotal to guiding and informing IMBeR Grand Challenges II and III. Achieving sustainable ocean governance is a rapidly developing field of research potentially heightened by a global focus on blue growth/economy. Because the human dimensions of ocean governance and understanding use and interactions with the marine system is such a broad and widening area of research the activities of the HDWG group are wide-ranging.

Several session proposals were submitted for conferences in 2020. These have all been postponed to 2021:

Marine Socio-Ecological Systems (MSEAS), will now be held in Yokohama, Japan in 2021 (Ingrid van Putten, HDWG Chair is on the Organising Committee). Two sessions were proposed:

We all think we are inter- and transdisciplinary – but are we really and what makes it work?

Dynamic ocean governance: Linking environmental variability and local users.

World Fisheries Congress will now be held in Adelaide, Australia in September 2021.

Anticipating future fisheries management: Scientific advances for marine socio-ecological models.

IMBeR-CLIVAR Eastern Boundary Upwelling Systems (EBUS) Working Group

http://www.imber.info/en/projects/imber/science/working-groups-1/eastern-boundary-upwelling-systems-ebus

The EBUS Working Group (WG) focuses on the potential effects of climate change on the intensity, seasonality and geography of upwelling systems and their ecological and socio-economic consequences. The WG aims to better understand the biogeochemical, biological, fish and fisheries processes and trends in the four major coastal upwelling regions, i.e. California, Humboldt, Canary and Benguela, and the resultant socio-economic impacts. In 2017, members of the IMBeR-CLIVAR EBUS WG contributed to a successful proposal to form a SCOR WG, co-chaired by IMBeR SSC member Ruben Escribano.

***Integrated Ocean Carbon Research* (*IOC-R*)**
This working group is a collaboration between SOLAS, IMBeR, the Intergovernmental Oceanographic Commission - International Ocean Carbon Coordination Project (IOC-IOCCP), Global Carbon Project, World Climate Research Programme (WCRP) and CLIVAR.

IOC-R aims to address integrated ocean carbon research including the need for sustained observations and monitoring, and also the need for improved understanding of rates and processes that were emphasized in the *What We Have Learned From the Framework for Ocean Observing: Evolution of the Global Ocean Observing System* publication (Tanhua et al., 2019).

The IOC-R group is developing a high-level White Paper with contributions from Carol Robinson and Jeomshik Hwang (the IMBeR nominee on this group). Jeomshik attended the first working group meeting held at IOC, Paris in October 2019.

SOLAS-IMBeR Ocean Acidification (SIOA)
https://www.iaea.org/ocean-acidification

SIOA plays a key advisory role in the Ocean Acidification International Coordination Centre (OA-ICC), and advances its core activities of setting up a Global Observing Network, organising joint experiments and intercomparison exercises, providing advice on best practises and contributing to capacity building and outreach.

SIOA was involved in the launch of a new IAEA Coordinated Research Project (CRP) to study the impacts of ocean acidification on socio-economically important seafood species.

SIOA made a significant contribution to the OceanObs'19 Community White Paper on the Global Ocean Acidification Observing Network progress and vision (see https://doi.org/10.3389/fmars.2019.00337).

See the quarterly OA-ICC Highlights newsletter for more Science highlights: https://www.iaea.org/services/oa-icc/highlights.
Endorsed projects
The science objectives of IMBeR are broad and as such lend themselves to collaborations with other projects that are focused on aspects of IMBeR science. Endorsement of marine research projects and activities provides an open, flexible framework to encourage national, regional, and international participation in its scientific activities, and to achieve its objectives as outlined in the IMBeR Science Plan and Implementation Strategy.

Atlantic Meridional Transect (AMT)
https://www.amt-uk.org/
AMT is a multidisciplinary programme that provides information on the response of the Atlantic Ocean to environmental change, to better understand the fundamental links between biodiversity, ecosystem function, ecosystem services and human wellbeing.

Biological, chemical and physical oceanographic research is undertaken during an annual voyage between the UK and destinations in the South Atlantic. So far there have been 29 cruises and all the data are accessible through the British Oceanographic Data Centre (BODC). Over 350 scientific papers have been published (see https://www.amt-uk.org/Publications).

AMT provides exceptional opportunities to UK and international partners to access the remote regions of the Atlantic Ocean including the rarely visited South Atlantic Gyre. To date 289 individuals from 77 institutes in 29 countries have taken part in AMT cruises and according to BODC records there have been 124000 downloads of AMT data since 2011 by the international community. AMT also contributes to capacity building in developing nations through support from POGO (Partnership for Observation of the Global Ocean).

Gulf of Trieste – Time-series (GoTTs)
http://gotts.inogs.it
GoTTs is part of the International Long-Term Ecological Research network (ILTER) of marine and coastal sites. Research activities aim to understand the dynamics governing marine ecosystems, and to evaluate the role of oceans in the global energy balance. At the local scale, GoTTs focuses on coastal and transition waters and addressing issues relating to their sustainable management.

A recent publication (Muelbert, et al., 2019) explores the potential for the coastal and marine components of ILTER to provide integrated global observations to address the challenges posed by climate change and human impacts within the coastal zone.

Integrated Arctic Observation System (INTAROS)
www.intaros.eu and https://intaros.nersc.no
Many activities are involved in monitoring and observations in the Arctic. A key objective of INTAROS is to build synergies with these, for example, the Arctic Council´s Sustaining Arctic Observing Networks (SAON), the Global Earth Observations (GEO) Cold Region Initiative (CRI) and the European Earth observation and monitoring programme – Copernicus, the Japanese led Arctic Challenge for Sustainability (ArCS) project and a number of United States of America and Canadian programmes.

The Coordinated Arctic Acoustic Thermometry Experiment (CAATEX) research cruise was carried out in the Eurasian Basin with the Norwegian icebreaker KV Svalbard in August-September 2019 to gather information about variations in ocean temperature under the sea ice, and ice thickness throughout the winter and summer melt. Improved links were made with community-based observing networks in Greenland, Svalbard and Russia were strengthened, for example the PISUNA network organised through the Greenland Ministry of Fisheries, Hunting and Agriculture to strengthen the involvement of fishermen, hunters and other environmentally interested people in the management of living resources.

A review article by Lee, et al., 2019 presents a roadmap for establishing the Arctic Region Component of the Global Ocean Observing System (ARCGOOS).

Marine Ecosystem-based Management Progress Evaluation Group: tracking the global progress of EBM (MEBM-PEG) (new endorsed project in 2020)
http://imber.info/en/science/endorsed-projects/mebm-peg
MEBM-PEG is an international group of ecosystem-based management (EBM) experts that will systematically track progress towards EBM, communicate its benefits, and identify where remaining impediments to implementing EBM persist. Potential solutions to achieve further implementation of EBM. The kick-off meeting was postponed due to COVID-19, delaying the start of the project.

Marine Ecosystem Modelling and Forecasting System in the China Seas and Northwestern Pacific (MEMFiS)
http://imber.info/en/science/endorsed-projects/memfis
The MEMFiS project focuses on the ecology of the Bohai, Yellow, East and South China Seas, and the northwestern Pacific and aims to develop an integrated modelling and forecasting framework, using high-resolution physical-ecosystem models and data from multiple sources. By investigating ecosystem variability at different temporal and spatial scales, several key scientific questions are being tackled. Marine ecosystem variability is addressed at the interface of different systems, parameterizations optimised for biogeochemical processes in different regions, data assimilation and ecosystem forecasting using multiple observations, not only from moorings, buoys and ships, but also from bio-Argo, gliders and high-resolution satellite imagery.

The significance of the Kuroshio Current to the East China Sea has long been recognized. However, the quantitative contribution of nutrients from the Kuroshio to the East China Sea shelf is unclear due to the lack of data, particularly on an inter-annual time scale. Based on velocity calculated with geostrophy and satellite altimetry, and nutrient data from in situ measurements, the temporal and spatial variations for the 22-year period from 1993-2014 cross-shelf nutrient exchange at the 200-m isobath section in the East China Sea was determined. Nitrate transport shows a significant three-dimensional spatial structure with annual and inter-annual variations. The spatial structure of nitrate transport is determined by velocity in the horizontal and nitrate concentration in the vertical, while temporal variation in nitrate transport is mainly determined by velocity and especially its geostrophic component (Ding et al., 2019).

Mechanisms of Marine Carbon Storage and Coupled Carbon, Nitrogen and Sulphur cycles in response to global change (MCS-CNS)
http://www.imber.info/en/projects/imber/science/endorsed-projects/mcs-cns
The sensitivity of marine biogeochemical cycles to climate change remains unclear, especially for key processes which influence the long-term health of marine ecosystems. By understanding the interactions between the microbial carbon pump and the biological carbon pump, MCS-CNS aims to decipher the mechanisms of marine carbon storage, and the response of biogeochemical processes to climate change and anthropogenic activities.

Three different kinds of physical forcings on mesopelagic sinking particle fluxes were found in less than a year at a single location in the South China Sea. This confirmed the frequent impact of physical processes of various scales on South China Sea biogeochemistry and highlighted the important role of physical processes and episodic events (Zhang et al., 2019).

Importance of Physico-Chemical cycling of nutrients and carbon in Marine Transitional Zones (NUTS & BOLTS) (new endorsed project in 2020)
https://www.nuigalway.ie/science/school-of-natural-sciences/disciplines/earth-ocean-science/research/nutsbolts
NUTS & BOLTS is an interdisciplinary project to address knowledge gaps with regard to the impact of multiple environmental stressors on the cycling of nutrients and carbon in Ireland's marine transitional zones. The IMBeR Endorsement Committee approved its endorsement at the SSC meeting in June 2020.

Ocean Acidification and Biogeochemistry: variability, trends and vulnerability (VOCAB)
http://www.imber.info/en/projects/imber/science/endorsed-projects/vocab
VOCAB aims for greater understanding of the impacts of climate change in the NE Atlantic, focusing on ocean acidification in Irish coastal and offshore waters, and feeding into policy and governance.

Activities in the past year included the Ocean Climate Rockall Trough Survey May-June 2019 in collaboration with the Marine Institute of Ireland.

Processes and Approaches of Coastal Ecosystem Carbon Sequestration (PACECS)
http://www.imber.info/en/projects/imber/science/endorsed-projects/pacecs
PACECS aims to understand the key processes and mechanisms of carbon sequestration in coastal ecosystems in order to propose ways to increase the ocean carbon sink. Most of this 'Blue Carbon Sink' resides in the biomass of phytoplankton, bacteria, archaea, and protozoa, and so maximizing the efficiency of this sink requires fundamental knowledge of the dynamics of marine microbes. A seminar was convened to integrate and discuss the annual progress of the four subprojects in Xiamen on 28-29 November 2019.

PACECS co-organised several cruises including the SILICON cruise (SprIng time cycLonIc eddy in the northwest paCific Ocean off taiwaN) from 15 March to 20 April 2019, and a time-series cruise of the South East Asia Time-Series Station (SEATS) in the South China Sea during July 2019.

Study of Kuroshio Ecosystem Dynamics for Sustainable Fisheries (SKED)
http://snf.fra.affrc.go.jp/html/english/index.html
The North Pacific western boundary Kuroshio current is nutrient-poor, yet it is an important spawning and nursery ground for various fish species and a productive fishing ground. SKED aims to understand the mechanisms of how this high fisheries productivity results from the oligotrophic conditions, i.e., the Kuroshio Paradox, and to determine how to use the ecosystem services sustainably. The book by Nagai, et al., 2019, presents the physical, chemical and biological data from SKED, and compares them with the Gulf Stream, the western boundary current of the North Atlantic Ocean.

Implementation of the IMBeR Science Plan

Progress towards achieving the objectives of the Grand and Innovation Challenges during the 2019-2020 period is outlined below:

Grand Challenge I (GCI): Understanding and quantifying the state and variability of marine ecosystems

The Challenge: To develop whole system level understanding of ecosystems, including complex biogeochemical cycles and human interactions, together with understanding of the scales of spatial and temporal variability of their structure and functioning.

SIBER
GCI represents an overarching objective of SIBER; to improve understanding of the Indian Ocean's role in global biogeochemical cycles and the interaction between these and marine ecosystem dynamics. SIBER is addressing this by fostering and leading international collaborations amongst Indian Ocean rim countries and countries in Asia, Europe and North America. The 2nd International Indian Ocean Expedition (IIOE-2), the Eastern Indian Ocean Upwelling Research Initiative (EIOURI), and the UK-South African SOLSTICE-WIO project in the Western Indian Ocean, are examples of projects dedicated to understanding and quantifying the state and variability of marine ecosystems and the physical forcing that drives this variability. All were fostered by SIBER, with active participation and leadership from the SIBER community. Examples of such activity during the last year include multiple research projects and cruises involving SIBER SSC members and SIBER-related science (see for example the SIBER science highlight in Section C).

ICED

ICED has continued to develop whole ecosystem level understanding of the structure and functioning of Southern Ocean ecosystems and their variability and response to change across a range of spatial and temporal scales. Detailed work has focused on key species from phytoplankton to higher predators, and the structure of food webs. ICED continues to examine physical, chemical and biological interactions and the effects of past and recent variability and change, such as ocean acidification; work in these areas is pivotal to guiding and informing our work under GC II and GC III.

ESSAS

Understanding variability in high-latitude marine ecosystems in response to climate variability and change is a central goal of ESSAS. A major initiative by ESSAS to further this goal was the Resilience and Adaptive Capacity of Arctic marine ecosystems (RACArctic) project, supported by the Belmont Forum. The project is culminating in a special issue with four synthesis papers to be published in the ICES Journal of Marine Science.

To foster a better understanding of high-latitude changes and their consequences for humans, ESSAS was planning to hold an Annual Meeting in Sapporo, Japan in June 2020 under the theme of *Linking past and present marine ecosystems to inform future fisheries and aquaculture*. A total of 47 abstracts were submitted by the deadline in early 2020, but the meeting was postponed due to the COVID-19 pandemic.

CLIOTOP

Two of the CLIOTOP task teams are contributing towards GCI. The Operational Oceanography in Support of Sustainable Top Predators (OOSTOP) Task Team has been working towards the inclusion of environmental variability in the International Commission for the Conservation of Atlantic Tunas (ICCAT) ecosystem report card.

The Modelling Animal Behaviour in a Changing Climate Task Team is designing and working through the necessary steps for developing robust predictions of marine predator at-sea distributions under current and future climate scenarios. This work is premised on using individual-based movement data from satellite telemetry devices combined with state-of-the-art statistical modelling tools for inference of animal movement patterns, associated behaviour and habitat preference.

SIOA

The SIOA plays a key advisory role to the Ocean Acidification International Coordination Centre (OA-ICC) based at the International Atomic Energy Agency Environment Laboratories in Monaco. Recent and ongoing OA-ICC activities relevant for GC I include:

Supporting the Global Ocean Acidification Observing Network (GOA-ON), a worldwide collaborative approach with the goal to expand ocean acidification monitoring and capacity building, especially in areas where there is little or no data. The IAEA OA-ICC together with IOC-UNESCO and the NOAA OA program are currently providing support for a distributed GOA-ON Secretariat (three staff based at IAEA Monaco, IOC in Paris and NOAA OAP in Washington DC). The GOA-ON highlights from this reporting period include contributing to a Community White Paper presented at the OceanObs'19 Decadal Conference (https://doi.org/10.3389/fmars.2019.00337), co-organizing side-events at the UNFCCC COP25, adding new data streams to the GOA-ON Data Portal, hosting ocean acidification training workshops, and contributing to WMO Global Climate reports.

Launching of a new 4-year IAEA Coordinated Research Project (CRP) to study the impacts of ocean acidification on socio-economically important seafood species. This project involves 17 countries that are using standardized methodologies to test ocean acidification impacts on various species of shrimp, sea urchins, fish, and molluscs. Project participants are assessing a set of commercially relevant parameters such as growth, survival, taste and texture. These same scientists will study

additional parameters depending on the expertise of their respective laboratories. These include calcification, metabolic change, and bioaccumulation of metals. The participants of the project met in Kristineberg, Sweden in August 2019 to launch the project and finalise methods before beginning the experiments.
Updating and improving accessible best practices for making ocean acidification measurements. The OA-ICC continues to work with experts to improve the low-cost monitoring kit referred to as *GOA-ON in a Box*. Several standard operating procedures (SOPs) and spreadsheets for making ocean acidification calculations have been published on the GOA-ON website: http://goa-on.org/resources/kits.php
Building capacity of scientists around the world to advance ocean acidification research. In December 2019, 15 participants met at the IAEA Environment Laboratories in Monaco for ocean acidification monitoring training. Participants learned how to measure pH and total alkalinity using a set of simplified methodologies to exploit their '*GOA-ON in a Box'* kit.

The SIOA ensures that the international symposium series on the Ocean in a High CO_2 World is convened every four years, e.g., by launching and evaluating bids to host this event for the ocean acidification community. Some SIOA members were involved in organizing the 5th Ocean in a High CO_2 World Symposium scheduled for September 2020 in Lima, Peru. However, given the current pandemic it has been postponed.

Grand Challenge II: Improving scenarios, predictions and projections of future ocean-human systems at multiple scales.

The Challenge: To incorporate understanding of the drivers and consequences of global change on marine ecosystems and human societies at multiple scales into models to project and predict future states.

ESSAS
As part of the RACArctic project, ESSAS has focused on developing plausible scenarios for anticipated changes in high-latitude marine ecosystems, and in particular its consequences for fish populations and fisheries, based on a review of available literature including qualitative predictions and available projections. Three manuscripts are being prepared for submission in June 2020, as well as an informational sheet for stakeholders.

ICED
ICED has continued model development in support of creating a suite of models of physical dynamics (ocean circulation and climate), biogeochemical cycles, and biological dynamics (life histories, population dynamics, food web structure) within a hierarchical framework of models of different spatial, temporal and trophic resolution. The ultimate aim of these activities is to advance end-to-end ecosystem modelling approaches that integrate physical, chemical and biological processes and generate projections of Southern Ocean ecosystems. ICED used their understanding of the drivers and impacts of climate change (under GC I) in the Southern Ocean to further work on developing scenarios of key drivers and projections of ecological change, for example, outlining future collaborations in areas of mutual interest with the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) (see Cavanagh et al. 2019).

CLIOTOP
The *Seasonal Forecasting and Dynamic Ocean Management for Pelagic Ecosystems Task Team*, led by Kylie Scales and Jason Hartog began in 2016. Kylie gave a presentation on
Investigating oceanographic and environmental factors impacting on Australia's eastern tuna and

billfish fishery at the Australian Society for Fish Biology Conference in October 2019, and a session titled *Dynamic ocean management: disrupting the static management paradigm to support sustainable use of marine resources* was planned for the now postponed EcoSummit2020.

During lockdown, Task Team members have continued to collaborate with fisheries forecasting projects in different ecoregions, particularly with groups at the National Oceanic and Atmospheric Administration (NOAA) in the USA and Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia. Sharing of code and resources for common applications through GitHub repositories has also continued.

Human Dimensions Working Group

A study is being undertaken by Camilla Novaglio (UTAS and CSIRO, Australia) and Ingrid van Putten (HDWG co-Chair) to improve representation of fishing in ecosystem models through consideration of social factors in models. A survey was implemented to advance our understanding of fishing and its implication on whole socio-ecological systems. The results are currently being analysed and written up.

A study (currently in review by the Journal of Environmental Management) by Monalisa Rodrigues, Maria G. Pennino, and Priscila Lopes illustrated how some fisheries management measures (e.g., fishing bans on specific species) could result in fishers switching their effort to other species that may be just as vulnerable as those that are banned. The results suggest that well-intentioned management measures may backfire if the socio-ecological system is not viewed as a whole.

Grand Challenge III: Improving and achieving sustainable ocean governance

The Challenge: To improve communication and understanding between IMBeR science, policy and society to achieve better governance, adaptation to and mitigation of global change, and transition towards ocean sustainability.

SIBER

The ongoing Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosystem research in the Western Indian Ocean (SOLSTICE-WIO) programme (co-led by SIBER SSC member Mike Roberts; https://www.solstice-wio.org/), is focused on fisheries and food security in the western Indian Ocean, and combines environmental and socio-economic research with state-of-the art techniques and knowledge transfer, to develop policies for sustainable and resilient fisheries.

The protection of seamount benthic ecosystems in the high seas (or Areas Beyond National Jurisdiction (ABNJ)) is an ocean governance challenge derived from SIBER scientific activities and taken up by members of its SSC. Due to their fragility and poor resilience seamount ecosystems can be threatened by unregulated fisheries and possible future deep-sea mining to exploit their mineral resources. This issue has been addressed in the shallow seamount project carried out in the South West Indian Ocean under the French/South African scientific partnership. A study will be published soon in a Special Issue of Deep Sea Research II, where an emblematic seamount, the Walters Shoal, is selected as a case study to discuss how this site could become a fully-protected space in the ABNJ. Recent advances towards an international legally binding instrument negotiated under the Law of the Sea (UNCLOS) will provide a framework to implement conservation measures of habitats and biodiversity in the ABNJ. Such a new opportunity in ocean governance must be backed by improved scientific knowledge in the functioning of these deep-sea ecosystems.

ESSAS

One of three RACArctic synthesis papers will assess the ability of current management structures in the Pacific and Atlantic Arctic to address challenges associated with the effects of climate change on marine systems.

ICED

On-going work under ICED's third scientific objective has contributed directly to GC III. ICED has worked with stakeholders to ensure the science under GC I and II is incorporated into adaptation, mitigation and sustainable management and conservation procedures by improving two-way communications and understanding between science, policy and society. ICED is continuing its work with the Antarctic Treaty Commission via the Scientific Committee for Antarctic Research (SCAR, within which ICED is a 'Co-Sponsored Programme'), and with a number of Antarctic Treaty agreements including the Committee for Environmental Protection (CEP) and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). ICED also continues to work with other international environmental treaties and organisations, conservation groups, and international committees, including the International Whaling Committee (IWC). ICED continues to guide the development of a policy focused activity - Marine Ecosystem Assessment of the Southern Ocean (MEASO) that aims to provide a quantitative assessment of the status of Southern Ocean ecosystems that will enable managers to achieve consensus in adapting their management strategies to change. More recently, ICED was involved in coordinating Southern Ocean input into the United Nation's Decade of Ocean Science for Sustainable Development (2021-2030) and reviewing the Decade's Implementation plan.

CLIOTOP

Karen Evans (CLIOTOP co-Chair), is a member of the Group of Experts who are coordinating the second World Ocean Assessment and was the lead author of a chapter on the assessment of cumulative impacts. She also contributed to chapters relating to management approaches. These chapters will provide an overview of current processes for the assessment of cumulative impacts and varying management approaches.

HDWG

A high-Level Panel commissioned a series of *Blue Papers* to explore pressing challenges at the nexus of the ocean and the economy. A number of HDWG members were involved in a publication on ocean equity led by Henrik Österblom. See https://www.oceanpanel.org/blue-papers/towards-ocean-equity.

SIOA

The OA-ICC was involved in the Sustainable Development Goal 14.3.1 process, working closely with IOC-UNESCO on the development of the SDG 14.3.1 Methodology. Countries have now been requested to submit ocean acidification data as part of this process. This global submission of ocean acidification data will raise awareness at the government/policy level and will hopefully increase funding from governments to maintain ocean acidification studies.

The OA-ICC supports the UN Community of Ocean Action on Ocean Acidification (COA on OA), an initiative launched for stakeholders to submit Voluntary Commitments (VCs) to help address the SDG 14.3, over 250 of which have been submitted for this SDG target. One of the COA on OA focal points is at the IAEA and involved in the OA-ICC. The OA-ICC has helped to organize a webinar series to highlight the various ocean acidification VCs.

The OA-ICC was involved in the preparatory process of the UN Ocean Conference, originally planned for June 2020, but now postponed. The OA-ICC is co-leading a Preparatory Working Group on ocean acidification, ocean warming, and deoxygenation. This working group, comprised of stakeholders and UN agencies, is producing a Concept Paper that will be used to lead the Interactive Dialogues of the Conference. The OA-ICC also plans to help organise and participate in side-events during the conference to highlight the work being done by the global ocean acidification community.

The OA-ICC and its partners were involved in a series of side events on ocean acidification during the UNFCCC Conference of the Parties (COP25) in Madrid, Spain from 2-13 December 2019. These sessions highlighted regional and global efforts on ocean acidification, including OA-ICC activities, the Global Ocean Acidification Observing Network (GOA-ON), the Intergovernmental Panel on Climate Change (IPCC) Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), the Community of Ocean Action on Ocean Acidification (COA on OA), and other initiatives. The OA-ICC supported three ocean acidification scientists representing GOA-ON regional hubs to participate in a COP25 side event entitled “Understanding Changing Ocean Conditions and Impacts to Marine Species and Ecosystems: Global Networks that are Advancing Regional Science, Monitoring, and Response Strategies”, organized by the International Alliance to Combat Ocean Acidification.

Innovation Challenge 1 – To enhance understanding of the role of metabolic diversity and evolution in marine biogeochemical cycling and ocean ecosystem processes.

SIBER

SIBER promotes studies that include assessment of metabolic diversity and evolution in the Indian Ocean and their role in marine biogeochemical cycling and ocean ecosystem processes. Multiple projects and cruises carried out or planned as part of IIOE-2 have incorporated these science elements. Examples include the recent RV Investigator 110° cruise that addressed microbial processes and gene expression in relation to nitrogen and sulphur cycling, and multiple aspects of ocean food webs, including microzooplankton grazing and feeding of mesopelagic fishes.

ICED

As a co-sponsored programme of SCAR, ICED has continued to develop links with SCAR’s Antarctic Thresholds - Ecosystem Resilience and Adaptation (AnT-ERA) and State of the Antarctic Ecosystem (AntEco) programmes (both of which are due to come to an end in 2020). ICED members intend to further their involvement with omics research conducted by the next generation of SCAR programmes, that are currently being planned with the involvement of ICED scientists. Omics is not an area in which ICED has invested strongly, yet in addition to helping us understand biodiversity, structure and functioning of Southern Ocean ecosystems and their response to change, it will be key to informing the wider ecological debate about the nature of stability and change in ecosystems.

The **IMBeR IMBIZO 5** metabolic diversity and evolution workshop in Woods Hole in 2017 resulted in the publication of *Towards integrating evolution, metabolism and climate change studies of marine ecosystems* in Trends in Ecology and Evolution. The study suggests that marine communities and ecosystems are responding to climate change. Environmental shifts can cause evolution of species, affecting both realised and fundamental niches. Local adaptation to environmental conditions is also occurring. Since local adaptation is related to genetic diversity, the loss of realised niche breadth might be linked to a loss of adaptive genetic diversity. This will impact the evolutionary responses to climate change and the ability of a species to change both its fundamental and realised niche (Baltar et al., 2019).

After the publication of Baltar et al., (2019) and the rotation off the IMBeR SSC of IC1 champion Gerhard Herndl, the SSC took the decision to reduce focus on the role of metabolic diversity and evolution on biogeochemical cycling, and to use the capacity to initiate a new Innovation Challenge in 2020.

Innovation Challenge 2 – To contribute to the development of a global ecosystem observational and modelling network that provides essential ocean variables (EOVs) and to improve marine data and information management.

SIBER

Innovation Challenge 2 represents one of the central goals of SIBER. The most relevant SIBER activities have involved the development of collaborations between biogeochemical and ecosystem research scientists, physical oceanographers and atmospheric scientists, facilitated through close ties between SIBER and the CLIVAR Indian Ocean Regional Panel (IORP). SIBER emerged as a result of the potential opportunity to leverage the CLIVAR/GOOS Indian Ocean mooring array RAMA/IndOOS) and associated measurements and cruises for doing biogeochemical and ecological research. This opportunity continues to be realised through deployment of biogeochemical sensors on the RAMA mooring array and the deployment of bio-Argo floats in the northern and southwestern Indian Ocean. SIBER has been actively engaged throughout the recently completed IndOOS decadal review process (http://www.clivar.org/indoos-decadal-review-2006-2016). Plans are being developed for the deployment of many more biogeochemical sensors in the Indian Ocean as part of IIOE-2 and the second phase of IndOOS. Other examples include over 10 years of observations around Australia via its Integrated Marine Observing System (IMOS; http://imos.org.au/), as well as deployment of biological and biogeochemical sensors as part of EIOURI and Indian IIOE-2 programmes (e.g. MOSAIC; http://www.ocean-partners.org/marine-observation-system-along-indian-coast-mosaic-new-initiative). These efforts are all focused on measuring biogeochemical EOVs that contribute to the development of a global ecosystem observational and modelling network.

ICED

The ICED community has strong links with relevant SCAR groups, the SCAR-SCOR Southern Ocean Observing System (SOOS) and the CCAMLR Ecosystem Monitoring Program to progress integrated ecosystem observing. These, together with ICED's Marine Ecosystem Assessment of the Southern Ocean (MEASO) will:
support assessments of current status and trends of Southern Ocean ecosystems, and
provide foundation data for assessing the likelihood of future states of the system.
ICED scientists will continue to be involved in SOOS's efforts to assess physical and biological states through the MEASO initiative.

ESSAS

ESSAS-endorsed national projects provide observations of EOVs in high-latitude marine ecosystems. For example, the Arctic Marine Biological Observation Network (AMBON) is developing a long-term observing programme in the Chukchi Sea to monitor EOVs and biodiversity at all trophic levels, from microbes to whales. Several Japanese programmes routinely contribute to sampling standard transect lines in the northern Bering Sea and Chukchi Sea that together form the 'Distributed Biological Observatory'.

Former ESSAS co-Chair Sei-Ichi Saitoh and current co-Chair Franz Mueter participated in workshops on the development of *Integrated Ecosystem Assessments* (IEA) for the Central Arctic Ocean, and several AMBON researchers took part in a preliminary meeting to set up a working group for an IEA for the Chukchi Sea. Co-Chair Benjamin Planque is involved in IEAs for the Norwegian and Barents Seas.

CLIOTOP

Karen Evans participated in the PEGASuS working group *Designing the observing system for the world's ocean – from microbes to whales* in March and December 2019. This working group is funded by Future Earth and supported through the PEGASuS-NCEAS programme. The working group, and especially Karen's role to contribute to the development of EOVs for seabirds, marine turtles and marine mammals, directly aligns with IMBeR's Innovation Challenge 2.

SIOA

The SIOA and OA-ICC continue to ensure sustained archival data on biological responses to ocean acidification in a dedicated database. This effort promotes easy access to the data for all users. A data portal has been developed to facilitate searching and accessing of data sets in the OA-ICC data compilation, which is updated regularly. The compilation is maintained by the OA-ICC in cooperation with Xiamen University and is hosted at Pangaea, a World Data Centre, based in Germany.

The OA-ICC bibliographic database is continually updated and now holds over 6,000 freely accessible references on ocean acidification. New publications are entered each working day while being assigned consistent keywords by OA-ICC staff in Monaco, thus facilitating user searches for relevant publications. The SIOA and OA-ICC are also currently undertaking a bibliometric analysis to assess ongoing developments in the field of ocean acidification and expect to publish the results in early 2021.

Innovation Challenge 3 – To advance understanding of ecological feedbacks in the Earth System.

ICED

The SCAR Ocean Acidification review was led by ICED SSC member Richard Bellerby. The following were evaluated:
Regional ocean acidification from observations and CMIP5 models
Species and functional group responses to ocean acidification and other stressors
Ecological change
Marine biogeochemical feedbacks resulting from plankton community stoichiometry changes to ocean acidification and climate change.
Eugene Murphy (ICED Chair) and others convened a session titled *Ecological Feedbacks in the Earth System* at the IMBeR 2019 Open Science Conference.

Innovation Challenge 4 – To advance and improve the use of social science data for ocean management, decision making and policy development

SIBER

A primary example of emerging SIBER-driven projects that address this IMBeR challenge is the SOLSTICE-WIO programme (co-led by SIBER SCC member Mike Roberts). It involves case studies of threatened, emerging and collapsed fisheries in Tanzania, Kenya and South Africa, respectively, including socio-economic as well as environmental research through to outreach and briefs to stakeholders and policy makers (https://www.solstice-wio.org/). More widely, collection and use of social science data are written into the IIOE-2 Science Plan and Implementation Strategy, overseen through IIOE-2 Science Theme 1 ("Human Benefits and Impacts") and Working Group 6 ("Translating Science for Society") (https://iioe-2.incois.gov.in/IIOE-2/index.jsp).

ESSAS

Alan Haynie, Chair of the ESSAS working group on Human Dimensions, continues to be active at national and international levels to develop better approaches to using economic data to support decision making in fishery management. Activities include:
Participation in the Climate Fisheries Initiative, which is working to plan how NOAA and partners couple ocean modelling and fisheries management over the coming decade. Alan's experiences in ESSAS and RACArctic were valuable for his contributions in this effort.
Co-PI of the Alaska Climate Integrated Modeling (ACLIM) project, an effort that partners NOAA and university partners to make fisheries management in the North Pacific "climate ready". ESSAS and the IMBeR Open Science meetings were valuable contributors to this work.

ICED
ICED scientists have been developing work on ecosystem services in the Southern Ocean, particularly as a contribution to MEASO and it is hoped that the outcomes will be useful to CEP and CCAMLR. The use of social science data in decision-making is an area ICED is particularly keen to develop through IMBeR. ICED scientists Rachel Cavanagh and Susie Grant continue to co-lead the joint BAS-CCI workshop series on science-policy challenges and have collaborated with social scientists and policy makers in this regard. The most recent workshop held in November 2019 looked at the role of Bright Spots in science-policy and included insights from a behavioural scientist and a government scientist. The outputs from this workshop are currently in preparation.

Other IMBeR activities

Future Oceans$_2$ Open Science Conference (OSC)
IMBeR held its second Open Science Conference – Future Oceans$_2$ - in Brest, France in June 2019 which, by all accounts, was a great success. Almost 600 researchers from a range of marine science disciplines attended to consider: *Ocean sustainability for the benefit of society: understanding, challenges, and solutions. Almost half the attendees were students and early career researchers*. A mentoring programme matched students with established scientists with similar research interests, and a ‘lunch with the scientists’ enabled further networking. The *Whova* Conference App. was very useful for navigating the 10 parallel sessions, daily plenary keynote talks and peripheral workshops.

Frontiers Research Topics from Future Oceans$_2$
Future Oceans$_2$, led to the development of two separate Research Topics in Frontiers in Marine Science:
Research Topic 1 - Integrated Marine Biosphere Research: Ocean Sustainability, Under Global Change, for the Benefit of Society https://www.frontiersin.org/research-topics/11599/integrated-marine-biosphere-research-ocean-sustainability-under-global-change-for-the-benefit-of-soc
Sixteen articles are currently under review.

Research Topic 2 - Solving Complex Ocean Challenges Through Interdisciplinary Research: Advances from Early Career Marine Scientists
https://www.frontiersin.org/research-topics/11540/solving-complex-ocean-challenges-through-interdisciplinary-research-advances-from-early-career-marin#overview
This research topic was developed by IMBeR’s Interdisciplinary Marine Early Career Network (IMECaN, formally launched at Future Oceans$_2$). Fifty-three abstracts have been submitted and six articles have been published so far.

A recently published article by (Gullestad et al., 2020) discusses the management of transboundary and straddling stocks in the Northeast Atlantic in light of climate induced shifts in distribution. This arose from the Future Oceans$_2$ session on *Transboundary fisheries management in changing North Atlantic and Pacific Oceans* and a second paper discussing this in the Pacific is in preparation.

Interdisciplinary Marine Early Career Network (IMECaN)

IMBeR's Interdisciplinary Marine Early Career Network (IMECaN) was formally launched at Future Oceans$_2$, IMBeR's 2nd Open Science Conference, in June 2019. Since then IMECaN has recruited 547 members from 42 countries. IMECaN convened an early career day prior to Future Oceans$_2$, that included training courses on communicating marine research to diverse audiences, how to make good graphics for your publications, and developing a policy pitch. Panel discussions with more established researchers who reflected on their careers in marine science and the things that they wish they had known as early career researchers, as well as alternative marine science careers to academia.

IMECaN is organising a virtual workshop covering marine spatial planning and how to balance social, economic, cultural, and ecological objectives, to be held in August 2020. IMECaN is also integral to the planning of ClimEco7, IMBeR's summer school which has been postponed until August 2021.

Dialogue on the Maritime Silk Road, Doctoral Forum

The IPO-China co-organised the IMBeR-endorsed Doctoral Forum Experiencing China – *Dialogue on the Maritime Silk Road* held in Shanghai, China, in October 2019. The forum covered *Culture and Civilization*, *Estuaries and Coasts* and *Economics and Trade* and consisted of three concurrent but interacting sessions. The forum was attended by participants from 25 countries and has led to a special issue in the Journal of East China Normal University and 44 manuscripts have been submitted.

IMBeR Project Offices

International Project Office (IPO) Norway moved to Canada

The IPO hosting arrangement with the Institute of Marine Research, Bergen, Norway, ended on 31 March 2020. The IPO moved to Canada and is hosted in Halifax by Dalhousie University, the Ocean Frontier Institute (OFI), Ocean Tracking Network (OTN) and Marine Environmental Observation, Prediction and Response Network (MEOPAR). Lisa Maddison (Deputy Director) relocated to Halifax in March 2020; John Claydon (Director) continues to work remotely from Italy (due to Covid-19 travel restrictions). Tracey Woodhouse has been hired as the part-time Executive Assistant to the IPO-Canada. The four-year hosting arrangement (with the intention to extend for a 5th year) was formalised through an MOU (signed by SCOR on IMBeR's behalf).

International Project Office China (formerly IMBeR Regional Project Office)

Kai Qin was appointed as Executive Assistant in 2019. An MOU to support the IMBeR IPO-China for the next five years was signed by the IMBeR Scientific Steering Committee Chair, Carol Robinson and Prof. Qian Xuhong, President of the East China Normal University. The IPO-China is also supported by a consortium of marine institutions and projects. Fang Zuo is the Deputy Director and recruitment of a second Deputy Director will begin later in 2020.

Scientific Steering Committee (SSC)
The 2020 Scientific Steering Committee consists of a chair, Carol Robinson (F, UK), three vice-chairs: Marion Glaser (F, Germany), Eugene Murphy (M, UK) and Alice Newton (F, Portugal) and 13 members (7 male and 6 female).

Four new members joined the SSC in January 2020: Stephanie Brodie (F, early career researcher, USA), Marion Gehlen (F, France), Nyawira Muthiga (F, Kenya) and Narriman Jiddawi (F, Tanzania).

In order to have a more systematic approach for identifying expertise/skills gaps on the SSC, the IPOs conducted a survey of the current SSC members. The survey assessed how well the IMBeR Science

Plan and Implementation Strategy (2016-2025) was covered by current members' self-declared expertise. The survey revealed that Grand Challenge II is under-represented. At the end of 2020, Rubén Escribano will rotate off the SSC. IMBeR is therefore seeking a new member who will fit the expertise and/or geographical gap (Central and South America, North and West Africa, and Middle East) on the SSC.

The 2020 IMBeR SSC meeting was held virtually, with two 3-hour plenary sessions separated by a period of 10 days during which time was spent working on common tasks:
Exploring synergies between Regional Programmes and Working Groups
IMBeR Future science strategy
Mapping IMBeR outputs to the UN Sustainable Development Goals
Engagement with IMBeR - how can people get involved?
How to improve IMBeR's value to the hosts of the International Project Offices
Creating a new Innovation Challenge
IMBIZO6 conference
Exploring IMBeR's contribution to the UN Decade of Ocean Science for Sustainable Development
Improving IMBeR's website and social media use, developing a communication strategy, and scheduling delivery of content

These tasks have led to the development of publications (task 1), strategic direction for IMBeR (tasks 2, 4, 5, 6, 7, 8 and 9), ability to assess IMBeR's impact (tasks 3 and 5), and planning for the next conference in IMBeR's innovative IMBIZO series (task 7).

Collaborative partners
IMBeR science is strengthened and its impacts extended through on-going and new partnerships and collaborations with international and national organisations, including co-sponsors the Scientific Committee on Oceanic Research (SCOR) and Future Earth, the World Climate Research Programme (WCRP), and the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) which sponsors the Global Ocean Observing System (GOOS) and the International Ocean Carbon Coordination Project (IOCCP).

IMBeR continues to have long standing collaborations with the SCOR and Future Earth global research projects GEOTRACES, SOLAS, Future Earth Coasts, PAGES, Earth System Governance and bioDiscovery.

Too Big To Ignore (TBTI)
IMBeR is a partner of the TBTI project that is a global research network focusing on addressing issues and concerns affecting the viability and sustainability of small-scale fisheries. It includes 15 partners, 400 researchers from 45 countries. TBTI conducted a global analysis, based on information systems, to better understand small-scale fisheries and to develop research and governance capacity to address global fisheries challenges. Although TBTI was originally scheduled to finish in 2018, the project is still ongoing.

Ocean Carbon Biogeochemistry (OCB)
OCB continues to actively support IMBeR by advertising its activities and events, and by providing financial support for activities. Most recently, OCB has sponsored IMBeR's upcoming ClimEco7 summer school (2021).

World Climate Research Project (WCRP)
CLIVAR, a core project of WCRP, and its Indian Ocean Panel works closely with SIBER. CLIVAR is also part of the newly established Integrated Ocean Carbon Research (IOC-R).

GOOS
SIBER has strong connections with the Global Ocean Observing System in the Indian Ocean – IOGOOS.

PICES
IMBeR and PICES continue to collaborate, with representatives from both communities attending each other's summer schools and science meetings. PICES provided travel support for the IMBeR Future Oceans$_2$ Conference that enabled nine students and early career researchers from PICES member countries to attend. Sponsorship for the now postponed ClimEco7 summer school will be considered at the PICES 2020 Annual Meeting in October.

Vulnerability to Viability (V2V): Global Partnership for Building Strong Small-Scale Fisheries Communities
IMBeR is a partner on the V2V project that was recently awarded a seven-year Social Sciences and Humanities Research Council Partnership Grant. The project has 51 listed co-applicants and collaborators and 45 partner institutions, in total representing 24 countries. Among other methods, V2V will use the decision support tool I-ADApT (Assessment based on Description, responses, and Appraisal for a Typology) developed within the IMBeR Human Dimensions Working Group.

Selected IMBeR Publications
IMBeR has produced more than 2500 peer-reviewed research papers since 2005, with around 150 papers published in 2019-2020. The publications listed below are 'Class 1' publications, i.e. they have been specifically generated through/by/from/during IMBeR activities (e.g. publications arising from IMBeR conferences, and from the activities of the working groups and regional programmes).

ICED Publications
Papers
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Endorsed projects

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Future Oceans$_2$

Gullestad, P., Sundby, S., Kjesbu, O.S. (2020) Management of transboundary and straddling fish stocks in the Northeast Atlantic in view of climate-induced shifts in spatial distribution. Fish and Fisheries, 2020; 00: 1-10. https://doi.org/10.1111/faf.12485

Other IMBeR-relevant publications

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Support from SCOR

IMBeR would like to thank SCOR for its support. We greatly appreciate the ongoing support received from SCOR, and the additional support for specific IMBeR activities provided or managed by SCOR from other funding sources.

We are especially grateful for the wisdom, advice and assistance from the SCOR Executive Director, Ed Urban and Financial Officer, Liz Gross.

We would like to welcome Patricia Miloslavich as the new SCOR Executive Director and look forward to working together.

Budget

All values USD	Calendar Year	2019	2020	2020	2020	2021
INCOME			**Budgeted**	**Current**	**Predicted**	
SCOR (NSF 3-yr grants)		47 189	50 000	50 000	50 000	50 000
Future Earth	(received as EURO 15 000)	16 868	16 094	16 094	16 094	-
Reg. fees + sponsors	IMBeR OSC	279 000	-	-	-	-
	ClimEco	-	90 000	0	0	90 000
	IMBIZO	-	-	-	-	110 000
	West Pacific Symposium	-	125 000	0	125 000	-
BALANCE from previous year		44 786	60 025	58 127	58 127	115 221
TOTAL AVAILABLE FUNDS		**387 843**	**341 119**	**124 221**	**249 221**	**365 221**
EXPENSES			**Budgeted**	**Current**	**Predicted**	
Meetings	IMBeR SSC	20 831	30 000	0	0	32 000
	OSC (excl. ECR Day)	264 600	-	-	-	-
	OSC - IMECaN ECR Day	14 400	-	-	-	-
	OSC contingency	0	-	-	-	-
	ClimEco	-	90 000	0	0	90 000
	ClimEco contingency	-	17 000	0	0	17 000
	West Pacific Symposium	-	118 000	0	125 000	-
	West Pacific contingency	-	17 000	0	17 000	-
	IMBIZO	-	-	-	-	110 000
	IMBIZO contingency	-	-	-	-	10 000
IMECaN		0	3 000	0	1 500	3 000
Working Grps	Carbon WG (IOC-R)	1 435	2 000	0	0	2 000
	Ocean Acidification	4 936	7 500	0	0	7 500
	E. Boundary Upwelling Sys	-	-	-	-	-
	Continental Margins WG	0	5 000	0	0	5 000
	Human Dimensions WG	0	7 500	0	7 500	7 500
Regional Progs	CLIOTOP	1 124	15 500	0	0	15 500
	ESSAS	8 386	8 519	0	0	8 519
	ICED	6 006	7 500	0	0	7 500
	SIBER	7 998	7 500	0	0	7 500
Total EXPENSES		329 716	**302 019**	**0**	**134 000**	**296 019**
BALANCE end of year	**without contingency**	**58 127**	**39 100**	**124 221**	**115 221**	**69 202**
	including contingency	58 127	5 100	124 221	98 221	42 202

IQOE – Quiet Ocean

See Newsletters:
Number 4, January 2020: https://scor-int.org/IQOE/IQOE_Newsletter_4.pdf
Number 5, June 2020: https://scor-int.org/wp-content/uploads/2020/06/IQOE_Newsletter_5.pdf
Number 6, November 2020: https://scor-int.org/wp-content/uploads/2020/11/6_IQOE_Newsletter_FINAL.pdf

IIOE-2 – Indian Ocean expedition II

SCOR/IOC/IOGOOS Second International Indian Ocean Expedition (IIOE-2)
Report to SCOR 2019/20

GOAL
The goal of IIOE-2 remains as *to advance our understanding of the Indian Ocean and its role in the Earth System in order to enable informed decisions in support of sustainable development and the well-being of humankind*.

MANAGEMENT
While delivery of IIOE-2 occurs through national activities[1] these are coordinated by a Core Group comprising the following key personnel:

Role	*Name*	*Affiliation*
Co-Chair IIOE-2	Peter Burkill[a]	SCOR
	Vladimir Ryabinin	IOC
	Sateesh Shenoi	IOGOOS
Co-Chair WG 1 (Science & Research)	Raleigh Hood	USA
	Hermann Bange	Germany
Co-Chairs WG 2 (Data & Information Management)	Cyndy Chandler[b]	USA
	Harrison Ong'Anda	Kenya
Chair WG 4 (Operational Coordination)	Shailesh Nayak	India
Supported by		
International Project Office (Perth)	Nick d'Adamo	IOC
International Project Office (Hydrabad)	Satya Prakash	IOGOOS
SCOR Office	Patricia Miloslavich[c]	SCOR

a) Marie-Alexandrine Sicre will take over as Co-Chair IIOE-2 representing SCOR in October 2020.
b) Resigned in 2020.
c) Patricia Miloslavich took over from Ed Urban in January 2020

The Core Group has met electronically 4 times: in Nov 2019, in February 2020, in April and July 2020 over the last year to deal with strategic issues. The International Project Offices in Perth Australia and Hyderabad, India have dealt with a day-to-day issues within IIOE-2.

DEVELOPMENTS
The Indian Ocean community was to have met from 16th to 20th March 2020 in Goa, India for the *International Indian Ocean Science Conference 2020*. This open science conference was set up to debate and consider new understanding gained in first four years of results of IIOE-2; this conference has an International Board. The 2020 IIOE-2 SSC meeting was also scheduled to take place to discuss development and evolution of IIOE-2. One of the main focus of the this was how IIOE-2 might best contribute to the development of the *UN Decade of Ocean Science for Sustainable Development*.

Sadly, both these key meetings have had to be postponed to a future, and as yet, unknown date because of the Covid problem. It was hoped that the meeting could be rescheduled for later in 2020

1: Nations with IIOE-2 committees (chair) are: Australia (Lynnath Beckley), France (Francis Marsac), Germany (Birgir Gaye & Hermann Bange), India (Madhavan Nair Rajeevan), Japan (Yukio Masumoto), UK (Greg Cowie), USA (Raleigh Hood).

but this depends on Indian Government approval and it now looks increasingly likely this will be impossible in 2020.

PEER-REVIEWED RESEARCH OUTPUTS

For those seeking, a summary of the current state of understanding of the Indian Ocean, please see Hermes *et al* (2019)[2]. While the IIOE-2 community publishes its findings anywhere in the open literature, many key publications are to be found in the Special Issues of Deep-Sea Research II Volumes 161 and 166. These are coordinated by Raleigh Hood and are summarized below:

Volume 161:

Wiles et al. (2019) Submarine canyons of NW Madagascar: A first geomorphological insight. DSR2 Special Issue on IIOE2, 161: 5-15.

Singh et al. (2019) The community structure of the deep-sea nematode community associated with polymetallic nodules in the Central Indian Ocean Basin. DSR2 Special Issue on IIOE2, 161: 16-28.

White et al. (2019) Resilience of benthic ecosystem C-cycling to future changes in dissolved oxygen availability. DSR2 Special Issue on IIOE2, 161: 29-37.

Saalim et al. (2019) Assessing the ecological preferences of agglutinated benthic foraminiferal morphogroups from the western Bay of Bengal. DSR2 Special Issue on IIOE2, 161: 38-51.

Mao et al. (2019) Mesoscale eddy characteristics in the interior subtropical southeast Indian Ocean, tracked from the Leeuwin Current system. DSR2 Special Issue on IIOE2, 161: 52-62.

Prend et al. (2019) Impact of freshwater plumes on intraseasonal upper ocean variability in the Bay of Bengal. DSR2 Special Issue on IIOE2, 161: 63-71.

Yamani and Naqvi (2019) Chemical oceanography of the Arabian Gulf. DSR2 Special Issue on IIOE2, 161: 72-80.

Baer et al. (2019) Carbon and nitrogen productivity during spring in the oligotrophic Indian Ocean along the GOSHIP IO9N transect. DSR2 Special Issue on IIOE2, 161: 81-91.

Rigual-Hernández et al. (2019) Diatom species fluxes in the seasonally icecovered Antarctic Zone: New data from offshore Prydz Bay and comparison with other regions from the eastern Antarctic and western Pacific sectors of the Southern Ocean. DSR2 Special Issue on IIOE2, 161: 92-104.

Beckley et al. (2019) Structuring of larval fi sh assemblages along a coastal-oceanic gradient in the macro-tidal, tropical Eastern Indian Ocean. DSR2 Special Issue on IIOE2, 161: 105-119.

Miller et al. (2019) Contrasting biodiversity of eel larvae across the central Indian Ocean subtropical gyre. DSR2 Special Issue on IIOE2, 161: 120-131.

Dréo et al. (2019) Baleen whale distribution and seasonal occurrence revealed by an ocean bottom seismometer network in the Western Indian Ocean. DSR2 Special Issue on IIOE2, 161: 132-144.

Volume 166:

Burdanowitz et al. (2019) Holocene monsoon and sea level-related changes of sedimentation in the northeastern Arabian Sea. DSR2 Special Issue on IIOE2, 166: 6-18.

Krishnamohan et al. (2019) Is there an effect of Bay of Bengal salinity on the northern Indian Ocean climatological rainfall? DSR2 Special Issue on IIOE2, 166: 19-33.

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2) Hermes JC, Masumoto Y, Beal LM, Roxy MK, Vialard J, Andres M, Annamalai H, Behera S, D'Adamo N, Doi T, Feng M, Han W, Hardman-Mountford N, Hendon H, Hood R, Kido S, Lee C, Lee T, Lengaigne M, Li J, Lumpkin R, Navaneeth KN, Milligan B, McPhaden MJ, Ravichandran M, Shinoda T, Singh A, Sloyan B, Strutton PG, Subramanian AC, Thurston S, Tozuka T, Ummenhofer CC, Unnikrishnan AS, Venkatesan R, Wang D, Wiggert J, Yu L and Yu W (2019) *A Sustained Ocean Observing System in the Indian Ocean for Climate Related Scientific Knowledge and Societal Needs.* **Front. Mar. Sci. 6**:355. doi: 10.3389/fmars.2019.00355

Pearce et al. (2019) Marine debris pathways across the southern Indian Ocean. DSR2 Special Issue on IIOE2, 166: 34-42.

Menezes and Vianna (2019) Quasi-biennial Rossby and Kelvin waves in the South Indian Ocean: Tropical and subtropical modes and the Indian Ocean Dipole. DSR2 Special Issue on IIOE2, 166: 43-63.

Kämpf and Kavi (2019) SST variability in the eastern intertropical Indian Ocean – On the search for trigger mechanisms of IOD events. DSR2 Special Issue on IIOE2, 166: 64-74.

Huot et al. (2019) Partitioning the Indian Ocean based on surface fields of physical and biological properties. DSR2 Special Issue on IIOE2, 166: 75-89.

Bange et al. (2019) Nitrous oxide in the northern Gulf of Aqaba and the central Red Sea. DSR2 Special Issue on IIOE2, 166: 90-103.

Suntharalingam et al. (2019) Anthropogenic nitrogen inputs and impacts on oceanic N2O fluxes in the northern Indian Ocean: The need for an integrated observation and modelling approach. DSR2 Special Issue on IIOE2, 166: 104-113.

Beckmann and Hense (2019) Modelling nitrogen-oxygen dynamics in the central Arabian Sea: Large-scale meridional structure and seasonal variations. DSR2 Special Issue on IIOE2, 166: 114-124.

Twining et al. (2019) A nutrient limitation mosaic in the eastern tropical Indian Ocean. DSR2 Special Issue on IIOE2, 166: 125-140.

Noyon et al. (2019) Plankton distribution within a young cyclonic eddy off south-western Madagascar. DSR2 Special Issue on IIOE2, 166: 141-150.

Al-Yamani et al. (2019) The response of microzooplankton (tintinnid) community to salinity related environmental changes in a hypersaline marine system in the northwestern Arabian Gulf. DSR2 Special Issue on IIOE2, 166: 151-170.

Sutton et al. (2019) Habitat associations of cetaceans and seabirds in the tropical eastern Indian Ocean. DSR2 Special Issue on IIOE2, 166: 171-186.

Two further volumes of the DSR2 Special Issue Series on IIOE-2 are pending and these include the following MSS which are in press or under review

Urban (2020) Outcomes of the U.S. Program in Biology of the International Indian Ocean Expedition. DSR2 Special Issue on IIOE2, available online 9 April 2020, 104780, https://doi.org/10.1016/j.dsr2.2020.104780.

Cedras et al. (2020) Biogeography of pelagic calanoid copepods in the Western Indian Ocean. DSR2 Special Issue on IIOE2, in press.

Bernal et al. (2020) Mesopelagic fish composition and diets of three myctophid species with potential incidence of microplastics, across the southern tropical gyre. DSR2 Special Issue on IIOE2, in press.

Moffett and Landry (2020) Grazing control and iron limitation of primary production in the Arabian Sea: Implications for anticipated shifts in Southwest Monsoon intensity. DSR2 Special Issue on IIOE2, in press.

D'Asaro et al. (2020) Structure of the Bay of Bengal oxygen deficient zone. DSR2 Special Issue on IIOE2, in press.

Vinayachandran et al. (2020) Maintenance of the southern Bay of Bengal cold pool. DSR2 Special Issue on IIOE2, in press.

Amol et al. (2020) Effect of freshwater advection and winds on the vertical structure of chlorophyll in the northern Bay of Bengal. DSR2 Special Issue on IIOE2, in press.

Sreeush et al. (2020) Biological production in the Indian Ocean upwelling zones - Part 2: Data based estimates of variable compensation depth for ocean carbon models via cyclo-stationary Bayesian Inversion. DSR2 Special Issue on IIOE2, in press.

Sarma et al. (2020) Physical forcing controls spatial variability in primary production in the Indian Ocean. DSR2 Special Issue on IIOE2, in review.

Bernal et al. (2020) Diet composition of myctophid larvae off western Australia. DSR2 Special Issue on IIOE2, in review.

Liu et al. (2020) Eddy–current interaction in the Leeuwin Current off the lower west coast of Australia. DSR2 Special Issue on IIOE2, in review.

Vinayachandran et al. (2020) Processes governing the seasonality of vertical chlorophyll-a distribution in the central Arabian Sea: Bio-Argo observations and ecosystem model simulation. DSR2 Special Issue on IIOE2, in review.

Huang et al. (2020) MJO induced diurnal sea surface temperature variations off the Northwest Shelf of Australia observed from Himawari geostationary satellite. DSR2 Special Issue on IIOE2, in review.

Prakash et al. (2020) Observed variability of monsoon blooms in the north-central Arabian Sea and its implication to deeper water oxygen concentration: A Bio-Argo study. DSR2 Special Issue on IIOE2, in review.

Sprintall et al. (2020) Seasonality of the Somali Current/Undercurrent System. DSR2 Special Issue on IIOE2, in review.

Harms et al. (2020) Particulate matter fluxes reveal no coherence between primary production and organic carbon export in the Indian Ocean subtropical gyre. DSR2 Special Issue on IIOE2, in review.

Ningish et al. (2020) Zonal Current Characteristics in the Southeastern Tropical Indian Ocean (SETIO). DSR2 Special Issue on IIOE2, in review.

A further volume in the DSR II series is planned based on the 2019 IIO degree East cruise on the R.V. Investigator. It current has 23 MSS planned.

There is also a further series of MSS arising from this Australian lead cruise. These are at various stages of development as follows:

Authors	Title/content	Comments	Date expected
Landry et al.	Mesozooplankton biomass and temperature-enhanced grazing along a 110°E transect in the eastern Indian Ocean	Submitted MEPS	Feb 2020
Beckley et al.	Data report overview paper on the 110E voyage	Something similar to Jovane et al. (2019) South Atlantic multidisciplinary voyage paper – still awaiting response from Editor of Frontiers	
Thompson et al.	Long term change along 110E: comparison of 1963 & 2019 observations	Workshop held Sept 2019 at Murdoch. Most required data now processed and some text written – urgently awaiting physical oceanography density layers	June 2020

Phillips et al.	Variability/change of water mass properties near 20S	GRL	Dec 2020
Phillips	Long term variability 1960s to 2019		2021
O'Brien, Seymour et al.	Sulphur cycling (concentrations and qPCRs)	Progress has been made with biogeochemistry & extraction of DNA for qPCR. Hoping to publish the 110E line with not just biogeochemistry & qPCR but incorporation of some community data (amplicons) and metagenomics. This has become a thesis chapter & I would like to aim for a journal like ISME	2021
Focardi et al.	DNA - amplicon 16S and 18S biogeography paper	Maybe in DSR?	
Raleigh Hood	Model biogeochemistry of the IO with a focus on Nitrogen supply pathways to the Leeuwin Current and the SE Indian Ocean	Applied for funding for modelling	
Thompson, Meng Han & Phillips	Triaxus data for nitrate supply to LC	Could make DSR volume	2020
Beckley, Focardi et al.	Synthesis paper on the cold core eddy from cyclone Veronica.	Will need compilation of all eddy biological data & some physical & chemical data & satellite imagery	
Antoine et al.	UVP	UVP data (particle size distributions) has been done	
Antoine et al.	Assessment of the biological pump in the Eastern Indian Ocean	Won't make DSR issue	
Jeffs	Laser experiments on transparent zooplankton		
Antoine et al.	Pigments HPLC	Samples in France not yet analysed	
Antoine et al.	Cytometry	Sorting and determination of phytoplankton carbon on hold.	

There are other special journal issues for IIOE-2 in *Acta Oceanologica Sinica*, the *Journal of Marine Systems* and jointly in *Biogeosciences*, *Atmospheric Chemistry and Physics, Ocean Science, and Solid Earth* on « Understanding the Indian Ocean system: past, present and future (BG/ACP/OS/SE inter-journal SI), Editor(s): Hermann Bange, Raleigh Hood, Viviane Menezes, Colin W. Devey, and S. Wajih A. Naqvi.

INFORMAL PUBLICATIONS

IIOE-2 also communicates about the project through a monthly newsletter, quarterly publication (*Indian Ocean Bubble-2*), and its website (see below)

IIOE-2 WEBSITE

This is found at www.iioe-2.incois.gov.in and is IIOE-2's main interface with the world.

APPENDIX 6. INFRASTRUCTURAL PROJECT REPORTS

COBS – Changing ocean on biota

Annual report from COBS (Formerly SCOR WG149)
Accomplishments from the past year (in the context of our terms of reference)

In the last 12 months we have made substantial progress in achieving the goals and objectives set out in our Terms of Reference (ToR, see Appendix). We now have three new members (Jason Hall-Spencer (UK), Paul Renaud (Norway)) of the WG (including one ECR, Mridul Thomas (Switzerland).

Major efforts this year included:
Raising awareness of the availability of the www-based BPG through a suite of national, regional and international presentations and 1 day workshops.
For example, in February 2020, working group members led a 1-day MEDDLE workshop following the 13th New Zealand Ocean Acidification Conference. This workshop attracted 17 early career researchers, who used MEDDLE resources to design experiments to study the impact of environmental change on New Zealand's green-lipped mussel.
For example, WG member Dave Hutchins gave a 30 minute tutorial on the www-based BPG at the 2020 Ocean Sciences meeting in San Diego.
We also had posters at the SCOR booth throughout the week. We also sought out national advocates for the www-based BPG (from countries not represented by our WG membership). We now have advocates in Spain, Mexico, Portugal and Israel. The BGP continues to be popular based on data from both Google Analytics and You-Tube.
We also worked closely with the IOC as they develop multiple drivers as a key strand of their UN Decade of Ocean Science. Several members of WG149 are leading the development of a Guide for policy makers for the IOC (as part of the UN Decade of Ocean Science, see "About" on https://en.unesco.org/ocean-decade/). This guide also involves other groups we regularly liaise with such as Denise Breitburg (GO2NE). This forms our ongoing work on ToR's 2 and 7.
Sinead Collins is revising a Perspective entitled "Novel experimental frameworks are essential to reveal the rules shaping ocean global change biology". This Perspective (ToR #6) was written with both other WG members (Hutchins, Boyd, Havenhand) and with other scientists from a range of disciplines such as Francis Chan (coastal ecology), Naomi Levine (biogeochemical modelling) and Tatiana Rynerson (molecular biology) and so helps us attain ToR 2 (Raise awareness across different scientific communities).
Bridge-building with disparate disciplines including eco-toxicology, epi-genetics, and paleo-oceanography continues through a number of fora, including the Ocean Global Change Biology Gordon Research Conference (https://www.grc.org/ocean-global-change-biology-conference/2020/ postponed due to COVID-19) and Early Career event (Gordon Research Seminar) that will be chaired by WG member Sinead Collins. We also maintain and regularly update our website (https://scor149-ocean.com/) by adding new research papers and partners every 3-4 months to provide a useful repository of information on multiple drivers.

Plans for the coming year
The Annual meeting will be virtual this year, and we plan to have it in mid July 2020 as planned. We will try to use a rolling meeting format where we have three groups:
Europe (am) and Pacifica (pm);
Europe (pm) and the Americas (am);
Americas (pm) and Pacifica (am)

With short summaries being delivered to the next group so that we maintain continuity.

Europe – Sinead, Jon, Jason, Paul, Mridul, Marion, Marcello, Hans, Goran, Sam
(Haimanti is in between)
Pacifica – Christina, Philip, Catriona, Haruko, Kunshan, Katharina
Americas – Dave, Aurea, Uta

A key focus of this year's meeting will be to review the new suite of ToR's (listed below and drafted at the 2019 annual meeting in Brest).
Revision of our original terms of reference, with several of the goals such as #4 (www BPG now complete) to be replace with new activities and other more generic ToR's such as #2, #3 and #6 to be continued.

A number of events – such as the Gordon Research Conference on Ocean Global Change Biology (to have been curated and chaired by WG member Sinead Collins) have been put back to mid 2022. Also, Christina McGraw was to have run a training workshop at the Oceans in a high CO2 World meeting in Peru (rescheduled 2021).

We will also talk with the programme officers at NSF to explore continuation of our funding of the SCOR project. (NSF funding means that we can continue as a WG until at least August 2022, given the rollover of funds from SCOR due to the COVID-19 crisis).

Thanks to Ed Urban for support and advice since the inception of this WG, to Patricia Miloslavich for her help during the 2020 Ocean Sciences meeting (we look forward to working with you this year!). To NSF for ongoing support, to Axel Durand (IMAS) for maintaining the www site, and to the members of WG149 (Jean-Pierre, Ulf and Jorge) who have been so generous with their time and energy in 2018 and 2019.

Appendix
Terms of Reference of the current working group:

1. Assess the current status of emerging research themes 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. (Completed in 2017/18, Boyd et al., Global Change Biology Review paper)
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. Completed April 2019 https://meddle-scor149.org/ and comprises three components – decision support for design, MEDDLE (Multiple Environmental Driver Design Lab for Experiments) experimental simulator, and a library of video tutorials.
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. Ongoing – we are running courses internationally and nationally (see above). A handbook is available to step the reader through the BPG (https://doi.org/10.25959/5c92fdf0d3c7a).
6. Publish a series of short articles in both the scientific media and with scientific journalists to disseminate the challenges and opportunities surrounding multiple drivers and ecosystems. Ongoing

- Sinead Collins is currently revising a Perspective piece entitled "Novel, coordinated experimental frameworks are essential to reveal the rules shaping ocean global change biology"
7. Engage with policy-makers and science communication experts to produce a glossary of terms and an implementation guide for policy-makers to better understand the role of multiple drivers in altering marine living resources and ecosystem services. Ongoing – several members of WG149 are leading the development of a Guide for policy makers for the IOC (as part of the UN Decade of Ocean Science).

Proposed ToRs from 2019 Annual meeting in Brest – as the WG is now to transitioning into a SCOR project

1. Develop resources based on the Best Practice Guide and MEDDLE to train scientists in multiple driver research within connection with existing programs, e.g. MSc programmes, summer schools (e.g. IMBeR, SOLAS) and training sessions.
2. Advocate coordination by providing guidance on how to maximise overlap between experiments and analysis to allow intercomparison.
3. Progress the science towards a more holistic approach to address how multiple drivers will reshuffle marine ecosystems at a decadal scale. To do this, we will develop a strong conceptual framework around a subset of key questions. This will allow us to bridge disjoints between models, experiments and observations.
4. 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.
5. Link to societal questions, such as food security, by expanding multiple driver research to include higher trophic levels.
6. Engage with IOC-endorsed and other initiatives to promote an interdisciplinary process-based approach linking observations, models, and experiments within the UN Decade of Ocean Science for Sustainable Development.

GlobalHAB – Harmful Algal Blooms

GlobalHAB - the International SCOR-IOC Science Program on Harmful Algal Blooms

Activities 2019-2020 and Plans for 2020-2021

GlobalHAB Scientific Steering Committee members 2016-2020:

Elisa Berdalet, Institute of Marine Sciences, CSIC, Spain, Chair
Raphael Kudela, University of California, Santa Cruz, USA, Vice-chair

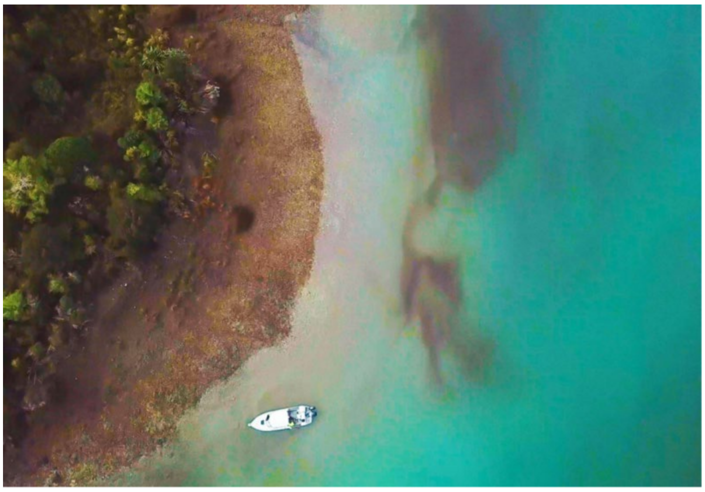
Neil S. Banas, University of Strathclyde, United Kingdom
Michele Burford, Griffith University, Australia
Christopher J. Gobler, Stony Brook University, USA
Bengt Karlson, Swedish Meteorological and Hydrological Institute, Sweden
Po Teen Lim, University of Malaya, Kuala Lumpur, Malaysia
Lincoln Mackenzie, Cawthron Institute, New Zealand
Marina Montresor, Stazione Zoologica Anton Dohrn, Italy
Kedong Yin, Sun Yat-Sen (Zhongshan) University, China

Eileen Bresnan, Marine Scotland Science, United Kingdom, ICES representative (2016-2020)
Dave Clarke, Marine Institute, Ireland, ICES representative after April 2020
Keith Davidson, The Scottish Association for Marine Science, United Kingdom, Ex-officio

Vera L. Trainer, National Oceanic and Atmospheric Administration, USA, ISSHA and PICES representative (2016-2020)
Gires Usup, Universiti Kebangsaan Malaysia, Malaysia, IPHAB representative (2015-2019)
Joe Silke, Marine Institute, Ireland, IPHAB representative (2019-2023)

Henrik Enevoldsen, IOC UNESCO, IOC Science and Communication Centre on Harmful Algae at the University of Copenhagen, Denmark (2016-
Ed Urban, Scientific Committee on Oceanic Research, USA (2016-2020)
Patricia Miloslavich, Scientific Committee on Oceanic Research, USA (2020-)

The GlobalHAB Scientific Steering Committee (SSC) acknowledges the financial and logistic support received from SCOR and IOC during the 2015-2019 period. The funds made possible the elaboration of the GlobalHAB Science and Implementation Plan, representation of the programme at international meetings and publications completing the work of the GEOHAB program.



Arial photo of a bloom of *Alexandrium pacificum* in the Marlborough Sounds, New Zealand. Photo: Cawthron Institute, New Zealand.

1. Meetings of the GlobalHAB SSC

Since the last SSC meeting at the Laboratoire d'Océanographie de Villefranche (LOV) in Villefranche-sur-mer (France) on April 10 and 11, 2018, the GlobalHAB SSC members worked on the implementation of the GlobalHAB activites by communication through email, virtual meetings, and meetings of opportunity (e.g. 18th International Conference on Harmful Algae, Nantes, France, October 21-26, 2018). Among other items, the SSC reviewed the status of ongoing activities, prioritized new activities. This saved funds to be used for specific activities and products.

For 2020, GlobalHAB has received support from NOAA (see section 5) to conduct a physical meeting. However, it has been postponed due to the Covid-19 pandemic. Thus, the coordination continues through email and virtual meetings.

2. *Science highlights in the 2019-2020 period*

2.1. Communications about the GlobalHAB program from GlobalHAB endorsed projects and other programmes related to GlobalHAB at international scientific events:

* UN DOALAS, Multi-Stakeholder Dialogue and Capacity-Building Partnership Event, New York, January 24-25, 2019. Kedong Yin was invited to give the presentation *Science-Driven Management Decision Making in Formulating Sewage Treatment Strategy*.

* International Conference on Toxic Cyanobacteria, Krakow, Poland, 2019, Poster presentation on GlobalHAB program and activities associated with cyanobacteria research. Presenter Michele Burford.

* Representation at the UN Ocean Decade Copenhagen 13-14 May 2019. Bengt Karlson gave the presentation "Reducing HAB problems for sustainable development".

Accumulations of cyanobacteria in the Baltic Sea between the islands of Gotland and Öland, 10 August, 2015. Photo courtesy of the Swedish Coast Guard

* Berdalet, E. *Climate Change and Harmful Algal Blooms: Challenges and Strategies*, https://www.youtube.com/watch?v=-Yidh1cTcpA&feature=youtu.be, Congreso MIMAR. Cambio Global en la Región Macaronésica, Technological Institute of Canarias (ITC), Pozo Izquierdo, Gran Canaria, 3-4 Dec 2019

* Representation of GlobalHAB at the COP25 in Madrid, by Elisa Berdalet

2.2. Paper on HAB Observing System: C. R. Anderson, E. Berdalet, R.M. Kudela, C. Cusack, J. Silke, E. O'Rourke, D. Dugan, M. McCammon, J. Newton, S. K. Moore, K. Paige, S. Ruberg, J. R. Morrison, B. Kirkpatrick, K. Hubbard, J. Morell. 2019. *Scaling Up From Regional Case Studies to a Global Harmful Algal Bloom Observing System*. Frontiers in Marine Science, https://www.frontiersin.org/articles/10.3389/fmars.2019.00250/full, doi:10.3389/fmars.2019.00250

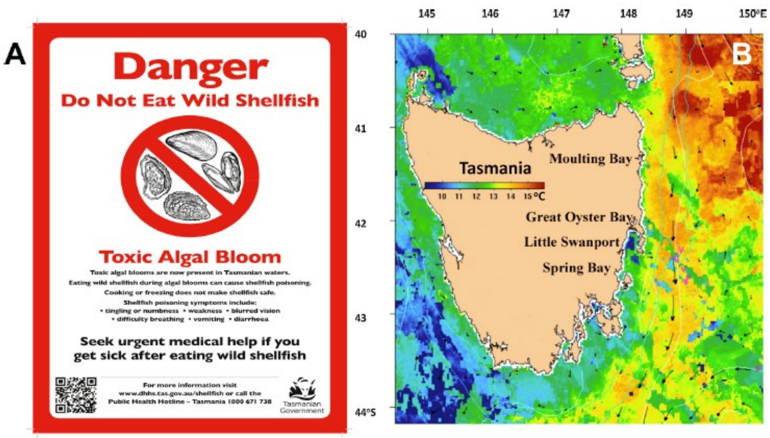
2.3. Paper on HABs and Oceans and Human Health (see also section 3). Borja, A., White, M.P., **Berdalet, E.**, Bock, N., Eatock, C., Kristensen, P., Leonard, A., Lloret, J., Pahl, S., Parga, M., Vera Prieto, J., Wuijts, S., Fleming, L.E. 2020. *Moving towards an agenda on ocean health and human health*. Frontiers in Marine Sciences, section Marine Ecosystem Ecology. *Front. Mar. Sci.* 7:37. doi: 10.3389/fmars.2020.00037

2.4. Inclusion of data on cyanobacterial blooms and toxins in HAEDAT database which presents reporting of HAB blooms globally (http://haedat.iode.org/index.php).

2.5. Manual for water managers on mitigation of cyanobacterial HABs: M.A. Burford, C.J. Gobler, P.M. Visser, M. Lurling, G.A. Codd. 2019. *Solutions for managing cyanobacterial blooms: A scientific summary for policy makers*. IOC/UNESCO, Paris (IOC/INF-1382). An aesthetically appealing, easy to understand document for drinking and recreational water managers on managing cyanobacterial HABs was produced. The document is available in print and on web: (http://www.globalhab.info/files/GlobalHAB_SSPM_Cyano_IOCINF-1382.pdf).

2.6. Special issue on *Harmful Algae* journal focused on "Climate Change and HABs", was completed in February 2020: https://www.sciencedirect.com/journal/harmful-algae/vol/91/suppl/C
It included the following papers:

1. C.G. Gobler. *Climate Change and Harmful Algal Blooms: Insights and perspective.* HA 91 (2020) 101731
2. V. L. Trainer, S. K. Moore, G. Hallegraeff, R. M. Kudela, A. Clement, J. Mardones, W. Cochlan. *Pelagic harmful algal blooms and climate change: Lessons from nature experiments with extremes*. HA 91 (2020) 101591
3. M.A. Burford, C.C. Carey, D.P. Hamilton, J. Huisman, H.W., Paerl, S.A. Wood, A. Wulff. *Perspective: Advancing the research agenda for improving understanding of cyanobacteria in a future of global change*. HA 91 (2020) 101601
4. P.A. Tester, E. Berdalet, W. Litaker. *Climate change and benthic harmful algae*. HA 91 (2020) 101728
5. M. Olofsson, S. Suikkanen, J. Kobos, N. Wasmund, B. Karlson. *Basin-specific changes in filamentous cyanobacteria community composition across four decades in the Baltic Sea*. HA 91 (2020) 101685
6. M. L. Brosnahan, A. D. Fischer, C. B. Lopez, S. K. Moore, D. M. Anderson. *Cyst-forming dinoflagellates in a warming climate*. HA 91 (2020) 101728
7. J. Raven, C. Gobler, P. J. Hansen. *Dynamic CO_2 and pH levels in coastal, estuarine, and inland waters: theoretical and observed effects on harmful algal blooms*. 91 (2020) 101594
8. P. Glibert. *Harmful algae at the complex nexus of eutrophication and climate change*. HA 91 (2020) 101583
9. A. Griffith, C. J. Gobler. *HABs: a climate change co-stressor in marine and freshwater ecosystems*. HA 91 (2020) 101590
10. G. M.M. Hennon, S. T. Dhyrman. *Progress and promise of omics for predicting the impacts of climate change on harmful algal blooms*. HA 91 (2020) 101587
11. D. K. Ralston, S. K. Moore. *Modeling harmful algal blooms in a changing climate*. HA 91 (2020) 101729
12. M.L. Wells, B. Karlson, A. Wulff, R.M. Kudela, C. Trick, V. Asnaghi, E. Berdalet, W. Cochlan, K. Davidson, M. De Rijcke, S. Dutkiewicz, G. Hallegraeff, K. Flynn, C. Legrand, H. Paerl, J. Silke, S. Suikkanen, P. Thompson, V.L. Trainer. *Future HAB Science: Directions and Challenges in a Changing Climate*. HA 91:101632



Trainer et al. 2020. Fig. 6. Signage (A) and SST (B) during the anomalous Paralytic Shellfish Toxin event in eastern Tasmania. Map of Tasmania, south of the mainland of Australia, showing sea surface temperatures on 27 September 2015 during peak PST, with the East Australian Current (in red) interacting with the continental shelf. Locations of the main affected shellfish farm areas.

3. *Implemented activities 2019-2020*

In addition to the Science Highlights in the previous Section 2, other activities have been conducted by the GlobalHAB SSC:

- February 25-27, 2019. A workshop was organized by IOC WESTPAC-HAB at Chulalongkorn University from to review the status of HABs and fish-killing Raphidophytes species in Western Pacific region. Two related papers have been published from this activity and another publication of the impacts of *Chatonella* in the region is expected by 2021:

Yñiguez, A.T., Lim, P.T., Leaw, C.P., Jipanin, S.J., Iwataki, M., Benico, G. Azanza, R.V. 2020. Over 30 years of HABs in the Philippines and Malaysia: What have we learned? *Harmful Algae*, https://doi.org/10.1016/j.hal.2020.101776.

Lum, W.M., Benico, G., Azanza, R., Furio, E., Lim, P.T., Lim, H.C. 2019. Morphology and molecular phylogeny of the harmful raphidophyte *Chattonella subsalsa* isolated from Bolinao, Philippines. *Philippine Journal of Natural Sciences* 24: 50-56.

- June 5-7, 2019. AZTI-SOPHIE project Summer School: *"Does human health and Wellbeing depend on a healthy Ocean?"* Aquarium of San Sebastian (Spain). This was a GlobalHAB endorsed project. Elisa Berdalet gave a lecture, representing GlobalHAB (https://www.azti.es/eventos/azti-sophie-project-summer-school-2019-does-human-health-and-wellbeing-depend-on-a-healthy-ocean/). The activity was linked to the World Oceans Day (http://www.worldoceansday.org/Default.aspx?CCID=31759&FID=343862&ExcludeBoolFalse=True&PageID=17466397). A paper was produced: Borja, A. et al. (2020), acknowledging GlobalHAB (see section 2.6).

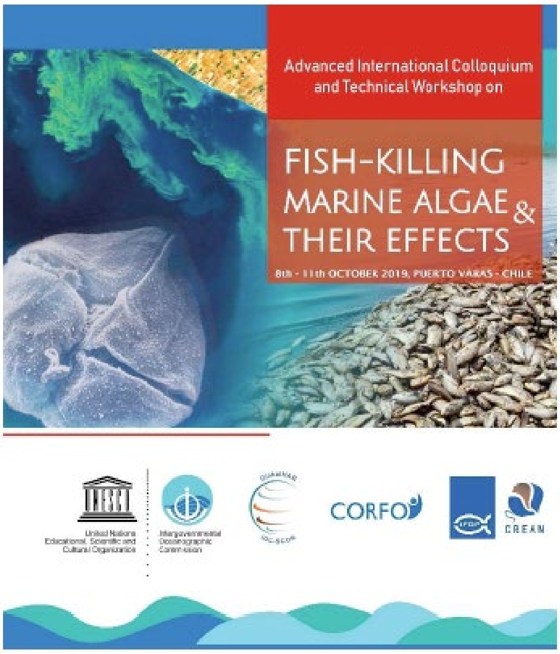
- June 10-11, 2019. As already initiated within GEOHAB (lead by Grant Pitcher and Raphael Kudela) GlobalHAB included fostering research on the potential links between ocean deoxygenation and HABs through interaction with IOC GO2NE (Global Ocean Oxygen Network, http://www.unesco.org/new/en/natural-sciences/ioc-oceans/sections-and-programmes/ocean-sciences/global-ocean-oxygen-network/). A joint GO2NE - GlobalHAB workshop was organized to identify potential research on this topic in 2019. It was held in Paris immediately prior to the next GO2NE workshop (http://hab.ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=2469).

- August 25-30, 2019. A session on HABs was conducted within the 7th European Phycological Conference (http://epcseven.biol.pmf.hr/), Zagreb (Croatia). The session was chaired by S. Accoroni and P.M. Visser, and M. Montresor was member of the Organizing Committee.

- October 8-11, 2019. An Advanced International Colloquium and Technical Workshop, under the auspices of IOC-IPHAB and GlobalHAB, with the support of the government of Chile through CORFO and collaboration of CREAN-IFOP, was held in Puerto Varas, Chile. Ten invited participants (D.M. Anderson, A.D. Cembella -WG chair-, O. Espinosa, L. Guzman, G.M. Hallegraeff, P.J. Hansen -acting chair-, H. Hégaret, T.O. Larsen, J. Mardones, M.Iwataki, L.MacKenzie) reviewed state-of-knowledge and addressed gaps in knowledge to develop strategies for technological and scientific approaches to mitigate impacts of fish killing algal blooms.

The workshop included Closed sessions with presentations and discussions within the participants group, and an Open session with public from the area and offered in streaming as well. A white paper, ***Fish-Killing Algal Blooms and Ichthyotoxins: Prevention, Mitigation and Control,*** with the outcomes of the workshop is under process. The contents include:

1. *Taxonomy*. M. Iwataki
2. *Chemistry and analytic methods – how to deal with the many congeners*. T. Larsen
3. *Modulation of toxin production and release*. P. J. Hansen
4. *Mechanisms of effect (dissolved, cell bound, micropredation)*. P. J. Hansen
5. *Modes of action, toxicology and biotechnological applications.* TBD
6. *The necessity of bioassays – and which ones to select*. H. Hégaret, J. Mardones
7. *Ecology and physiology of Fish Killing Algae*. A. Cembella
8. *Ecosystem effects*. L. MacKenzie
9. *Climate change*. G. Hallegraeff
10. *Prevention, control, mitigation*. D.M. Anderson
11. *Socio-economics*. J. Mardones
12. *Implementation*. TBD



Venue: Puerto Varas, Chile
Dates: 8th – 11th October, 2019

- October 17-19, 2019. An international workshop, "*Evaluating, reducing and mitigating the cost of harmful algal blooms: a compendium of case studies*", was held in Victoria, British Columbia, Canada as part of the Annual Meeting of the North Pacific Marine Science Organization (PICES). The workshop co-convenors were Drs Vera Trainer (USA), Keith Davidson (UK) and Kazumi Wakita (Japan). It was jointly sponsored by GlobalHAB (SCOR and IOC), PICES, NOWPAP, ISSHA, NOAA, FAO and private companies. The goal of the 2.5-day workshop was to bring together international experts in economics, social sciences, and the study of harmful algal blooms (HABs) to develop a compendium of case studies to guide future research on the economic and social costs of HABs, identify priorities and unify methods for future collaborative assessments of HAB impacts. https://meetings.pices.int/meetings/annual/2019/PICES/Program. Information about the event was included in:

PICES Press 2020, 28(1): 30-32. Trainer, V. L., Davidson, K., Wakita, K., Berdalet, E. Suddleson, M., Myre, G., Trethewey, D. GlobalHAB: Evaluating, Reducing and Mitigating the Cost of Harmful Algal Blooms, a Compendium of Case Studies.

Harmful Algal News 2019, 63. Trainer, V.L., Davidson, K., Wakita, K., Berdalet E., Suddleson, M., Myre, G., Trethewey, D. IOC-SCOR GlobalHAB Workshop: Evaluating, Reducing and Mitigating the Cost of Harmful Algal Blooms, a Compendium of Case Studies.

Participants from the GlobalHAB Workshop (W18): Evaluating, reducing and mitigating the cost of Harmful Algal Blooms, at PICES-2019, Victoria, British Columbia, Canada.

<u>A Report is going to be completed in July 2020 (after revision) and including the following sections:</u>

Chapter 1. *GlobalHAB Workshop: Evaluating, Reducing and Mitigating the Cost of Harmful Algal Blooms, a Compendium of Case Studies. Introduction*. V. L. Trainer, K. Davidson, K. Wakita, E. Berdalet, M. Suddleson, G. Myre, D. Trethewey.

Chapter 2. *Evaluating the economic impacts of harmful algal blooms: Issues, methods, and examples.* D. Jin, S. Moore, D. Holland, L. Anderson, W.-A. Lim, S. Jardine, S. Martino, F. Gianella, D.-H Kim.

Chapter 3. *Situation, Management and Economic Impacts of Cochlodinium in Korea.* W.-A. Lim, D. Kim, K. Wakita.

Chapter 4. *An economic assessment of ciguatera outbreaks – an island model.* C. Trick, L. Anderson, E. Berdalet, W.P. Cochlan, P. Wang, M.L. Wells.

Chapter 6. *Estimating and mitigating the economic costs of Harmful Algal Blooms (HABs) on commercial and recreational shellfish harvesters.* J. Mardones, D.S. Holland, L. Anderson, V. LeBihan, f. Gianella, A. Clement, V.L. Trainer.

Chapter 7. *The economic impacts of harmful algal blooms on salmon cage aquaculture.* K. Davidson, S.L. Jardine, S. Martino, G. Myre, L.E. Peck, R.N. Raymond, J. J. West.

Chapter 8. *Commonalities and Summary recommendations*. V. Trainer, R. Kudela, T. Yoshida, V. LeBihan, W. Cochlan, W.-A. Lim, D.-H. Kim, et al.

4. New activities to be implemented2020-2021

4.1. Ongoing and confirmed activities

- March 2018 to June 2020. E. Berdalet has been participating, in representation of GlobalHAB at the CLEFSA project activities *"Emerging threats on human health in Europe due to climate change"*. CLEFSA is a project of the European Food Safety Agency (EFSA) that explores the risks of food intoxication in future climate change scenarios. CLEFSA included aquatic biotoxins in the European landscape. E. Berdalet is collaborating in the analysis through online communication and attendance to a unique first meeting (April 2018, funded by GlobalHAB). The final Report is expected on June 2020.

- May 2020. A 3.5-day workshop on "*Modelling and prediction of harmful algal blooms, from event response to multi-decadal projections*" was planned to be held in Glasgow, UK. The organising committee consists of Neil Banas, David McKee, Bingzhang Chen, Paul Udom (University of Strathclyde), Bengt Karlson (Swedish Meteorological and Hydrological Institute), Keith Davidson, Dmitri Aleynik (Scottish Association of Marine Science), Clarissa Anderson (Scripps / SCCOOS), Dennis McGillicuddy (Woods Hole Oceanographic Institution), Beatrix Siemering (UK Food Standards Agency), and is also coordinating with Katja Fennel and Marion Gehlen, chairs of the Marine Ecosystem Analysis and Prediction Task Team (MEAP-TT) of the GODAE OceanView programme.

The organizers secured enough funds from different institutions, including co-fund from GlobalHAB, to invite a substantial number of early-career and developing-world scientists. A programme of summer-school-like tutorials will be woven into conference-style presentations and discussions. The draft programme is organised into four parts:
- Exploring the diversity of HAB modelling approaches
- Emerging technologies and platforms to support HAB monitoring
- Linking models, observations, and stakeholder needs
- Scaling up: the global impact of global change on HABs

Information is shown at:
http://www.globalhab.info/activities/globalhab-activities
http://habmodelworkshop.sccoos.org

The workshop has been postponed from May 2020 to May 2021 because of disruption caused by Covid-19. The organisers will confirm and refine this plan in summer 2020, and more information will follow in autumn 2020.

- **Summer 2020.** A *Mini-symposium on automated in situ observations of plankton*, was planned to be hosted at Kristineberg Marine Research Station, Sweden on June 1-6, 2020.
In recent years novel in situ instrumentation has been developed for automated high frequency HAB detection in near real time. Also instruments for observing grazers, e.g. microzooplankton and multicellular zooplankton are becoming available commercially. These instruments are now being adopted in research and also in monitoring programmes. The aim of the mini-symposium is to bring together experts on, and users of, in automated in situ imaging systems, novel sampling equipment etc. to present methods, recent results and to share experiences. Another aim is to carry out a comparison of results when analysing plankton communities quantitatively. Young scientists is one target group of the symposium. After the main symposium a young scientist's data workshop for data processing and report/article writing is planned. The organizers secured enough funds from different institutions, including co-fund from GlobalHAB.

Information is shown at:
http://www.globalhab.info/activities/globalhab-activities

Dates

1-6 June 2020

Venue

Kristineberg Marine Research Station, Fiskebäckskil, Sweden
This is well-equipped field station is located at the mouth of the Gullmar fjord on the Swedish west coast, adjacent to the North Sea. More information is available at:

https://mi.gu.se/kristineberg-marina-forskningsstation (select English in menu)

The Mini-symposium has been postponed to June 2021 because of disruption caused by Covid-19. New information will be provided when possible.

- **2020.** The elaboration of a "*Best Practice Guidelines for the Study of HABs and Climate Change*", editorial team constituted by Mark Wells (chair), Michele Burford, Anke Kremp, Marina Montresor, Grant Pitcher and Gires Usup, started on March 2018. A tentative deadline for the submission of the draft chapters was the month of May 2019. When closing this report, the chapters have been reviewed and authors are completing the final version, expected by early July.

The Manual includes the following chapters:

Overview (Editorial Board)
Chapter 1 - Rationale and Introduction (Editorial Board)
Chapter 2 - Observing changes in HABs over time — Long Term Observations (Richardson AJ, Eriksen R, Hallegraeff GM, Rochester W, Pitcher GC, Burford M)
Chapter 3 - Databases for the study of harmful algae, their global distribution and their trends (Zingone A, Escalera L, Bresnan E, Enevoldsen H, Provoost P, Richardson A, Hallegraeff G)
Chapter 4 - Experimental approaches (van der Waal D, Kremp A)
Authors have received feedback from reviewers and are currently revising the manuscript.
Chapter 5 - Understanding Responses of HAB Species to climate change through experimentation (Dyhrman S, Godhe A, Hennon G, Sefbom J)
Chapter 6 - Future Perspectives in Modeling Harmful Algal Blooms (HABs) - Guidelines for HABs modelling (Hense I, Anderson CR, Hamilton D, Chapra S)

Authors have received feedback from reviewers. Hamilton is leading a major revision of the manuscript.

Funds for the first working meeting of the editorial team were provided by GlobalHAB. *The initiative of the Best Practices Manual for HAB and Climate Change is in line with the activities of SCOR WG149 that is focusing on Changing Ocean Biological Systems (COBS) and particularly on "How will biota respond to a changing ocean?" (https://scor149-ocean.com/)*.

4.2. Other activities ongoing and under exploration by the GlobalHAB SSC members and collaborators:

*** Global Harmful Algal Bloom Status Report**
The first Global HAB Status Report is an initiative of IOC UNESCO with the support of IAEA, ICES, PICES and ISSHA. The GlobalHAB SSC is following and supporting the initiative where it can. In order to develop and launch the first Global HAB Status Report a network of data providers for OBIS-HAB and HAEDAT has been established and an Editorial Team for the First Global HAB Status Report was established together with a data flow structure. A data compilation template for HAB data in OBIS has been developed and reviewed and is in use (https://github.com/iobis/habtemplate/blob/master/habtemplate_a_v4.xlsx). This will allow to complement, and add value to, data already in OBIS with baseline observations recorded in the literature. Focus continues to be on data compilation and upgrades and adjustments to the data systems (HAEDAT as well as the OBIS-HAB data entry template). Additionally, the Editorial Team for the GHSR has developed the outline of the GHSR and chapters are drafted. Regional summaries on HAB based on OBIS, HAEDAT and the literature will constitute a special issue of the Elsevier Journal *Harmful Algae* in 2020. The planned online tools to create information products have yet to be developed and will focus on creating the products for the GHSR. Currently, a new data portal for HAEDAT is in development (http://dev.iobis.org/haedat/). The GHSR is foreseen to be complete by end 2019/early 2020.

* **New GlobalHAB Theme: *Sargassum* Blooms.** The GlobalHAB Science and Implementation Plan identifies that new emerging HAB related issues can be incorporated into the program after its launch. This is the case of the blooms of green macroalgae and *Sargassum*. **Elisa Berdalet** and **Henrik Enevoldsen** have been in touch with several researchers about this topic since 2016. The SSC have with Brian Lapointe (US) developed a short overview paper and the GESAMP Group of Experts have prepared a longer scoping paper on the *Sargassum* issue. The SSC proposed to GESAMP at its 2018 session to organize a joint Open Science Meeting (OSM) to identify the main research questions to understand the population dynamics of *Sargassum*. Several of the GESAMP (represented by Peter Kershaw) sponsoring agencies and the European Funded project EuroSea (coordinated by Caroline Cusack) have shown interests in the topic.

The GlobalHAB SSC has established a subcommittee, based on the experience on *Sargassum* to organize the OSM integrated by:

* Brigitta van Tussenbroek, UNAM, Mexico, vantuss@cmarl.unam.mx
* Brian Lapointe, Harbor Branch Oceanographic Institute, Fl, US, blapoin1@fau.edu
* Ester Serrao, University of Algarve, Portugal, eserrao@ualg.pt
* José E. Martinelli Filho, Federal University of Parà, Brazil, martinelli@ufpa.br
* Hoang C. Tin, University of Sciences, Hue City, Vietnam, hoangcongtin@gmail.com
* Elisa Berdalet, GlobalHAB SSC Chair, ICM-CSIC, Spain
* Henrik Enevoldsen, IOC representative

On May 26, Elisa Berdalet, Henrik Enevoldsen and Brian Lapointe participated in a Webinar organized by UNEP "*Sargassum in the Caribbean and West Africa: Key Challenges, Responses and Collaboration*" and presented the progress on the OSM to be hosted by Universidad Autónoma Nacional de México (UNAM). The OSM was very well received and different research initiatives, including SPAW RAC and IOCARIBE, manifested their interest to be engaged as well. Although initially planned to be held in May 2020, the Covid-19 posponed it.

UN environment programme

GPNM

WEBINAR AGENDA:

Sargassum in the Caribbean and West Africa:
Key Challenges, Responses and Collaboration

TUESDAY, 26 May 2020
East Africa: 17:00-18:30; West Africa: 15:00-16:30; Jamaica: 09:00-10:30

Time (Kenya time)	Agenda item	Discussant/Facilitator
17:00 - 17:10	Welcome remarks	• Habib El-Habr, UNEP GPA • Henrik Enevoldsen, IOC/UNESCO *Facilitator: Joana Akrofi, UNEP Science Division*
17:10 - 17:30	Sargassum: Key issues and challenges	• Peter Kershaw, GESAMP • Brian LaPointe, Marine Scientist *Facilitator: Joana Akrofi, UNEP Science Division*
17:30 - 17:50	Sargassum: Regional Reflections ▪ Caribbean Region ▪ West Africa (Abidjan Convention)	• Ileana Lopez, Cartagena Convention Secretariat, CEP, SPAW Protocol • Sandrine Pivard, SPAW RAC Director • Jaques Abe, Abidjan Convention *Facilitator: Mahesh Pradhan, UNEP GPA GPNM*
17:50 – 18:00	Research Update on Harmful Algal Blooms (HABs)	• Elisa Berdalet, Institute of Marine Sciences (ICM-CSIC) *Facilitator: Mahesh Pradhan, UNEP GPA GPNM*
18:00 - 18:20	Sargassum: Challenges, Responses and Collaboration Q&A	*Facilitator: Mahesh Pradhan, UNEP GPA GPNM*
18:20 - 18:30	Conclusions and way forward	• Joana Akrofi, UNEP Science Division • Mahesh Pradhan, UNEP GPA GPNM

Registrations online at: https://attendee.gotowebinar.com/register/8127154217602616445

For more information: Milcah.Ndegwa@un.org

* Workshop and a Summer school on analysis and interpretation of genetic data on HABs. The activity is followed by Po Teen Lim who hosted regional workshops/training courses on HABs species and detection using molecular techniques for Southeast Asia in 2017 and 2018. More details of these activities are available in Harmful Algae News 58 and 61 (http://hab.ioc-unesco.org/index.php?option=com_content&view=article&id=22&Itemid=0). **National and regional workshop will be planned in collaboration with other international and regional agencies interested in HABs.**

Training workshops have been organized on molecular characterization and detection, 4-8 Dec 2018 and 10-14 June 2019. The two workshop organized at Institute of Oceanography (IO), Vietnam have benefited 40 participants with lectures and practical sessions.

HABs session and a workshop on HABs metabarcoding using Next-generation sequencing have been planned at the coming 5th International Symposium on Marine Environmental Sciences (XMAS-V), Xiamen 2021. https://melmeeting.xmu.edu.cn/xmas5/

* A workshop on the use of the artificial substrate for sampling harmful species (*Gambierdiscus, Ostreopsis, Prorocentrum*, cyanobacteria) had been organized by Elisa Berdalet, Pat Tester and Emilio Soler-Onís to be conducted during the DINO12 Conference to be hosted in Gran Canaria, Canary Islands in July 2020. However, the meeting has been posponed to 2021 due to the Covid-19 pandemic.

* A Scientific Summary for Policy Makers (SSPM) on HABs and Climate Change will be elaborated based on the main key messages from the special issue in *Harmful Algae* and the Manual on Best Practices to investigate HABs and Climate Change. The SSPM could be linked to the two IPCC 1.5C special reports that are coming out this year and next year. The SSC will determine how to address it.

5. Funding considerations and future funding plans

The scientific meetings of the GlobalHAB SSC have been supported by IOC UNESCO and SCOR (with funding from the U.S. National Science Foundation), and by in-kind contributions from ICES, PICES and SAMS. Additional funds have been received from other institutions to conduct the specific activities indicated previously.

The US NSF earmarked contribution to SCOR was exhausted on August 31st, 2019. SCOR authorized GlobalHAB to use the remaining funds on that date to contribute to the implementation of the planned activities in 2020. Unfortunately, the Covid-19 pandemic has forced to postpone them until 2021. **The GlobalHAB SSC to SCOR sollicits that these secured funds could be used in 2021.** This extension will allow conducting the planned activities and produce the scientific outcomes papers, new knowledge, training and coordination) that implement GlobalHAB goal.

Support has been provided by NOAA's National Centers for Coastal Ocean Science (NCCOS) Competitive Research Program (CRP) via the US National HAB Office. Funding is provided through the IOC Science and Communication Centre on Harmful Algae at University of Copenhagen, Denmark.

6. GlobalHAB SSC members renewal 2020

The Scientific Steering Committee of the SCOR and IOC GlobalHAB program was constituted in January 2016, at the launch of the program. It was constituted by 10 members (Table 1) with diverse expertise to address the challenges and priorities of the research on Harmful Algal Blooms during a three years period. During this time, the SSC worked in the development of the GlobalHAB Science and Implementation Plan and other tasks identified in the Terms of Reference of the SSC (www.globalhab.info). In addition, the GlobalHAB SSC includes ex-officio members acting as liaisons with other organizations.

An extension of the SSC term until 31 December 2019 was allowed by IOC and SCOR in order to facilitate the consolidation of the program and because all SSC members were involved in many activities programmed in 2019 and 2020.

Towards the end of 2019, the whole SSC started an internal analysis to conduct a partial renew of the membership for the 2020-2022 period (Table 2). In order to provide some continuity, only those members having a direct responsibility on a planned activity on that period were invited to continue in the SSC until this activity is accomplished. This continuation could be as "core SSC members" or as members of a new operational structure on Subcommittees (Tables 3 and 4) defined to conduct some ongoing tasks. Once these activities will be achieved (including finishing products, e.g. papers, reports, …), the turnover scheme will continue. Based on this, 4 people, Neil Banas, Elisa Berdalet, Bengt Karlson and Po Teen would remain as core SSC members. Michele Burford, Raphael Kudela, Lincoln Mackenzie and Marina Montresor would continue as members of specific subcommittees. Chris Gobler and Kedong Yin would step down.

In addition, the SSC members were invited to nominate candidates with energy, motivation and generosity for implementing the GlobalHAB Science Plan and addressing new challenges. Through email communication and two conference calls 24 candidates were shortlisted and a preferential ranking was established. The two main criteria were to ensure that the SSC will cover all the diverse expertise and to have a biogeographic representation. The first names in the list were invited to join the SSC with accompanying information about the GlobalHAB program, the SSC Terms of Reference, the last Report of conducted and planned activities and the funds conditions for the 2020-2022 period. The six candidates hat accepted to join the GlobalHAB SSC are: Clarissa Anderson, Tim Davis, Hae Jin Jeong, Raffaele Siano, Susie Wood and Aletta Íñiguez. Some of the names in the highest positions, namely, Tomasa Cuéllar-Martínez, Chuanmin Hu and Sanna Suikanen, will be invited to join the subcommittees.

Concerning the Chair, different possibilities were considered. By consensus the SSC decided that Elisa Berdalet will continue to serve as Chair of the SSC until 31 December 2020 in order to facilitate transfer of all the different program activities and issues she is in charge. Raphael Kudela, Vice-Chair, will step down from the SSC but will continue to participate as a liaison for some of the programs and activities (i.e. not a full SSC member). The new Vice-Chair will be decided when the new SSC will be established. The renewal of the members that started in 2016 is expected at the end of 2020, and the new members will serve until 2022. New rotation rules should be established as part of the GlobalHAB SSC Terms of Reference.

When closing this Report, the new composition of the SSC has been submitted to SCOR and IOC/IPHAB for consideration.

GlobalHAB**, on behalf of all the international community working on HABs, **thanks all the SSC members and liaisons that step down for their dedication and engagement with the program along the 2016-2019 period.

Table 1. Composition of the first GlobalHAB SSC in the period 2016-2019.

GlobalHAB SSC 2016-2019				
SSC Scientific Members	**Country / Entity**	**Main SSC 2016-2019**		**Expertise / Theme**
		Start	End	
Berdalet, Elisa	ES	2016	2019	**Chair.** 6-BHAB, 10-Health
Banas, Neil	UK	2016	2019	9-Modeling, 12-CC
Burford, Michele	AU	2016	2019	2-Adaptive strategies; 5-FHABs, cyano
Gobler, Chris	USA	2016	2019	5- FHABs, cyano
Karlson, Bengt	SE	2016	2019	8-Comparative; 9-Observation
Kudela, Raphael	USA	2016	2019	**Vice-Chair.** GO2NE, GOOS

Lim, Po Teen	MY	2016	2019	3-Toxins, 7-Fish kills
Mackenzie, Lincoln	NZ	2016	2019	7-Aquaculture
Montresor, Marina	IT	2016	2019	1-Biodiversity
Yin, Kedong	CN	2016	2019	4-Eutrophication

Ex-officio				
Davidson, Keith	UK	2017	2019	7-Aquaculture, 11-Economics

Liaisons with partner entities				
Bresnan, Eileen	ICES-IOC WGHABD	2016	2020	
Usup, Gires	IPHAB	2016	2019	
Silke, Joe	IPHAB	2019	2021	
Trainer, Vera	PICES and ISSHA	2016	2019	
Kudela, Raphael	GOOS Bio & Eco Panel	2017	2019	

Sponsors Representatives				
Enevoldsen, Henrik	IOC UNESCO	2016		
Urban, Ed	SCOR	2016	2019	

Table 2. Composition of the first GlobalHAB SSC in the period 2020-2022. A short description of the new candidates and their CV follows after table 4.

GlobalHAB SSC 2020-2022				
SSC Scientific Members		**Main SSC 2020 - 2022**		**Expertise / Theme**
Former SSC members	Country / Entity	Start	End	
Berdalet, Elisa	Spain	2020	2020	**Chair.** 6-BHAB, 10-Health
Banas, Neil	United Kingdom	2020	2020	9-Modeling, 12-Climate Change
Karlson, Bengt	Sweden	2020	2020	8-Comparative; 9-Observation
Lim, Po Teen	Malaysia	2020	2020	3-Toxins, 7-Aquaculture (Fish kills)

New SSC members				
Anderson, Clarissa	USA	2020	2022	9-Observation, Modeling
Davis, Tim	USA	2020	2022	5-FHABs, cyano; 4-Nutrients
Jeong, Hae Jin	Korea	2020	2022	1-Taxonomy, 2-Physiology, 3-Toxins
Siano, Raffaele	*France*	2020	2022	9-Observations
Wood, Susie	New Zealand	2020	2022	5-FHABs, cyano
Yñiguez, Aletta	Philippines	2020	2022	9-Observation, Modeling. Molecular tools. Citizen science

Table 3. Structure of GlobalHAB SSC including the new Subcommittees, with participation of different SSC members and external collaborators

GlobalHAB SSC 2020-2022				**Subcommittees to implement ongoing and pipeline activities in the 2020-2022 period**													
SSC Scientific Members	**Main SSC 2020 - 2022**		**Expertise / Theme #**	9-Modelling		12-Best Practise Manual HABs & CC		7-Aquaculture & Fish Kills		8-Observations		5-Freshwater & Brackish Water HABs		10&11-Economics & Health		13-Sargassum	
Former SSC members	**Start**	**End**		Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
E. Berdalet	2020	2020	**Chair.** 6, 10, 11, 13							2019	2021			2016	2020	2016	2021
N. Banas	2020	2020	9, 12	2020	2021												
B. Karlson	2020	2020	8, 9	2020	2021					2019	2021						
P.T. Lim	2020	2020	3, 7					2016	2020								
M. Burford			2, 5			2017	2020					2016	TBD				
R.M. Kudela	2020	2022	9, 12	2020	2021					2019	2021						
L. Mackenzie			7					2016	2020								
M. Montresor			1, 12			2017	2020			2019	2021						

New SSC members			**Expertise / Theme #**	9-Modelling		12-Best Practise Manual HABs & CC		7-Aquaculture & Fish Kills		8-Observations		5-Freshwater & Brackish Water HABs		10&11-Economics & Health		13-Sargassum	
C. Anderson	2020	2022	9																		
T. Davis	2020	2022	4, 5																		
H.J. Jeong	2020	2022	1, 2, 3																		
R. Siano	2020	2022	9																		
S. Wood	2020	2022	5																		
A. Yñiguez	2020	2022	9																		
New Subcommittee Members			**Expertise / Theme #**	9-Modelling		12-Best Practise Manual HABs & CC		7-Aquaculture & Fish Kills		8-Observations		5-Freshwater & Brackish Water HABs		10&11-Economics & Health		13-Sargassum	
Cuéllar-Martínez, Tomasa			1																		
Hu, Chuanmin			13																		
Suikanen, Sanna			5																		

Ex-officio			**Expertise / Theme #**	9-Modelling		12-Best Practise Manual HABs & CC		7-Aquaculture & Fish Kills		8-Observations		5-Freshwater & Brackish Water HABs		10&11-Economics & Health		13-Sargassum	
K. Davidson			7, 11	2020	2021			2016	2020					2016	2020		
V. Trainer			11											2016	2020		

Liaisons with partner entities			**Expertise / Theme #**	9-Modelling		12-Best Practise Manual HABs & CC		7-Aquaculture & Fish Kills		8-Observations		5-Freshwater & Brackish Water HABs		10&11-Economics & Health		13-Sargassum	
D. Clarke	2020	2022	ICES-IOC WGHABD														
R.M. Kudela	2018	2022	GOOS Bio & Eco Panel. IPCC	2020	2021					2019	2021						
J. Silke	2019	2022	IPHAB														
NN	2020	?	PICES														

Sponsors Representa-tives																	
H. Enevoldsen	2016		IOC UNESCO														
P. Miloslavich	2020		SCOR														
NN - Not in the SSC			NOAA co-sponsor														

Table 4. Members of the operative Subcommittees in 2020, including SSC and non SSC members. In red, persons already involved in the SSC during some period. Note that the new SSC members starting in 2020 have not been assigned to any subcommittee. This will be decided once the SSC will be approved and constituted.

Modelling Organizing Committee	
Chair	Members
N. Banas	D. Aleynik
	C. Anderson
	K. Davidson
	B. Karlson
	D. McGillicuddy
	B. Siemering
Task	**Workshop + product**
Expected finalisation	**Dec 2021**

Best Practices Manual CC HABs - Editors	
Chair	Members
M. Wells	A. Kremp
	M. Burford
	M. Montresor
	G. Pitcher
Task	**Manual**
Expected finalisation	**Dec 2020**

Fish Killing Algal Blooms	
Chair	Members
L. Guzmán	D. Anderson
	A. Cembella
	G. Hallegraeff
	H. Hégaret
	M. Iwataki
	P.T. Lim
	T.O. Larsen
	L. Mackenzie
Task	**Workshop + product**
Expected finalisation	**Dec 2020**

Observations Organizing Committee	
Chair	Members
B. Karlson	K. Davidson R. Kudela L. Naustvoll P. Tiselius M. Montresor E. Berdalet
Task	**Minisymposium + product**
Expected finalisation	**Dec 2021**

Freshwater Subcommittee to be decided	
Chair	Members
M. Burford	*Suikanen, Sanna*
Task	**TBD**
Expected finalisation	**TBD**

Economics Organizing / Follow up Committee	
Chair	Members
V. Trainer	E. Berdalet K. Davidson S. Moore K. Wakita
Task	**Finish Report and possible peer-review paper**
Expected finalisation	**Dec 2020**

Sargassu	
Chair	
TBD	
Task	
Expecte finalisat	

IOCCP – Ocean carbon

International Ocean Carbon Coordination Project
Progress Report for SCOR, June 2020

PROJECTS AND MAJOR ACTIVITIES

IOCCP & BONUS-INTEGRAL Training Course on a Suite of Biogeochemical Sensors

In June 2019, IOCCP and EU BONUS INTEGRAL Project (Integrated carboN and TracE Gas monitoRing for the bALtic sea) held a 10-day international training course on "Instrumenting our ocean for better observation:a training course on a suite of biogeochemical sensors." As described in the 2019 annual report to SCOR, course organisation involved a significant amount of IOCCP human and financial resources, the allocation of which followed the decision of IOCCP SSG to strengthen our role in technical capacity building and thus better realize our Terms of Reference #7:

7) Develop and support training activities for users of observing technologies (instruments, sensors and platforms) for ocean carbon and biogeochemistry.

The course took place on June 10-19, 2019 at the Sven Lovén Center for Marine Sciences, in Kristineberg, Sweden. Building on the success of the 2015 summer school, the course responded to the growing demand of the global ocean observing system and the marine biogeochemistry community for expanding the correct usage and generation of information from a suite of autonomous biogeochemical sensors.

27 outstanding early-career scientists, including 18 women scientists, selected from almost 140 applicants, attended the course. The attendees were joined by 20 dedicated instructors, who shared their practical expertise with a variety of sensors:

Multiple optode-type optical oxygen sensors
Chlorophyll fluorescence and backscatter/turbidity sensors for bio-optical measurements
Ion-sensitive field-effect transistor (ISFET)- and spectrophotometry-based pH sensors
Membrane-based sensors and an underway system for measuring partial pressure of carbon dioxide (pCO_2)

This intensive course provided trainees with lectures and hands-on experience across the whole spectrum of operations—from deployment and interfacing, through troubleshooting and calibration, to data reduction, quality control, and data management. Insights into complementary use of remote sensing, modeling, and smart data extrapolation techniques not only broadened participants' perspectives, but also effectively opened new avenues for research ideas and collaborations that they initiated during the course. More information about the course goals, agenda, instructors and materials can be found on the course website at:
http://www.ioccp.org/2019-training-course

In their post-workshop evaluations, the participants agreed that the course succeeded in teaching best practices for the selected biogeochemical sensors and autonomous measurement systems and provided ample guidelines and practical tips regarding specific reporting requirements (e.g., metadata, calibration, validation, error estimates). This training course was thus well suited for the next generation of users of large-scale biogeochemical ocean observation networks centered around profiling floats, moorings, and gliders, as well as around research and commercial vessels.

As also described in an *Eos* article published in November 2019, this course succeeded in forming a tight network of almost 50 biogeochemical sensor users, combining experts with beginners from 19 countries and six continents and representing a total of 26 nationalities. The benefits of networking enabled by this workshop are already evident through active communication maintained among the participants. The self-organised, informal network is used to pursue new research collaborations, exchange papers and technical advice, and organise course graduate meetings such as in San Diego after the 2020 Ocean Sciences conference.

Based on the course proceedings, and in collaboration with IOC-UNESCO IODE's Ocean Teacher Global Academy (OTGA), IOCCP prepared an online version of this course in an attempt to meet the overwhelming demand for such training opportunities. The comprehensive set of training materials divided into a number of topics, include video recorded lectures and/or lecture slideshows in PDF supplemented with links and references to various materials such as manuals, guides and best practices. The online course materials are open to all and are meant to expand the impact of the training beyond the initial group of 27 which could attend the course in Kristineberg in June 2019.

The online course materials can be accessed freely and openly by following this link: https://classroom.oceanteacher.org/course/view.php?id=394.

Next edition(s) of the IOCCP Sensors Training Course

Based on the very successful two editions of the sensors training course in 2015 and 2019, and in response to a great demand for such technical capacity building, the IOCCP SSG strongly supported organizing the sensors training course as a recurrent event. The SSG approved of the proposal to hold the course on a bi-annual basis, provided that we avoid overlap with other major international summer schools (IMBeR, SOLAS) to avoid competing for funding as well as participants. Overlap with SOLAS Summer School will happen in 2021, as SOLAS shifted their activity by one year. However, both SOLAS and IOCCP are in agreement that such overlap should be avoided at all costs in the future.

Arrangements have already been made to organize the 3rd IOCCP Sensors Training Course in June 2021, also in Kristineberg, Sweden. Currently, IOCCP is inquiring about funding opportunities with the goal of securing co-sponsorship by the end of boreal summer 2020.

Global data synthesis activities

New releases of Surface Ocean CO_2 Atlas (SOCAT) and Global Ocean Data Analysis Project (GLODAP)

On June 18th, 2019 SOCAT version 2019 was proudly released on behalf of over 100 contributors. SOCATv2019 has 25.7 million quality controlled surface ocean fCO_2 (fugacity of CO_2) observations from 1957 to 2019 for the global oceans and coastal seas. SOCAT enables quantification of the ocean carbon sink and ocean acidification, as well as evaluation of sensor data and ocean biogeochemical models. The product represents a milestone in biogeochemical and climate research, and it informs policy and high-profile climate negotiations. Importantly, SOCAT version 6, released in 2018, was mentioned in the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) IPCC report published in 2019.

Communication on SOCATv2019 took place through various channels, including, but not limited to, a release poster at OceanObs'19 Conference in September 2019, a presentation at the 2019 Challenger Advances in Marine Biogeochemistry meeting, and a webinar to the Community of Ocean Action on Ocean Acidification.

Preparations are ongoing for the release of GLODAPv2.2020, with Nico Lange (GEOMAR, Germany) taking the lead on work with quality control for data from over 100 new cruises which were submitted to GLODAP by the end of January 2020. A series of virtual meetings of GLODAP Reference Group was concluded in early 2020 to agree on adjustment tables for the new release. The new release is planned for boreal summer 2020.

A GLODAP meeting was held on 16 February 2020 ahead of the 2020 Ocean Sciences Meeting in San Diego, CA, USA. The meeting addressed issues related to the long-term functioning of the activity such as data submission and acquisition, automation, role of key people, as well as funding.

Development of a Global Ocean Oxygen Atlas (GO_2AT)

Following the discussions initiated at the joint VOICE & GO_2NE meeting in Monterey, CA, USA, in September 2017, and in line with one of the recommendations from the OceanObs'19 Community White Paper published by the VOICE initiative (Garçon et al., 2019), IOCCP (through its SSG member Véronique Garçon) has gradually been working towards enabling the development of an oxygen-related data platform and synthesis product, mimicking the process of developing SOCAT.
The overarching goal of this initiative is to obtain more reliable climate and ecosystem models and gaining a better understanding of the ecology of the marine systems. Model evaluations and IPCC-type assessments provide just two types of examples motivating improved global oxygen data availability, quality and comparability.
To this end, in 2019 IOCCP engaged several international partners: IOC-UNESCO, Global Ocean Oxygen Network (GO_2NE), Collaborative Research Center (SFB 754), and US NOAA; to develop a roadmap towards creating a "SOCAT-like" synthesis data product for oxygen observations. An initial scoping workshop was held in Sopot, Poland, in November 2019. Please see the details of the workshop goals and proceedings under the Workshops and Meetings section of this report.
Currently the work is ongoing in several sub-groups, and an advanced draft white paper on the roadmap towards the proposed GO_2AT is being circulated for internal review. A second, follow-up workshop is tentatively planned for October 2020, pending sufficient progress within the sub-groups and removal of global travel restrictions.

Time-series biogeochemistry data product

Over the past 12 months progress has been made on the development of a biogeochemistry time-series data product - an effort led by IOCCP SSG member, Björn Fiedler, in collaboration with other international bodies coordinating time series observing and data dissemination efforts, primarily US OCB and IGMETS (https://igmets.net/).
As noted in the 2019 IOCCP report to SCOR, two main challenges need to be overcome in order to deliver the product: (i) establishing a community-based working group that defines requirements and steers the process, and (ii) funds need to be raised to enable the work on a pilot data product.
Much has been achieved to address the first challenge over the past 12-month cycle. First, Björn Fiedler in consultation with and on behalf of the IOCCP SSG, contributed to the OceanObs'19 Community White Paper (CWP) "Ocean Time Series Observations of Changing Marine Ecosystems: An Era of Integration, Synthesis, and Societal Applications" led by Heather Benway (US OCB). The paper outlines "near-term observing priorities and technology needs; explores potential mechanisms to broaden ocean time series data applications and end-user communities; and describes current tools and future requirements for managing increasingly complex multi-platform data streams and developing synthesis products that support science and society." Actionable recommendations which are put forward in this CWP would help develop "a robust, sustainable, fit-for-purpose time series network that will foster a predictive understanding of changing ocean systems for the benefit of society." The publication of this paper fulfills the action item from the 12th Session of IOCCP SSG which called for a 10-year strategy for internationally coordinated biogeochemistry time series observations.
The NSF EarthCube Time series workshop, held just prior to OceanObs'19 Conference in Hawaii, provided an excellent opportunity to discuss the needs of the community with respect to developing future data products, among other things. Workshop proceedings and outcomes are further described under the Workshops and Meetings section of this report.
The second challenge of fundraising has also been addressed very successfully with the EU H2020 EuroSea project providing funds for further development of multi-platform time series observations in the Atlantic Ocean, and a demonstration of a first time-series based data synthesis product. Funds have been allocated for a postdoc position at GEOMAR and partially for organisation of a large community workshop, which IOCCP has agreed to co-sponsor (see more information under Future Directions section of this report).

Most recently, the EuroSea effort was presented to the attendees of a time series workshop organized by the US Ocean Acidification Programme, held in February 2020 in Seattle, WA, USA. The workshop focused on creating consistent trends from time series data for particular applications, such as detecting anthropogenic trends, and fulfilling high level policy obligations, e.g. through SDG target 14.3.1 which calls for the "Average marine acidity (pH) measured at agreed suite of representative sampling stations". The undertaking requires discussions on deseasonalization and trend analysis routines, which will also be part of the EuroSea effort. Unlike the planned EuroSea workshop, the Seattle event focused specifically on surface ocean carbonate observations. Thanks to good communication between the two efforts in their early stages of development, as advised by IOCCP, maximum complementarity can be obtained.

IOC-UNESCO Working Group on Integrated Ocean Carbon Research (IOCR)

On 28 - 30 October 2019 the first Experts Workshop of the Integrated Ocean Carbon Research Working Group (IOCR) took place at the headquarters of the Intergovernmental Oceanographic Commission of UNESCO (IOC) in Paris, France. This expert workshop was co-convened by the IOC, IOCCP, SOLAS, IMBeR, CLIVAR and the Global Carbon Project (GCP). The objective of this workshop was to bring together the decades of collective experiences of the IOC, IOCCP, SOLAS, IMBeR, CLIVAR and GCP expert groups to inform the next generation of integrated ocean carbon research.
35 participants from 15 countries focused on three specific issues:

- Identification of critical knowledge gaps in the ocean carbon cycle;
- Identification of research activities in order to close this gap;
- Bridging between science and policy: the United Nations Decade of Ocean Science for Sustainable Development (2021-2030), the United Nations Framework Convention on Climate Change and its Paris agreement, the Intergovernmental Panel on Climate Change 6th Assessment Report.

During discussions leading to the workshop several key elements critical for the integration into the future ocean carbon research were identified and formed the basis of workshop discussions:

A. Policy and societal implications and applications of ocean carbon research and observations

Under this item, the societal value of ocean carbon research and observations was thoroughly considered from a UN and multilateral perspective. Specifically, the discussions dealt with relevant demands by the UN Framework Convention on Climate Convention, its Paris Agreement, and the Convention's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTA). The discussions also identified research and observations needed to inform Sustainable Development Goal (SDG) 14, and the UN Decade of Ocean Science for Sustainable Development.

B. Integrating surface and interior and connecting coastal and open ocean carbon observations and products to enhance a 3D understanding of carbon distribution and variability

Currently existing connections and disconnections in research and products were highlighted. Surface fluxes relate to the pCO_2 of the water and air (evaluated by SOCAT) whereas storage of inorganic carbon is in the form of dissolved inorganic carbon (DIC; summarized by GLODAP). Given the temporal and spatial variability in pCO_2, SOCAT is evaluated at a much higher resolution (annually) than ocean inventories (once a decade). Evaluation of the fundamental question:"Do we fully understand the relationship between uptake and storage?" involved topics like water mass formation and the conversion of pCO_2 to DIC, which brought in aspects of the changing Revelle Factor. This session dealt with multiple dimensions of ocean biogeochemistry and changes therein: terrestrial influences on coastal biogeochemistry; biogeochemical and carbonate buffer factor feedbacks and tipping points that may shift ocean CO_2 net uptake and storage; understanding of how surface fluxes are connected to interior carbon storage;

C. Connecting carbon fluxes research with physical drivers, specifically heat and freshwater fluxes in the global ocean

Heat flux directly influences pCO_2 and fresh water fluxes directly influence DIC. We know reasonably well the relationship between temperature and pCO_2, but the question how tight is the relationship between heat flux and CO_2 fluxes remains open. Can the community constrain estimates of these fluxes? Also, can measurements of total alkalinity (TA) and DIC help constrain freshwater fluxes or vise versa? The most challenging aspects of the interconnections amongst these three flux variabilities (heat, freshwater, CO_2) link closely with themes B and D.

D. Interaction with biology including detection and impacts of ocean acidification
This was potentially the most complex theme discussed at the workshop as it requires insight into biological aspects of ocean carbon research, including the biological pump, the microbial carbon pump, and organic to inorganic carbon transformations in the ocean. Several specific issues were highlighted, for example our ability to definitively document any anthropogenic changes in the biological pump (including both the organic carbon pump and the inorganic carbonate pump). Can we as a community continue to support the claim that Total Alkalinity is and will always be constant with time? Perhaps we are only in a position to start answering these and other relevant questions now, that our measurements are getting more integrated and accurate. Part of these divagations were naturally focused on impacts of ocean acidification on the ecosystem.

Each of the themes described above was thoroughly investigated for identification of existing knowledge gaps with focus on several aspects like different temporal and spatial scales of ocean carbon uptake from intra seasonal to decadal and from upwelling regions to other targeted sampling regions, the role of climate variability in ocean carbon uptake, targeted sampling of key regions, research gaps to improve the global and regional carbon assessments ie. the Regional Carbon Cycle Assessment and Processes (RECCAP). Also considered were gaps related to the use of the selected elements of the entire portfolio of observing platforms (underpinning aspects such as observing/analysis techniques, logistical challenges, feasibility and more). The adequacy of existing data streams and data syntheses products (if they exist) was also investigated in relation to currently existing modelling efforts. Specific research gaps and needs related to uncertainties in model predictions as well as data assimilation activities were also highlighted. Finally gaps related to standard protocols and best practices were discussed and highlighted.
Following the workshop, the Scientific Steering Committee of the IOCR WG (including IOCCP's Rik Wanninkhof and Maciej Telszewski) met to develop an exploitation plan allowing to influence a wide variety of community members, end-users and stakeholders. The SSC decided to focus the following 6-12 months on producing three documents based on the workshop proceedings:

- an Integrated Ocean Carbon Research Plan
- a high-level, short peer reviewed article illustrating the strategy of the IOCR plan to be submitted to Nature or Science by late 2020 to outline the major findings of the IOCR Plan
- a progress report highlighting the accomplishments of the IOCR Working Group to its main sponsor, the IOC.

Of these, the IOCR Plan is utterly the most important tool to advance ocean carbon research and give the ocean carbon community (and IOCCP) guidance on what specific activities are needed to do so. To that end a work plan was developed including the timeline, the structure of the Plan and an agreed list of chapter co-authors responsible for developing the first draft by mid-2020. The first draft will be shared with all workshop participants for input and then open for community review before formal approval by all co-convening organizations.

Providing authoritative guidance on observing system design

IOCCP contributes to many of the GOOS Strategic Objectives as described in the GOOS 2030 Strategy. GOOS Strategic Objective #5: "Provide authoritative guidance on integrated observing system design, synthesizing across evolving requirements and identifying gaps" puts a specific charge on the GOOS Panels of Experts, including IOCCP. To this end, IOCCP and other Panels have been involved in horizon-scanning and dialogue with the community over emerging areas of need for coordinated and sustained observations, and the subsequent development of EOVs.

In advance of the 9th Session of GOOS Steering Committee Meeting, IOCCP Office was asked to prepare a teleconference for members of GOOS Executive to discuss more efficient joint implementation of GOOS Strategic Objective (SO) #5 on "Authoritative guidance on co-design" and to a large extent also the closely related SO#3 on "Observing System evaluation."

The recent draft Roadmap to Implementation of the GOOS 2030 Strategy provided a much needed context for the discussions. The document describes our charge for the next few years in terms of what GOOS wants to achieve in dialogue with the many existing and future new partners. According to the Roadmap, authoritative guidance on observing system design (SO5) in this context is meant as:

"(...) undertaking of multidisciplinary assessment and synthesis across a range of evolving requirements, in order to guide and support implementation decisions from global to regional, and across platforms, networks and technologies."

The objectives of the Call were not to discuss the partnership aspect per se, but rather to (i) decide on the shared role of GOOS Panels in providing authoritative guidance on observing system co-design, and (ii) agree on a consistent and transparent process of providing authoritative guidance, and its efficient communication.

The group acknowledged the urgent need for GOOS to show more effective leadership in providing guidance on the observing system design and evaluation to the community, and made a number of specific recommendations which will be put up for discussion by GOOS SC. It was agreed that while the core of the process should rely on tight collaboration between the GOOS structures, it is critical to eventually invite relevant stakeholders to co-develop guidelines for the global community. To this end, the Roadmap to Implementation of GOOS 2030 Strategy should ensure due acknowledgement of community and many stakeholder efforts, and ensure inclusivity in the future process.

It was recommended that an analysis of roles and responsibilities of all GOOS structures be performed, akin to e.g. what IOCCP carried out on a smaller scale for the panel. Equally important would be an analysis of the current vs required resources for successful implementation of GOOS actions, including decisions to re-allocate effort elsewhere to increase efficiency for the core business of GOOS.

The group further discussed how to revive the efforts initiated at GOOS-SC-8 with the proposed Task Team on System Evaluation and Task Team on EOVs. To deliver a document providing actual guidelines for observing system design and evaluation it was recommended to initiate a broader process which is based on co-development with stakeholders, and a process which ensures their buy-in. It was noted that from a broad perspective EOVs are of paramount importance for the global observing system, e.g. for satellite agencies justifying their operations based on whether a given parameter is an ECV/EOV. It was recommended that we continue to collect feedback on the current and potential usage of EOV/ECV by the community. In general, the priority is to document and publish a set of transparent guidelines for how GOOS sets and reviews requirements around EOVs, and how to communicate the process with the community. A peer-reviewed publication on the overall GOOS implementation of the Framework for Ocean Observing remains very much needed.

A proposal with estimates of human and financial resources needed to address the issues through two GOOS Task Teams was presented by IOCCP Project Officer during the virtual meeting of GOOS Steering Committee (20-24 April 2020), and subsequently endorsed by the Committee members.

Establishing global coordination of an Integrated Marine Debris Observing System (IMDOS) through the EuroSea Project

During the 7th Session of the GOOS Steering Committee (June 2018), it was recommended that IOCCP as GOOS Biogeochemistry Panel takes charge of scoping the community needs for international coordination of sustained ocean observations of marine plastics contaminants. GOOS acknowledges that Marine Plastics is not within the domain of expertise of IOCCP, but at the same time recognizes that IOCCP has a long and successful track record of building partnerships with expert working groups and dedicated institutions and organizations to initiate new elements of the observing system. Thus, GOOS hopes to build on this experience in its efforts to support the global coordination of an Integrated Marine Debris Observing System (IMDOS) and the development of Marine (Plastics) Debris as a new type of Human Pressure/Activity EOV. To this end, GOOS has offered to commit explicit funds for IOCCP Project Officer to overlook the coordination work within the new EU H2020 EuroSea project.

IOCCP SSG has very carefully considered this issue during its 13th Session in October 2018, and communicated its decision and put forward adequate recommendations for GOOS on how to proceed on this task. In summary, IOCCP SSG decided not to take this up as a long-term task, however in the short term, in its capacity as GOOS Biogeochemistry Panel of Experts, IOCCP would act on behalf of GOOS as a conduit for key international organizations and initiatives engaged in developing a coordinated observing system for marine debris. This short-term action, contributing to the GOOS Strategic Objective #10 “Impact of human activities on the ocean,” involves collecting information on the status and needs of marine plastics monitoring towards creating a Marine Plastics Debris EOV; and support for the establishment of global coordination of IMDOS. What’s more, IOCCP SSG concluded that taking up this activity directly fulfils Recommendation #20 from the IOCCP Sponsors Review Panel to “diversify the funding sources for IOCCP” as it allowed to secure the contract of IOCCP Project Officer for another 3 year term via EU Horizon 2020 EuroSea Project.

Formally, IOCCP’s activities in this domain were initiated in the second part of 2019 in preparation for the OceanObs’19 Conference, and then intensified with the start of the EuroSea project (November 2019) and the task on establishing global coordination of marine plastics monitoring. After a series of meetings and individual consultations in late 2019 (see details under the Workshops and Meetings section), in early 2020 IOCCP on behalf of GOOS prepared a first draft of a proposed “Action Plan for establishing global coordination of the Integrated Marine Debris Observing System (IMDOS): Phase I (2020-2022).”

This document is a direct follow-up on the commitment expressed by GOOS during OceanObs’19 Conference which was made in response to a clearly articulated need for IMDOS as envisioned in the OceanObs’19 Community White Paper by Maximenko et al. (2019). The Action Plan is meant to identify specific actions which would enable implementation of ideas and recommendations from Maximenko et al. (2019), contributing to OceanObs’19 Living Action Plan, and being in concert with the related international initiatives led by UNEP, IOC-UNESCO, SCOR, Arctic Council, and GEO Blue Planet, among many others contributing to the mission of the Global Partnership on Marine Litter (GPML).

The design of IMDOS as a backbone observing system needs to ensure delivery of adequate data and information which could then be integrated and synthesized into indicators and decision-support tools via relevant data centres and knowledge platforms, in line with the proposed Global Platform for Monitoring Marine Litter and Informing Action (Smail et al., draft) and more broadly a Digital Ecosystem for the Environment (UNEP, 2019).

Successful coordination of marine debris monitoring requires a complex approach that considers the entire life cycle of artificial debris in the marine environment. Currently, this Action Plan identifies actions which would focus on the backbone of such an observing system, to provide reliable information on the state of marine pollution due to artificial debris deposited into the marine environment, and to some extent, on its impacts on marine life. This backbone would not necessarily be able to answer all the questions which motivate maintaining a marine debris monitoring system, in particular those related to monitoring land-based sources of marine litter, or the dispersion and accumulation pathways.

As such, this Action Plan addresses only the sea-based (including shoreline) activities related to marine debris monitoring, and therefore, does not necessarily apply the entire concept of IMDOS as envisioned by Maximenko et al. (2019). The exact scope of IMDOS would be decided by the Steering Committee and described in the Terms of Reference.

Establishing a globally coordinated IMDOS would fill the need for a coordinating body providing authoritative guidance on how to develop and evolve a global sustained observing system providing adequate data and information on marine debris in response to diverse stakeholder needs. IMDOS would thus occupy an important niche in a very complex and full landscape of organizations and initiatives involved in tackling the problem of marine litter pollution.

The draft Action Plan proposes a two-phase process to establish global coordination and operational capacity of IMDOS as a system which enables monitoring and potentially also assessing the risk posed by marine debris, while leveraging global coordination mechanisms for data collection and dissemination set up by the UN system and other organizations.

As of May 2020, the document remains subject to initial consultations among leaders of marine debris monitoring efforts and lead authors of the IMDOS CWP, as well as members of selected GOOS structures. Details of the proposed Action Plan are described in the relevant section on IMDOS under the Future Directions section of this report. These plans will be modified pending the final revision of the Action Plan by the wider marine debris monitoring community.

Harmonization of requirements for EOV and ECV observations

In 2019, IOCCP worked closely with OOPC and the Biology & Ecosystems Panels of GOOS on improving how GOOS articulates requirements for the ocean observing system. The concept of setting requirements for EOVs has been evolving since their first drafting in 2013. More recent developments; particularly, clear articulation from Global Climate Observing System (GCOS) of their reporting needs, and the move towards strengthened engagement with the World Meteorological Organisation (WMO), which also means engaging in the WMO Rolling Review of Requirements process, meant it was timely to revisit the information included in the EOV Specification Sheets curated by GOOS Panels. The goal was to harmonize the GOOS EOV and GCOS ECV approach to setting requirements for what essentially is the same observing system. Recognizing discrepancies in definitions and formats used by GOOS and GCOS and lack of flexibility from GCOS to better adapt to the needs of the ocean community, we opted to further modify the table of requirements for EOVs to make it a source of all requirements information to be used for various reporting needs as the most efficient and consistent way to advocate for observation requirements.

The rationale for refining existing EOV requirements, the motivation for working with GCOS and the recommended process as outlined above was discussed at length with IOCCP SSG. The SSG decided that refining the requirements to the level of setting goals for coverage, resolution, uncertainty and timeliness of EOV sub-variable observations would be a worthwhile exercise. However, the SSG was strongly insistent on such refinement taking place through dedicated workshops engaging an adequate pool of experts. It was suggested that throughout 2020 we plan for one or two such type workshops, starting with EOVs on highest overall readiness level: inorganic carbon and oxygen. It was tentatively proposed that a workshop on Inorganic Carbon EOV requirements could take place in conjunction with the 15th Session of IOCCP SSG, while the workshop on oxygen EOV requirements be combined with the already planned oxygen data workshop.

In early 2020, GOOS Biogeochemistry Panel continued to support OOPC in their obligation to provide input into the GCOS processes. In particular the Panel engaged in the following activities:

- Reviewing progress against the 2015 GCOS Implementation Plan actions
- Reviewing any public comments on the new proposed ECV requirements as received by GCOS
- Evaluating the current adequacy of ECV products with respect to the 2015 requirements
- Drafting the 2021 GCOS Status Report

Coordination of global ocean acidification observations

IOCCP continues to play a very active role in coordination of ocean acidification (OA) observations on global and regional scales, through the work of two dedicated SSG members: Kim Currie and Cristian Vargas, respectively. Currently three IOCCP SSG members sit on the Executive Council of the Global Ocean Acidification Observing Network (GOA-ON) - an IOCCP spin off project which has quickly developed into an international partnership (to large extent thanks to huge support and dedication of the US NOAA OA Program and IOC-UNESCO Ocean Sciences Section) facilitating the documentation of the status and progress of OA, the understanding of the impacts and the forecasting of OA conditions. As a leading authority on OA observations requirements and status, it is also the vehicle through which IOCCP realises its mandate for implementing global coordination of sustained observations of OA as one of the key ocean biogeochemical phenomena.

Close collaboration between GOA-ON, IOCCP and GOOS (among others) brings high on the scientific and political agenda the need to understand ocean acidification (OA) conditions globally and the consequent need to expand OA monitoring. Recently, these efforts have been augmented thanks to WMO which established OA as a Global Climate Indicator in 2018, and published the WMO Report on the Global Climate in 2015–2019 in 2019. The report, with input from individual scientists, GOA-ON, IOC-UNESCO and other UN agencies, showed that ocean acidification continues to increase, with observed pH values at open ocean observing stations steadily decreasing. Moreover, a vision for the next decade of OA observations was presented jointly by GOA-ON and its partners during the OceanObs'19 Conference, based on a Community White Paper by Tilbrook et al. (2019), co-authored by IOCCP Project Director and published in Frontiers of Marine Science in advance of the meeting.

In that context, IOCCP is happy to report that the GOA-ON continues to grow in size and scope. As of 2020, there are over 730 scientists from 100 countries as members of the global network, though not all of these members are actively engaged in OA monitoring or research. The Regional Hub programme coordinates geographical groupings which enhances collaboration and the sharing of OA monitoring expertise and resources. There are now 7 active hubs – North America, NE Atlantic, Mediterranean, PI-TOA, LAOCA, OA-Africa and Westpac. A representative from each Regional Hub serves on the GOA-ON Executive Committee, and a Regional Hub meeting is planned in conjunction with the up-coming Oceans in a High CO_2 World Symposium.

The growth of GOA-ON, especially into regions where there is currently limited expertise and infrastructure, is primarily made possible through widespread and comprehensive training and capacity building efforts. There are two main approaches to this: (i) mentoring, and (ii) direct training and equipment provision. The Pier2Peer mentorship programme assists with knowledge exchange and collaborations, with the opportunity for scholarships and financial assistance. A number of direct training activities were run in 2019, with significant input from IOCCP.

Thanks to a strong focus on the theory behind and best practices of using pH sensors, the 2019 IOCCP-BONUS INTEGRAL Training Course (described in a previous section of this report) made a unique contribution to the otherwise rich portfolio of capacity building efforts in this domain. IOCCP also contributed to the workshop on practical guidelines for OA research co-organized by OA-ICC, GOA-ON and The Ocean Foundation. Held on 29-31 May in Monaco, the workshop gathered 15 participants from 7 countries who assessed needs and issues faced when undertaking ocean acidification monitoring and research in different regions, and developed practical resources to help respond to those needs. A list of tools useful for “GOA-ON in a Box” users and those starting ocean acidification research will be released as a package for the community.

Access to resources and opportunities for training and re-training are among the priorities for increasing the readiness level in many of the GOA-ON regional hubs, and enhancing the delivery of high quality data to international databases for better informing SDG and other policy targets. Currently, IOCCP together with GOA-ON leadership have initiated efforts to develop a state-of-the-art online product to provide a universal and long-term solution for online training as an alternative to the costly and logistically challenging on the ground training carried out repeatedly across the globe.

Enhanced delivery of high quality pH data is critical to effectively respond to the UN SDG Target 14.3 which is to “Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels”. The methodology associated with the SDG Indicator 14.3.1, now upgraded to Tier II, is available on the GOA-ON webpage, including the associated data and metadata files. GOA-ON has committed to expand the spatial and temporal coverage of ocean acidification observations around the world (Voluntary Commitment #OceanAction16542) in support of the Target 14.3. The UN Community of Action now has 267 OA relevant commitments.

In 2019, SDG 14.3.1 Data Portal (https://oa.iode.org) was launched as a tool for the submission, collection, validation, storage and sharing of ocean acidification data and metadata submitted towards the SDG 14.3.1 Indicator: Average marine acidity (pH) measured at agreed suite of representative sampling stations. The GOA-ON Data Portal (http://portal.goa-on.org/Explorer), has also been revamped in 2019 with multiple search and visualisation options, and links to data and data synthesis products. The GOA-ON Data Portal is not a data archive, but collates metadata on observing platforms with links to data repositories. Over 580 data assets measuring sub-variables of Inorganic Carbon EOV are registered. Real time data from several platforms are available, and more are currently being added, including from South American moorings, European ships of opportunity lines and most recently, Biogeochemical Argo profiling floats.

IOCCP contribution to OceanObs’19
IOCCP was heavily engaged in shaping the community vision and recommendations for sustained marine biogeochemistry and integrated ocean observations for the next decade. We had a marked presence during the OceanObs’19 Conference, co-organizing a series of breakout sessions on Integrated Ocean Observing (actionable details below), and actively participating in others, including as panel members in the one on Marine Debris. For several months in advance of the Conference and also just after the event, there were a number of Community White Papers (CWPs) published in the special issue of Frontiers in Marine Science, which IOCCP members either led or contributed to. The papers touch on a number of topics ranging from broad considerations of future ocean governance models, or challenges to more efficient implementation of the Framework for Ocean Observing, to review articles on more specific elements of the observing system which looked at

challenges and recommendations from the GOA-ON, SOCONET, Argo networks or the time series community. A comprehensive list with full references to these CWPs can be found under the Publications section of this report.

Breakout Sessions on Integrated Ocean Observing

IOCCP along with representatives of other GOOS Panels has devoted a lot of time and effort to prepare a series of three breakout sessions on Integrated Ocean Observing for the OceanObs'19 Conference. Kim Currie and Artur Palacz represented IOCCP in the organizing team which met frequently online between June and September 2019 to prepare the breakout session agenda, provide a charge to invited speakers and panel members, and coordinate the process of synthesising recommendations from many relevant CWPs.

On Tuesday, Sep. 17, Jack Barth (Oregon State University, USA) and Sung Yong Kim (KAIST, South Korea) led the discussion on "Integrated Ocean Observations I: Across Geographic Scales." On Wednesday, September 18, Meghan Cronin (NOAA, USA), Eitarou Oka (University of Tokyo, Japan), Kim Currie (NIWA, New Zealand) and Artur Palacz (IOPAN, Poland) led the session "Integrated Ocean Observations II: Diverse Stakeholder Needs" to discuss how diverse stakeholders can work together to improve and build existing and emerging observing systems under the Framework for Ocean Observing in the next decade. The series was concluded on Thursday, Sep. 19, when Patricia Miloslavich (formerly University of Tasmania, Australia; Universidad Simón Bolívar, Venezuela) and Nic Bax (CSIRO, Australia) led the breakout session on "Integrated Ocean Observations III: Across disciplines and networks."

The goal of the 2-h breakout session on Integrated Ocean Observing: Across Diverse Stakeholder Needs, co-led by IOCCP members, was to discuss how diverse stakeholders can work together to improve and build existing and emerging observing systems under the Framework for Ocean Observing (FOO) in the next decade. During the session, 4 speakers were invited on a panel to present perspectives from communities they represent, and offer their recommendations.

Susan Wijfels (WHOI, USA), speaking on behalf of the research community, suggested that the ultimate responsibility for setting priorities for what to observe is with the national governments among other stakeholders. The process of setting requirements should aim at serving multiple uses, identifying critical cross-system interdependencies and closing critical gaps, and be based on an ongoing system-wide assessment of design efficiency and product adequacy. Acknowledging limited resources, the system should promote implementing technological innovations and their gradual increase in readiness level from concept through pilot to mature.

Lisa Levin (SIO, USA), speaking on behalf of the deep sea stakeholder groups, described the challenges and opportunities of designing a multi-purpose observing system in the deep sea realm. She recommended that in this particular case the observing system design be cross-sectorial, should engage industry, managers, governments, educators, civil society as well as the future generations. To demonstrate the value of stakeholders converging in the process of requirement setting, Lisa recommended focusing on a specific region of interest to such a diverse group of stakeholders, e.g. the Clarion Clipperton Zone.

Nadia Pinardi (U. Bologna, Italy), speaking on behalf of the climate and operational services community, presented good working examples of generic and customized information services that succeed in realizing the so-called ocean value chain advocated for by the FOO. Her recommendations were to: (i) promote the development of multidisciplinary data sets available in near-real time, (ii) ensure state-of-the-art data management, (iii) develop standards for customized products, and (iv) establish a review process of the observing system and delivery of information as its outputs.

Sebastian de Halleux (Saildrone Inc.), speaking on behalf of surface ocean observers as well as private partnerships, talked about the need and proposed ways to simultaneously deliver diverse sets of data to diverse stakeholder groups in diverse regions. He emphasized the need for developing new business models capable of providing adequate ocean information on many levels of stakeholders and/or users, and argued for the important role of public-private partnerships in achieving that goal.

When drawing conclusions from the session discussions it should be kept in mind that: (i) there was limited geographical diversity among the breakout session participants, and (ii) that only a selected group of stakeholders could have been represented among the panel of speakers as well as in the audience. Based on a number of relevant Community White Papers and as a result of breakout session discussions with the panelists and the audience via slid.do, the following three recommendations were put forward:

<u>Recommendation #1:</u> Develop new mechanisms within the Framework for Ocean Observing (FOO) to ensure that the observing system is truly multi-purpose and multi-disciplinary and serves diverse stakeholders. This may include developing new categories of Essential Ocean Variables (EOVs) connected to human activities.

Regardless of whether the global ocean observing system already is multi-disciplinary and multi-purpose in nature or not, further significant integration efforts are needed to sustain and evolve it as the system grows more complex and needs to respond to more and ever changing user requirements. The success of these efforts depends on a proper recognition that there is both a direct cost (measurements) and an indirect cost (data management) in the observing system. The current funding reality prevents from building and sustaining a fit-for-purpose ocean observing system that would also be visionary in its design. It was thus recommended that:
each observing system initiative needs to be accompanied by sufficient funding for both data production and distribution, and that
new business models be explored, e.g. developed through public-private partnerships, to offset the total observing cost and ensure delivery of societal benefit products.

The process of observing system design needs to be cross-sectorial, and should therefore engage industry, managers, governments, educators, civil societies as well as the future generations. A system that serves such diverse stakeholders is bound to face stakeholder incompatibilities (e.g. oil/gas regulators, fisheries managers, vs conservation) and/or competition (e.g. between companies) which hinders dialogue and collaboration among stakeholders to reach consensus on the required ocean observations, priorities therein, and joint responsibilities for adequate investment. These issues, particularly among the private sector, could be overcome if and when the industry becomes heavily reliant on the public goods provided by the academic and government bodies so that they too become important advocates for investment in ocean observing. It was further recommended to consider that ocean discovery, though distinct from the routine/operational measurements, is another aspect of ocean observing which may serve multiple purposes.

As the requirements space grows more complex, one of the challenges is to integrate and prioritize the various requirements under the conditions where multiple funding sources are used to drive observing efforts and where the budget is strongly constrained. The integration could first be done on a sector by sector basis, and then across the sectors, considering the need for stakeholder equity in the process. While global "high stakes" issues should be among the priorities, issues considered “less stakes” globally should not be neglected on regional scales where they have greater societal value.

While the current set of requirements expressed through Essential Ocean Variables is already comprehensive, it does not fully address the need for measuring the status and evolution of human activities and their impacts on the ocean. Similarly, there is a lack of data products informing on the human activities in the ocean. Therefore, it was recommended to:
better link the existing EOV requirements to human activities in the ocean, and if needed, establish a separate set of requirements for measuring a new category of ocean variables related to human impacts.
promote the development of new data products focused specifically on human activities in the ocean

<u>Recommendation #2:</u> Develop incentives to reward data providers, and invest in data assembly centres (DACs) and Integrated Data Services with expert curation, to ensure that data from all stakeholders are FAIR, open, and free, contributing to the ocean observing system value chain.

The discrepancy between involvement of developed vs developing countries in ocean observing is a major obstacle to an integrated observing system. Lack of data sharing practices will only further contribute to the inequality. Majority of the developing countries require better quality of data and easier access to data, especially in the coastal ocean regimes. Greater consideration of the requirements for coastal ocean data and derived services is needed in the global planning of GOOS and other bodies.

With respect to developing new mechanisms, incentives, policies, rewards and responsibilities among stakeholders and data providers, it was recommended that:

- The UN Decade of Ocean Science for Sustained Development becomes the main conduit for developing what these mechanisms should be, and how to implement them through governments and funding agencies.
- These mechanisms should develop professional metrics and rewards for good data sharing, similar to other measures of research impact, likely a mix of qualitative and quantitative measures.
- Traceability of data from its collection to inclusion in information products be established.
- Different levels of incentives are considered: high level endorsements, a system of royalty on data used for commercial (profitable) activities, inclusiveness in observing system design decision making, etc.
- In parallel to generating new ocean data, the system supports extracting novelty from existing data to facilitate their re-use, often for new purposes previously not envisaged. Such a paradigm shift and dedicated funding is needed to establish and further develop data centres and data integrators capable of analyzing data and transforming them into generic and customized information products and services.

<u>Recommendation #3:</u> Develop tailored communication strategies for the integrated observing system, to encourage stakeholder feedback and engagement processes. The strategies should include prioritization of ocean information and ocean observation needs.

In order to meaningfully include diverse stakeholders in ocean observing system planning and evaluation, two levels of communication and engagement strategies are needed: one on the higher level of GOOS, and another more nuanced and tailored to specific needs of given stakeholder/user groups. It is recommended that stakeholder input be part of the formal process of an ongoing system-wide assessment of design efficiency and information product adequacy. This process requires developing performance metrics which are relevant to stakeholder needs and not only to observing network managers. Acknowledging limited resources, the observing system evaluation should include mechanisms of prioritization, and promote implementing technological innovations by gradually increasing their readiness level from concept through pilot to mature.

Breakout Session on Global observing system for marine debris
The goal of this session, held on Tuesday, September 17th, was to advance a harmonized approach to the design of regional/national programs and their integration in a global platform/repository. Participants discussed common approaches to data collection and management and proposed their unification and harmonization. The session also proposed post-conference activities and programs for the next decade and discussed marine litter observation governance. The Panel of speakers included representatives of many international organisations, institutions and expert working groups including UNEP, GEO Blue Planet, GESAMP WG 40, SCOR WG FLOTSAM, JAMSTEC, EMODnet and GOOS. IOCCP Project Officer was invited to the panel of speakers and presented the offer of GOOS to support the efforts to establish a globally coordinated Integrated Marine Debris Observing System (IMDOS) according to the vision presented in an OceanObs'19 CWP by Maximenko et al.

The breakout session concluded with the following recommendations, to the implementation of which GOOS will contribute as part of its 10th Strategic Objective on Observing Human Impacts in the Ocean.

- A comprehensive global observing & information system is necessary to evaluate sources/sinks, abundance, trends, risks and the efficiency of reduction measures and finally to get the problem under control.
- To achieve fundamental understanding of the issues of marine debris, develop efficient in situ observation technology, remote sensors, models and monitoring strategies, involving citizen scientists when possible.
- Build an integrated, standardized and harmonized collaborative network, using commonly accepted methods & definitions, whose structure (variables, coverage, and products) answers fundamental scientific questions and societal demands.

Within the scope of our ToR's, the IOCCP is now involved in follow-up actions leading to prioritising implementation of recommendations relevant to the biogeochemistry component of the integrated global ocean observing system.

Late Community White Paper on VOICE
In December 2019, the OceanObs'19 Community White Paper on "Multidisciplinary Observing in the World Ocean's Oxygen Minimum Zone Regions: From Climate to Fish — The VOICE Initiative" was published. The Variability of the Oxycline and its ImpaCt on the Ecosystem (VOICE; http://www.ioccp.org/voice) initiative, supported by IOCCP since its beginning in 2017, aims to demonstrate how societal benefits drive the need for integration and optimization of biological, biogeochemical, and physical components of regional ocean observing related to eastern boundary systems (EBSs). VOICE chose to focus on the upper oxycline (transition between high and low oxygen waters) which is fundamentally important for the ecosystem structure and can be a useful proxy for multiple observing objectives connected to EBSs that neighbour oxygen minimum zones. In this paper, we present a first, to our knowledge, comprehensive global readiness level assessment for ocean observing according to the principles of the Framework for Ocean Observing adapted to a particular observing objective related to oxygen minimum zones, drivers of change and impacts on

ecosystems. The paper can be accessed at:
https://www.frontiersin.org/articles/10.3389/fmars.2019.00722/full

WORKSHOPS AND MEETINGS

4th GO_2NE Annual Meeting, Paris, France, 13-14 June 2019

As with all Project's annual meetings, several strategic, administrative and logistical topics are covered and decided. From IOCCP's perspective the main issue discussed and decided at this meeting was one around development of a roadmap leading to establishment of an open access oxygen data platform for the world ocean.

The participants agreed that the oxygen data synthesis product should include ultimately all eulerian and lagrangian observations, i.e. Winkler titration measurements, sensor data from CTDs and from fixed moorings/time series, sensor data from BGC-Argo floats and gliders/wavegliders as well as any additional AUVs. It was also agreed that all data has to be quality controlled (data quality flags assigned based on consensus reached by data contributors and users), with underlying raw data available in one place or if impossible then distributed but available, with metadata clearly defined and available for each data and with a DOI assigned to each data set.

During this meeting, Hernan Garcia from NOAA (USA) presented the World Ocean Data Atlas and World Ocean Database. He invited GO_2NE members to assist with the quality control of data sets to obtain relevant data products and facilitate access to data. In addition, the map and data collection produced by Bob Diaz (VIMS, USA) focusing on hypoxic coastal zones was discussed. The group explored the possibility of a small international workshop, including interested GO_2NE members, ocean data experts, and experts focusing on second level data quality control for ocean oxygen measurements.

Participants agreed that a dedicated workshop including representatives of several involved groups should be held in boreal fall 2019. IOCCP, US NOAA and German SFB 754 agreed to co-sponsor this technical workshop. IOCCP offered to host it in Sopot, Poland.

Meeting on reconciling EOV-ECV Requirements, Geneva, Switzerland, 30 July-1 August 2019

In July 2019, IOCCP Project Officer travelled to WMO headquarters in Geneva to work with the OOPC Secretariat and GCOS Secretariat on improving how we articulate requirements and meet our various reporting responsibilities. The group was joined remotely by OOPC Chair Bernadette Sloyan and Patricia Miloslavich as GOOS BioEco Panel Secretariat.

The group recognized that in the GOOS approach, characteristic scales of phenomena provide the framework for articulating what the observing requirements are for EOVs, and provide authoritative guidance for the design of an integrated multi-scale, multi-disciplinary, multi-platform observing system. On the other hand, the reporting pathways both GCOS and WMO consider requirements for each ECV by sub-variables, or products, which has its own merits.

As an outcome of the work done during this meeting, it was recommended a two-step process be employed. The process would (i) determine the phenomena in the ocean we need to capture, and the scales (and regions) which they operate, and (ii) then use this information to determine the relevant requirements for individual sub-variables/products depending on the particular observing objective/application (e.g. climate vs operation services).

The first step was largely completed and required only an incremental update to the information already provided in Table 2 of the current version of EOV Specification Sheets. The second step meant that for every EOV a new table needed to be produced to encompass the resolution and uncertainty requirements for EOV sub-variables taken into account the need for potentially distinct requirements depending on the coverage (global vs coastal, surface vs interior vs deep ocean) and application if relevant.

The recommendations were presented to GOOS Executive and later presented to all three Panels of GOOS during respective panel meetings, including IOCCP-SSG-14. The new table with sub-variable requirements was initially filled out based on the information provided in 2015 for the previous GCOS Implementation Plan, using information from existing EOV Specification Sheet, and other available documents (e.g. GOA-ON Implementation Plan, Biogeochemical Argo Implementation Plan, GO-SHIP data requirements).

1st Global Ocean Oxygen Network (GO$_2$NE) International Summer School, Xiamen, China, 2 - 8 September 2019

The 1st International Summer School from the Global Ocean Oxygen Network (GO$_2$NE) from the IOC-UNESCO took place on 2 - 8 September, in Xiang'an Campus of Xiamen University, China. The summer school was sponsored by IOC UNESCO, GO$_2$NE, IOCCP, the Collaborative Research Center 754 (SFB754), the State Key Laboratory of Marine Environmental Science (MEL) of China, the French National Centre for Scientific Research (CNRS), the National Fund for Scientific Research (FNRS), University of Liège, SOLAS, the European Geosciences Union (EGU), the US Ocean Carbon and Biogeochemistry (OCB) program, the National Oceanic and Atmospheric Administration (NOAA) and SCOR, and by several other individual advisors and institutes.

The GO$_2$NE Summer School 2019 offered a mix of lectures and practical workshops, and stakeholder engagement activities to a group of 37 PhD students and early career scientists from 19 countries coming from across all continents. The attendants were instructed by 14 world-leading international scientists from 12 countries. The topics covered included open ocean deoxygenation, closed seas and coastal waters deoxygenation, introduction to modelling ocean physics, introduction to modelling ocean biogeochemistry, ocean observing systems design in relation to the deoxygenation issue, effects of ocean deoxygenation including biological responses, etc.

There were also special sessions organised on "Ethics in Science" and "How to interact with the press and social media and NGOs." Attendants had ample opportunities to present their own research, and received feedback from a science communication perspective. During the cruise aboard the research vessel Tan Kah Kee from Xiamen University, students were introduced on how to use the most recent oxygen sensors of the market together with performing Winkler titrations and using a CTD with Niskin bottles, and plankton nets.

The event was reported on in detail in Issue 15 of the SOLAS Newsletter.

NSF EarthCube Workshop for Ocean Time Series Data (13-15 September 2019, Hawaii, USA)

On 13-15 September 2019, just prior to the OceanOb'19 Conference in Hawaii, IOCCP took part in the NSF EarthCube time series workshop. The rationale for the workshop stated that data synthesis and modeling efforts across ocean time-series represent an important and necessary step forward in broadening our view of a changing ocean and improving our return on investment in ocean time-series. Despite the advances achieved over the past decade, significant barriers remain that hinder work across time-series, including issues related to data access, discoverability, and metadata reporting. Furthermore, incorporation of ocean time series data into ocean and earth system models is currently limited due to the lack of a standardized data format and user interface. More details can be found at: https://www.us-ocb.org/earthcube-workshop-ocean-time-series-data/

Participants agreed to work on the following actions as outcomes of the workshop: (i) developing a pilot data product test case, (ii) developing an international time series working group to implement best practices and (iii) work on high-profile briefs and visualizations to increase awareness of time series stations.

IOCCP plays a leading role in addressing the first outcome through its role in the EU H2020 project EuroSea (see details in the Future Directions section of this report), while US OCB committed to addressing the remaining two outcomes.

OceanObs'19 Conference, 16-20 September 2019, Honolulu, Hawaii, USA
IOCCP made a significant contribution to the process of writing Community White Papers as a lead up to the OceanObs'19 Conference. This work, highlighted in the Major Activities, Publications and Future Directions sections of this report, focused on identifying the vision forward and recommendations for its implementation within the field of marine biogeochemistry. However, IOCCP has also supported ideas of further evolving the entire integrated global ocean observing system in line with the new GOOS 2030 Strategy. To this end, we took part in organizing several breakout sessions which provided discussion fora for the 1000+ conference attendants.

Oxygen data workshop, 11-12 November 2019, Sopot, Poland
As part of the ongoing IOCCP efforts to further develop global coordination of oxygen observations, and in follow-up of recommendations from the VOICE project and the GO_2NE group, IOCCP co-organized the first scoping workshop on developing a global oxygen data product. The workshop, supported by IOCCP, IOC-UNESCO, GO_2NE, US NOAA and the German project SFB754, was a direct execution of Action Item #10 as agreed and detailed in the report from IOCCP-SSG-13.

The workshop took place on 11-12 November 2019 in Sopot, Poland, just prior to the 14th Session of IOCCP SSG. Co-location of the two meetings led to a significant reduction of travel costs and optimal use of time of the experts invited to attend both events: Maciej Telszewski, Benjamin Pfeil, Masao Ishii, Kim Currie, Siv Lauvset and Véronique Garçon from IOCCP SSG, as well as Fei Chai and Toste Tanhua who were invited as guests to parts of the IOCCP annual meeting.

The overarching goal of this 2-day scoping workshop was to bring a community of observationalists, modellers and data managers to develop a roadmap towards an open access oxygen data platform for the world ocean - an atlas akin to the Surface Ocean CO_2 Atlas (SOCAT). The atlas would be a quality controlled (data quality flags assigned based on consensus reached by data contributors and users) data synthesis product, with underlying raw data centrally archived, or if impossible, then distributed but available, with metadata clearly defined and available for each data and with a DOI assigned to each data set.
The oxygen data synthesis product would include ultimately all eulerian and lagrangian observations, i.e. Winkler titrations measurements, sensor data on CTDs and on fixed moorings/time series, sensors on BGC-Argo floats and on gliders/wavegliders and on any remote vehicle/platform. A strategy could be to first include additional eulerian (sensors on CTD data) then tackle the lagrangian oxygen data.
Workshop participants discussed several levels of improvements to current oxygen data management in order to enable such a product. First level improvements would be to gather data from the existing databases in which data is readily freely accessible in electronic format, without restriction, to remove duplicate data and to define consistent quality checks agreed by the community. Second level improvements are to identify and correct information from additional datasets for OMZs, coastal hypoxic sites and other ocean depths and regions based on experts' recommendation. Integration with the Argo, OceanGliders and coastal regional community is

targeted through the efforts of GO_2NE, WESTPAC, VOICE, EBUS SCOR WG, EMODnet Chemistry, NOAA, etc.
Complete workshop report is expected to be published before mid-2020. Currently, a draft roadmap is being circulated internally among several task groups identified during the workshop. The roadmap is expected to be published as a community white paper in a peer-reviewed journal in late 2020, or early 2021.

14th Session of IOCCP SSG, 13-15 November 2019, Sopot, Poland
The meeting took place on 13-15 November 2019 at the Institute of Oceanology Polish Academy of Sciences in Sopot, Poland. Five IOCCP SSG members and Office staff attended the meeting in person, three SSG members attended remotely, and one SSG member was unable to attend the meeting due to other commitments. Two invited guests joined the first day of the meeting.

The meeting started with a summary of IOCCP accomplishments from 2018-2019, with a focus on key outcomes which had the biggest impact with respect to the IOCCP Terms of Reference. These are listed below. Each of these points was later elaborated on during sessions relevant to individual IOCCP themes, and documented in the meeting report available from IOCCP website. The different accomplishments and plans for their follow up, if relevant, are described in some detail across various sections of this IOCCP report to SCOR.

IOCCP ToR #7: Training Activities / ToR#8,9: FAIR data

- IOCCP & BONUS INTEGRAL Training Course on a Suite of Biogeochemical Sensors
- AtlantOS workshop on Underway and Sensor CO_2 Data and Metadata QC Procedures
- Global Ocean Oxygen Network (GO_2NE) Summer School

IOCCP ToR #8,9: FAIR, open and quality controlled data

- Supporting data synthesis of Inorganic Carbon EOV products through SOCAT and GLODAP
- Supporting the Global Ocean Acidification Observing Network Data Portal and phenomena-based products (ocean acidification)
- Developing a roadmap towards an Oxygen Data Portal and phenomena-based products (deoxygenation)
- Development of the Marine BGC Global Data Assembly Centre (GDAC)

IOCCP ToR #1,2: Observing system implementation

- Expansion of coordination activities onto new Biogeochemistry EOVs

IOCCP ToR #2,6: Fit-for-purpose BGC observing system

- IOCCP partnership with the modelling community
- Surface Ocean pCO_2 Mapping intercomparison (SOCOM)
- Towards ocean biogeochemistry data model assimilations
- Contribution to the synthesis and intercomparison of ocean carbon uptake in CMIP6 models
- IOC WG on Integrated Ocean Carbon Research (IOCR)
- Contribution to the Global Climate Observing System (GCOS)

IOCCP ToR #3,4: Goals, Metrics, Standards and Best Practices

- SDG Target 14.3: Minimize impacts of ocean acidification

Significant contribution to the OceanObs'19 Conference and Community White Papers - pertaining to virtually all IOCCP Terms of Reference.

EU H2020 EuroSea Project Kick-Off meeting, 27-29 November 2019, Brussels, Belgium
The EU Innovation Action "Improving and Integrating European Ocean Observing and Forecasting Systems for Sustainable Use of the Oceans (EuroSea)" officially started on 1 November 2019. The kick-off meeting took place at the Royal Belgian Museum of Natural Sciences (RBINS) in Brussels on 27-29 November 2019, co-organized by GEOMAR, RBINS, and EuroGOOS.

The kick-off meeting offered a unique opportunity to plan the project's success from the outset, bringing together representatives of most partners making up the interdisciplinary and international consortium of 55 partners who will work together for the next 4 years, with an allocated budget of almost € 12.6M. IOCCP was represented by Maciej Telszewski, Artur Palacz, Benjamin Pfeil, Bjorn Fiedler, all of whom are assuming roles of work package or task leads in this project.

EuroSea is part of "The Future of Seas and Oceans Flagship Initiative" funded through the Horizon 2020 Blue Growth call (BG-07-2019-2020). EuroSea brings together key European actors of ocean observation and forecasting with key end users of ocean observations. The kick-off meeting was also the 1st General Assembly of EuroSea during which decisions on the Steering Committee, Gender and Equality Committee and other project governing bodies were made. The meeting was also an opportunity to discuss work plans within individual work packages, present initial plans for cross-project aspects such as data management plan, communication and results exploitation plans, as well as strategies for engaging stakeholders - a critical aspect of this project.

Detailed agenda and proceedings can be found in the kick-off meeting programme and in a list of meeting presentations.

Ocean Best Practices Workshop, 2-3 December, Oostende, Belgium
The Ocean Best Practices Workshop III (OBP Workshop III) was held at the International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission of UNESCO, Project Office for IODE, Oostende, Belgium, 2-3 December 2019.

It was organized with support from IODE, GOOS and IEEE Oceanic Engineering Society with the objective of better understanding the future needs of the ocean observing community. Specifically, also to provide recommendations to the IOC Ocean Best Practices System Steering Group for its inaugural meeting that followed the workshop. The workshop outcomes were defined as: (1) an articulated strategic direction for ocean best practices; (2) recommendations for best practice synthesis and 3) recommendations for further Ocean Best Practices System development/implementation, embedding outcomes from community input.

Over the 2 days, 50 international ocean experts from 20 countries representing international agencies, Programmes, Projects and Organizations participated in presentations and panel discussions. The workshop encouraged maximum audience participation and was structured with several thematic, hour-long Panels followed by plenary discussion. This format was effective in stimulating ideas and discussions to lay out a future vision of ocean best practices and how OBPS will contribute to improving ocean observing in the decade to come. Breakout Sessions were also a major part of the agenda, to provide opportunities for participants to share insights and importantly to make recommendations to the Panel on Vision for the Next Decade and ultimately the OBPS Steering Group.

Maciej Telszewski lead the Panel on Capacity Building and Training. Maciej was joined by 5 panelists representing IODE - Ocean Teacher Global Academy, POGO, GEO-Blue Planet, SCOR, Nippon Foundation and national efforts. The Panelists described in detail several types of training/capacity development modes focusing on their attributes related to the feasibility of each modality for global implementation. Panelists also highlighted challenges related to individual modalities as well as suggested types of outcomes which might be expected when certain modality is implemented.

After a brief presentation from each Panelist a long and vigorous plenary discussion started leading to the major conclusion suggesting that a highly anticipated outcome of this session would be for the OBPS Steering Group to develop a Work Package on Capacity Development. Ideally such a package would come in a form of a comprehensive product (paper, best practice, training module) which would describe various types of capacity development activities (with their pros and cons) in relation to various types of best practices in OBPS.

Full proceedings from the meeting are available from the OBPS website: https://www.oceanbestpractices.org/

Marine debris indicators-What's next?, 16-18 December 2019, Brest, France
On December 16-18, 2019, IOCCP project officer attended the workshop on "Marine Debris Indicators: What is Next?" held in Brest, France. Building on the first workshop in a series held in November 2018 also in Brest on "Technologies for Observing and Monitoring Plastics in the Oceans'' this workshop aimed to strengthen the link between observation, extracted information, and decision and policy making related to the problem of marine litter. Participation in the workshop meant that IOCCP took part in further development of a community focusing on monitoring and measuring of marine debris, thus enhancing our capacity to establish global coordination of an Integrated Marine Debris Observing System (IMDOS) as part of the EuroSea project, and in fulfilment of obligations as GOOS Biogeochemistry Panel.

Building on the recommendations and draft road map of the 2018 Workshop, the main goals for this activity was to further develop a community of stakeholders around marine debris and to further detail the road map towards a joint goal. The overarching goal for this community is to achieve a comprehensive description of observation means (underwater, satellite-borne, in situ, crowdsourcing, Big Data analyses) and assess their technological readiness, as well as their availability for relevant indicators, including the SDG Indicator 14.1.1, and to ensure that a range of emerging efforts to address the global challenge of marine debris can be based on sufficient observational evidence.

In that context, the workshop explored the potential for a platform linking the data to actions and for development of an implementation strategy for observing networks and modeling platforms to support co-creation of knowledge needed by those addressing all aspects of marine debris.

The first part of the workshop included several sessions with invited presentations and brief discussions. This part aimed at reviewing the current state in monitoring marine debris and relevant modeling, and aimed at an overview of the knowledge needed for societal decision making on mitigating the threat marine debris poses to the ocean and human beings. The second part took a participatory approach in which the participants worked together to improve the draft road map that resulted from the first workshop in 2018. Initially, several groups collected sets of relevant terms and developed graphics of their vision for the next five years.

In a collaborative effort, input for a case study on "Reducing Plastics in the Ocean within a Growing Global Economy: Understanding the Data Needs to Inform Actions" was compiled for the following sections of the case study report: Introduction, Wicked Problem, Conceptual Model, Decision Space, Hazards, Vulnerabilities, Foresight, Interventions, and Recommendations. It was agreed to carry out this case study over the six months prior to the Third Workshop planned at the end of May 2020.

The planned third workshop, Linking Data to Actions on Marine Debris for the Ocean Decade, was postponed due to COVID-19 and will be rescheduled according to the new venue and date of the UN Ocean Conference.

GLODAP data meeting, 16 February 2020, San Diego, USA
As part of its commitment to support the ongoing efforts of GLODAP, several IOCCP SSG members attended a GLODAP Data Meeting which took place on 16 February 2020 in San Diego, CA, USA just prior to the 2020 Ocean Sciences Meeting.

The purpose of this meeting, attended by 19 participants, was to address the effects and possible solutions to Bob Key's 2019 retirement, in particular with respect to the process of acquisition, flow, and quality control of data for GLODAPv2020 and beyond. Participants reviewed the current state of the GLODAP (and GO-SHIP) data, from in situ measurements to final products, formalized the data flow for 2020 and beyond, and discussed a software data system, based on SOCAT, to normalize the submission of GO-SHIP quality data.

What is more, suggestions were made as to the vision for optimal coordination between different entities engaged in collection and dissemination of hydrographic biogeochemistry data, and clarifying the roles played by each among NOAA NCEI, CCHDO, GO-SHIP, GLODAP, IOCCP and national contributions from Germany, Norway and others. Following the meeting, a preliminary budget estimate has been made for GLODAP, in response to the need for a resource plan outlining the personnel and other needs to sustain these important efforts as recommended by IOCCP and GOOS. IOCCP will support the GLODAP community in finalizing and publishing the resource plan, ideally by the end of 2020.

OceanObs Research Coordination Network (RCN) Annual Meeting, 16 February 2020, San Diego, CA, USA
The OceanObs Research Coordination Network (RCN) hosted its annual meeting on February 16, 2020, in San Diego, CA, just prior to the 2020 Ocean Sciences Meeting. Several members of the global ocean research and observation communities joined the meeting responding to the RCN invitation to join discussions aiming to synthesize threads and recommendations emerging from the OceanObs'19 Conference, including planning for the implementation of initiatives emerging from OceanObs'19.

The objective of the RCN meeting was to provide avenues for these communities to discuss and advance outcomes and priorities that emerged from theOceanObs'19 Conference of September 2019. The challenge following the OceanObs'19 Conference is to integrate the diverse activities of the ocean research and application communities into focused and sustained efforts that address important societal priorities, and that help inform international initiatives such as the UN Decade of Ocean Science for Sustainable Development and others, as well as important national priorities.

The February 2020 RCN meeting was structured to encourage dialogue and clear definition of next steps. In one day, the meeting could address only a subset of the OceanObs'19 themes and outcomes. Five Breakout Sessions were organized for the community during the RCN meeting. Each of the breakouts defined specific actions and identified leads to carry these forward. Some of these actions are substantive new directions, and some are expansions of current efforts.

Three major themes emerged from the February 2020 OceanObs RCN meeting:

- Expansion of coordinated observing systems and global scale measurements relevant to a Global Ocean Observing System. Some of these are the Deep Ocean Observing System, Integrated Surface Ocean Observing System, Seabed mapping, a HABs Initiative and Smart Cables and integration across parallel observing capabilities (e.g. VOS, SOT and SOOP, all ship observing efforts). There are some that have not yet fully emerged such as a coordinated global effort for biological observations.
- Cross-cutting efforts that underpin ocean observing across the value chain from observations to applications and policy. Examples of there are data management, interoperability, community building, best practices, open science/open access and capacity development.
- Resources, the blue economy and the need for expanding collaboration across the ocean research community and engagement with industry, sponsors and policy organizations.

The RCN meeting produced specific actions with assigned leads in areas covered at the meeting. From IOCCP perspective, theme 1 was of major interest, with Meghan Cronin specifically proposing and describing the Integrated Surface Ocean Observing System (ISOOS, currently SCOR WG proposal OASIS). Rik Wanninkhof and Maciej Telszewski attended the related parts of the meeting and the resulting developments are described under Surface ocean observations of biogeochemical parameters in the Future Directions section of this report.

One of the major issues raised during the discussions were partnerships. There were many examples where partnerships are happening in a successful manner: across international organizations (e.g. IOC and WMO), across research and the private sector (e.g. maritime operators), with research science and citizen science and across national funding agencies. Further efforts are needed as the ocean community takes a global perspective. Participants recognized that major international ocean research efforts need to better link research and operations, for example in support of agreements such as UN Agenda 2030 (the UN Sustainable Development Goals). Finally, the participants recognized that the successful outcomes of this meeting are another step in shaping the research for the next decade. Full proceedings with detailed discussions, action items and plans forward were distributed in early May 2020. Current global situation is impacted by COVID19 pandemic and related limitations will continue to impact the implementation of these actions and plans but the community will continue to move forward even if at a slower than optimal pace.

PROJECT OFFICE

Open calls, nominations for new IOCCP SSG members

During the XIV Session of the IOCCP SSG in Sopot, Poland (13-15 November 2019), the Panel discussed the fact that according to the current Terms of Reference for members of the IOCCP SSG, our co-Chair (Masao Ishii) should rotate off the group at the end of 2019 due to the fact that the total service on the Panel is limited to 9 years. However, since Masao has only been the Co-Chair for the past 3 years, having served as a “regular” member for 6 years prior to becoming a co-Chair, the SSG suggested that it would be more beneficial for IOCCP now and into the future, if Masao (and every new co-chair) had the choice of serving two terms on this position regardless of the duration of their earlier service as an IOCCP SSG member. The suggestion was grounded on the fact that it takes a considerable amount of time to acquire sufficient level of understanding and experience needed to efficiently steer the group. Therefore, SSG approved the notion to update the Terms of Reference for members of the IOCCP SSG to allow a co-Chair to serve for up to 6 years. This proposal was presented to our Sponsors who did not approve of this notion. While SCOR and IOC expressed their understanding of the value of maintaining Masao Ishii in the SSG due to his experience and to provide continuity, SCOR and IOC are not inclined to approve a change in the ToRs to allow for an extension of service to 12 years. Our sponsors feel strong about rotation and renewal being healthy practices for a project to build capacity for the next generation of leaders. SCOR and IOC agreed, as an exception, that the current co-chair Masao Ishii continues to serve until the end of the calendar year (total of 7 years as co-Chair). Our sponsors recommended that the process to nominate the new co-Chair to succeed Masao Ishii starts in due time considering the new co-Chair will commence duties on 1 January, 2021.

The SSG approved the IOCCP Executive proposal to extend by 1 year the second term of Benjamin Pfeil as SSG member. This decision was motivated by the fact that the work on creating the Biogeochemistry Global Data Assembly Centre (GDAC), initiated and coordinated by Benjamin for the past several years, is nearly complete and that it would be highly beneficial for both IOCCP and the GDAC effort to ensure Benjamin's position as IOCCP SSG member until the end of 2020. This decision was approved by IOCCP Sponsors.

Following the decisions from the XIII Session of the IOCCP SSG, an open call for new SSG members was drafted and released to the public in October 2019 via several communication channels. The news was shared widely through our partner organization newsletters, Twitter channels, and even through the ECO Magazine. Based on the submitted applications, the IOCCP SSG identified two outstanding candidates who were subsequently nominated to IOCCP sponsors, who approved our nominations. These new SSG members will take charge of (among other things): (i) coordination of Particulate Matter EOV observations, and (ii) coordination between marine biogeochemistry observationalist and modelling communities. It is anticipated that the new themes will be added to the IOCCP portfolio by mid-2020.

In February 2020, Douglas Connelly announced his decision to step down from IOCCP SSG. This decision motivated IOCCP SSG to re-evaluate the criteria for selecting his replacement prior to releasing an open call for this position (see discussion under Future Directions section of this report). A new open call for an IOCCP SSG member was advertised in March 2020. By the deadline of April 10th, IOCCP Office received four applications for the position. Currently, the applications are being reviewed by the Panel, and nominations will be presented to the sponsors by mid 2020.

Communication services

Twitter

During the 2019 Sensors Training Course in June 2019 IOCCP Project Office launched its Twitter account, thus fulfilling *Action Item #36* from IOCCP-SSG-13. You can now follow news relevant to marine biogeochemistry through @ioccp_org. This new communication service responds to the needs of the predominantly younger generation of marine biogeochemists who seem to prefer short and frequent updates to be distributed via social media. We do not only share but also receive important news through Twitter which is gradually replacing daily to weekly email communications used by other international projects of a similar profile, such as IMBeR, SOLAS, or US OCB.

The IOCCP Twitter account received plenty of attention right from the start thanks to an enthusiastic crowd of #2019SensorsTraining course attendees and course instructions, many of which are frequent Twitter users. By the end of April 2020, after almost 12 months of Twitter activity, we have 218 followers. During this period we posted 122 tweets, many of which were re-tweeted by our followers, eventually reaching an estimated 2,000 - 8,800 users per tweet.

It is worth pointing out that daily news on job postings, training courses, workshop reports and scientific publications, are currently more easily (and often exclusively) available from Twitter. We perform daily filtering of information shared by individuals and organizations strategically "followed" by IOCCP, and often instantly share with our followers (and their followers) any unique information acquired by the Project Office through more traditional communications means. We reckon that thanks to the new (for IOCCP) Twitter service we have greatly expanded our capability to timely and efficiently reach out to the global community of marine biogeochemistry observationalists and thus better serve as a communication hub.

Website and email newsletter

The Office is committed to using the IOCCP website and (sub-)weekly email newsletter as its primary means of communicating with the core of the marine biogeochemistry community, i.e. those who explicitly subscribe to our services (currently 600 subscribers). Over the past 12 months, we have distributed over 70 news pieces through our newsletter. We consider the new Twitter service as complementary to this core communication activity. Currently, we use Twitter for short, rapid and/or urgent communications, followed by or linked to a more extensive news article posted on the web and shared via the email newsletter.

The IOCCP Conveyor

The shift towards more frequent and short communications shed new light on our quarterly newsletter The IOCCP Conveyor. An internal analysis revealed several reasons to suggest that this particular communication service might be obsolete.

Firstly, there is a lack of input from the community on what topics and articles that could be of interest to those on the receiving end of this service. Secondly, the majority of the articles written for the past issues heavily relied on news already communicated via website and email weeks or months prior to the publication of the Conveyor. Thirdly, the purposefulness of communicating on a quarterly to bi-annual time scale seems questionable considering the daily to weekly Twitter and email communication on one end, and the annual reporting from IOCCP SSG meetings on the other end. Fourth, it is difficult to estimate who reads the newsletter, or which sections of it. Finally, in an environment that is supersaturated with lengthy newsletters on one hand, and tweets designed for the new generation characterized by an average 8-second attention span (Microsoft Attention Span Report, 2015), IOCCP’s strength and communication niche could be the weekly email newsletter.

After a comprehensive discussion, the SSG endorsed the suggestion from the Office to discontinue the quarterly newsletter service, to maintain the weekly to monthly website updates and email newsletters, and shift the efforts towards the shorter, frequent and up to date messages distributed via Twitter.

Funding for Project Office and activities

Since 2012, upon request by NSF, IOCCP continues fundraising efforts for salary support for the Project Officer. Since 2015, these efforts have been successful enough to maintain the position of Project Officer with 100% external (to NSF award through SCOR) funding. Successful collaborations related to the previous funding source (2015-2019, EU H2020 AtlantOS Project) allowed our participation in a bidding consortium responding to the EU Horizon2020 call in early 2019. This required tremendous effort at the end of 2018 and in the first half of 2019, however our bid was successful again and will allow the Project Office to focus on implementing the Project ToRs in the next 3 years (2020-2022). The funding secured for the Project Officer comes from the EU H2020 EuroSea Project. It’s important to note that our participation in the Project consortium has been assured directly by the GOOS co-Chair and the GOOS Head Office.
For almost a decade now, IOCCP has also been able to significantly diversify funding sources for a great majority of its activities. There are many examples of activities which were led or co-organized by IOCCP and which were in fact carried out with >50% external sponsorship. This is achieved almost exclusively via successful and long-lasting partnerships with several organizations, where mutual

benefit is obtained and often the impact of an activity is more prominent than what would have been expected without partnering. Several specific examples of such partnerships were given in a recent IOCCP Sponsor's Review 2012-2022. Recent (2019) examples of more prominent activities initiated and coordinated by IOCCP include:

<u>2019 IOCCP & BONUS Integral Training Course on a Suite of Biogeochemical Sensors</u>

- Total budget: US$ 105,000; IOCCP contribution: US$ 40,000
- Co-sponsors: BONUS-INTEGRAL Project, US Ocean Carbon and Biogeochemistry Program, European Research Infrastructure: Integrated Carbon Observing System Ocean Thematic Center and EU RINGO Project

<u>2019 Oxygen Data Platform Scoping Workshop</u>

- Total budget: US$ 35,000; IOCCP contribution: US$ 10,000
- Co-sponsors: US NOAA, US NCEI, German SFB754 Project

Every year there are also several activities initiated and coordinated by our partners, where IOCCP plays a co-sponsor role helping the main organizer meet its budgetary requirements and at the same time fulfilling IOCCP's ToR's which we would not be able to do otherwise. Recent (2019) examples of these type of partnerships around specific activities include:

<u>4th GOA-ON International Workshop</u>

- IOCCP contribution: US$ 5,000
- Main sponsor and organizer: Global Ocean Acidification Observing Network

<u>GO_2NE Oxygen Summer School</u>

- IOCCP contribution: US$ 7,500
- Main sponsor and organizer: Global Ocean Oxygen Network

<u>Experts Workshop of the Integrated Ocean Carbon Research Working Group</u>

- IOCCP contribution: US$ 10,000
- Main sponsor and organizer: Intergovernmental Oceanographic Commission of UNESCO

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FUTURE DIRECTIONS

Developing an IOCCP Strategy

Over the next 12 months IOCCP aims to compile a comprehensive set of observing strategies for biogeochemical EOVs by forming effective partnerships with relevant interested players. To initiate this process we plan to submit a White Paper laying out these individual strategies and call on relevant partnerships. The complexity of the marine biogeochemical cycles with numerous connections to their atmospheric and terrestrial pathways means that a wide range of approaches have to be used in order to embed marine biogeochemistry observations into globally integrated earth system observing networks. In order to fulfil the 2030 vision for a mature, sustained marine biogeochemistry observations being a part of a global, integrated system delivering essential information to the society, we will expand on the following draft recommendations:

- To reconcile the societal and scientific requirements for biogeochemistry observations by strengthening or establishing new partnerships between observing networks and relevant expert working groups (in particular IOC-UNESCO WGs such as GO2NE and IOCR, SCOR WGs such as P-OBS and newly proposed OASIS, and UNEP expert communities).
- To establish partnership between IOCCP and GEOTRACES to support the implementation and increase of readiness level of sustained observations of EOVs, such as Particulate Matter and Nutrients.
- To actively guide the co-design of the observing system by engaging expert WGs and observing networks to determine phenomena-based observing targets and jointly agree on implementation plans for all EOVs for the period 2025-2030.
- To increase the comparability of measurements and thus increase the quality of information products and generated knowledge by:

establishing globally agreed-upon standards and protocols;
whenever possible, support producing Certified Reference Materials for EOVs, e.g. through establishment of central calibration facilities and regular inter-laboratory comparison studies;
enforcing strict requirements for use of globally-accepted standards, protocols and CRMs in all observing networks recognized by the GOOS Observations Coordination Group.

- To support centralized monitoring and performance evaluation of all observing networks carrying out biogeochemistry EOV observations (i.e. through JCOMMOPS).

- To increase the observing capacity by adding routine biogeochemistry (and biology) EOV measurements on existing observing networks, in particular GO-SHIP and OceanSITES.
- To strengthen existing and promote creation of new EOV-based observing networks that would facilitate implementation of EOV requirements across platforms
- To create new data synthesis products based on multi-EOV and multi-platform observations needed to fulfil the end user product requirements for various applications globally (e.g. SDG14 indicators, Global Carbon Budget, IPCC and World Ocean Assessment) and regionally (e.g. harmful algal bloom forecasts, regional carbon budgets, integrated ecosystem assessments).
- To increase the availability, discoverability and interoperability of marine biogeochemistry data and to enable product development by end users. To this end we recommend creating and maintaining a Global Data Assembly Centre for Biogeochemistry EOVs, and where relevant (e.g. Particulate Matter EOV) designing new data repositories capable of integrating EOV data from many heterogeneous sources.
- To support observing networks and communities in regularly assessing the potential of newly developed observing techniques to better elucidate changes in key ocean phenomena, (e.g. ventilation, biological carbon uptake, deoxygenation).

New coordination activities of GOOS Biogeochemistry Panel
Partnership with the modelling community
During IOCCP-SSG-13 it was recognized that IOCCP would like to strengthen its dialogue with the modelling community and through partnership foster the delivery of observational data required for the development and evaluation of biogeochemical forecasts as a new frontier in oceanography.

During IOCCP-SSG-14, the IOCCP dedicated a separate session to this issue to better identify what biogeochemical observations are needed to support model development, and at the same time how models can be used to optimize the observing system design. Through an open call in 2019, IOCCP has successfully recruited a new IOCCP SSG member who, pending SCOR's approval, would take on this responsibility. Fei Chai (SIO, China / University of Maine, USA), is a modeller and observationalist in one, who is in an excellent position to provide a perspective and represent global community views as a member of the OceanPredict Marine Ecosystem Analysis and Prediction Task Team (MEAP-TT) and a Biogeochemical Argo Steering Committee member.

When reviewing the observing system requirements, there will be a strong need to engage various model developing communities as users of ocean data. There are multiple modelling communities operating on national and regional levels, as well as groups with truly global representation and focus (e.g. OceanPredict (GODAE), CMIP).

One of the challenges the modelling community needs to address is the need to account for multiple stressors in models, even when operating on a local scale. Phenomena such as hypoxia, ocean acidification, eutrophication, harmful algal blooms and others often control the marine environment. There are examples of successful forecasts of nutrients, pH, oxygen and other parameters at sites where nested models and observational assets from multiple platforms were assimilated and used to constrain the models. These models provide information in response to ocean health applications, and so can be used to derive observing requirements for ocean health monitoring.

The Argo 2020 program, with a significant expansion of deep Argo and Biogeochemical Argo is an essential source of oceanographic data describing multiple stressors in a given location, thus being useful for climate, operational and ocean health applications. However, there are still many issues with assimilating profiling float data, strictly related to inorganic carbon data analysis - which IOCCP can ensure are well documented, communicated and eventually resolved by consensus efforts.

Overall IOCCP's main role in coordination with the modelling community will be to promote the availability of metadata and quality control information to benefit modellers building or evaluating their ocean forecasts. On the other hand, there are examples of the modelling community successfully providing guidance to the observing networks/programs. For instance, the design of the SOCCOM array of profiling floats was based on the results of Observing System Simulation Experiments (OSSEs).

Partnership with remote sensing community for Particulate Matter EOV coordination
Particulate matter concentration and fluxes play a major role in regulating cycling of organic matter, and thus affect carbon sequestration, biological production and deoxygenation among other ocean phenomena. Yet their routine observations remain limited and insufficient to determine with any certainty even the direction of future changes in the biological carbon pump - a significant knowledge gap according to the IPCC AR5. Currently, very few ship-based monitoring efforts include routine measurements of particulate matter, although these have been given greater priority by satellite observing networks and recently also by networks of autonomous observations from gliders and profiling floats. There is a growing need to better coordinate global efforts related to setting requirements, observing and managing data related to the Particulate Matter EOV, which IOCCP is a custodian of.

Estimates of particulate material concentration are based on empirical relationship between optical properties and concentration of different particulate pools. These relationships have typical uncertainties on the order of +/-50%, are mostly limited to the sun-lit surface ocean, and most often do not separate living and non-living particles. Furthermore, they most frequently provide no information on particles' micro-physical properties such as composition, size, shape and degree of aggregation, all necessary to understand their role in the carbon cycle. With respect to biological particles, we lack information regarding partition into groups (e.g. bacteria, phytoplankton, detritus and zooplankton) and within groups with respect to function (e.g. nitrogen fixing, DMS producing, toxic etc'). These are critical for the development and to provide constraints on biogeochemical or ecosystem models, in which particles are important state variables. These models are key to develop our understanding about how the ocean cycles elements and for predicting its evolution under different climate change scenarios.

To improve over the gaps identified in the above paragraph, it is critical that the community:

- develops internationally agreed-upon protocols to measure particulate properties,
- expand our capacity to make these observations, and
- design data repositories where these data can be readily accessed (including single particle analysis data such as from cameras and cytometers).

In the aftermath of the 2019 Open Call for IOCCP SSG members, IOCCP nominated Emmanuel Boss (University of Maine, USA) to join our Panel to more effectively realize our Terms of Reference with respect to coordination of Particulate Matter EOV while addressing the gaps mentioned above. Dr Boss would bring valuable experience and programmatic connections which would help re-establish the once prominent relationship between IOCCP and the International Ocean Colour Coordinating Group (IOCCG), with both organisations likely to play a key role in strengthening the interface between sustained in situ and remote sensing observations of particulate matter and related EOVs (e.g. Ocean Colour, Phytoplankton Biomass and Diversity).

Developing Marine Debris (Plastics) Essential Ocean Variable

The EU Horizon 2020 project EuroSea, aimed at improving and integrating European ocean observing and forecasting systems for sustainable use of the oceans, provides explicit resources to develop Marine Debris as a new type of Human Activity/Impact EOV, and pursue initial selected global coordination activities. Further resources will need to be identified to fully implement the proposed Action Plan for Establishing Global Coordination of IMDOS - introduced under the Major Activities section of this report.

In Phase I, extending from 2020 to mid-2022, the goal would be to initiate a global coordination of IMDOS by:

- establishing an international Steering Committee and approved Terms of Reference (ToR) for IMDOS;
- developing Marine Debris as a new type of Human Activity/Impact EOV, while also integrating relevant requirements in the existing framework (e.g. Particulate Matter EOV);
- developing first platform-specific standard operating procedures (SOPs) based on GESAMP 'Guidelines for the monitoring and assessment of plastic litter in the ocean' (GESAMP, 2019);
- interfacing in situ and remote sensing observations according to EOV requirements.

In Phase II, extending from 2022 to 2025, the goal would be to increase the readiness level of selected elements of IMDOS and their data management streams by integrating them into the global system of coordinated observing networks. This would improve the global coverage, resolution, accuracy and interoperability of marine debris data and thus better inform indicators and sub-indicators of SDG target 14.1 and any regional policy targets set, e.g. by the European Union (Marine Strategy Framework Directive, Marine Plastics Directive), the Arctic Council (Arctic Monitoring & Assessment Programme), other identified governing bodies. Emphasis would also be placed on improving the coordination on the interface between in situ and remote sensing operations (e.g. ESA, NASA, NOAA, JAXA), based on a common set of observing requirements. Exact objectives for Phase II would be determined in the Terms of Reference for IMDOS.

Below is a list and timeline of activities suggested to be carried out as part of this Action Plan during Phase 1 of the project, from 2020 to 2022. The list of activities and their scope will ultimately be refined according to the Terms of Reference adopted by the IMDOS Steering Committee pending its suggested initiation in 2021.

1.Establish an international Steering Committee and ToRs for IMDOS

Developing the right governance model for IMDOS requires careful consideration. In this Action Plan we propose to establish a Scientific Committee composed of members of international organizations and regional initiatives spearheading the process of regional to global coordination of marine debris monitoring focused on sea-based activities, representing expertise in various observing approaches, data management, and considering geographic balance among other criteria.

The Committee would be an independent coordination body, responsible for overseeing the execution of ToRs approved during their first in-person meeting scheduled tentatively for early 2021. In order to foster the interaction with other coordinating bodies and structures of GOOS, it is proposed that IMDOS would apply to be an affiliated project of GOOS. Most of the GOOS project requirements could be met in time for the 10th Session of the GOOS Steering Committee (April 2021) to consider such an application.

2.Develop the concept of Marine Debris as a Human Activity/Impact EOV and publish the Marine Debris EOV Specification Sheet

This process will build on an early draft of a Plastics Contaminants EOV Specification Sheet which was based on initial input provided by Peter Kershaw (GESAMP) during an AtlantOS workshop on setting targets for the Atlantic ocean observing system. The document should contain a summary of the observing requirements for marine debris as an EOV, including which parameters/indicators to measure, and if possible, specify at what coverage, resolution and accuracy. The document should also list any coordinated monitoring efforts on regional to global scale, as well as those at concept stage but with potential to emerge as vital elements of IMDOS. Key established data streams, databases and information synthesis products will be described, along with a list of monitoring guidelines, best practices, and if available any SOPs among other reference documents.

The document would be published on the GOOS website (www.goosocean.org/eov) and be subject to periodic updates aligned with updates to all other EOVs. IMDOS SC would be the formal curator of the Marine Debris EOV.

3.Synthesize currently available information on requirements for in situ and remote sensing components of IMDOS

There are ongoing guidelines and recommendations for setting requirements for marine debris monitoring to provide adequate data to realize policy targets, such as SGD 14.1. 'Guidelines for monitoring and assessment of plastic litter in the ocean' is provided in the GESAMP (2019) report. Requirements should carefully consider the needs of the modelling community, in particular as global model projections inform the SDG 14.1.1b indicators on a global scale. Additional recommendations are already being put forward for remote sensing measurements of marine debris and the processes affecting the distribution, e.g. based on characteristic scales of the processes/phenomena (Martinez-Vicente et al., 2019) – taking an approach which is fully in line with the phenomena-based approach adopted by the GOOS Panels of Experts.

A combination of policy, scientific and user-defined requirements provide the basis for setting specific observing targets expressed in terms of coverage, resolution, accuracy and latency. For the benefit of designing an integrated ocean observing system which is fit for many purposes and for ease of performance tracking, setting observing targets for marine debris will be a long-term process but one which should be part of a coordinated process across ocean disciplines and across observing networks.

4.Develop and promote the use of first SOPs for marine debris monitoring estimated at pilot or mature

This activity would build on the guidelines and recommendations from GESAMP (2019). Focus will be given to those observing approaches and methodologies with highest impact and feasibility, but which lack global standardization of methodology and data interoperability. This could include human observations (beach and river mouth surveys), visual imagery and video surveillance of the seafloor (SCUBA, ROV), or in-line/underway sampling (net tows, pumps, CPR). IMDOS SC would determine the priority for addressing standardization of the methods recommended for global monitoring, in close alignment with recommendations from GESAMP.

Where possible and relevant, SOPs should be aligned with existing coordinated observing network and program protocols (e.g. SOOP for ships of opportunity, ICES for bottom trawl surveys) or co-developed with similar initiatives leading to expansion of current sustained efforts (e.g. SCOR WG P-OBS for water sampling on ship-based and fixed-point open ocean observatories).

The draft SOPs developed will be shared for input with a much larger representative group from each research community of practice. Developing and promoting the use of SOPs would benefit from collaboration with Ocean Best Practices (OBP), including from technical workshops potentially co-organized by OBP and GOOS.

5.Integrate elements of IMDOS into the existing coordinated observing networks, and enhance platform sharing

While the development of a dedicated global sustained observing network for marine debris is a long-term development, Phase 1 of this Action Plan recommends an analysis of feasibility and cost of adding a marine debris component to established (e.g. GO-SHIP, SOOP, OceanSITES, GACS) and/or emerging globally coordinated observing networks (e.g. OTN, ASV fleets). A recent model of such analysis is provided by the report from SCOR WG 154 P-OBS on 'Recommendations for plankton measurements on the GO-SHIP program with relevance to other sea-going expeditions'.

One aspect of such analysis considers addition of new sensors and instruments designed specifically for marine debris monitoring. For instance, it might be relevant to scope the possibility of expanding video camera observations of marine litter (e.g. littercam) on autonomous platforms (e.g. wave gliders) and ships. Similarly there is interest among the sailing community to contribute to marine debris monitoring. However, there are no formal contact points and documents providing guidelines on technical specifications and cost estimates for yachts (racing and recreational) willing to support sampling and delivering data to international databases (such as EMODnet).

Another aspect of enhanced platform sharing concerns minimal adjustments to existing data collection methods and protocols to enable collection of data for multiple-applications, e.g. from visual and bio-optical observations from existing in-line/underway surveys used for particulate matter and biological sampling.

GOOS is currently supporting efforts leading to enhanced coordination of Particulate Matter EOV observations. Several of the observing approaches used for particulate matter observations, traditionally focused on estimating particulate carbon and nutrient pools and fluxes, are similar to those used for marine debris. Moreover, the International Ocean Colour Coordination Group (IOCCG) has been developing technical reports and protocols for both in situ and remote sensing observations of ocean colour and its applications, with possible high relevance to marine plastics and other debris observations. A joint technical workshop between experts from particulate carbon and debris observations could provide a useful step in cross-checking and potentially harmonizing best practices for water column particulate monitoring in situ and from space.

Global Data Assembly Centre for marine biogeochemistry and data synthesis products
Global Data Assembly Centre (GDAC) for marine Biogeochemistry
Developments are ongoing and funding was secured in Europe and in the US for future GDAC partners. After US NOAA Pacific Marine Environmental Laboratory (PMEL) and the Bjerknes Climate Data Centre (BCDC) at the University of Bergen signed a Memorandum of Understanding in 2018, the two organizations will apply to become official IODE Associated Data Units (ADU) in 2020 - thus completing one of the last steps prior to a formal GDAC application.

BCDC at the University of Bergen made an assessment of related tasks for an operational GDAC, which is covered by current and future activities. Technical Readiness Levels for data management activities are continuously increasing, and becoming a formal part of IODE will help to increase the visibility and usability of biogeochemical data. BCDC representatives attended several IOC UNESCO IODE meetings and will apply to become an official IODE GDAC in 2020. NOAA NCEI is interested in becoming a partner as well - an idea discussed during a visit to BCDC in November 2019. The overall concept of streaming data through the GDAC and how the effort relates to the needs for national data reporting and reporting into the UN system is briefly introduced below.

While the GDAC is primarily funded from European sources, it is a global effort based on the existing national data management structures and regional hubs or assembly centres. In most countries, data can be submitted via a National Oceanographic Data Centre (NODC). If a country does not have an NODC, one can submit the data via a regional DAC or hub. For instance, NOAA NCEI would be considered a hub in North America, and an Integrated Carbon Observing System (ICOS) would be a hub in Europe. For scientists working e.g. in South America, the simplest way would be to put an ERDDAP on the datastream used, which would then get picked up by the GDAC. In some instances, data providers might prefer to bypass the NODC and still be able to deliver into the UN system. In response to IOC requests, they can submit their data directly through the regional DAC or the GDAC which has the status of an IODE unit. Regardless of how the data providers choose to submit the data, it must be clear that GDAC is only responsible for streaming data, and not for reporting the data. The actual reporting takes place through the national bureau of statistics, and this need not go through the GDAC.

Operational data flow developments

While operational data flow including NRT (Near Real-Time) data distribution has been established for decades for mainly physical oceanographic parameters like temperature and salinity – the entire field of operational data flow is relatively new to many of the parameters in the field of marine biogeochemistry. Data obtained from biogeochemical sensors is often obtained in NRT mode (e.g. Biogeochemical Argo) made available to portals e.g. GOA-ON, but data is often not automatically quality controlled or integrated in global/regional NRT data products. There are many valid reasons, one major is the non-standardized system setups with a variety of measurement devices which makes it challenging to automate data flow and QC. Higher financial resources are needed to overcome this burden. At the same time data is often obtained in research projects with limited resources where the major focus is on science with and not on establishing an operational data flow. Activities in the US (e.g. IOOS, NOAA), Australia (e.g. IMOS) and in Europe (e.g. ICOS, EMODnet) are moving towards making the data flow for the EOVs that are of interest for IOCCP (e.g. Inorganic Carbon EOV) operational, and to speed up data availability.

Addressing lack of sustained funding for SOCAT and GLODAP projects

Both GLODAP and SOCAT, two IOCCP flagship products, are community efforts that have become “brand names”. Both data products are much used and well cited in literature. Both efforts are great successes and show the dedication of the ocean carbon cycle community to produce high-quality data. Efficient communication of the high impact of the products is the successful part of the “branding” process. However, both efforts remain practically unfunded, and rely on volunteer contributions.

There is an urgent need for the community to abandon the misconception that SOCAT and GLODAP are funded projects, and instead recognize the immense vulnerability of these voluntary efforts. While IOCCP continues to support SOCAT and GLODAP to a limited extent, e.g. to organize meetings, our priority is to help bring both efforts to a self-sustained mode.

In early 2020 IOCCP has taken initial steps in coordinating and galvanizing the community to assure stronger financial footing for global synthesis efforts such as SOCAT and GLODAP. A first step will be to provide a clear picture of the elements and resources needed for robust operations. This could be done through a report outlining the scope of the efforts, voluntary contributions to the SOCAT enterprise, and required resources for the core effort. It could include a view of the evolution of SOCAT to include more parameters, linking to other datasets and improved automation and visualization, and the resources needed for this. This report would provide a holistic view and offer funding agencies a clear picture of how they could contribute to the sustainability of the effort. A similarly scoped report could potentially be produced for GLODAP within the EU EuroSea project. IOCCP SSG suggested committing adequate resources to realizing this proposed action, and recommended that the report should have a form of a business plan that could be used to successfully communicate both the value and needs of SOCAT and GLODAP efforts. IOCCP will coordinate the effort, ensuring that a common template is used for SOCAT, GLODAP and future data synthesis initiatives such as the one initiated for oxygen data, and ship-based time-series data.

Ship-based time-series product including development of QC routines

As already described elsewhere in the report, IOCCP SSG members Björn Fiedler and Benjamin Pfeil are leading the effort of developing a new pilot time-series data product. Within the EuroSea project, existing EOV synthesis products from in situ biogeochemical observations and high quality and long-term ship-based time series data will be optimally fused to obtain optimal estimates of EOVs and derived quantities in support of ocean climate and ocean health monitoring. This task will focus on the Inorganic Carbon EOV with all four of its sub-variables (Dissolved Inorganic Carbon (DIC), Total Alkalinity (TA), Partial pressure of carbon dioxide (pCO_2) and pH) and potentially the Oxygen EOV, including how to operationalise data flow and availability. The effort will develop quality control procedures for data from certain platforms e.g. ship-based time series stations, and subsequently integrate those quality controlled data with data from the GLODAP data product. As part of the tasks led by University of Bergen, European SOCAT and GLODAP quality control efforts will be operationalised, and the implementation of the quality control routines for ship-based time-series EOV data will be tested.

The next step towards the creation of the product will be a workshop which would discuss procedures for quality control of bottle data. It was decided that the work would not consider quality control of sensor data, indicating strong complementarity between this workshop and the oxygen atlas undertaking where a task team was created to deal with mooring and other sensor oxygen data for the purpose of data management and synthesis product development.

IOCCP has recommended that the time series workshop be run back to back with the second workshop on oxygen data product in order to better align the two efforts, and reduce travel and logistics costs for experts likely to attend both events. IOC-UNESCO has tentatively agreed to host both events in Paris, France, likely to be held towards the end of October 2020.

As of February 2020, PIs of nine ship-based open-ocean time series sites have confirmed their interest in the workshop and data product development. While there is already a wide geographical coverage included, other station managers will need to be re-approached to maximize the community involvement. The initial focus will be on the open-ocean sites only because issues with quality control and comparability between coastal sites would be too challenging and beyond the scope of the initial demonstrator planned under EuroSea.

Technical capacity development, standards and best practices

Online training tool for ocean acidification data quality control

During IOCCP-SSG-14, Crisitan Vargas proposed to partially fund and organize a regional workshop on data quality control and data management for ocean acidification research in Latin America and other regions. Cristian requested co-sponsorship from IOCCP and mentioned the possibility of additional funding to be requested from the International Atomic Energy Agency's Ocean Acidification International Coordination Centre (IAEA OA-ICC), and multiple local funding partners, such as the Millennium Institute of Oceanography (IMO), in Chile. The workshop would give us the opportunity to incorporate a community of new ocean observers from, among others, Colombia, Costa Rica, Mexico, and Ecuador, which were funded by The Ocean Foundation for implementing carbon chemistry (pH mostly) monitoring in their respective countries, and whose instruments will have been deployed by the time of the workshop.

In order to better streamline such regional technical capacity building efforts related to ocean acidification, IOCCP decided to consult with GOA-ON prior to approving sponsorship and organisation of the workshop. Such a consultation involved GOA-ON Co-Chairs and Adrienne Sutton who has been involved in developing quality control guidance for the ocean acidification community through IAEA.

During a virtual meeting held in March 2020, the group agreed that there is a need for finding a creative approach (e.g. an online training platform / virtual user guide) to providing adequate online training (and re-training) resources in response to such a large demand among the community, and especially in light of restricted travel for an unforeseeable future. A potential project could involve a portfolio of online resources, including best practice documents, video instructions, discussion fora, webinars, etc.

Cristian confirmed that a project resulting in widely distributed manuals and protocols and associated training resources for carbonate system measurements would be suitable for the needs of the Latin American and supposedly other regional communities from developing countries. However, he also stressed that the basic information would need to be provided in at least a few languages, not just in English. Cristian agreed with the recommendations to invest resources into developing such a comprehensive online product instead of organising one or more dedicated in-person training workshops.

It was further recommended to consult with members of existing working groups the main themes of which are related to ocean acidification observations, both to avoid overlap and to identify potential synergies. These include:

- IAPSO WG on Best Practice Study Group to identify approaches to be recommended for seawater pH measurement
- Co-led by Andrew Dickson (Scripps) with Kim and Bronte as members;
- http://iapso.iugg.org/images/stories/_working_groups/Best_practice_study_groups/pH_Best_Practice_Study_Group_2019-proposal.pdf
- Initial meeting took place after OSM 2020. The work of the WG would likely be too theoretical to fit into the proposed project but a link is clearly needed.
- SCOR WG 149: Launch of the Multiple Environmental Driver Design Lab for Experiments (MEDDLE; www.meddle-scor149.org), led by Phil Boyd.
- Kim Currie is to contact WG member Christina McGraw
- US OCB Working Group on Ocean Carbonate System Intercomparison Forum,
- Led by Brendan Carter (NOAA PMEL) https://www.us-ocb.org/ocean-carbonate-system-intercomparison-forum/
- Scope of the work likely does not consider quality control of pH measurements.

Consequently the decision for IOCCP was not to sponsor the regional workshop but instead engage in a broader collaborative project to develop best practice documents and corresponding online training resources for the ocean acidification observing community. In the next few months IOCCP and GOA-ON members will jointly develop an action plan and seek to obtain adequate financial support.

Sensors Training Course 2021 planning

Based on the very successful two editions of the sensors training course in 2015 and 2019 and in response to a great demand for such technical capacity building, the IOCCP SSG strongly supported organizing the sensors training course as a recurrent event. The SSG approved of the proposal to hold the course on a bi-annual basis, provided that we avoid overlap with other major international summer schools with which we might compete for funding as well as participants.

Tentative plans have been made to organize the 3rd IOCCP Sensors Training Course in June 2021, also in Kristineberg, Sweden. IOCCP SSG recommended supporting the organization of the course at a level of ca. 30,000 USD. IOCCP Co-Chairs and the Office have started a fundraising campaign in late 2019 in order to identify partners interested in co-sponsorship of the event allowing to secure 80%

of the approximate budget of 100,000 USD by mid- 2020. By mid-May 2020 we managed to secure 50% of the total budget, with several ongoing co-sponsorship discussions.

1st ICOS OTC pCO_2 instrument inter-comparison

As announced by IOCCP through the communication channels, the 1st ICOS OTC pCO_2 instrument inter-comparison exercise was scheduled to take place on 24 Aug - 4 Sep 2020, at VLIZ in Oostende, Belgium. Tobias Steinhoff (GEOMAR, Germany) and Thanos Gritzalis (VLIZ, Belgium) are leading the effort. IOCCP was invited to join the Organizing Committee and provide know-how and experience related to organizing similar scale events. Organizers are committed to making this intercomparison global and to invite explicitly those colleagues who work at laboratories submitting their data to SOCAT.

The SSG approved the request to support travel for participants from developing countries, with a total contribution of 5,000 USD. The organizers ensured that there will be a final report with the results of the intercomparison published under the IOCCP umbrella. The IOCCP Director met the organizers at VLIZ in December 2019, a few weeks after the IOCCP SSG meeting in Sopot, to discuss the details and agree on IOCCP commitments as co-organizers of the event.

Due to COVID-19, the inter-comparison has been postponed until July 2021.

Surface ocean observations of biogeochemical parameters
SOCONET and OASIS

IOCCP will continue coordination efforts to operationalize surface ocean biogeochemical observations. Scientific evidence of the critical role that carbon dioxide (CO_2) levels in (and fluxes between) the ocean surface and atmospheric marine boundary layer (MBL) play in sequestering the anthropogenic CO_2 and therefore mitigating man-made climate change, has been overwhelming. The need for long-term sustained and accurate monitoring of those levels and fluxes has been called upon to enable accurate assessments for policy and decision making at regional and global levels. However, the measurements enabling monitoring surface ocean CO_2 and CO_2 ocean-atmosphere flux continue to be driven by scientific curiosity and is achieved mainly via research funding. IOCCP has already started engaging with several partners to work out a more suitable model where the need for monitoring is fulfilled by infrastructural support rather than piggybacked on research proposals, consuming our capacity (human and in terms of resources) to engage in other types of observations-based research.

In late 2018 and first half 2019, IOCCP experts contributed to the vision for surface CO_2 observations in the next decade by a review of the challenges and recommendations for the Surface Ocean CO_2 NETwork (SOCONET) and the wider community in an OceanObs'19 Community White Paper led by Rik Wanninkhof, published in July 2019 in Frontiers in Marine Science. The paper can be accessed at: https://www.frontiersin.org/articles/10.3389/fmars.2019.00400/full

SOCONET is a partnership of many investigators that have a major goal measuring surface ocean CO_2 and MBL CO_2 levels on an operational basis following agreed upon procedures. The accurate measurements will be disseminated within a year of measurement. Platform and instrument metadata tracking would occur in near-real time. The current list of platforms and participants that expressed interest in being part of SOCONET can be found at www.aoml.noaa.gov/ocd/gcc/SOCONET. The measurements are key inputs to products addressing important social, policy, and economic issues of our time as they pertain to marine health and anthropogenic carbon sequestration. While the surface ocean and MBL measurements are automated, the data reduction and quality control for the level of accuracy required for SOCONET are labor intensive, adding to the challenges of timeliness and cost of operation of the network.

From an organizational perspective, securing and maintaining resources in these international distributed networks is critical, and means need to be explored to accomplish this. This holds true particularly for the communal aspects, including network design, data tracking, and coordination. IOCCP is devoted to implementing individual recommendations from the Community White Paper over the next several years, working with several national, international and intergovernmental partners. Simultaneously, we will work closely with surface observing communities across disciplines to co-design, or rather adapt existing elements of the surface ocean observing system for maximum efficiency, fitness for purpose and flexibility in terms of temporal and spatial coverage and a suite of parameters measured in any given time and space.
This work has also already started, triggered by several CWP's published in preparation for the OceanObs19. Cronin et al., Wanninkof et al., Centurioni et al., Muller-Karger et al., Pinardi et al., Steinhoff et al., just to name a few. Intense communication in the last 6-8 months resulted in a well described strategy for harmonization of proposed recommendations aimed at working towards an Integrated Surface Ocean Observing System. The concept of integrating, coordinating, and leveraging across disciplines (physics, biogeochemistry and biology and ecosystem observations) will hopefully be part of the UN Decade of the Ocean Science for Sustainable Development, allowing this multidisciplinary and multifunctional part of the observing system to fully develop.

In May 2020, a proposal to create a SCOR Working Group to harmonize the recommendations from the OceanObs'19 CWPs into a unified Observing Air-Sea Interaction Strategy (OASIS) has been submitted with the following initial core drivers:

- monitoring and predicting the ocean's influence on global weather and climate on timescales of days-seasons-decades
- monitoring and predicting marine weather in the ocean and atmosphere
- tracking ocean uptake of carbon dioxide and oceanic deoxygenation and denitrification
- studying how biology, biodiversity, and the surface ecosystems relate to changes in surface concentrations and fluxes of CO_2, DMS, and N_2O

Regardless of the outcome of the SCOR Working Group selection process, there are almost a hundred individuals committed to making an operational OASIS a reality and IOCCP as an organization as well as its individual members are part of this process. Specific proposed implementation timeline is described in the proposal which is available for review at https://scor-int.org/events/2020-scor-annual-meeting/

Autonomous surface vehicles

During IOCCP-SSG-14 the group discussed some new technological developments which should be on the radar of IOCCP. For instance, Saildrone Inc. has greatly increased the readiness level of the autonomous surface vehicles (ASVs) as an observing approach, performing important demonstrations of successful marine biogeochemistry surface measurements in both open ocean and regional seas through partnerships with leading research institutes such as NOAA, GEOMAR and University of Bergen.

A new model of data collection and dissemination, based on private-public partnerships (see OceanObs'19 CWP by Meinig et al., 2019), is opening up new opportunities for sustained marine biogeochemistry, not only in terms of coverage and resolution but also cross-platform data validation and multidisciplinary information product creation. IOCCP will consider whether a person familiar with running an ASV fleet sampling campaign be potentially invited to the IOCCP-SSG-15 meeting.

Meeting the needs of the coastal observing community

The Panel has discussed the current gap in Nutrients EOV expertise and whether there is a need to nominate another SSG member who would fill this gap. This position has remained vacant since the start of 2019 and related issues are tentatively a responsibility of IOCCP co-Chair, Masao Ishii. During 14th Session of IOCCP SSG, IOCCP Executive was asked to perform a thorough analysis of the IOCCP Skills, Roles and Responsibilities Matrix (see report from IOCCP-SSG-13) and provide recommendation(s) on IOCCP's approach to future curation of the Nutrients EOV and identify criteria for subsequent open calls for new SSG members.

On one hand, it should be considered that the SCOR Working Group 147: Towards comparability of global oceanic nutrient data (COMPONUT) has already been dissolved and that there is currently no group conducting work related to coordinating nutrient observations in seawater. It was mentioned that there are a lot of issues with nutrient observations at the land-ocean interface and in the coastal zone. These would require application of sensors which were not considered by COMPONUT at all. A large increase in their deployment around the world for various applications is accompanied by challenges related to data quality control procedures, best practices and technical training. Nutrient sensors applications reach beyond climate studies, and are increasingly used for ocean health (e.g. water quality) purposes.

Developing indicators of nutrient pollution in marine waters to inform SDG targets has been on the agenda of UNEP as the custodian agency for the relevant targets. UNEP is responsible for promoting standards and methods applicable for national and regional monitoring efforts, including many parameters common to the Nutrients EOV. However, there has been no interaction between IOCCP and UNEP in this domain. As GOOS is looking to establish strong partnerships with UNEP on aspects of water quality and environmental monitoring requirements and capacities, IOCCP could play a vital role in joint coordination of standards and best practices as well as data management activities for nutrients measurements in both open ocean and coastal waters.

In effect of Douglas Connelly stepping down from IOCCP SSG in February 2020, the group decided to issue an early open call for a position which would not only maintain our capacity to coordinate and communicate with users of instruments and sensors in the open ocean domain, but also expand our focus onto nutrient and other inorganic biogeochemistry measurements performed routinely in the coastal environments, for various applications. The candidate would moreover need to take charge of technical capacity building initiatives, in particular organizing next editions of the training course on a suite of biogeochemical sensors.

Considering the excellence of all applications received in response to the March 2020 open call for a new IOCCP SSG member, we are confident that the nominated expert, once approved by the sponsors, will significantly improve IOCCP's capacity to better fulfill our Terms of Reference, and thus serve the growing needs of our community.

SOOS – Southern Ocean observing

The
Southern Ocean Observing System
2019 Annual Report

Summary
The Southern Ocean Observing System (SOOS) is a joint initiative of the Scientific Committee on Antarctic Research (SCAR) and the Scientific Committee on Oceanic Research (SCOR); and is endorsed by the Partnership for Observations of the Global Ocean (POGO), and the "Climate Variability and Predictability (CLIVAR)" and "Climate and Cryosphere (CliC)" projects of the World Climate Research Programme (WCRP).
SOOS was launched in 2011 with the mission to facilitate the collection and delivery of essential observations on dynamics and change of Southern Ocean systems to all international stakeholders, through design, advocacy, and implementation of cost-effective observing and data delivery systems.

The SOOS International Project Office Core Sponsorship 2019

Contents

2019 in review

This report marks 8 years since the first Scientific Steering Committee meeting in 2012. Under the auspices of SCAR and SCOR, SOOS has become an important part of the Southern Ocean community, and many developments contribute more broadly to global ocean observing. 2019 has been an important year for consolidating key SOOS initiatives. Our five regional working groups (RWGs) are now established. The first meetings of the Amundsen and Weddell-Dronning Maud Land groups were held, resulting in consolidated work programs into the future. All RWGs are also expanding their membership to enable greater collaboration amongst nations in the different regions.

SOOS increased its profile in the Antarctic Treaty System, through representation at the Antarctic Treaty Consultative Meeting, the Commission for the Conservation of Antarctic Marine Living Resources, collaboration with the Council of Managers for National Antarctic Programs, and a MoU with the International Association of Antarctic Tourism Operators. These relationships deliver increased contributions to DueSouth for enhanced use of ships of opportunity for science.

Our 2019 annual Scientific Steering Committee meeting was held in Incheon, South Korea. We extend heartfelt thanks to our colleagues at KOPRI for their incredible hosting of our meetings and side meetings, such as a “Datahack” workshop that helped streamline data processing and availability. Data availability has further improved through the work of the Data Management Subcommittee (DMSC). SOOSmap had fantastic end-user uptake, with over 53,000 visits to the site and 17,000 data downloads. Thank you to EMODnet for delivering this data sharing facility.

SOOS now has demonstrable globally significant contributions. In 2019, we contributed to the Bulletin of the American Meteorological Society’s “State of the Climate” for the fifth year in a row. SOOS led an OceanObs19 community paper on the development and priorities for Southern Ocean observations, and the air-sea flux capability WG and DMSC also contributed focused papers showing SOOS’ leading role in developing regional observing systems. Further, SOOS was invited to COP25 Earth Observation Day, and is now coordinating the planning of a Southern Ocean contribution to the UN Decade of Ocean Science.

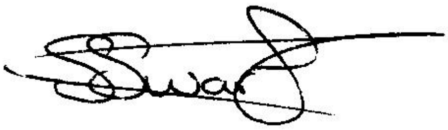
This year has also seen a consolidation of our International Project Office. We thank Louise Newman, Pip Bricher and Alyce Hancock for their dedication to excellence and support. We thank Richard Coleman for his service to SOOS and the establishment of the IPO at the University of Tasmania. We

thank him and the Australian Research Council's Antarctic Gateway Partnership for the last 5 years of funding. Further, we thank our other 2019 sponsors, Antarctica New Zealand, the State Oceanic Administration (China) and the University of Gothenburg for their continued support of SOOS.
Looking forward, we are pleased by support from a wider-Hobart consortium of the University of Tasmania IMAS, CSIRO and the Tasmanian State Government for hosting of the IPO in Hobart for 2020 – 2022, and are excited by a new collaboration with the Swedish Polar Research Secretariat for support of the Swedish SOOS community.
Lastly, we thank our community for the continuing support of SOOS and for assisting with its development into an integral part of the Southern Ocean marine science community.

Signed:

Dr. Andrew Constable; Biological Sciences Co-Chair
Australian Antarctic Division, Australia

Signed:



Dr. Sebastiaan Swart; Physical Sciences Co-Chair
University of Gothenburg, Sweden

Performance Report

SOOS published its 5-Year Implementation Plan in 2016, which articulated the key challenges driving SOOS, and resulted in the identification of 4 Objectives and specific Key Result Areas (KRAs) that will address the causes of these challenges. The annual report for SOOS is the mechanism through which we review progress against the KRAs, to ensure the Objectives are being met.
The 5-Year Implementation Plan is available at http://soos.aq/activities/implementation

Progress report against Objectives and Key Result Areas

Objective One: Facilitate the design of a comprehensive and multi-disciplinary observing system for the Southern Ocean

Objective 1 will support delivery of a coordinated, integrated and efficient program that provides sustained observations of Southern Ocean systems, following the Framework for Ocean Observing (FOO, 2010) and the identification of Essential Ocean Variables (EOVs). Activity towards achieving Objective 1 will be carried out by the Regional Working Groups (RWGs) and Capability Working Groups (CWGs).

As reported in 2018, the focus and mechanisms to achieve this Objective have changed since 2015, and several of the KRAs are no longer practical priorities. Instead, SOOS will be working through CWGs, RWGs, and specific Task Teams, to identify, prioritise and document EOV coverage and requirements (KRA 1.3), which will result in a more “organic” delivery of Objective 1 rather than a top-down directed effort.

Objective One includes 4 KRAs, and although only KRA 1.3 and 1.4 were identified for action in 2019, some efforts that deliver into KRAs 1.1 and 1.2 were also supported and are reported herein.

Key Result Area 1.1: Establish Criteria for adopting EOVs and communicate them

2019 Intended Actions	Progress Made (Y/X)	Comment
No intended actions for 2019, however: MEASO/eEOV Task Team	Y	SOOS approved development of an eEOV Task Team to support EOV identification through the Marine Ecosystem Assessment of the Southern Ocean (MEASO) effort. Efforts of this group contribute to this KRA and will be published as part of the MEASO Special Issue. Full achievements of this group on pg 40

Key Result Area 1.2: Southern Ocean EOVs are identified and the manner in which they satisfy the criteria are communicated

2018 Intended Actions	Progress Made (Y/X)	Comment

No intended actions for 2019, however: MEASO/eEOV Task Team	Y	The MEASO TT will be articulating ecosystem EOVs and assessment requirements in a publication

Key Result Area 1.3: Spatio-temporal, system-level EOV sampling requirements are identified, documented and agreed, and strategies for implementation developed if needed

2019 Intended Actions	Progress Made (Y/X)	Comment
Review of current status of EOV coverage, key gaps and requirements	Y	Regional Working Groups are developing sub-regions to enable quantification of observational coverage and requirements. All 5 RWGs worked towards defining sub-regions and requirements
International strategic plan for observing the ocean beneath Antarctic sea ice and ice shelves (OASIIS Working Group)	Y	A POGO Fact Sheet was drafted. The report is planned and will be delivered in 2020. Issues – Products from this group continue to be delayed and have been modified in scope to account for changing requirements. The report is planned for delivery by end-2020
Observing system design for Southern Ocean Flux moorings	Y	A joint effort between the SOFLUX and Observing System Design working groups. Work was carried out by a Postdoc funded by the State Oceanic Administration, China. Resulting publication: Wei et al., 2020: Optimizing mooring placement to constrain Southern Ocean air-sea fluxes, Journal of Atmos. Ocean. Tech. DOI: 10.1175/JTECH-D-19-0203.1
International standards, methodology and strategy for sustained and reliable remote sensing-based monitoring of pack-ice seal populations	Y	SOOS CWG Censusing Animal Populations from Space (CAPS) continued to deliver methods, standards and outcomes towards this KRA. See pg 36 for more details

Development of international initiative to Benchmark Southern Ocean ecosystems	X	This effort did not gain traction with the community. Key components of this effort were incorporated into the deliverables of the MEASO effort and are now delivered by the eEOV TT

Key Result Area 1.4: A strategy for the uptake of EOVs within the RWGs is developed

2019 Intended Actions	Progress Made (Y/X)	Comment
Regional Implementation Strategies developed	Y	Regional Working Groups are developing sub-regions to enable quantification of observational coverage and requirements. All 5 RWGs worked towards defining sub-regions and requirements

Objective Two: Unify and enhance current observation efforts and leverage further resources across disciplines, and between nations and programs

Delivering Objective 2 will ensure regional implementation of long-term, sustained observations to achieve circumpolar coverage of Southern Ocean systems, built by integrating across internationally coordinated observation programs and existing efforts by national programs.

There are 3 KRAs that will focus work towards achieving this objective, and all were identified for action in 2019. Progress is shown in the tables below.

2019 focused on maintenance and continuity in delivery of key products and networks. Capability and Regional Working Groups continued to coordinate activities in their communities, and the Data Management Sub-Committee and IPO continued to support and maintain the Key Products. Importantly, the lack of capacity in the IPO to provide communication and networking support for all working groups was partly resolved, as the new multi-year sponsoring partnership for 2020 (see pg 26) enabled stable forecasting of the operational budget, and thus the hire of a Communications and Project Officer.

Key Result Area 2.1: Working Groups and Task Teams that coordinate efforts across disciplines and programs, and between nations are developed to fill priority gaps

2019 Intended Actions	Progress Made (Y/X)	Comment
Continuation of active Working Groups and Task Teams (TTs) against group-specific TORs	Y	SOOS has 10 Working Groups and 4 TT and all were active in 2019. For detailed reports, see pages 31-43 Issue: The Benchmarking2020 WG was not able to build the required community interest to achieve its objectives, and was therefore sunsetted

		in 2019; capacity on eEOVs was redirected to eEOV TT (see below)
Development of new WGs and Task Teams (as required)	Y	The Flux Moorings Task Team (a joint effort between SOFLUX and OSD working groups), identified where and how many flux moorings are required to constrain large-scale fluxes of heat in the Southern Ocean. The Task Team lead was a PostDoc sponsored by the State Oceanic Administration, China. The ecosystem Essential Ocean Variables Task Team (eEOV TT) is a contribution to the Marine Ecosystem Assessment of the Southern Ocean (MEASO) and will work with MEASO to identify and describe eEOVs The AUV Task Team is tasked with matching polar AUV science objectives and engineering capabilities with deployment capabilities and sensor development from across National Antarctic Programs. An initial planning workshop was held in Norway

Key Result Area 2.2: Key products for the Southern Ocean that aid in information transfer and facilitate collaborative efforts are identified and produced

2019 Intended Actions	Progress Made (Y/X)	Comment
Database of Upcoming Expeditions to the Southern Ocean	Y	Considerable progress in populating DueSouth with expedition information. COMNAP provided its Regional Information Exchanges and JCOMMOPS provided automated updates from their shipping database. CCAMLR's commission approved the republication of fisheries notifications, in line with the 2018 approval by CCAMLR's Science Committee. Negotiations continued with IAATO for tourist vessel movements resulting in an MoU for integrating IAATO vessel movements into DueSouth. More details available on page 22. Issues – The AADC can no longer provide hosting and maintenance support for DueSouth, and a new host/coder is being sought; Specific observational projects remain unpopulated; Inability to obtain user statistics; limited input of plans by community; Low level of control over timing and delivery of enhancements and modifications due to in-kind delivery of product.
SOOSmap	Y	Product is delivered and is being used by the community; improvements to core functionality; new data layers added; future data layers identified; modifications to user interface initiated. SOOSmap was moved to its own stand-alone domain, http://soosmap.aq/ to facilitate additional functionality. SOOSmap received ~8000 pageviews per month, with ~2500 near-real time files and ~11 long-term archive files downloaded each month. More details available on page 24. Issues – Low level of control over timing and delivery of enhancements and modifications to functionality due to in-kind delivery of product

Community annual calendar	Y	Product was maintained and updated as required
SOOS Publications	Y	Newman et al., 2019: Delivering sustained, coordinated and integrated observations of the Southern Ocean for global impact: https://doi.org/10.3389/fmars.2019.00433 Swart et al., 2019: Constraining Southern Ocean air-sea-ice fluxes through enhanced observations: https://doi.org/10.3389/fmars.2019.00433 Tanhua et al., 2019: Ocean FAIR Data services: https://doi.org/10.3389/fmars.2019.00440 Meijers et al., 2019: Southern Ocean [in "State of the Climate in 2018"] doi:10.1175/2019BAMSStateoftheClimate.1.

Key Result Area 2.3: Collaborative, multidisciplinary and multinational workshops and meetings are undertaken, resulting in the SOOS mission being achieved

2019 Intended Actions	Progress Made (Y/X)	Comment
Task Team, Capability and Regional Working Group workshops	Y	Amundsen Sea RWG, Weddell and Dronning Maud Land RWG, AUV Task Team, Data Management Sub-Committee meeting
Capacity- or Community-building workshops	Y	Polar Data Policy Alignment Workshop; Polar Federated Search Workshop; SOOS Datathon; Polar oceanographic data management workshop
International conference sessions, town-halls, side meetings, information sessions	Y	Polar Data Forum III; OceanObs19 Arctic Observing System

Objective Three: Facilitate linking of sustained long-term observations to provide a system of enhanced data discovery and delivery, utilising existing data centres and programmatic efforts combined with, as needed, purpose-built data management and storage systems

Achieving Objective 3 will enhance access to multidisciplinary, quality-controlled observational data from the Southern Ocean. Currently, such data is difficult and time consuming to access as there are many fragmented, mono-disciplinary, mono-platform, or mono-national data centres; a shortage of focused effort towards data sharing and platform interoperability; large variations in national/institutional data policies and data-sharing cultures; and a lack of general knowledge on the data that are being collected.

There are 4 KRAs that focus work towards achieving this objective, and all were identified for action in 2019. Progress is shown in the tables below.

In 2019, SOOS consolidated progress and continued the strategic community engagement and consultation of recent years. These connections are vital to maintain in the coming years. As the SOOS data vision has developed, the focus of activity shifted away from several KRAs and this is reflected by a lower intensity of effort on these fronts. In particular, KRA 3.4 “Community-developed data synthesis tools and products for the Southern Ocean are accessible through the SOOS website”, was identified as being beyond the capability of the IPO to make appropriately comprehensive and useful at this point in time.

Key Result Area 3.1: A multidisciplinary metadata portal is developed and populated and continuously updated with records. Efforts include archiving of orphan datasets and advocating for direct links to data in metadata records

2018 Intended Actions	Progress Made (Y/X)	Comment
Maintenance of the SOOS NASA GCMD metadata portal	Y	NASA GCMD rebuilt the portal for the second time in two years. The new SOOS portal has 16% fewer records (3676) due to filter changes and a redundancy clean-up. Between Jan 2018 - May 2019, there were 2589 unique visits to the two (old and new) portals, with 18,116 page views. Issue: It is difficult to track usage and content between years. There is a lack of interest from oceanographic institutions to engage with the GCMD, and the decrease in relevance of this product for our community increases the importance of POLDER and development of the federated metadata search.

SOOS mooring network	Y	Corrections to minor errors in some records in the mooring network and an updated version published through SOOSmap. Historic moorings from US Antarctic Programs were identified for inclusion
Chinese CTD data sharing	Y	DMSC members, Chinese researchers and data managers, and CCHDO staff continued to calibrate historic Chinese CTD observations and negotiate incorporation of these datasets in international aggregations of CTD data. This resulted in direct collaboration between Ocean University of China and CCHDO.
Southern Ocean glider network	Y	A report was drafted to identify the core needs of Southern Ocean glider users, in terms of data standards and management. Delivered in 2020. Swart et al., 2020: Report on the data management needs of Southern Ocean glider users DOI: 10.5281/zenodo.3826080

Key Result Area 3.2: Up-to-date information on key Southern Ocean data programmes, centres and repositories is provided

2019 Intended Actions	Progress Made (Y/X)	Comment
New content management system developed for website descriptions of key programs	Y	As part of the development of SOOS IPO's content and contact management system, information on key Southern Ocean data programs was collated into an Airtable database, for publication through the new SOOS website in 2020.

Key Result Area 3.3: Web-based tools will be explored and, as needed, developed to aid data discovery and delivery; the wider community is encouraged to adopt and enhance tools that already exist

2019 Intended Actions	Progress Made (Y/X)	Comment
Federated metadata search tool	Y	Due to SOOS advocacy action, several polar data centres adopted schema.org, the technology expected to underpin federated search. A workshop in Finland (Nov 2019) educated many on the

		process for making metadata machine-searchable enabled investigation of existing search tools that could underpin a polar federated search. See page 42 for information on this effort
Brokering data discovery and interoperability	Y	All CTD datasets held by PANGAEA were added to SOOSmap and the main EMODnet Physics portal resulting in a 12-fold increase in the number of CTD casts (166 998 casts compared with 12,929). The SOOS Datathon in Incheon, Korea, brought together DMSC and SSC members to deliver small projects to enhance data discovery: identifying additional sources of mooring data; tidying up data flow into SOOSmap; standardising BEPSII sea-ice chlorophyll data for SOOSmap; identifying Southern Ocean glider community data needs; and defining a project to rescue historic oceanographic data from the Argentinian Antarctic research program.
General data management advocacy and advice	Y	Advice was given to Australian Autonomous Underwater Vehicle scientists on data management practices for an academic program with commercial applications. Ad hoc advice also provided to other Australian Antarctic Gateway scientists on publishing data alongside research papers.

Key Result Area 3.4: Data synthesis tools and products are made accessible

2019 Intended Actions	Progress Made (Y/X)	Comment
Online catalogue of data products	X	This KRA requires considerable resources to develop and maintain. Following several efforts to scope a useful, sustainable product, SOOS have put this KRA aside pending resources or increased priority

Objective Four: Provide services to communicate, coordinate, advocate and facilitate SOOS objectives and activities

Objective 4 provides the foundation for the work program of the International Project Office (IPO). It outlines the activities required to support the sustained implementation of SOOS, delivery of SOOS tools and products, and facilitate activities of the SOOS network.

There are 6 KRAs that focus work towards achieving this objective, and all were scheduled for action in 2019. Progress is shown in the tables below.

The latter half of 2019 saw a step-change in the ability of the SOOS IPO to support the actions required to deliver the Implementation Plan. With enhanced security in funding, the IPO was able to grow in capacity through the employment of a Communications and Project Officer.

Key Result Area 4.1: The need for sustained Southern Ocean observations is strongly articulated

2019 Intended Actions	Progress Made (Y/X)	Comment
Endorsement of observational research projects	Y	Review and endorsement of 6 international observational research projects
High-level advocacy actions	Y	Attendance and representation at: Antarctic Treaty Consultative Meeting CCAMLR OceanObs19 COP25 Earth Observation Day

Key Result Area 4.2: Engagement with international stakeholders, across all disciplines and nations, is maintained

2019 Intended Actions	Progress Made (Y/X)	Comment
Reporting	Y	In 2019, annual reports were prepared for SCAR, SCOR, CCAMLR, ATCM-CEP, Australian Research Council's Antarctic Gateway Partnership, POGO, SCADM, and the SOOS SSC Issue: Reporting requirements are a significant overhead, particularly given the lack of standardisation in the required information.

Development of SOOS Engagement Strategy	Y	A database of key contacts, institutions, nations, programs, projects, events, and products was developed. It underpins all tables on the new SOOS website, simplifying the process of updating the website; provides contact management support for SOOS groups; and simplifies reporting on SOOS' activities and network. This database will form the basis of a strategic engagement strategy to be developed in 2021
Community Engagement and conference presentations	Y	Direct engagement included: IICWG, COMNAP, CCAMLR, SORP, IAATO, GOOS, APECS, POGO, OOPC, SCAR Programs, SCADM, ICED, IASC,, IMBeR, IMOS, IAPSO, SCOR, OceanObs19, EGU, ADC, AOGS All engagement/presentations were carried out directly by IPO staff or by a community member facilitated by IPO
Engagement with core IPO sponsors and stakeholders	Y	Regular engagement was maintained through in-person meetings and email correspondence: Engagement included: IMAS, UTAS, AAD, ACE CRC, CSIRO, AGP, IMOS, TPN, Tas. State Government, Antarctic NZ, University of Gothenburg, SOA-China, Swedish Polar Research Secretariat, National Centre for Polar and Ocean Research India

Key Result Area 4.3: A SOOS community bibliography is developed

2019 Intended Actions	Progress Made (Y/X)	Comment
Scoping of requirements and delivery of product	Y	The need for this product has changed and a bibliography will no longer be developed. The IPO will continue to track all published references to SOOS using AirTable, which was initiated in 2018.

Key Result Area 4.4: The SOOS Communication Strategy is implemented

2019 Intended Actions	Progress Made (Y/X)	Comment

Maintaining the SOOS Website	Y	Development of a new website was initiated in 2019 to enhance functionality. A standardised Joomla template was selected and the transfer and update of information from the old website to the new one was progressed. Issue: This is a high priority but has taken a considerable proportion of the IPO's capacity to implement.Was achieved only after hiring of new Communications Officer
Online database of presentations, posters, publications and other products	Y	As described under KRA 4.2, all products (including posters, maps, and slide presentations) were updated and maintained in the SOOS database, newly developed in Airtable (see 4.2 above).
Delivery of the SOOS Newsletter	Y	Two issues were produced in October and December 2019 following the hiring of the SOOS Communications Officer
SOOS Publications (not including WG-specific publications)	Y	As above in KRA 2.2
Other communication activities	Y	Preparation for SOOS tutorials as part of the SCOR Booth at Ocean Sciences 2020
Social Media	Y	Basic-level updates to SOOS Facebook and Twitter accounts was maintained and automated where possible Issue: Social media is ad-hoc and not strategic. Facebook posts are automatically delivered to Twitter irrespective of the different type of engagement that Twitter facilitates

Key Result Area 4.5: Support for SOOS International Project Office is maintained and enhanced

2019 Intended Actions	Progress Made (Y/X)	Comment

Engagement and brokering of new hosting agreement for the IPO	Y	Significant engagement with Australian organisations for brokering of a new hosting agreement for the IPO; resulting in the formation of a Partnership Agreement between UTAS-IMAS, the Tasmanian Government Department of State Growth, and CSIRO for a 3-year hosting of the IPO in Hobart, Australia
Maintenance of existing IPO and SOOS sponsorship	Y	Regular engagement with existing sponsors; Oversight of finance and budget; Development of annual sponsorship agreements and project schedules; Management of in-kind services and agreements Issue: Most in-kind services are agreed verbally without the ability to develop a Service Level Agreement on delivery of product/service
Actions on new sponsorship opportunities	Y	Engagement with potential new sponsors of SOOS; significant progress in new sponsorship by the Swedish Polar Research Secretariat for 2020-2022.

Key Result Area 4.6: SOOS Administration, facilitation of Strategic Plan activities and delivery of support services is maintained

2019 Intended Actions	Progress Made (Y/X)	Comment
Maintenance and support of SOOS Governance	Y	Engagement with governing bodies SCAR and SCOR Management of Executive Committee (meetings, membership, activities, TORs) Management of Scientific Steering Committee (meetings, membership, activities, TORs) Management of Data Management Sub-Committee (meetings, membership, activities, TORs)
Management of Implementation Plan monitoring and progress review	Y	Weekly IPO review and recording of activities against all KRAs

Administrative finance	Y	Development of 2019 budget Management of income and expenditure Sponsorship of SOOS events
Office administration and staff development/support	Y	Management and support of SOOS IPO staff

SOOS Key Products

Database of Upcoming Expeditions to the Southern Ocean

DueSouth is a community-populated database for the sharing of information on upcoming field campaigns and expeditions. It enhances opportunities for collaboration and sharing of field resources.

Key Sponsors / People:

DueSouth coding and hosting is provided to SOOS by James Cusick of the Australian Antarctic Data Centre. Antarctic Sea Ice Processes and Climate (ASPeCt) has provided funding to complete the coding. Expedition plans are systematically provided by JCOMMOPS, CCAMLR, and COMNAP. DueSouth is available at https://data.aad.gov.au/duesouth/

2019 Milestones:

The upgraded DueSouth portal was completed and launched to the public in 2019. The portal supports:

Many-to-many mappings of projects and expeditions so that multi-year projects can easily be mapped to all relevant expeditions and Antarctic research stations

A polar-projected map for better visualisation of expedition plans

Automated data transfers from JCOMMOPS, with the capacity to add other organisations in the future,

Bulk uploads from tables of planned expeditions

Allows users to edit their contribution

Greater ability for SOOS Data Officer to edit submitted expeditions and projects

2019 Achievements:

Refactoring of the code to support enhanced functionality.

Approval sought and gained from CCAMLR for publication of future notifications from their krill and new and exploratory fishery notification systems

Work with the CCAMLR secretariat for bulk upload of fisheries notifications into DueSouth

Memorandum of understanding signed with IAATO to allow the development of a workflow for ingesting planned IAATO vessel movements into DueSouth, with appropriate redactions of data to protect commercially sensitive data. (NB - publication of this data will be dependent on approval from the IAATO membership.)

Engage the SOOS community to populate DueSouth with expedition plans for 2019/20 and beyond

Implement site analytics to enable user statistics to be collected

2020 Plans:

Work with AADC to finalise the documentation of the code and final improvements

Negotiate a hosting agreement with a new host/code maintainer for DueSouth and implement the transfer

Work with the IAATO secretariat to develop a workflow for publishing planned IAATO vessel movements in DueSouth

Present the IAATO propose workflow to IAATO membership for approval and implement it if approved

Work with the COMNAP secretariat to improve the compatibility of information shared through the COMNAP Regional Information Exchange with DueSouth's data requirements

Encourage the SOOS Regional Working Groups to populate the expedition and project records for 2020/21 and beyond.

SOOSmap

SOOSmap is an interactive web map that allows users to explore circumpolar datasets before downloading the data they need. SOOSmap was developed for SOOS by the European Marine Observations and Data Network (EMODnet) Physics group.

Key Sponsors/People

All development and hosting are provided by Antonio Novellino and Marco Alba at EMODnet Physics as part of their mandate to support regional ocean observing systems and under the banner of EMODnet For Global. The relationship between SOOS and EMODnet was negotiated by Patrick Gorringe from the EuroGOOS secretariat.

2019 Milestones

During 2019, the focus for SOOSmap was on consolidating the functionality developed in 2018. Major improvements to the functionality include:

Restructuring portal architecture to speed up drawing times to cope with the growth in the number of observations included in EMODnet Physics' servers.

Completing the development of pop-up boxes with cleanly structured metadata for SOOS-specific layers

Allowing users to select the transect for any individual mobile platform (e.g. Argo floats, drifting buoys, or MEOP seals) in addition to the default display of most recent recorded location for each data point

Transfer of SOOSmap to a standalone domain soosmap.aq, which allows users to share specific views of the map - i.e. zoom, time filter, and layers - for reporting purposes.

For the seven months in 2019 for which analytics data are available, SOOSmap received 57,311 page views, with 19,782 requests to the servers for further information. A total of 17,268 near-real-time monthly files were downloaded, along with 79 long-term repository files. Visitors were primarily from Spain (45,844), France (9715), United States (394), Netherlands (199), India (160), and China (134).

In terms of adding new data to SOOSmap, in 2019 there were two significant additions:

The actual data for CTD casts hosted by PANGAEA, were included in SOOSmap for the first time increasing the CTD data holdings of SOOSmap by 12 times as many as were in SOOSmap before this collaboration. This required technical collaboration between EMODnet Physics and PANGAEA, as well as policy agreement involving SOOS, PANGAEA, and EMODnet. This is the first time that PANGAEA-curated data are being republished outside PANGAEA itself, and is thus a significant achievement.

The addition of data from the first Antarctic circumnavigation by Saildrone is a significant milestone for SOOSmap because it is the first time that SOOSmap has published data collected by a private company

Following the SOOS Datathon in Incheon, South Korea, in May 2019, an updated version of the SOOS Mooring Network was added to SOOSmap.

2020 Plans:

In 2020, we plan to:

Re-engineer the backend architecture for hosting data through EMODnet Physics to speed up loading times when drawing new datasets, which remains slow, despite improvements in 2019

Provide input into EMODnet Physics' new user interface to make it more intuitive for Southern Ocean researchers

Publish datasets from GLODAP and SOCAT

Work with Australian curators of CTD data to design a workflow that makes it simple for Australian CTD data to be served through SOOSmap
Take direct feeds from the British Oceanographic Data Centre into EMODnet servers, since SeaDataNet (the current intermediate step) contains a limited portion of BODC's total holdings.

SOOS Sponsorship

SOOS IPO Sponsorship in 2019

SOOS remains an initiative of SCAR and SCOR, and in 2019 this support, governance and sponsorship continued, highlighted by the support provided for the Annual SOOS Scientific Steering Committee Meeting (see page 30).
Further, in 2019, SOOS maintained its broad sponsorship base. Core sponsors remained the Australian Research Council's Antarctic Gateway Partnership (AGP), the University of Tasmania, Australia, the State Oceanic Administration of China, the University of Gothenburg, Sweden, and Antarctica New Zealand.
In-kind Service Providers are important and enable SOOS to achieve outputs and outcomes that would not be possible if they had to be funded directly by SOOS. The figure below shows the Service Providers for SOOS in 2019.
SOOS is grateful to all sponsors for the contribution they make to ensuring the efficient and sustained delivery of SOOS for the community.
Sustained support for the IPO
Sustaining funding and support of the IPO remains a significant activity of the IPO. Building on the significant effort in 2018 to secure sustained hosting for the SOOS office, SOOS delivered enhanced engagement with the partners of the newly developed SOOS funding partnership that is to run from 2020-2022: the University of Tasmania, Commonwealth Scientific and Industrial Research Organisation and the Tasmanian State Government Department of State Growth. Additionally, SOOS engaged with the Swedish Polar Research Secretariat to draft a new collaboration to enhance Swedish community efforts in the Southern Ocean, to be started in 2020. Further discussions took place with a number of other national communities on potential sponsorship opportunities.

Sponsorship of SOOS Activities
Sponsors of SOOS events provide a vital service in enabling the delivery of SOOS activities. In 2019, the following institutes sponsored SOOS events, and we thank them for their important support.

Event	Sponsoring Institute/Organisation
Workshop on the development of the SOOS RWG Weddell Sea-Dronning Maud Land (Tromso, Norway, Jan 2019)	Norwegian Polar Institute, Alfred Wegener Institute, SOOS Report: http://soos.aq/activities/rwg/wsdml
1st Workshop of the Amundsen Bellingshausen Seas RWG (Incheon, Republic of Korea, May 2019)	SCAR, SCOR, SOOS, Korean Polar Research Institute (KOPRI), AGP Report: http://soos.aq/activities/rwg/abs
SOOS Scientific Steering Committee Meeting (Incheon, Republic of Korea, May 2019)	SCAR, SCOR, SOOS, Korean Polar Research Institute (KOPRI), AGP Minutes: http://soos.aq/about-us/ssc/meeting-minutes
SOOS Data Management Sub-Committee Meeting (Incheon, Republic of Korea, May 2019)	SCAR, SCOR, SOOS, Korean Polar Research Institute (KOPRI), AGP Minutes: http://soos.aq/data/dmsc/dmsc-minutes
Southern Ocean Data Hackathon (Incheon, Republic of Korea, May 2019)	SCAR, SCOR, SOOS, Korean Polar Research Institute (KOPRI), AGP
SOOS Executive Committee Meeting (Incheon, Republic of Korea, May 2019)	SCAR, SCOR, SOOS, Korean Polar Research Institute (KOPRI)
Polar Data Forum (Davos, Switzerland; June 2018)	SCAR Data Management Committee, Arctic Data Committee, Finnish Met. Institute, World Data Service, Royal Netherlands Institute for Sea Research

Governance

Executive Committee

In 2019, the SOOS Executive Committee (EXCOM) held one in-person meeting, and several virtual meetings. Andrew Constable (AUS) and Sebastiaan Swart (Sweden) continued as Co-Chairs, and Mike Williams (NZ) and Eileen Hofmann (USA) continued as Vice Chairs.

Scientific Steering Committee

One SSC member rotated off the SSC in 201: Sang Hoon Lee (S. Korea). We thank Hoon for his contribution to SOOS! No new members were brought on to the committee in 2019, however an open call for nominations was held in late-2019 – early 2020 for new members starting in mid-2020. The composition of the SSC in 2019, including the RWG Co-Chair ex-officios, is shown below:

Name	Country	Region	Gender	Expertise	2015	2016*	2017-Mid 2018	Mid 2018-2019	Mid 2019-2020	Mid 2020-2021
Sebastiaan Swart	Sweden	EU	M	Physical	2^	2^	2^	3^	3^	
Andrew Constable	Australia	Aus/Pac	M	Biology	1^	1^	2^	2^	2^	
Matthew Mazloff	USA	N. Am	M	Physical	1	1	1	2	2	2
JB Sallee	France	EU	M	Physical	1	1	1	2	2	2
Mike Williams	NZ	Aus/Pac	M	Physical	1	1	1^	2^	2^	2^
Dake Chen	China	Asia	M	Physical			1	1	1	
Burcu Ozsoy	Turkey	EU/Asia	F	Sea ice			1	1	1	
Anya Waite	Canada	N. Am	F	Biology			1	1	1	
Eileen Hofmann	USA	N. Am	F	Biology				1^	1^	1^
Irene Schloss	Argentina	S. Am	F	Biology				1	1	1
Andrew Meijers	UK	EU	M	Physical				1	1	1
Sarah Fawcett	S. Africa	Africa	F	Biogeoch				1	1	1
DMSC Co-Chairs										
Sian Henley	UK	EU	F	WAPSA						
Kate Hendry	UK	EU	F	WAPSA						
Oscar Schofield^^	USA	N. Am	M	WAPSA						
Philippe Koubbi	France	EU	M	SOIS						
Tsuneo Odate	Japan	Asia	M	SOIS						
Walker Smith	USA	N. Am	M	Ross						
Sebastian Moreau	Norway	EU	M	WSDML						
Laura de Steur	Norway	EU	F	WSDML						
Julian Gutt	Germany	EU	M	WSDML						
Markus Janout	Germany	EU	M	WSDML						
Bastien Queste	UK	EU	M	ABS						
Patricia Yager	USA	N. Am	F	ABS						

Annual Scientific Steering Committee Meeting

The annual meeting for the SSC and Executive Committee took place in Incheon, South Korea (May 2019), hosted by the Korean Polar Research Institute. These meetings took place alongside the SOOS Data Management Sub-Committee meeting, Amundsen Sea Regional Working Group Meeting, and the KOPRI Symposium.

In addition to reviewing progress, a focus of the 2019 SSC meeting was strategic planning for the future. This was in recognition of the fact that we are nearing the end of the current Implementation Plan (2016-2020) and will need to start preparation for development of the next 5-year plan. This meeting also focused on the need to update the SOOS Science Plan, and discussions were held on how this can best be delivered.

The minutes from the SSC meeting are available on the SOOS website (soos.aq/about-us/scientific-steering-committee). SOOS thanks the sponsors and our host KOPRI for the significant organisation and financial support provided in hosting these meetings. SOOS also thanks SCOR and SCAR for their continued support of these annual meetings.

SOOS Executive Committee at KOPRI

SOOS Implementation Groups

Data Management Sub-Committee

The SOOS Data Management Sub-Committee (DMSC) has been engaged on a wide range of data activities, in addition to the development of DueSouth and SOOSmap (documented in other sections of this report).

Southern Ocean data rescue efforts

In 2019, the additional datasets discovered and documented in the SOOS Mooring Network were published through SOOSmap in 2019.

The DMSC continued to facilitate a collaboration between the Chinese National Arctic and Antarctic Data Centre, CLIVAR and Carbon Hydrographic Data Office, and the Ocean University China, to calibrate historic Chinese CTD data against other co-located observations. This collaboration also looked to publish these datasets alongside other international CTD observations, to improve access and use. Initial calibration trials were successful and negotiations on re-publication of the data through CCHDO or other CTD data aggregators is now underway.

Data Management Advocacy

In 2019, the DMSC drafted proposed new Terms of Reference for the DMSC and began discussions on a new consistent data policy for three key polar data committees - the SOOS DMSC, the Standing Committee on Antarctic Data Management, and the Arctic Data Committee. Core principles were suggested and discussed at the Polar Data Forum III in Helsinki, Finland in November 2019. A community discussion process is expected to agree on a core policy during 2020.

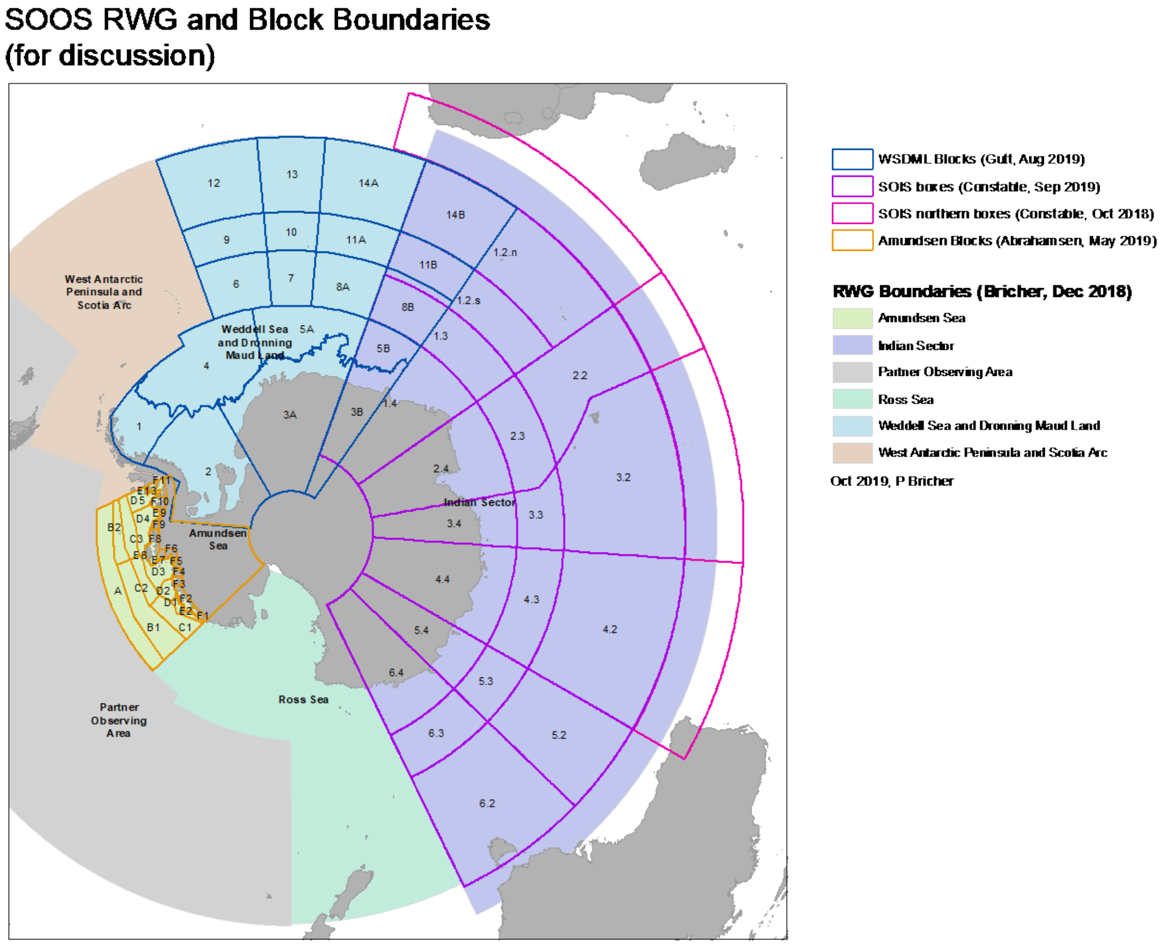
SOOS Datathon

Alongside the SSC and DMSC meetings in Incheon, Korea, the two committees worked together for a day of data management activities that resulted in several new projects that will improve SOOSmap and the broader SOOS data ecosystem. Among the main projects, a collaboration was organised to standardise chlorophyll data from sea ice cores for publication in SOOSmap; a team identified key sources of duplication and potential new sources of oceanographic data for SOOSmap; the SOOS mooring network was checked for errors and new sources of data identified; the data needs of Southern Ocean glider scientists were identified; coding improvements were made to DueSouth; a team explored the potential and the challenges in trying to aggregate biogeochemical data beyond GEOTRACES and various carbon databases; and a project was defined to rescue and reuse historic Argentinian oceanographic data from the Antarctic Peninsula. The glider project has resulted in a report, and the chlorophyll data is expected to be published in SOOSmap in 2020, where the mooring network layer has been updated. The other projects have identified pathways to future improvements in Southern Ocean data management and created relationships among SOOS scientists and data managers that may underpin ongoing collaborations.

Federated Metadata Search

The Polar Data Discovery Enhancement Research (POLDER) continued its work in 2019. Details of this working group are highlighted in the Task Teams section below.

Regional Working Groups
SOOS Regional Working Groups will develop, coordinate and implement the observing system in their defined region. The regions align with the natural areas of focus of nations involved in Southern Ocean activities (although some activities will be coordinated at a circumpolar scale e.g., Argo). Given the long-term requirements for coordination and implementation, the SOOS Regional Working Groups are viewed as ongoing efforts, whilst still undergoing annual reviews by SOOS governance. In 2018, SOOS SSC recommended that all RWGs develop sub-regions for quantification of observational requirements, coverage and gaps. In 2019, two RWGs defined their sub-regions (ABS and WSDML) and other groups initiated discussions on this. The sub-regions identified are shown in the map below, with justifications provided in individual RWG workshop reports.



West Antarctic Peninsula and Scotia Arc (WAPSA) WG
Leadership:
K. Hendry (Co-Chair, UK); O. Schofield (Co-Chair, USA); S. Henley (Co-Chair, UK); I. Schloss (Argentina); M. Mata (Brazil); J. Arata (Chile); D. Abele (Germany); In-Young Ahn (Korea); A. Meijers (UK); E. Hofmann (USA); B. Ozsoy (Turkey); J. Hofer (APECS, Chile); P. Trathan (CCAMLR, UK)
2019 Milestones:
WG Community Publication:
Henley et al., 2019: Variability and change in the West Antarctic Peninsula marine system: Research priorities and opportunities. Progress in Oceanography.
https://doi.org/10.1016/j.pocean.2019.03.003
Submission of key West Antarctic Peninsula and Scotia Arc datasets in SOOSmap and cruises into DueSouth with support from the DMSC
Student projects co-developed with the DMSC to improve discoverability, accessibility and usability of Southern Ocean datasets. For example, Masters project on Southern Ocean Argo data co-

supervised by Kate Hendry (University of Bristol, WAPSA co-chair) and Matt Donnelly (BODC, DMSC). Published in Challenger Society: https://challengercaptainsblog.wordpress.com/2019/12/02/the-antarctic-circumpolar-current-what-can-argo-floats-tell-us/
Engagement with the Scotia Arc scientific community
Establishment of WG newsletter using Airtable and Mailchimp with support from the IPO
Ross Sea WG
Leadership:
M. Williams (Co-Chair, NZ); W. Smith (Co-Chair; USA)

2019 Milestones:
2019 saw little activity by the Ross due to time limitations of the Co-Chairs. Following discussions with the group, Mike Williams stepped down from Ross co-chair positions and an open call for new Leadership Group members was made, closing in 2020.
SOOS continued engagement with CCAMLR with respect to the Ross Sea Marine Protected Area and planned monitoring activities to support the MPA.
Indian Sector WG
Leadership:
T. Odate (Co-Chair, Japan); A. Constable (Co-Chair; Aus); P. Koubbi (France)
2019 Milestones:
Presentations were made to the Leadership groups of ABS and WSDML in support of discussions on sub-region development and heat maps of observational coverage. Other than this, 2019 saw little additional activity by the SOIS due to time limitations of the Co-Chairs. Following discussions with the group, Andrew Constable and Philippe Koubbi both stepped down from SOIS co-chair positions and an open call for new Leadership Group members was made, closing in 2020.
Weddell Sea and Dronning Maud Land (WSDML) WG
Leadership:
J. Gutt (Co-Chair, Germany); L. de Steur (Co-Chair; Norway); S. Moreau (Co-Chair, Norway); M. Janout (Co-Chair, Germany); JB Sallee (France); A. Meijers (UK); L. Biddle (Sweden); S. Fawcett (S. Africa); M. Wege (APECS, S. Africa); U. Nixdorf (COMNAP, Germany); OA Bergstad (Norway)
2019 Milestones:
The first workshop for the working group was held in Tromsø, Norway, in January 2019. The workshop was jointly sponsored by the Norwegian Polar Institute and Alfred Wegener Institute.
The objectives of the workshop were;
Identify the community of researchers in the Weddell Sea - Dronning Maud Land
Gain consensus on the key drivers of biological and physical systems in the region
Develop a picture of the status of multidisciplinary observations in the region
Discuss key observational gaps, regional priorities, and challenges
The workshop was attended by 22 people (18 in person and 4 online) representing 16 countries.
Report available here (de Steur, L., et al., 2019: DOI: 10.5281/zenodo.3941419).
Organisation and planning for a second workshop were also undertaken in 2019, to be held 28-30th April 2020 in Delmenhorst, Germany. This workshop was being sponsored by Hanse Wissenschaftskolleg, Alfred Wegener Institute, and Helmholtz Centre for Polar and Marine Research, as well as ECR support by SCOR. The workshop had 50 registrations but was unfortunately cancelled in early 2020 due to COVID-19.

Amundsen-Bellingshausen Sector (ABS) WG
Leadership:
B. Queste (Chair, UK); A. Wåhlin (Sweden); T-W Kim (Korea); T. Yager (USA); P. Abrahamson (UK); Y. Nakayama (APECS, Japan)
2019 Milestones:

The first workshop for the Amundsen and Bellinghausen Sector Regional Working Group was hosted by KOPRI, 8-10th May 2019.
The objectives of the workshop were;
Identify community of active researchers and operators in the ABS Sector
Gain consensus on the key drivers of the region
Develop a picture of the status of multidisciplinary observations in the ABS
Discuss key observational gaps, regional priorities, and challenges
Collate a list of upcoming work in the region to promote collaborative opportunities
The workshop was attended by 26 people representing 6 countries and 19 institutions.
A full report from the workshop is available here (Lowry, K., et al 2019: DOI: 105281/zenodo.3941417).
Capability Working Groups
SOOS Capability Working Groups enhance observational capabilities for SOOS, such as:
Developing and implementing technologies
Improving observational design, efficiency and coverage
Developing associated methods for managing and disseminating information.
The enhanced knowledge, technology and observing capabilities from these groups are intended to feed directly into the implementation plans of the Regional Working Groups. Capability Working Groups are, generally speaking, limited to multi-year efforts, with annual review of progress provided by SOOS governance.
Censusing Animal Populations from Space (CAPS) WG
Leadership:
M. Hindell (Co-Chair, Aus); P. Fretwell (Co-Chair, UK); P. Trathan (UK); H. Lynch (USA); D. Costa (USA); K. Kovacs (Norway); A. Lowther (Norway); A. Constable (Aus); C. Southwell (Aus); B. de la Mare (Aus); M. LaRue (NZ); C. McMahon (Aus); H. Bornemann (Germany)
2019 Milestones:
CAPS has a 4-year work plan, starting in 2015, and is completing its final year.
Spectral measurements of four seals species to assist with remote species discrimination were taken at Rothera in 2020.
“Counting seals in Antarctica” through Tomrod crowdsourcing platform is now complete, and the WG is working on a final census and habitat suitability for Weddell seals.
Distribution of Weddell seals along the Antarctic coastline via VHR and citizen science has been completed and is published in Remote Sensing for Ecology and Conservation (LaRue, M.A., et al., 2019).
Tasked the first set of images for the circumpolar census of pack-ice seals and established a stratified sampling regime based on past sea-ice extents and concentrations (images provided by NASA CAPS members, funded by NSF).
Acoustic Trends in Antarctic Blue and Fin whales in the Southern Ocean (ATWG) WG
Leadership:
F. Samaran (Co-Chair, France); K. Stafford (Co-Chair, USA); S. Buchan (Chile); F. Castro (Chile); K. Findlay (S. Africa); D. Harris (UK); B. Miller (Aus); I. van Opzeeland (Germany); A. Sirovic (USA)
2019 Milestones:
Deployment of 4 autonomous recording devices and retrieval of 2 previously deployed autonomous recording devices in the Southern Ocean during the 2019/2020 summer
Deployment of a number of autonomous recorders in low and mid-latitude Indian Ocean, which will value-add and supplement the Southern Ocean Hydrophone Network
Publication of a conference proceedings report on passive acoustic results from blue whale-krill voyage (ENRICH) during 2018. [Miller BS, et al 2019 A passive acoustic survey for marine mammals conducted during the 2019 Antarctic voyage on Euphausiids and Nutrient Recycling in Cetacean Hotspots (ENRICH). In: Proceedings of Acoustics 2019. Australian Acoustical Society, Cape Schanck, Victoria, Australia, p 1–10]

Annotated library has been completed (early 2020) and manuscript detailing its contents and applications have been submitted to Scientific Reports.
[https://data.aad.gov.au/metadata/records/AcousticTrends_BlueFinLibrary]
Drafted, Balcazar N, et. al. (Submitted). An open access dataset for developing automated detectors of Antarctic baleen whale sounds and performance evaluation of two commonly used detectors. Scientific Reports
WG meeting held in December 2019, alongside the World Marine Mammal Conference, Barcelona, Spain.
Hired a post-doctoral researcher, Dr Franciele Castro (University of Concepcion, Chile) under Dr Susannah Buchan, to undertake the analysis of the working group call library

Southern Ocean Fluxes (SOFLUX) WG
Leadership:
S. Gille (Co-Chair, USA); S. Swart (Co-Chair, Sweden); B. Delille (Belgium); M. Bourassa (USA); C-A. Clayson (USA); S. Josey (UK); A. Lenton (Aus); I. Smith (NZ) E. Schulz (Aus); B. Ward (UK); M. du Plessis (APECS, S. Africa)
2019 Milestones:
2019 was the 4th year of a 5-year work plan for SOFLUX (ending 2020).
Growth in membership of the WG for 65 (2018) to 89
The WG coordinated and published a review paper on Southern Ocean fluxes as a white paper to the OceanObs 2019 special issue
Swart, S., et al 2019 Constraining Southern Ocean air-sea-ice fluxes through enhanced observations. Frontiers Mar. Sci., 6:421, doi: 10.3389/fmars.2019.00421.
WG members also contributed Southern Ocean flux information and recommendations in other OceanObs papers;
Cronin M., et al., 2019. doi: 10.3389/fmars.2019.00430.
Smith G., et al., 2019 doi: 10.3389/fmars.2019.00429. 2019.
Smith, S., et al., 2019. doi: 10.3389/fmars.2019.00434.
WG members contributed Southern Ocean air-sea heat fluxes products to the BAMS State of the Climate 2019.
Queste, B.Y., et al., 2020. Southern Ocean [in “State of the Climate in 2019”]. Bull. Amer. Meteor. Soc., accepted, 2020
Town Hall at the Ocean Sciences Meeting with sponsorship from Saildrone, with 64 attendees, representing 10 countries and 36 institutions.
Regular communication to all members through newsletters (every 1-3 months) to update on key events, papers, field activities etc)
In collaboration with the Observing System Design Capability Working Group, SOFLUX submitted a manuscript on the designing a mooring array for constraining air-sea heat exchanges (see Flux Mooring Project below)

Observing and Understanding the Ocean beneath Antarctic sea ice and ice shelves (OASIIS) WG
Leadership:
E. van Wijk (Co-Chair, Aus); R. Coleman (Co-Chair, Aus); A. Breierly (UK); L. Herraiz-Borreguero (Aus); P. Dutrieux (USA)
2019 Milestones:
A number of meetings of the leadership group were held throughout 2019 to discuss the best way forward for the WG. It was acknowledged that a number of recent community publications and reports on under ice observation requirements had filled the niche that was to be covered by the OASIIS update to the Observing Under Ice Strategy document. In light of this, the WG has re-aligned

their efforts to focus on the review of under ice observing technology and platforms, for delivery in 2020.
A planning and scoping document of the review of under ice observing technology and platforms was achieved and is planned to be delivered in 2020.
Observing System Design (OSD) WG
Leadership:
M. Mazloff (USA)
2019 Milestones:
This working group was proposed in mid-2018, builds on the priorities identified in the Observing System Design Task Team (2017).
Contributed to the AniBOS proposal to form a GOOS network of Animal Borne Ocean Sensors, by showing the value of animal-borne observations to GOOS.
In collaboration with SOFLUX submitted a manuscript on the designing a mooring array for constraining air-sea heat exchanges (see Flux Mooring Project below).
Worked with the IPO to build membership and define a clear way forward for 2020

Task Teams
SOOS Task Teams are developed to produce specific products, organise events, or solve a particular problem. Each Task Team is made up of a small group of experts and aims to complete its work within weeks or months. SOOS Capability Working Groups can be formed to address issues requiring a long-term effort (e.g., months to years).

Ecosystem Essential Ocean Variables (eEOVs) Task Team
Leadership:
A. Constable (Co-Chair, Aus); I. Schloss (Co-Chair, Argentina); O. Schofield (US); M. Muelbert (Brazil); J. Melbourne-Thomas (Aus)
2019 Milestones:
The Task Team was approved in mid-2019, and has worked to document, evaluate and scope routine reporting products for ecosystem Essential Ocean Variables (eEOVs) to support assessments of the status and trends of Southern Ocean ecosystems, and to prepare a publication on these efforts. The publication is being delivered as a component of the Marine Ecosystem Assessment for the Southern Ocean (MEASO) being undertaken by the program Integrating Climate and Ecosystem Dynamics, a joint program of IMBeR and SCAR.
All above publications are being prepared for submission in a MEASO special issue in Frontiers of Ecology and Evolution, due October 2020.

Autonomous Underwater Vehicles (AUVs) Task Team
Leadership:
G. Williams (Co-Chair, Aus); P. King (Co-Chair, Aus)
2019 Milestones:
The Task Team on Autonomous Underwater Vehicles (AUVs) was approved in mid-2019 and aims to match polar AUV science objectives and engineering abilities with deployment capabilities and sensor development across National Antarctic Programs. A workshop was held in 2019, to develop collaborative efforts with the Swedish AUV program and other nations involved in deployment of large AUVs in Antarctica. Engagement through SOOS at the Amundsen Bellingshausen Sea RWG workshop at KOPRI, resulted in a new partnership and field campaign with the Australian AUV being successfully deployed in the Amundsen on the Korean research vessel in the 2019/2020 season. Alignment with the Society for Underwater Technology's Polar AUV group and the international Expert Panel on Polar AUV (IEP-PAUV) has resulted more recently in a shift of focus for the SOOS Task Team, with a re-proposal of focus to be made in 2020.

Flux Mooring Project
Leadership:
Y. Wei (China); Sarah Gille (USA); M. Mazloff (USA); Veronica Tamsitt (AUS); Sebastiaan Swart (Sweden); D. Chen (China); Louise Newman (AUS)
2019 Milestones:
The task team was a joint initiative of SOFLUX and OSD working groups and supported by a Chinese-funded Post-Doc (Yanzhou Wei) and aimed to identify the optimal placement of moorings in the Southern Ocean to constrain large scale air-sea fluxes. This study was initiated in 2019 and resulted in a publication in 2020.
Wei et al., Optimizing mooring placement to constrain Southern Ocean air-sea fluxes, J. Atm. and Ocean. Tech. DOI: 10.1175/JTECH-D-19-0203.1. Accepted.

POLDER
Leadership:
P. Bricher (SOOS); A. Smirnov (Iceland); T. De Bruin (Netherlands)
2019 Milestones:
Polar Data Discovery Enhancement Research (POLDER) is a collaboration between the Arctic Data Committee (ADC), Standing Committee on Antarctic Data Management (SCADM) and SOOS, to develop tools and resources to support metadata aggregation, and federated search tools to improve the discoverability of polar science data.

POLDER made considerable progress and also evolved its focus during 2019. POLDER has
Helped organise and convene the Polar Data Forum III (PDFIII) in Helsinki, Finland, in November 2019.
Led a community discussion for the three polar data committees (SOOS DMSC, SCADM, and ADC) about ways to prepare for and to speed up the adoption of the tools that underpin federated search.
Coordinated a two-day workshop on implementing schema.org and identified ways for polar data centres to participate in global discussions on best-practice implementation of schema.org.
Delivered a new webpage hosted by SOOS website.
POLDER members contributed to the OceanObs Community White Paper on FAIR data principles in oceanographic data management.
2020 Plans
To finalise and publish the research paper associated with the survey of metadata repositories
To publish the results of the survey of metadata repositories as a dataset for the broader community
To continue to advocate for the adoption of the Science On Schema.org best practices by the polar data community

Acronyms

AAD - Australian Antarctic Division
AADC - Australian Antarctic Division Data Centre
ABS - Amundsen and Bellingshausen Sector
ACE CRC - Antarctic Climate and Ecosystem Cooperative Research CentreADC - Arctic Data Committee
AGP - Antarctic Gateway Partnership
AniBOS - Animal Borne Ocean Sensors
Antarctic NZ - Antarctica New Zealand
AOGS - Asia and Oceania Geosciences Society
APECS - Association of Polar Early Career Scientists
ASPeCt - Antarctic Sea Ice Processes and Climate
ATCM-CEP - Antarctic Treaty Consultative Meeting - Committee for Environmental Protection
ATWG - Acoustic Trends in Antarctic Blue and Fin Whales in the Southern Ocean Working Group
AUVs) - Autonomous Underwater Vehicle(s)
BODC - British Oceanographic Data Centre
CAPS - Censusing Animal Populations from Space
CCAMLR - Commission for the Conservation of Antarctic Marine Living Resources
CCHDO - CLIVAR and Carbon Hydrographic Office
CLIVAR - Climate Variability and Predictability
CliC - Climate and Cryosphere
COMNAP - Council of Managers of National Antarctic Programs
COP25 - UN Climate Change Conference COP25 (Conference of Parties)
CTD - Conductivity, Temperature, Depth
CWG(s) - Capability Working Group(s)
DMSC - Data Management Subcommittee
EGU - European Geosciences Union
EMODnet - European Marine Observation and Data Network
ENRICH - Euphausids and Nutrient Recycling In Cetacean Hotspots
EOVs - Essential Ocean Variables
eEOV - ecosystem Essential Ocean Variables
EuroGOOS - European Global Ocean Observing System
FAIR - Findable, Accessible, Interoperable, Reusable
FOO - Framework for Ocean Observing
GCMD - Global Change Master Directory
GOOS - Global Ocean Observing System
GO-SHIP - The Global Ocean Ship-Based Hydrographic Investigations Program
IAATO - International Association of Antarctic Tour Operators
JCOMMOPS - Joint Technical Commission for Oceanography and Marine Meteorology in situ Observations Programme Support Centre
KOPRI - Korean Polar Research Institute
KRAs - Key Result Areas
IAPSO - International Association for the Physical Sciences of the Ocean
IASC - International Arctic Science Committee
ICED - Integrated Climate and Ecosystem Dynamics
IMBeR - Integrated Marine Biosphere Research
IMAS - Institute for Marine and Antarctic Studies
IMOS - Integrated Marine Observing System
IPO - International Project Office
IWC-SORP - International Whaling Commission Southern Ocean Research Partnership
MEASO - Marine Ecosystem Assessment of the Southern Ocean

MEOP - Marine Mammals Exploring the Oceans Pole to Pole
MPA - Marine Protected Area
NASA - National Aeronautics and Space Administration
NSF - National Science Foundation
OASIIS - Observing and Understanding the Ocean below Antarctic Sea Ice and Ice ShelvesOOPC - Ocean Observations Physics and Climate Panel
OSD - Observing System Design
PDFIII - Polar Data Forum III
POGO - Partnership for Observations of the Global Ocean
POLDER - Polar Data Discovery Enhancement Research
RWG(s) - Regional Working Group(s)
SCADM - Standing Committee on Antarctic Data Management
SCAR - Scientific Committee on Antarctic Research
SCOR - Scientific Committee on Oceanic Research
SOA / SOA-China - State Oceanic Administration, China
SOFLUX - Southern Ocean Fluxes
SOIS - Southern Ocean Indian Secor
SOOS - Southern Ocean Observing System
SORP - Southern Ocean Regional Panel Expert Group
SSC - Scientific Steering Committee
TORs - Terms of Reference
TPN - Tasmanian Polar Network
TT - Task Team
UN - United Nations
UNFCCC - United Nations Framework Convention on Climate Change
UTAS - University of Tasmania
WAPSA - West Antarctic Peninsula and Scotia Arc
WCRP - World Climate Research Programme
WG - Working Group
WSDML - Weddell Sea and Dronning Maud Land

JCS – Joint Committee on Seawater

Report to SCOR on JCS Activities May 2019-May 2020

JCS Executive	
Rich Pawlowicz (Chair)	Canada
Rainer Feistel (Vice-chair)	Germany
Steffen Seitz (Vice-chair)	Germany
Salinity/Density Taskgroup	
(Rich Pawlowicz) (Chair)	
Frank J. Millero	USA
(Steffen Seitz)	
Hiroshi Uchida	Japan
Stefan Weinreben	Germany
Youngchao Pang	China
Ryan Woosley	USA
Yohei Kayukawa	Japan
pH Taskgroup	
Andrew Dickson (Chair)	USA
Maria Filomena Camoes	Portugal
Daniela Stoica	France
Simon Clegg	UK
Frank Bastkowski	Germany
Relative Humidity Taskgroup	
Olaf Hellmuth (Chair)	Germany
Jeremy Lovell-Smith	New Zealand
(Rainer Feistel)	
Stephanie Bell	UK
Expert subgroup: Thermodynamics	
(Rainer Feistel)	
Expert subgroup: Numerical Modelling and Applications	
Trevor J. McDougall	Australia
Expert subgroup: Software	
Paul Barker	Australia
Industry Representatives	
Richard Williams (OSIL)	UK
Barbara Laky (Anton Paar)	Austria

Meetings

IAPWS did not met as a full group in 2019-2020. However, discussions did take place at other meetings. 3 JCS members attended the 27th IUGG General Assembly (Montreal, Canada, 9-15 July);

RP also reported on JCS activity to the IAPSO Business meeting. 6 JCS members attended the 2019 IAPWS Annual Meeting in Banff, Canada (Sept 29-Oct 4, 2019) and, in addition to the regular IAPWS business, held a half-day JCS session to discuss progress on JCS Tasks. Members of the pH subgroup also held a workshop (under the auspices of SCOR WG 145) at the Ocean Sciences Meeting (San Diego, USA, Feb 16-22, 2020).
Plans to meet at the 2020 IAPWS Annual Meeting (Turin Italy, September 2020) were abandoned as the meeting was cancelled due to COVID-19.

Web site

JCS maintains a web site at www.teos-10.org. This site gets 750-1300 visitors per month (9,007 in the past year, with 73311 "unique views[3]" since Oct 2010). Annual downloads are stable.

Web site Item	**Unique downloads June 2011-June 2013**	**Unique downloads June 2013-June 2014**	**Unique downloads June 2014-June 2015**	**Unique downloads June 2015-June 2016**	**Unique downloads June 2016-June 2017**	**Unique downloads June 2017-June 2018**	**Unique downloads June 2018-Apr 2019**	**Unique downloads May 2019-May 2020**
Manual	920	360	535	552	418	427	349	472
Getting Started	879	362	558	547	427	475	349	444
Slides	704	284	374	318	219	248	204	272
Primer	584	197	289	297	222	217	187	253
Thermodynamics Lecture Notes								22
Thermodynamics Overview								24
GSW MATLAB_v3_0	1920	1102	1485	1814	1235	1552	1233	1556
GSW FORTRAN_v3_	366	222	171	162	127	116	82	98
GSW_C_v3_0	202	84	133	151	85	96	59	81
GSW_PHP	-	55	61	43	29	60	28	52
SIA_VB	72	100	46	45	45	48	43	47
SIA_FORTRAN	59	118	58	44	36	42	37	42

Other Progress

Both pH and salinity/density taskgroups submitted a proposal to the IAPSO `Best Practices' Call. The Ph proposal was accepted. An initial meeting, of a subset of members, was held during the Ocean Sciences meeting.
Progress in the pH taskgroup is being carried out under the auspices of SCOR WG 145.
SC has completed a first draft for speciation model that will allow for the estimation of uncertainties in chemical speciation in seawater, and in the pH buffers used in the determination of marine pH (demonstrated at the Ocean Sciences meeting, see http://www.aim.env.uea.ac.uk/osm/main_page.html).

3 The method of computing "unique views" changed in 2019.

SC and SCOR WG 145 collaborators at GEOMAR (Kiel, Germany) have completed experiments that contribute to a thermodynamic characterisation of Tris pH buffers in media containing the components of seawater. A manuscript is in preparation.
AD and SC are finalising an agreement with the National Institute of Standards and Technology (NIST) to carry out Harned Cell experiments that contribute to a thermodynamic characterisation of Tris pH buffers in media containing the components of seawater. Complementary experiments will be carried out by FB at Physikalisch-Technische Bundesanstalt. The NIST scientists who will be carrying out experiments, and FB, are associate members of SCOR WG 145. The work contributes to the chemical speciation model of pH buffers and seawater being developed by the working group.
FJM/RP continue analysis of East Pacific Rise density anomaly data.
RP is working on understanding the diffusion of seawater and possible fractionations that result from this (MSc thesis completed fall 2019, paper in progress)
SS is working towards making high-pressure measurements of conductivity traceable to the SI.
RF, OH and JLS continue working on introducing relative fugacity as a novel humidity measure of moist air, by Part 3 extending the former Metrologia papers in 2017 and 2019.
RW is continuing with development of the 'best practices in density measurements' document.

Papers published

- W. Ebeling, R. Feistel and M. F. Camões: Trends in statistical calculations of individual ionic activity coefficients of aqueous electrolytes and seawater. Trends in Physical Chemistry (in press)
- R. Feistel, O.Hellmuth: Zur Rolle des Wassers in der Energiebilanz des Klimasystems [On the role of water in the energy balance of the climate system] Sitzungsberichte der Leibniz-Sozietät Berlin (in press)
- O. Hellmuth, J. W. P. Schmelzer and R. Feistel: Ice-Crystal Nucleation in Water: Thermodynamic Driving Force and Surface Tension. Part I: Theoretical Foundation, Entropy 2020, 22, 50; doi:10.3390/e22010050
- S. Weinreben, R. Feistel: Anomalous salinity-density relations of seawater in the eastern central Atlantic, Deep–Sea Research I 154 (2019) 103160, https://doi.org/10.1016/j.dsr.2019.103160
- H. Uchida, Y. Kayukawa and Y. Maeda, Ultra high-resolution seawater density sensor based on a refractive index measurements using the spectroscopic interference method, Scientific Reports, 9 15483 (2019), https://doi.org/10.1038/s41598-019-52020-z
- H. Uchida, T. Kawano, T. Nakano, M. Wakita, T. Tanaka, and S. Tanihara, An expanded batch-to-batch correction for IAPSO standard seawater. *J. Atmos. Oceanic Technol.*, doi: https://doi.org/10.1175/JTECH-D-19-0184.1.
- Barker, P. M. and T. J. McDougall, 2020: Two Interpolation Methods using Multiply-Rotated Piecewise Cubic Hermite Interpolating Polynomials. *Journal of Atmospheric and Oceanic Technology,* **37**, 605-619. http://dx.doi.org/10.1175/JTECH-D-19-0211.1

APPENDIX 8. AFFILIATED PROJECT REPORTS

IOCCG – Ocean colour

IOCCG Annual Report to SCOR
Venetia Stuart (IOCCG Project Coordinator)
Reporting Period: May 2019 – April 2020

The International Ocean-Colour Co-ordinating Group (IOCCG) was established in 1996 to promote communication and co-operation between the space agencies and the ocean-colour user community. IOCCG is an Affiliated Program of SCOR, and an Associate member of CEOS (Committee on Earth Observation Satellites). The IOCCG has a wide-ranging mandate addressing technological and scientific issues through its scientific working groups and task forces, promoting capacity building through advanced training courses, and helping to ensure continuity and quality of the ocean-colour data stream though the CEOS Ocean Colour Radiometry-Virtual Constellation (OCR-VC) and Ocean Colour Radiometry-Implementation Team (OCR-IT). SCOR has been instrumental in helping the IOCCG secure funding from NASA for the IOCCG program, and also helps to support students from developing countries to attend IOCCG training courses and/or the International Ocean Colour Science (IOCS) meetings. The group is currently chaired by Cara Wilson (NOAA, USA), and the IOCCG Project Office is located at the Bedford Institute of Oceanography, Canada, staffed by Project Coordinator, Venetia Stuart.

1. IOCCG Scientific Working Groups

IOCCG scientific working groups are established to investigate various aspects of ocean colour science, technology and its applications. The working groups are relatively short-lived (2-4 years), and publish their findings in the IOCCG Report Series upon completion. Over the past year, two IOCCG scientific working groups have completed their deliberations and published their findings as IOCCG reports, and two other working groups are in various stages of completion.

The IOCCG Report Series all have an ISBN assignments as well as a digital object identifier (doi) provided by OceanBestPractises (OBP). Electronic versions of the reports are available through the IOCCG website, as well as the OBP Repository maintained by the International Oceanographic Data and Information Exchange (IODE) of UNESCO-IOC. Hardcopies are also mailed out free of charge. IOCCG reports are widely cited and are in high demand throughout the world, providing appropriate advice to space agencies, scientists and managers, as well as serving as a useful teaching aid for students. The two new IOCCG Reports, as well as the status of the two ongoing working groups are indicated below.

IOCCG Report 18 (2019). Uncertainties in Ocean Colour Remote Sensing, *e*dited by Frédéric Mélin (EC Joint Research Centre), published by the International Ocean Colour Coordinating Group, Dartmouth, Canada. http://dx.doi.org/10.25607/OBP-696IO

This report summarizes the state of knowledge on uncertainties related to ocean colour products and proposes recommendations to achieve progress on how uncertainties should be routinely quantified and distributed by the space agencies. A physical measurement is incomplete and meaningless unless accompanied by a statement of estimated uncertainty. Historically, ocean colour products have been distributed without estimates of uncertainty, and the community has had to rely on comparisons with *in situ* data to assess its products. This report reviews the various sources contributing to uncertainties in ocean colour data, from top-of-atmosphere (TOA) data to gridded products. It also describes how the uncertainties propagate through data processing, and proposes the best techniques to provide uncertainty estimates, as well as requirements for different applications of ocean colour data (e.g., numerical biogeochemical modeling, climate research, phenology studies, fisheries applications etc.).

The report also provides a series recommendations aimed at distributing fully documented uncertainty estimates and reducing the uncertainties associated with ocean colour products, with a final objective of ensuring traceability of ocean colour products to appropriate SI (International System of Units) standards. These include improving the statement of uncertainty requirements for missions or project deliverables, providing full documentation and source codes for the whole processing chain, and distribution of non-calibrated TOA data, amongst others. This report was recently printed by the EC Joint Research Centre (JRC) and will be distributed free of charge to all subscribers.

IOCCG Report 19 (2020). Synergy between Ocean Colour and Biogeochemical/Ecosystem Models, edited by Stephanie Dutkiewicz (MIT, USA), IOCCG Report Series, No. 19, International Ocean Colour Coordinating Group, Dartmouth, Canada. http://dx.doi.org/10.25607/OBP-711

The overall goal of this working group was to bridge the gap between the ocean colour community and the biogeochemical/climate numerical modelling communities by providing a better understanding of ocean colour products, the different types of models available, and the mismatches to model outputs. Models, in situ observations, and ocean colour products are different tools that can each be used to understand ecological and biogeochemical processes in the ocean. However, each provides a different "measurement" inhibiting straightforward inter-comparison.

Numerical modellers are frequent users of ocean colour products, but many modellers need better information about using satellite data. This report demonstrates that ocean colour products are uniquely important for model evaluation and data assimilation, and that models can also be useful for the ocean colour community by emphasizing the strength that can come from a more synergistic use of ocean colour and model products. Recommendations in the report encourage agencies to provide additional information alongside satellite products to help modellers make informed choices and interpretations. This report was recently printed by the Second Institute of Oceanography, China, and will be distributed free of charge to all subscribers.

IOCCG Working Group on Harmful Algal Blooms (Chair: Stewart Bernard, CSIR, South Africa).

Harmful algal blooms (HABs) and eutrophication events have had a significant global impact over the past few years. The frequency of these events, and the geographic extent of toxic/harmful algal blooms have been increasing globally. This joint working group between the IOCCG and the GlobalHAB programme of IOC-SCOR was established to produce a comprehensive guide to ocean colour remote sensing of HABs, summarising the state of knowledge and demonstrating the suitability of various ocean colour approaches through case studies from different ecosystems, as well as operational HAB applications. The primary focus areas are the technical difficulties of using ocean colour remote sensing in optically-complex coastal waters, and the need to understand the limitations of ocean colour for deriving phytoplankton community composition.

Recommendations form an important part of the report and include agency focussed sensor aspects (NIR bands, hyperspectral), as well as the importance of atmospheric correction. For intense blooms, Rayleigh-corrected reflectance can be used to determine Chl-a thus circumventing atmospheric correction problems associated with turbid waters and the correction of aerosol absorption. The group found that ocean colour remote sensing is effective in detecting high biomass blooms, but does not work well for low biomass blooms, so examples of indirect approaches are also shown. It is anticipated that the report will be published by the end of 2020.

IOCCG Working Group on "Evaluation of Atmospheric Correction over Turbid Waters" (Chair: Cédric Jamet, LOG, Wimereux, France).

Atmospheric correction is vital to obtain accurate ocean colour radiometry measurements, e.g., remote sensing reflectance. This process is more complicated in optically complex waters, especially turbid waters found in coastal environments. The goal of this working group is to provide an comprehensive evaluation of the most common atmospheric correction algorithms used over turbid waters, as well as to provide guidance to end-users on how and where to use specific atmospheric correction algorithms. A total of nine atmospheric correction algorithms are being evaluated using a simulated dataset for sensitivity studies.

This report is more technical than a traditional IOCCG report, so the IOCCG Committee suggested that it be published as an IOCCG Technical Report, as it deals primarily with methodology. It is anticipated that this report will be the first in the new "IOCCG Technical Report Series" and will likely be published this year, or early next year.

2.0 IOCCG Scientific Task Forces

In addition to the short-lived scientific working groups, the IOCCG also has a semi-permanent Task Force on *Satellite Sensor Calibration*, to help facilitate inter-agency collaboration on an ongoing basis. Under this inter-agency framework, calibration experts from various space agencies meet regularly to exchange ideas, information and data.

The IOCCG also has plans to form another Task Force to bring together experts specializing in hyperspectral remote-sensing methods for aquatic ecosystems. This Task Force could provide clarity on ocean requirements and specifications to help determine where hyperspectral remote sensing offers serious quantitative advantages to multispectral remote sensing. It could also provide recommendations on how to develop global databases that merge hyperspectral optics and phytoplankton group composition to support the next generation of hyperspectral satellites for assessing phytoplankton biodiversity.

3.0 IOCCG Protocol Series

The IOCCG established the IOCCG Protocol Series to publish peer-reviewed Ocean Optics and Biogeochemistry Protocols online. *In situ* optical and biogeochemical in- and above-water measurements are critical for calibration and validation of satellite ocean colour radiometry data products, and for refinement of ocean colour algorithms. Over the past few years NASA and IOCCG have sponsored several international workshops with the aim of updating and developing new community consensus protocols for ocean colour sensor validation. These new protocols are posted on the IOCCG webpage for a period of time for testing, public comment and review, before they are accepted as international reference standards. Two new protocols were recently published by the IOCCG (see below) and are available on the IOCCG website.

3.1 **Protocols for Satellite Ocean Colour Data Validation: In Situ Optical Radiometry** (Vol. 3.0, December 2019)
This document provides protocols for the collection, processing and quality assurance of *in situ* measurements of the apparent optical properties of natural water for the validation of satellite radiometric products. In addition to a general introduction on Elements of Marine Optical Radiometry Data and Analysis, the document addresses Radiometer Specifications, Calibration and Characterization of Optical Radiometers, In-water Radiometry Measurements and Data Analysis, and Above-water Radiometry Measurements and Data Analysis. The protocols put emphasis only on

measurements performed during clear sky conditions, which are most relevant for the validation of satellite ocean colour data products.

Inherent Optical Property Measurements and Protocols: Best Practices for the Collection and Processing of Ship-Based Underway Flow-Through Optical Data (Vol. 4.0, November 2019)

Optical data can be collected using the flow-through systems installed on research vessels and ships of opportunity taking advantage of the availability of seawater pumped into the vessel. These "in-line" or "underway" systems are able to provide data at spatial resolutions on the order of 10 to 100 m. As the number of research groups making these measurements grows, there is a need to provide coordinated data collection and processing protocols to standardize methodology and data quality. This report discusses the essential issues associated with in-line data collection, provides recommendations on best practices for collection and processing data, and provides details on available software.

4.0 Capacity Building

4.1 Training Course in Hangzhou, China

In October 2019 the IOCCG coordinated an international ocean colour remote sensing training course in Hangzhou, China, in conjunction with EUMETSAT and the Second Institute of Oceanography, China. A total of 20 trainees from seven different countries participated in the course, which lasted for one week. The key objective of this training was to help early career scientists to download, analyze and visualize data from the EUMETSAT Copernicus Marine Data Stream (Sentinel-3 OLCI data) as well as the Chinese HY-1C ocean colour mission. Participants also learnt how to use the Marine Satellite Data Online Analysis Platform (SatCO2) for environmental monitoring and scientific research, including water quality monitoring, red tide detection, and marine carbon cycling/climate change investigations. SCOR sponsored the return airfare of four students (from Thailand, Indonesia, India and Bangladesh), which is greatly appreciated.

4.2 IOCCG Summer Lecture Series

The fifth IOCCG Summer Lecture Series is scheduled to take place at the Laboratoire d'Océanographie de Villefranche (LOV, France) from 22 June – 3 July 2020. The course will be dedicated to high-level training in bio-optics and ocean colour remote sensing, and will focus on current critical issues in ocean colour science. A total of 112 applications were received, the majority of which were of excellent quality, making for a very competitive field. The final 24 students selected come from 16 different countries, and represent 17 different nationalities. All students have been notified about the success of their applications, but in light of the COVID-19 pandemic, the IOCCG may have to cancel the course (the LOV lab is currently closed, and there are global travel restrictions). A final decision will be made on 29 May 2020, and all students will be informed of the situation. Should the course be cancelled, IOCCG will consider various options (conducting the course remotely with live on-line discussion sessions, finding another date when the lecturers are available etc.).

5.0 IOCCG Committee Meetings

The IOCCG Committee meets once a year to coordinate the activities of the group as a whole, discuss plans for the year ahead and review the progress of the various working groups. The Executive Committee also meets to approve the budget for the coming year. This year, the annual IOCCG-25 Committee meeting was scheduled to take place from 27–29 March 2020 in Tokyo, Japan hosted by the Japan Aerospace Exploration Agency (JAXA). Because of the COVID-19 pandemic, the meeting had to be cancelled. There are tentative plans to hold a small IOCCG Executive meeting in conjunction with the Ocean Optics meeting in Virginia, USA (24-30 October 2020), as well as conducting several teleconferences with various groups to discuss pressing matters. The next full IOCCG Committee meeting is scheduled to take place in early February 2021.

6.0 IOCCG Membership (2020)

The IOCCG Committee consists of members drawn from space agencies as well as the scientific ocean-colour community. Rotation of members is being implemented according to a roster, but is currently the same as for 2019, due to cancellation of the Committee meeting. The IOCCG Executive Committee consists of all representatives from the sponsoring agencies, plus the IOCCG Chair and past-Chair.

Bernard, Stewart (past Chair) - CSIR, South Africa
Bontempi, Paula - NASA HQ, USA
Boss, Emmanuel - University of Maine, USA
Brando, Vittorio - CNR-ISMAR, Italy
Chauhan, Prakash - ISRO, India
Ciotti, Aurea - Universidade de São Paulo, Brazil
Devred, Emmanuel - Bedford Institute of Oceanography, Canada
Dogliotti, Ana - IAFE/CONICET, Argentina
Franz, Bryan - NASA GSFC, USA
Giardino, Claudia - CNR-IREA, Italy
Giugni, Laurent - CSA, Canada
He, Xianqiang - Second Institute of Oceanography, China
Hu, Chuanmin - University of South Florida, USA
Kampel, Milton - INPE, Brazil
Kim, Wonkook - Pusan National University, South Korea
Kwiatkowska, Ewa - EUMETSAT, EU, Germany
Lifermann, Anne - CNES, France
Loisel, Hubert - Université du Littoral, France
Malthus, Tim - CSIRO, Australia
Mélin, Frédéric - EU Joint Research Center, Italy
Murakami, Hiroshi - JAXA EORC, Japan
Rio, Marie-Hélène - ESA/ESRIN, Italy
Ryu, Joo-Hyung - KIOST, South Korea
Wang, Menghua - NOAA/NESDIS/STAR, USA
Wilson, Cara (Chair) - NOAA/NMFS, USA

7.0 IOCCG Sponsors

The IOCCG is sponsored and supported by contributions from various national space agencies and other organisations listed below:

Canadian Space Agency (CSA)
Centre National d'Etudes Spatiales (CNES, France)
Commonwealth Scientific and Industrial Research Organisation (CSIRO, Australia)
Department of Fisheries and Oceans (Bedford Institute of Oceanography, Canada)
European Space Agency (ESA)
European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
National Institute for Space Research (INPE, Brazil)
Indian Space Research Organisation (ISRO)
Japan Aerospace Exploration Agency (JAXA),
Joint Research Centre (JRC, EC)

Korea Institute of Ocean Science and Technology (KIOST)
National Aeronautics and Space Administration (NASA, USA)
National Oceanic and Atmospheric Administration (NOAA, USA)
Scientific Committee on Oceanic Research (SCOR)

The Bedford Institute of Oceanography (Canada) provides in-kind support, providing office space and informatics support, while SCOR provides infrastructure support to IOCCG and manages the NASA funds.

The affiliation to SCOR is critical for the IOCCG in that it provides an avenue for obtaining funding from US agencies such as NASA, which would be impossible without this affiliation. SCOR's support of students from developing countries to attend IOCCG training courses or the IOCS meetings is also gratefully acknowledged.

2020 InterRidge Update for SCOR

I) InterRidge – International Cooperation in Ridge-Crest Studies

Since its creation in early 1990's, InterRidge has been an international forum for mid-ocean ridge (MOR) scientists, expanded to regions beyond ridge crests to include deep-sea basins and other plate boundaries as well as biological processes in those extreme environments. InterRidge promotes interdisciplinary studies by creating a global research community, planning, and coordinating new science programs that no single nation can achieve alone, exchanging scientific information, and sharing new technologies and facilities. InterRidge plays a dual role. Its primary aim is to favor the emergence of new concepts and makes possible ambitious experiments at international level. InterRidge also supports community-wide initiatives such as the definition and dissemination of a code of conduct for scientific studies in relation to chemosynthetic hot-spot ecosystems and their vulnerable environments. More recently, with the growing interest of countries and industries for deep-sea mineral resources, including seafloor massive sulfide (SMS) deposits at MOR, InterRidge has become a voice of expert scientists in different fora. Through its observer status at the International Seabed Authority (since 2012), particularly, InterRidge developed formal interactions with this organization created under the United Nations Law of the Sea (UNCLOS).

InterRidge scientific activities are currently led under the frame of the 3rd Decadal Plan 2014-2023 'From Ridge Crest to Deep-Ocean Trench: Formation and Evolution of the Oceanic Crust and Its Interaction with the Ocean, Biosphere, Climate and Human Society' launched in 2012. Thus InterRidge expands its focus beyond the ridge crests and basically covers the entire ocean basins. Beside its affiliation with SCOR, InterRidge program has links with international research programs such as the International Ocean Discovery Program and the International Lithosphere Project. InterRidge activity includes meetings and workshops where the advancement of scientific knowledge, new issues, methodological improvements and standardized protocols are discussed. InterRidge also dedicates itself to interact with the public, scientists and governments, and to provide a unified voice for ocean ridge researchers worldwide. While committed to the advancement of fundamental science, an increasing role for InterRidge is our involvement in compiling information and advice for policy makers. The multidisciplinary coverage of InterRidge working groups give the organization a key role in future discussions concerning the exploration and exploitation of mineral resources associated with ridges, volcanic arcs, back-arcs, deep-sea basins and associated hydrothermal systems.

InterRidge has a Steering Committee comprising representatives of the member countries and of working group chairs that are scientists nominated for their expertise in a particular field. The Steering Committee meets at least once a year (the last meeting was held on 20-22 June 2018 in Bergen (Norway), the next one is planned on 13-14 June 2019 in Tokyo (Japan). The Steering committee considers updates to its Science Plan, endorses InterRidge memberships, approves the budget, decides on membership fees, oversees the operation of the InterRidge Office, reviews bids for the InterRidge Office and nominates the Program's chair. It also evaluates working group progress, assesses and admits/rejects working group proposals, and nominates the working group leaders.

The InterRidge contribution is 25 000 US$ for a Principal Member country and 5 000 US$ for a Regular Member country. Considering the present membership (China, Japan, Norway, and Republic of Korea as

Principal members and Canada, Germany, India, Norway, Poland, and UK as Regular members) and the double contribution for the host country, the resulting annual budget is c.a. 155 000 US$.
As a result of COVID-19 global pandemic, many past activities of InterRidge has to be changed in 2020. Many workshops and meetings will have to be done online. At present, as of June 2020, many countries cannot send their research vessels beyond their borders, because of the entry restrictions enacted at foreign ports.

II) Achievements and changes during the last year

1) InterRidge Office

Every three years the InterRidge office transfers to a new host institution in a new host country. This year the InterRidge office transferred from the Institut de Physique du Globe de Paris (IPGP) in France, to InterRidge Korea (IR Korea), in Republic of Korea managed under Seoul National University (SNU).
The InterRidge Office is hosted in Republic of Korea by InterRidge Korea, an organization formed under Seoul National University to take responsibility of budget management and administration of the program. Sang-Mook Lee (smlee@snu.ac.kr SNU, marine geophysics) is the chair of the program. Erik Sevre (interridge@gmail.com) is the InterRidge Coordinator since 1st January 2020. Seongjun "Kyle" Park (seongjun.kyle.park@gmail.com) is the InterRidge Logistics Coordinator since 1st January 2020.

2) Steering Committee Meetings

a) Steering Committee Meeting, Tokyo Japan 13-14 June, 2019.

The Steering Committee held the annual meeting to cover the usual auditing of the running of InterRidge. Additionally, we discussed the future hosting of InterRidge, which would eventually transfer host nations from France to the Republic of Korea.

b) Steering Committee 2020 Remote Meeting

On 21, May 2020 we held an online meeting for the IR Steering Committee.
During the Steering Committee meeting we discussed the possibilities of holding more meetings online during the travel restrictions and complications that have been presented in 2020. We are hoping to expand on using the online format to host more talks that people can participate in online. In particular, a suggestion was made to build an online InterRidge lecture series in this time of COVID-19.
During this meeting we discussed adding Seung-Sep Kim was introduced as a prospective new Steering Committee member for Korea. After the meeting, the committee was asked to vote on him joining the Steering Committee, and all votes affirmed his joining the Steering Committee so he is now a member of the Steering Committee.
A new working group candidate was introduced to the Steering Committee. The MacroCHESS proposal was presented to expand on the current IR Vents Database, by expanding the data that will be available to scientists. A vote was held over email, and all votes were in favor of adding the MacroCHESS WG, so it has been added as a new IR WG.

3) ISA 25th Session – DeepData

July 2019: Attendance to the 25th session of the ISA Council (Part 2) and General Assembly

The second part of the 25th annual session of the International Seabed Authority (ISA) was held in Kingston (Jamaica) between 15 and 26 July 2019. This Session included meetings of the Authority Council and Assembly, focused on the draft regulations on exploitation of mineral resources in the Area and on the ISA Strategic Plan, respectively.
Of major importance for the scientific community was the launch of the DeepData database, which will serve as the principle repository of all deep-seabed related data collected in the international seabed area (Area). In its current state, the database contains biological, physical and geochemical parameters of the marine ecosystems from the seafloor to the ocean surface, submitted by ISA's 29 contractors and covering approximately one per cent of the Area. The database can be accessed at: http://data.isa.org.jm.
Delegates from more than 70 countries commemorated the 25th anniversary of the ISA with a special session on Thursday, 25 July. Dr. Maurício Shimabukuro from the Institute of Oceanography at the University of São Paulo (Brazil) was granted the ISA Secretary-General Award for Excellence in Deep Sea Research.

4) InterRidge Working Groups

This year IR approved a new WG to focus on biological issues. InterRidge was founded initially with an interest in geophysical issues, however biological issues have expanded the interest in seafloor studies. This year a new MacroCHESS WG was proposed to explore the global distribution, composition, and relationship of species occurring in chemosynthesis-based-ecosystems (CBEs) at both global and regional scales. The goal is to expand the IR Vents Database by compiling a distribution of species occurring on hydrothermal vents, cold seeps, and organic remains.

5) Report on InterRidge Sponsored Meetings

a) Euromarine Foresight Workshop: Advances in Ocean Biological Observations

The workshop "Advances in ocean observations – sustained system for deep-sea meroplankton" took place at Aveiro University (Portugal) from May 27th to 29th 2019. The objectives of the workshop were: 1) to summarize knowledge and recent progresses on the distribution and biology of deep-sea larvae (the major part of meroplankton), and available instruments and technologies dedicated to the observation of plankton in surface and deep waters; 2) to develop a strategy to implement technological innovations for in-situ observations allowing larval distribution characterization at multiple scales.

b) Seamounts and Islands Associated with Mid-Ocean Ridges (Lisbon, 19-21 September 2019, Portugal)

Short report from the workshop of the WG on Seamounts and Islands associated with MOR. During the three days of the workshop of the Working Group on Seamounts and Islands associated with Mid-Ocean Ridges, held on 19-21 September in the Instituto Hidrográfico in Lisbon (Portugal), the international participants discussed the main scientific and logistic challenges related to research of seamounts and islands. They reshaped the definition of the working group so that it will act as an umbrella for fundamental and applied research on large edifices that formed in the proximity of Mid-Ocean Ridges. The main research questions to be addressed deal with the cycling of energy and materials in these

enigmatic environments and the interaction between processes related to solid Earth and those in the hydrosphere, biosphere and atmosphere. The possibilities of a larger networking proposal will be evaluated in the near future in a subsequent workshop to be held in 2020.
Final report here: https://www.interridge.org/files/interridge/MORISreport2019_final.pdf

c) Hydrothermal Ore-forming Processes and the Fate of Seafloor Massive Sulfides Deposits along Slow and Ultraslow Spreading Mid-Ocean Ridges, Hangzhou 19-21 September
Sept. 2019: InterRidge Workshop on Hydrothermal Ore-forming Processes and the Fate of Seafloor Massive Sulfides Deposits along Slow and Ultraslow Spreading Mid-Ocean Ridges, Hangzhou 19-21 September (Final Report here: https://www.interridge.org/node/17905#attachments) [Short report from the workshop of the WG on Seafloor Massive Sulfides Resource along MOR] More than 150 SMS-related international scientists and students participated in this workshop, organized by the Working Group on SMS resource along MOR and held on 19-21 September in Hangzhou (China), and had in-depth discussion with focus on the theme of "hydrothermal ore-forming processes". The participants exchanged ideas in various ways – primary/early career presentations, posters, plenary and break-out brainstorm. The most important outputs of this workshop are: the summary of the known/unknown BIG questions existing in the SMS formation, distribution and preservation; and the collected ideas on how to solve the questions of great significance to guide the subsequent SMS exploration and the related research along MOR. The Working Group has agreed to organize the next Workshop in 2020 to further promote the progress of SMS resource related disciplines.

d) InterRidge Theoretical Institute “Hydrothermalism in 4D”
The Theoretical Institute “Hydrothermalism in 4D” InterRidge was held on November 18-20, 2019 in Banyuls (France). Organized by the InterRidge office (CNRS-SU-IPGP), it was hosted at the Sorbonne University Marine Station and Oceanological Observatory of Banyuls. 33 participants from 9 countries (Canada, Chile, France Germany, India, Japan USA, Norway, Republic of Korea) attended the event, including 12 students and early carrier scientists.
Recent advances in fundamental research and exploration have raised new interest and scientific challenges concerning hydrothermal processes, their links with tectonic complexities and interactions with magmatic activity, contribution to ocean element budgets, role in deep-sea biodiversity and ecosystem functions, temporal dynamics and resilience to disturbance. Along with these emerging themes, the current scientific momentum is supported by methodology and knowledge transfer needs for mineral resource assessment and environmental and ecological status monitoring. In this context, building an integrated vision of hydrothermal processes over space and time, on which quantitative approaches and predictive models should be based, reveals crucial.
Invited lectures on the first two days, addressed fundamental issues at the forefront of current hydrothermal research. Lectures targeting young scientists from different disciplinary fields proposed syntheses of recent works, bridging methodological and theoretical advancement.
Following lectures, workshop sessions were organized on four emerging themes: **Session 1 ‘Export of vent derived chemicals: from near-vent reactivity to long-range transport’, Session 2 ‘Chemosynthetic**

carbon: drivers of productivity at active and inactive vents, Session 3 ' Basin scale distribution of hydrothermally driven processes from ridges to subduction zones, Session 4 'Massive Sulfide deposition, alteration and biological diversity'. Keynote talks introduced sessions focusing on state-of-the-art and recent advances from geoscience and ecology-biology perspectives, complemented by short talks and an early carrier poster session.

The discussions allowed to identify key issues and future topics and help structuring the writing groups and precise their objectives. Exchanges on new technologies, interdisciplinary challenges (including capacity building and methods/tools sharing across disciplines) contributed setting up the scene for the next decade plan of InterRidge, underlining critical knowledge gaps and perspectives from the current research momentum. The ultimate goal of discussions and writing sessions of the Theoretical Institute was to draft a position to suitable paper to strengthen the fundamental frame and develop strategies to fill remaining gaps, while sharing recent advances in basic knowledge with the growing community of scientists interested in vent systems.

Final Agenda and abstracts here:
https://www.interridge.org/files/interridge/IR_Theoretical_Institute_2019_Programme%20and%20Poster%20abstracts_Vf.pdf

III) InterRidge Outreach and Community Support

a) InterRidge Fellowship:

As every year the InterRidge Student and Postdoctoral Fellowship Program continues to play an important role in the careers of young ocean scientists. There was a high number of proposals submitted this year and we are pleased to award two early-career researchers in this call. The recipients of InterRidge Fellowships in 2019 were: Jakub Ciążela - a post-doc at Polish Academy of Sciences, Wrocław, Poland Guilherme Weber Sampaio de Melo - a graduate student at Federal University of Rio Grande do Norte, Brazil (See here for CVs and Report from the two awardees: https://www.interridge.org/2019awards)

b) InterRidge Cruise Bursaries:

In 2019 three bursaries were awarded to talented students.

Dominik Palgan, Poland, participated with Fernando Martinez from Hawai'I USA . Dominik Palgan participated on a cruise to research the formation and elimination of segmentation and transform faults on the Reykjanes Ridge.

Nicole Morgan, USA, participated with Dhugal Lindsay from Japan. Nicole Morgan joined a cruise funded by JAMSTEC to study characterize undersampled oligotrophic waters of the South Pacific.

Gabriella Alodia, UK, Joined Henry J. B. Dick, USA on scientific cruise to the Marion Rise, SW Indian Ridge, February-March 2019. This cruise investigated the hypothesis that the Marion Rise is isostatically supported by ancient residues of a prior melting event.

Three awarded in 2019, see Here: https://www.interridge.org/node/15913

c) Update of the IR Vent Database

The InterRidge Vent database has been continuously updated by Kamil Szafranski and Stace Beaulieu in 2019. The database is currently be transferred to the Korea office, where Erik Sevre will take over for Kamil in assisting Stace in the maintenance of the database. The InterRidge Cruise database was updated as information was made available to the Coordinator. In the coming year we are planning to update the database with new information that will be coming in from the newly formed MacroCHESS working group.

IV) Plans for the future development of InterRidge

It is our goal to maintain InterRidge as an efficient scientific forum of experts. We hope to expand online communities to facilitate communication during travel restrictions caused by COVID-19. We hope to open new working groups and co-organize workshops with our current working groups.

GACS – Alliance of Plankton Recorders

Global Alliance of Continuous Plankton Records Surveys (GACS) – report of activities

Anthony J. Richardson, Chair of the Board of Governance
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The COVID-19 pandemic has made it challenging to continue the science we do. With lockdowns in many countries, the continuation of some time series has been difficult. Generally, the Continuous Plankton Recorder (CPR) surveys have coped relatively well compared to other time series programs, as global shipping has been relatively unaffected by COVID-19 ensuring continued sample collection and there is not a requirement for scientists to accompany CPRs onboard ships. Although surveys have backlogs in counting samples, the continued collection of samples enables us to address the backlogs as labs have re-opened.

The annual GACS meeting was hosted in Hobart, Australia, on the 25-27 November 2019. A total of 18 participants attended, including the heads of all CPR surveys. The focus was on discussing collaborative science, how to best run CPR activities, new developments on the horizon, and how we could expand. On this theme, a recent output from the group is the Batten et al. (2019) paper where GACS members describe the existing surveys and what a global plankton diversity survey would look like.

The annual GACS meeting was followed by a 2-day molecular workshop with 25 participants. This was led by Professor Willie Wilson from the UK Marine Biological Association. We discussed strategies for using molecular techniques on plankton samples, including those preserved in formalin. There were many robust discussions by molecular experts. The formalin preservation used in CPR samples continues to be a challenge for molecular work. GACS would like to thanks POGO for sponsoring the molecular workshop.

The GACS community continued its exchange of members (pre-COVID). The Australian CPR (AusCPR) survey hosted Jenny Huggett and Marco Worship (South Africa CPR) and Octavio Esqivel (Brazil CPR) in the Brisbane CSIRO lab. They were embedded in the AusCPR lab for a week, learning CPR logistics, plankton taxonomy, databasing, the protocol for the Phytoplankton Colour Index, silk cutting, and data analysis. This exchange of personnel is important for training new GACS members and ensuring methods are consistent among surveys. Participants from the workshop can now apply their new skills to their home surveys. GACS would like to thanks POGO for sponsoring the three trainees from developing nations to attend the training workshop in Hobart and Brisbane.

A focus of GACS is producing combined, global science outputs. We are currently working on several papers including using CPR data to validate a global ecosystem size spectrum model, using CPR data to test ecological theory, and a global CPR methods paper. To facilitate our science, and after many years of work, there is now a global CPR database, with all data from CPR surveys globally. All data are stored in a common format, with the latest taxonomic identifiers. We also have a set of guidelines in place for its use.

In terms of engagement, the GACS community has been endorsed by GEOBON (Group on Earth Observations Biodiversity Observation Network). GACS has been engaging with SOOPIP (SOOP Implementation Panel). GACS will also contribute manuals of our methods to an Ocean Best Practices website. Strong engagement with the POGO continues. Given the COVID crisis, there is unlikely to be an in-person GACS meeting this year, but we are exploring options for a virtual meeting.

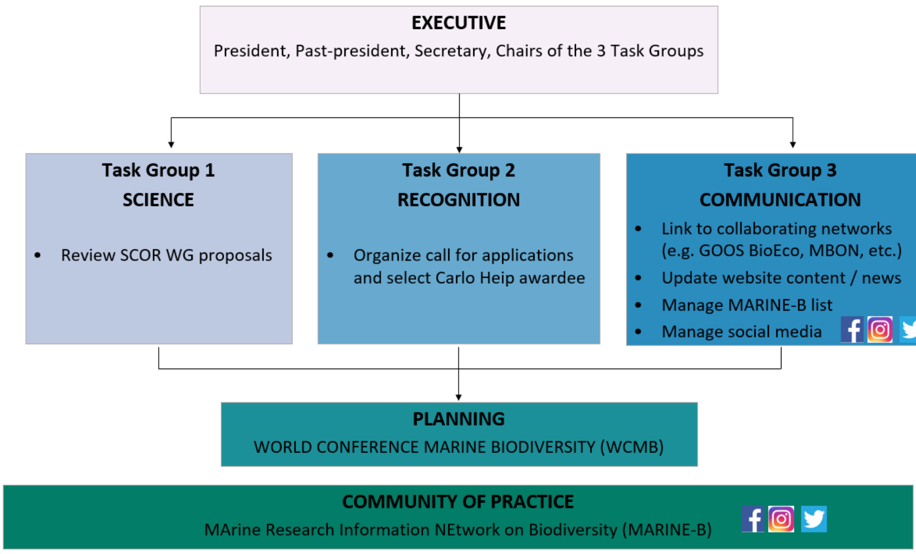
IABO – Biological Oceanography

June 8, 2020.

Annual Report of the International Association for Biological Oceanography (IABO)

Activities summary for 2019 - 2020

Over this period IABO has focused on the implementation of the new organizational structure following the Terms of References (ToRs) approved during the previous year by the Executive Committee. Details of the new ToRs are available in the IABO report for the 2018-2019 period. Under the new IABO structure the Executive Committee oversees and supports activities the Science, Recognition and Communication Task Groups (TG) as follows:



Members of the Executive Committee and three TGs have been selected and appointed according to the ToRs, taking into account gender, geographic and career level balance. Invitations to join the IABO leadership were sent last year based on results from a broad survey carried out to collect expressions of interest from the community. Details on geographic representation of respondents are available on the 2018-2019 report.

The IABO leadership is now composed by nine Executive Committee members including the current and past President, and Executive Secretary, and Chairs and Co-Chairs of each of the Task Groups. Eleven TG members from 14 countries now serve for the Science, Recognition and Communication TGs.

Details about affiliations and area of expertise of the Executive Committee (EC) and TGs members are available on the IABO website.

IABO Website - http://www.iabo.org/

Several updates have been made to the IABO site to highlight information of new members, new logo and about the upcoming 5th World Conference on Marine Biodiversity to be held in Auckland, New Zealand this year or early 2021 (depending on travel restrictions related to the Covid-19 pandemic).

Changes made to the IABO site include:

1. replacing names of the Executive Committee names with new members.
2. adding short bio and head shot of IABO members
3. adding the organizational chart to the main page
4. adding information about the 5th WCMB.
5. adding a ***WHO WE ARE*** description in the **About** page.
6. transferring website login credentials to the current Acting President, Enrique Montes.
7. displaying all IABO reports on site under the **Reports** page.
8. adding several banner photos to the main page.

The website will continue to be updated with information about research opportunities posted on the MARINE-B listserv and other relevant communications from the Marine Biodiversity Observation Network (MBON) of the Group on Earth Observation BON (GEO BON), the Global Ocean Observing System (GOOS) and SCOR Working Groups.

IABO Presidency

Dr. Patricia Miloslavich has been appointed the SCOR Executive Director and will no longer be able to fulfill responsabilities of the IABO Presidency. She therefore requested approval from the EC for the transfer of the IABO Presidency to Dr. Enrique Montes until end of 2020, or when the 5th WCMB is held. Dr. Montes is an early career biological oceanographer of the College of Marine Science at the University of South Florida with expertise in phytoplankton-mediated cycling of carbon, nitrogen and oxygen, satellite remote sensing of phytoplankton and ocean biogeography, and biodiversity. He currently co-leads the U.S. South Florida MBON project and is the Principal Investigator of the MBON Pole to Pole of the Americas program. He will continue his role as Acting President of IABO until elections of the new President to be held in the upcoming 5th WCMB.

Student and Early Career Travel Grant to Attend the 5th WCMB

The Acting President of IABO submitted a proposal to SCOR for consideration of support of developing country scientists to attend ocean science meetings and training. SCOR approved the proposal and has awarded $5,000 USD to provide small travel grants to 3-5 participants to attend the 5th WCBM. This travel opportunity has been posted on the conference website. Eligible candidates must be from one of the Developing Countries according to the World Bank categories (https://scor-int.org/wp-content/uploads/2020/03/Eligible_Countries-1April2020.pdf), have offered to present a talk or poster at the WCMB, and have made an application by the 31 June 2020. Priority will be given to applicants who will be providing a novel and relevant presentation at the WCMB, who have obtained partial funding for their attendance, and are early in their scientific career (defined as 10 years since their PhD and under 40 years of age by SCOR).

Review of SCOR Working Group Proposals

IABO's EC and Science TGs have initiated the review process of ten Working Group proposals submitted to SCOR in 2020. Reviews will be sent to SCOR's Executive Director before August 31th.

Carlo Heip Award

IABO's Recognition TG evaluated three nominations to the Carlo Heip medal and has elected the winners for 2019 and 2020. Selected nominees will be recognized in the 5th WCMB.

The International Association of Meteorology and Atmospheric Sciences 2020 Report to SCOR

(www.IAMAS.org)

IAMAS is one of the eight associations dealing with the Earth system and its environs that make up the International Union of Geodesy and Geophysics (IUGG). The scope of IAMAS includes the atmospheres of the Earth and other planets. IAMAS is made up of ten international commissions and one committee which together play a major role in implementing IAMAS's activities. The ten commissions cover *Atmospheric Chemistry and Global Pollution* (ICACGP), *Atmospheric Electricity* (ICAE), *Climate* (ICCL), *Clouds and Precipitation* (ICCP), *Dynamical Meteorology* (ICDM), the *Middle Atmosphere* (ICMA), stratospheric *Ozone* (IOC), *Planetary Atmospheres and their Evolution* (ICPAE), *Polar Meteorology* (ICPM), and atmospheric *Radiation* (IRC). The *Committee on Nucleation and Atmospheric Aerosols* (CNAA) brings together scientists covering the areas of Nucleation Theory and Experiment, Tropospheric and stratospheric aerosols, Cloud Drop and Ice Nucleation and Aerosol-Climate Interactions.

Many of these commissions play international leadership roles in their specialist areas [see http://www.iamas.org/commissions-within-iamas/]. The commissions provide an important supplement and extension to the leadership and research role of the *World Meteorological Organization* (WMO), which is the governmental body with a scientific scope that is comparable to that of IAMAS.

The current Bureau of IAMAS consists of:

- President – Joyce Penner (USA)
- Secretary General – Steven Ackerman (USA)
- Vice President – John Burrowsw (Germany)
- Vice President – Mary Scholes (South Africa)

The organization also has five Members at Large who promote IAMAS activities:

- Prof. Michiel R. van den Broeke (Netherlands) 2019-2023
- Prof. Mu Mu (China) 2019-2023
- Dr. Lisa Alexander (Australia) 2015-2023
- Dr. Keith Alverson (USA/Japan) 2015-2023
- Dr. Iracema Cavalcanti (Brazil) 2015-2023

a) IAMAS together with IUGG held a successful General Assembly in Montreal, Canada over 8 July– 18 July 2019. We held a special celebration for our 100th aniversary on July 10, with 6 invited presentations by renowned scientists covery different fields within atmospheric science and meteorology including a talk covering the historical develpment of our sciences (J. Fleming). The

IAMAS registered more than 900 participants contributing to 100 symposia and 32 joint sessions where IAMAS was the lead.

b) Since the Montreal General Assembly the IAMAS Bureau, commissions and Executive have started the planning for the next Assembly, to be held in Busan, South Korea, over 18 – 23 July 2021 in concert with 2 of the other associations under IUGG: IAPSO (International Association for the Physical Sciences of the Oceans) and IACS (International Association of Cryospheric Sciences). A planning meeting scheduled for late June 2020 in South Korea may be held remotely due to the coronavirus pandemic.

c) The successful collaboration between IAMAS and its associated journal Advances in Atmospheric Sciences (AAS) has continued. AAS regularly publishes meeting reports on IAMAS activities, such as the Cape Town assembly in 2017 and the IAMAS sponsored Twelfth Workshop on Antarctic Meteorology and Climate. A planned booth presentation at the 2020 European Geophysical Union was cancelled when that in-person meeting was cancelled.

d) The 2019 IAMAS Early Career Scientist Medal was awarded to Prof. Lei Bi of Zhejiang University for his work on light scattering by non-spherical and inhomogeneous particles. Prof. Bi was presented with his medal at the General Assembly in Montreal in July 2019.

e) Each year the IAMAS commissions hold a number of high profile conferences either alone or in conjunction with other organizations. Details of all IAMAS meetings can be found at http://www.iamas.org/meetings/. However, many of the major meetings of the Commissions that were planned for 2020 have been rescheduled for 2021 due to the coronavirus pandemic.

The IAMAS sponsored Quadrennial International Radiation Symposium **planned to be held in Thessaloniki, Greece, from 6 to 10 July 2020 has been postponed to 14 to 18 June 2021 to be held at the same place.**

The IAMAS sponsored Quadrennial Ozone Commission planned for October 2020 at Yonsei University, South Korea, has been postponed until October 3 to 9, 2021 to be held at the same location.

The IAMAS sponsored International Commission on Clouds and Precipitation conference planned for August 3 to 7 2020 in Pune, India is postponed to 2021.

The International Global Atmospheric Chemistry (in collaboration with the IAMAS sponsored Commission on Atmospheric Chemisry and Global Pollution) meeting planned for September 14 – 18, 2020 in Manchester, U. K. has been postponed to September 12 – 16, 2021 to be held at the same location.

For more information on IAMAS please contact :

Joyce Penner, President (penner@umich.edu)
Steve Ackerman, Secretary General (stevea@ssec.wisc.edu)

Submitted by Joyce Penner, IUGG/IAMAS representative to SCOR, 24 April 2020.

IAPSO – Physical Oceanography

International Association for the Physical Sciences of the Oceans (IAPSO)

http://iapso.iugg.org

INTRODUCTION

IAPSO has the prime goal of 'promoting the study of scientific problems relating to the oceans and the interactions taking place at the sea floor, coastal, and atmospheric boundaries insofar as such research is conducted by the use of mathematics, physics, and chemistry.' IAPSO works mainly through 1) biennial scientific assemblies; 2) working groups; 3) commissions; 4) services; and 5) website information. Of special importance to IAPSO is the involvement of early career scientists as well as those from least developed countries.

IAPSO maintains formal liaison with other scientific commissions and committees. These include the ISC's Scientific Committee on Oceanic Research (SCOR), and UNESCO's Intergovernmental Oceanographic Commission (IOC). For more information see http://iapso.iugg.org/.

ADMINISTRATION

The IAPSO Bureau was renewed in July 2019 during the IUGG General Assembly in Montreal. It comprises:

President:	Trevor McDougall (Australia)
Past President:	Denise Smythe-Wright, (UK)
Secretary General:	Stefania Sparnocchia (Italy)
Treasurer:	Ken Ridgway (Australia)

The Executive Committee comprises the Bureau members and

Vice-Presidents:	Agatha de Boer (Sweden)
	Hans van Haren (The Netherlands)
Members:	Edmo Campos (Brazil)
	Juliet Hermes (South Africa)
	Yukio Masumoto (Japan)
	Jae-Hun Park (Republic of Korea)
	Christa von Hildebrandt-Andrade (USA and Puerto Rico)

Peter Zavialov (Russia)

The IAPSO office is located at the Institute of Marine Science of the National Research Council of Italy, Trieste and day-to-day business is managed by Secretary General (SG), Stefania Sparnocchia. The SG is responsible for the IAPSO website. A page on the Facebook social network is also active with the aim of facilitating the spreading of information in the community (see https://www.facebook.com/iapso.iugg.org). Together with the President, the SG also prepares and distributes a bi-annual Newsletter to IAPSO delegates and interested parties.

IAPSO finances are managed by the Australian-based Treasurer, Ken Ridgway.

IAPSO business meetings were conducted in July 2019, during the IUGG General Assembly in Montreal, Canada. These included three meetings of the Executive Committee, on 8, 9 and 14 July, and one General Business meeting also involving National Correspondents or their Delegates on 11 July. No formal business meetings have been arranged for 2020 and any business will be conducted by email and Zoom where appropriate.

ACTIVITIES

2019 Assembly

The principal activity during 2019 was the IUGG 2019 General Assembly held in Montreal, Canada, from 8-18 July, 2019. The IAPSO scientific sessions were held from 9-14 July and included 11 IAPSO symposia (216 oral presentations and 94 posters) and 5 IAPSO-lead Association Joint symposia (111 oral presentations and 51 posters). IAPSO also co-sponsored 12 Joint symposia led by another Association (189 oral presentations and 104 posters). The program details can be found on the Assembly's website: http://www.iugg2019montreal.com/p.html. Approximately 4000 participants attended this General Assembly, of which 359 registered as IAPSO. There were many quality presentations together with much networking in the corridors.

The IAPSO highlight during the assembly included

- the Union Lecture 'The Ocean's Role in Atmospheric Carbon Dioxide Changes During Ice Age Cycles' given by Prof. Karen Kohfeld (Simon Fraser University, Canada);
- the Prince Albert I, 2019 lecture 'Decadal variability in the ocean CO2 sink' given by Prof. Corinne Le Quéré (University of East Anglia, United Kingdom), who was awarded the Prince Albert I Medal in connection with the lecture;
- the ECS Medal in Physical Oceanography, 2019 talk 'Overturning variability with observations' given by Gerard McCarthy (Maynooth University, Ireland);
- the ECS Medal in Chemical Oceanography, 2019 talk 'Nitrogen fixation across scales' given by Mar Benavides (Mediterranean Institute of Oceanography, France).

IAPSO also awarded a further medal, the Eugene Lafond Medal, to a developing world scientist who gave a notable paper at an IAPSO sponsored or co-sponsored symposium. Following the procedure, presentations (oral or poster) of self-nominating candidates were attended by a subset of the IAPSO Executive Committee and the Eugene LaFond Medal, 2019 was awarded to Mr. Rohith Balakrishnan, for his oral presentation ‘Basin-wide sea level coherency in the tropical Indian Ocean driven by Madden-Julian oscillations’ delivered on July 11, 2019 within the IAG-IAPSO joint symposium ‘Monitoring Sea Level Changes by Satellite and In-Situ Measurements’.

2021 Assembly

IAPSO has been actively organizing the IAPSO-IAMAS-IACS Joint Assembly in Busan, South Korea, 18-23, July 2021, but in early June 2020, in a Zoom meeting held between the Local Organizing Committee and the Presidents and Secretary Generals of IAPSO, IAMAS and IACS, we decided to cancel this in-person joint assembly, due to the COVID-induced uncertainty surrounding international travel. We are now in active discussions regarding what IAPSO on-line activity might occur on these same dates in 2021, and/or whether the meeting in Busan might simply be postponed by twelve months. These decisions are expected to be made in July 2020.

2023 General Assembly

The next General Assembly of IUGG is scheduled for Berlin, 12-19 July 2023.

IAPSO Early Career Scientist Working Group

The IAPSO Early Career Scientist (ECS) Working Group was established in 2018, chaired by Alejandra Sanchez-Franks (United Kingdom) and co-chaired by Malin Ödalen (Sweden). The first IAPSO ECS networking event was organized on 9 July, 2019, during the IUGG 2019 General Assembly, with about 30 early career scientists participating. This IAPSO ECS group has now produced a website (https://www.iapsoecs.org) and a twitter account (https://twitter.com/iapso_ecs?s=20) for this working group, where the newsletters, job and research cruise opportunities and ECS-related events get routinely updated. There are now over 100 members in the IAPSO ECS network signed up to the mailing list. The IAPSO ECS Working Group organized and submitted a review of the Second Order Draft of the Working Group I (WG1) contribution to the sixth IPCC Assessment Report.

IAPSO Best Practice Study Groups

IAPSO has begun to fund IAPSO Best Practice Study Groups, expecting to fund one of these per year. An IAPSO Best Practice Study Group will address an issue whose resolution will assist in the conduct of oceanographic research. In carrying out oceanographic research, a choice must frequently be made between a few options for measuring data, analysing data, processing software, or modelling a system. The reasons for choosing between competing methods are often not well documented and the relative strengths and weaknesses of these routes are usually not published or well known. Each Best Practice Study Group will receive up to US$10,000 towards the costs of a meeting. In January 2020 we chose the first two such IAPSO Best Practise Study Groups (out of nine quality applications), one concerned with the use of data from moored CTD instruments, and the other with the measurement accuracy and interpretation of pH measurements.

SCOR Administration

IAPSO has maintained its formal relations with SCOR during the year. The EC members were involved in the evaluation of the 2019 SCOR Working Group proposals and the President, Trevor McDougall, attended the 2019 SCOR Annual Meeting in Japan.

IUGG 100 years anniversary

Formed in Brussels (Belgium) on 28 July 1919, the International Union of Geodesy and Geophysics (IUGG) celebrated its 100th anniversary in 2019. At the meeting in Brussels in 1919 a Section of Physical Oceanography was also formed, which gave birth to the current IAPSO. The centennial year marks an important milestone for IUGG. Since its inception as a union of international scientific associations, IUGG has developed into a prominent scientific organizations promoting Earth and space sciences worldwide in the complicated political, economic and scientific landscapes of the 20th and the beginning of the 21st centuries. To celebrate the centenary of the IUGG and its Associations, various initiatives were implemented including:

- the implementation of a website that traces the history: http://100.iugg.org/index.php;
- the publication of the special issue of History of Geo- and Space Sciences (HGSS), 'The International Union of Geodesy and Geophysics: from different spheres to a common globe', https://www.hist-geo-space-sci.net/special_issue996.html, including the paper "IAPSO: tales from the ocean frontier", https://www.hist-geo-space-sci.net/10/137/2019/;
- the event 'Centennial International Cooperation in Earth and Space Sciences at the UNESCO Headquarters, Paris, FRANCE, 29 July 2019, program: http://100.iugg.org/events/IUGG_program_Paris_Jul_29_2019.pdf-.
  The Guest of Honour was HMSH Prince Albert II of Monaco and he made reference to the work of his great great grandfather who was the first President of IAPSO and applauded IAPSO's work. In turn Denise Smythe-Wright was able to thank him personally for his support of IAPSO and the IAPSO Prince Albert I medal.

IUGG/IAPSO support to scientific meetings

IAPSO endorsed the following two scientific meetings that were supported by IUGG:

- Workshop on Sea Level Data Archaeology, which took place in Paris, France, 10-12 March 2020.
- Tsunamis in Latin America and the Caribbean: Recent Developments and Plans for the Future, Quito, Ecuador, 3-5 August 2020. This meeting has been postponed due to the covid pandemic.

Submitted by
Trevor McDougall, IAPSO President
Denise Smythe-Wright, IAPSO Past President
Stefania Sparnocchia, IAPSO Secretary General
(June 2020)

APPENDIX 10. PARTNER ORGANIZATION UPDATES

IOC – Intergovernmental Oceanographic Commission

REPORT OF THE INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

I. Introduction: The UN Decade of Ocean Science for Sustainable Development

In December 2017, the United Nations General Assembly proclaimed the United Nations Decade of Ocean Science for Sustainable Development from 2021 to 2030 (hereafter, the Decade), building on the efforts of IOC Member States and the IOC Secretariat. The Decade is a once ina life-time opportunity to deliver a step-change in ocean science and to influence how countries invest, utilize, and participate in science and innovation to embrace societal goals and align research investment to contribute to common goals. The period from 2018 to 2020 is focusing on the preparation of the Decade Implementation Plan that will be submitted to the UN General Assembly for its consideration in 2020. This work is led by IOC, in consultation with Member States and all relevant stakeholders.

The scientific community remained a focus of engagement efforts during this period. A request for submissions to inform the development of the scientific framework of the Decade was sent to partner organizations by the Executive Secretary of the IOC in September 2019. Over 55 detailed written submissions were received in response to this request. The results were used as a primary input to a meeting of the EPG task group on the scientific framework that was held in Washington DC in November 2019. The Decade was the subject of discussions during dedicated sessions, meetings, and side events at a number of ocean science meetings that took place in the period to March 2020 before travel restrictions became widespread due to the Covid-19 pandemic. Key international meetings included OceanObs' 19 September 2019, Honolulu, Hawaii; Our Ocean Conference, October 2019, Oslo, Norway; Oceans'19 MTS, October 2019, Washington, US; AGU Town Hall meeting, San Francisco, USA, December 2019, All-Atlantic Ocean Research Forum - Brussels, Belgium, February 2020; and Ocean Science Meeting 2020 - San Diego, USA, February 2020.

More than 1 900 experts – including numerous representatives of the scientific community - participated in 11 regional consultation workshops co-organized by IOC and institutional partners[4] hosted by the governments of France, Japan, Italy, Brazil, Canada, India, Kenya, Norway, United States of America, and Mexico. Starting in July 2019, the first three regional workshops focused on the Pacific Ocean, and were followed by workshops for the northern and western Indian Ocean, the North Atlantic, the Arctic, the South Atlantic, and the Southern Ocean. Due to the Covid-19 pandemic, a virtual Western Tropical Atlantic Workshop closed the series in April 2020, gathering more than 350 participants, and 4 200 viewers of the live streaming of the event. Organized around the Decade societal outcomes, the workshops allowed for regional interdisciplinary and multi-stakeholder discussions to assess the status of regional ocean research and to co-design mission-oriented research strategies in line with the regional policy requirements. They focused on regional

4 Pacific Community, the Permanent Commission for the South Pacific, Arctic Frontiers, European Commission, UNEP/MAP, Mediterranean Science Commission, the Secretariat of the Cartagena Convention, Universidad Nacional Autónoma de México, the Secretariat of the Nairobi Convention, SCOR, and WIOMSA.

needs and priorities in data and capacity-development and reflected on the potential of transforming knowledge systems, accelerating transfer of technology, and enabling training and education. The regional consultations resulted in the production of a series of summary reports that have been posted online and will be published in the Decade report series.

An Informal Working Group (IWG) of Early Career Ocean Professionals (ECOP) was established in November 2019. The ECOP IWG coordinated a global survey of over 1000 ECOPs to ascertain interest in the Decade and generate suggestions for priority support needs and areas of engagement.

The Executive Planning Group continued to make significant contributions to the preparation phase of the Decade throughout this period. In its January 2020 meeting the EPG endorsed the proposed structure of the Implementation Plan. The resulting zero draft of the Implementation Plan was distributed for peer review between the 20 March and 24 April 2020. The document was distributed to IOC Member States, and shared with over 450 individuals representing scientific organizations, business and industry, philanthropic and corporate foundations, NGOS and civil society and ECOPs. Member States and peer reviewers were asked to submit feedback to the zero draft via an online survey. 228 responses were received to this process. The majority of responses were received from scientific community stakeholders, with responses also received from Member States, business and industry, philanthropic foundations, and NGOs. Most submissions were received from Europe, North America and Australia, with more limited input from Latin America and the Caribbean, South America and the Pacific regions.

A detailed analysis of the feedback received via the above processes was carried out by the IOC Secretariat. Reviewers of the plan provided detailed responses and the analysis revealed a set of clear and common messages to guide revision of the Plan. Overall, reviewers were supportive of the Plan in terms of content and structure, level of detail and length and ease of reading.

The review process culminated in the preparation of the Version 1.0 of the draft Implementation Plan. In addition to questions of clarification and better articulation of key issues, the main changes that were made in the revised version include: the development of a new mission statement to better reflect the ambition of the Decade; the inclusion of a seventh outcome “An inspiring and engaging ocean” to reflect the importance of the cultural and educational values of the ocean; the introduction of ten Ocean Decade Challenges as the most immediate and pressing needs of the Decade that aim to galvanize stakeholders around common priorities; and reworking of the discussion on monitoring and evaluation of the Decade to highlight the process that will be followed to develop a monitoring and evaluation framework that will be endorsed by the Decade Board in 2021. A Summary Version of the Implementation Plan and a Regional Synthesis Report which analyses the outcomes of the regional planning meetings in more detail are also being prepared

The next six months represent a critical phase in the preparation of the Decade. Version 1.0 of the Implementation Plan is currently being reviewed by Member States and UN-Oceans prior to its finalization and presentation to the UNGA in September 2020. A first Call for Actions under the Decade is planned for later in 2020, and guidance on this Call will be disseminated widely in coming months. Looking forward, major events planned to celebrate the start of the Decade in 2021 include the First International Conference in Berlin in May 2020, and dedicated events during the UN Ocean Conference in Lisbon (date TBC).

II. Activities involving close cooperation and coordination between IOC and SCOR

Harmful Algal Blooms
The long-term focus of the IOC Harmful Algal Bloom (HAB) programme is on improved understanding of the factors controlling HAB events and thereby improving management and mitigation options. The scientific key questions have for more than a decade been addressed jointly with SCOR through research programmes. The current decadal IOC-SCOR research programme to meet societal needs in a changing world, entitled GlobalHAB, launched its science and implementation plan in 2017 (www.globalhab.info). GlobalHAB is reported on in detail directly by the GlobalHAB SSC.
The IOC is coordinating and developing its work on HAB through the IOC Intergovernmental Panel on HABs (IPHAB). A number of Task Teams, working groups and activities are operating and reporting to the IPHAB. A core activity is the development of a 'Global HAB Status Report' with the aims of compiling an overview of HAB events and their societal impacts; providing a worldwide appraisal of the occurrence of toxin-producing microalgae; and assessing the status and probability of change in HAB frequencies, intensities, and range resulting from environmental changes at the local and global scale. The development of this report is intimately linked with the systematic compilation of HAB data in OBIS and the IOC Harmful Algal Event Data base HAEDAT and is funded by Flanders and cosponsored by the IAEA.

Time Series
Since 2013 the establishment of an interdisciplinary IOC working group, the International Group for Marine Ecological Time Series (IGMETS), has offered the possibility to improve model projections and forecasts needed to understand open ocean and coastal changes. The collected information addresses new scientific questions and serves a well-established community of practice related to ship-based time series. The interdisciplinary character of IGMETS provides new scientific insights to improve model projections and forecasts needed to understand open ocean and coastal changes. IGMETS met on 7-9 November 2018 at IOC HQ to develop the scope its second report (read the first IGMETS report at https://igmets.net/report).

Since 2016 an IOC Group of Expert has worked specifically to investigate Climate Change and Global Trends of Phytoplankton in the ocean, in particular the coastal ocean (TrendsPO). The Group continues the comparative analysis and synthesis of long time series data sets compiled by SCOR WG137, and expands the focus not only to the continental shelf and open oceans, but also to estuarine and upstream freshwater ecosystems where perturbations from terrestrial, atmospheric, oceanic sources and human activities converge to cause changes that ramify across local and global scales. TrendsPO is working on a plan for a Phyto-GOOS with BIO-ECO GOOS members. The Phyto-GOOS implementation is foreseen to at least cover all the Large Marine Ecosystems over a ten-year period.

De-oxygenation
De-oxygenation is a global problem in coastal and open regions of the ocean, which has led to expanding areas of oxygen minimum zones and coastal hypoxia. In the coastal ocean, the number of reported dead zones has increased exponentially since the 1960s, with more than 600 systems catalogued now. The recent expansion of hypoxia in coastal ecosystems has been primarily attributed to global warming and enhanced nutrient input from land and atmosphere. The global extent and threat of ocean deoxygenation to human health and marine ecosystem services are just beginning to be appreciated; the related social and economic consequences have yet to be determined but are likely to be significant.
In order to raise increase the scientific capacity globally the IOC Global Ocean Oxygen Network (GO2NE) working group organized the first international GO2NE Summer School, held from September 2 to 8, 2019 in China at Xiamen University Xiang'an Campus, which hosts the State Key

Laboratory of Marine Environmental Science. SCOR supported the participation of two young researchers. The summer school was attended by 37 students from 19 countries. The IOC Secretariat further coordinated the input to the WMO Climate Change bulletin (published in March 2020) addressing deoxygenation in the ocean in 2019; it also contributed to the production and launching at the UNFCCC COP25 of a major book on ocean deoxygenation coordinated by IUCN.

Multiple Stressors

In 2019 the IOC established an international Group of Experts which aims at identifying main ocean stressors and their interaction, with a view to elucidating possible actions related to ecosystem-based management (EBM).

The Working Group is composed of approximately 20 experts, the majority of whom are co-chairs of relevant IOC working groups (GOA-ON, GO2NE, HABs, TrendsPO, BCI, GESAMP WG 40 and nutrients), with the addition of expertise, including EBM, with a geographic and gender balanced representation. The group met for online workshop in March 2020 and used this opportunity to further develop and draft the publication 'Ocean under Stress: Managing a Changing Ocean at All Locations', which will be published during the second half of 2020.

Enhancing oceanography capacities in CCLME Western Africa countries (Eastern Boundary Upwelling Systems – EBUS)

Since 2013, the IOC has worked in the implementation of the project *Enhancing oceanography capacities in the CCLME Western Africa countries*. The overall goal of its third phase was to improve the existing knowledge on the possible effects of climate change on the Canary Current Eastern Boundary Upwelling System (EBUS) and to continue building regional science capacity in such knowledge.

Since a technical workshop held in 2018, coordination efforts have focused mainly on the implementation of the work packages included in the Research and Capacity Development Agendas for phase III of the project. With regards to the Research Agenda and based on the desktop research carried out, a data archive comprising 327 primary production *in situ* data points from 20 studies for the different EBUS was produced. A new layer will be made available in the CCLME Eco-GIS Viewer (http://www.ideo-cclme.ieo.es). A case study was elaborated as a first attempt to calibrate available satellite-based primary production estimates with *in situ* measurements in the Canary region near the NW-African coastal upwelling (from IEO surveys).

In what refers to the Capacity Development Agenda, significant progress was made in the inventory of capacity development programmes in the region. The list of training programmes now contains a total of 49 programmes, including University degrees, Master programmes and PhD programmes in 5 countries, as well as 9 international exchange programmes.

A Training Workshop on "The Canary Current Eastern Boundary Upwelling System" was held at the Ocean Science Centre Mindelo on 10-12 March 2020. The training was addressed to young researchers (post-graduate students and post-docs) from the countries in the region (Cabo Verde, Gambia, Guinea, Mauritania, Morocco, Senegal and Spain) whose research focuses on the Canary Current EBUS dynamics, biogeochemical processes or ecological processes. The meeting was attended by a total of 20 participants from 13 organizations in 8 countries (Cabo Verde, France, Gambia, Guinea, Mauritania, Morocco, Senegal and Spain). Trainers included one expert from SCOR WG155 on "EBUS: Diversity, coupled dynamics and sensitivity to climate change". 14 trainees benefited from the training, with equal participation of men and women.

A project meeting was organized back to back, on 13 March 2020. Its main aim was to provide room for discussions on the work carried out within the third phase of the project and on future regional and interregional cooperation on EBUS. A total of 16 participants attended the meeting, including 3 members of SCOR WG 155.

The Spanish Agency of International Development Cooperation (AECID) accepted a concept note for a phase IV of the project, which will allow, among other outcomes, a full implementation of the

Research and Capacity Development Agendas proposed within project's phase III, specific action on gender issues and to strengthen IOC collaborations with similar efforts on capacity development on EBUS, like the WCRP CLIVAR "Research Focus EBUS" and SCOR WG 155. This new project will frame IOC's contribution to the SCOR Summer School on EBUS (dates to be determined) and to the organization of the Conference on Open Science in EBUS, to be held in Lima (Peru) in 2021.

III. Other activities of actual or potential interest to SCOR

Ocean acidification

In view of the growing urgency and recognition of ocean acidification as one of the major stressors for the marine environment, improved observation and research are needed to help scientists and governments in implementing related mitigation and adaption measures.

IOC-UNESCO actively provided technical support to Member States to report towards the Sustainable Development Goal indicator 14.3.1, focusing on ocean acidification in theframework of sustainable development. The Commission provides the methodology guiding scientists and countries in terms of how to carry out measurements following the best practices established by the ocean acidification community. In this way, IOC and its networks, including the Global Ocean Acidification Observing Network (GOA-ON), directly contribute to the achievement of SDG Target 14.3. The Commission, together with its ocean acidification expert working group, is developing an IOC manual focusing on the 14.3.1 methodology, to be published in the third quarter of 2020, ahead of the second call for data submissions towards the SDG 14.3.1 Indicator.

The first call to Members States and researchers for the collection of data towards the SDG 14.3.1 Indicator was launched in late 2019. Data was submitted mainly through the 14.3.1 Data Portal, an online tool to facilitate the collection and quality control of ocean acidification data, developed by IOC and IODE. The Commission gave an account of the data collected towards the SDG 14.3.1 in its annual contribution to the UN SDG Report.

The IOC further contributed on ocean acidification to the WMO annual Statement on the State of the Global Climate. This is only the second year that ocean acidification is included in the Statement as one of the seven Global Climate Indicators. The IOC Secretariat also contributed to a Community White Paper for the OceanObs'19 conference, highlighting the 14.3.1 methodology. IOC co-organized the annual GOA-ON Executive Council meetings in 2019 (Hangzhou, China), and further actively supported and participated in the 4th international GOA- ON Workshop (14-17 April 2019, Hangzhou, China). IOC supported several side events at the UNFCCC COP25 highlighting ocean acidification together with members of the GOA-ON Executive Council and regional hubs. IOC will further support the 5th International Symposium on the Ocean in a High CO2 World, and the GOA-ON Executive Council Meeting in September 2021 in Lima, Peru.

GOA-ON has now more than 730 members from 100 countries (in 2015 there were 150 scientists from 31 countries) and is constantly growing; currently 23 SIDS and 23 African countries are represented in GOA-ON. This is also thanks to IOC engagement and involvement in Ocean Acidification projects in the Caribbean, the Middle East and East Africa. The network supports a scientific mentoring programme, Pier2Peer, and an online Explorer showcasing ocean acidification observing platforms. GOA-ON is planning a webinar series on ocean acidification beginning in September 2020 and invites expression of interest for presentations.

Nutrient's coastal Impacts research
Nutrient over-enrichment of coastal ecosystems is a major environmental problem globally, contributing to problems such as harmful algal blooms, dead zone formation, and fishery decline. Yet, quantitative relationships between nutrient loading and ecosystem effects are not well defined. The IOC Nutrients and Coastal Impacts Research Programme (N-CIRP) is focusing on integrated coastal research and coastal eutrophication and linking nutrient sources to coastal ecosystem effects and management in particular. As part of the implementation strategy for N-CIRP, IOC actively participates in a UN Environment led ´Global Partnership on Nutrient Management' (GPNM) with intergovernmental organizations, non-governmental organizations and governments. GPNM has an online information portal to enable GPNM partners to monitor progress on implementing activities related to the sustainable use of nutrients. IOC-UNESCO supports the development of the indicators for SDG 14.1, for which UN Environment is the custodian agency. A task force, which includes experts from IOC-UNESCO and GESAMP, the UN Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, supported by the Group on Earth Observation (GEO) Blue Planet, was established to provide the technical expertise during the course of the development of the methodology for the indicator. The core focus of IOC-UNESCO is to contribute to the development of the Index of Coastal Eutrophication (ICEP). Currently, IOC UNESCO together with UN Environment is soliciting for funding to finalize the Silica component of the model and for testing it.

Microplastics
Plastics form a large proportion of marine litter, and the widespread occurrence of macroscopic plastic debris and the direct impact this can have both on marine fauna and legitimate uses of the environment, sometimes remote from industrial or urban sources, has grown rapidly. Lately the existence of micro-plastics and their potential impact has received increasing attention. The extent of the impact of plastic litter in the oceans is uncertain, despite the considerable scientific effort that has been expended in recent years.
GESAMP Working Group 40 on 'Sources, Fate and Effects of plastics and micro-plastics in the marine environment', led by IOC and UNEP, was initiated in 2012. The Working Group has published guidelines on how to monitor plastics in the ocean, This set of publicly-available guidelines for monitoring plastics and microplastics in the oceans will help harmonize how scientists and others assess the scale of the marine plastic litter problem (read more at http://www.gesamp.org/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in-the-ocean). The focus for 2020–2021 is on an overview of risks associated with marine plastic litter; environmental risk from nano- and microplastics; and human health risks associated with nano- and microplastics.

Blue Carbon
The Blue Carbon Initiative, established in 2011 by the IOC, the International Union for the Conservation of Nature (IUCN) and Conservation International (CI), works to synthesize, scientific and technical knowledge, including policy mechanisms, for ensuring the conservation, restoration and sustainable use of coastal blue carbon ecosystems. The IOC is highly involved in the Blue Carbon Scientific Working Group, which provides the scientific foundation for the Blue Carbon Initiative by synthesizing current and emerging science on blue carbon assessment, conservation and management. Priority research activities coordinated by the Scientific Working Group are conducted in close partnership with the Initiative's Policy Working Group. IOC is further a coordinating member of the International Blue Carbon Partnership, a body that brings together governments, NGOs, IGOs and UN-Agencies.
IOC co-organized and co-sponsored the International Blue Carbon Initiative (BCI) annual meeting in in September 2019 in Denmark. IOC further supported several side events during the UNFCCC COP25 highlighting the potential of Blue Carbon Ecosystems as a Nature Based Solution to be applied in the NDCs to mitigate climate change.

Integrated Ocean Carbon Research
In 2018, the IOC Executive Council considered a note prepared by the IOC Secretariat on recent developments related to ocean carbon research and the landscape of ocean carbon research activities. Scientific considerations included the need for generating new knowledge on the role of ocean carbon in climate regulation and on the effects of climate change on ocean carbon, including carbon biology, thus responding to growing needs for such knowledge from relevant initiatives and processes, namely the IPCC (also taking into account the findings and knowledge gaps in the IPCC Special Report on Ocean and the Cryosphere, in due course) and scientific and technical work related to requests formulated by the UNFCCC and its Subsidiary Body on Scientific and Technical Advice (SBSTA).

The global ocean carbon research community is constituted by several initiatives carried out in the context of: the International Ocean Carbon Coordination Project (IOCCP); the Surface-Ocean Lower Atmosphere Study (SOLAS), the Integrated Marine Biosphere Research (IMBeR); the Global Carbon Project (GCP); WCRP's core project on Climate and Ocean Variability, Predictability and Change (CLIVAR), and numerous other relevant activities of IOC itself. Relevant national efforts on carbon research, as exemplified by the Ocean Carbon and Biogeochemistry programme under the US Carbon Cycle Science Program, contribute directly to such global efforts on ocean carbon research. Historically IOC played a central role in federating the global ocean carbon research community through the SOCOVV workshop held in April 2007 at IOC's headquarters and follow-up meetings. IOC had supported the creation of IOCCP in the early 2000s, building on joint efforts of IOC during the previous two decades with SCOR and ICSU, including the CO_2 Advisory Panel of the Committee on Climate Change and the Ocean and the subsequent Joint SCOR-JGOFS-CCCO Advisory Panel on Ocean CO_2. IOCCP was hosted at, and its secretariat supported by, IOC until 2012. IOCCP is co-sponsored by IOC and SCOR.

The IOC Executive Council concluded that these developments indicated the need to strengthen the IOC Ocean Science portfolio's focus related to ocean carbon, responding to the demand for such coordinating role by the scientific community. The IOC Executive Council noted that while IOCCP tends to focus on ocean carbon observations, assisting in the development of new needed technology, and developing relevant capacity, there is a continuous need for an integrative platform on ocean carbon research, and a clear role for IOC therein.

The discontinuation in 2017 of the IMBeR and SOLAS carbon working groups that, based on the Joint SOLAS/IMBeR Carbon Implementation Plan, were charged with coordination and synthesis of ocean carbon research related to both ocean surface and ocean interior, had created the need for such a new federating initiative on ocean carbon research. This would contribute to inter alia better-coordinated ocean carbon cycle simulations in the context of CMIP6 and of the Global Carbon Project's efforts to establish annual global carbon budgets with reduced uncertainty for each iteration.

The executive Council therefore decided to establish the IOC Working Group on Integrated Ocean Carbon Research, which will operate in in cooperation with IOCCP, IMBeR, SOLAS, WCRP/CLIVAR and GCP.
Some 30 experts designated by the above-mentioned organizations and programmes met at a workshop organized by IOC in Paris from 28 to 30 October 2019. As a result, a synthesis report on ocean carbon: current knowledge, gaps, and related research and observation requirements was prepared and is currently being finalized for consideration by the IOC governing bodies later in the year. This document will also be presented to the attention of the UNFCCC SBSTA and the Research Dialogue and the Ocean and Climate Dialogue convene under the auspices of the Subsidiary Body.

IV. Potential future IOC and SCOR cooperation

The IOC and SCOR have long successfully cooperated and thereby strengthened research and scientific programmes.
The IOC Secretariat looks forward to sharing with SCOR its views on those proposals for new and to-be-renewed SCOR Working Groups that more closely reflect the current priorities of IOC in the area of ocean science.

PICES - North Pacific Marine Science Organization

SCOR and PICES Collaborative Activities

Report from PICES for the 2020 Virtual SCOR Meeting
(19-23 October 2020)
Prepared by Hal Batchelder

The North Pacific Marine Science Organization (PICES) is an intergovernmental scientific organization established by an international convention in 1992, in order to promote and coordinate marine scientific research in the North Pacific and adjacent seas. Our current member countries are Canada, Japan, People's Republic of China, Republic of Korea, Russian Federation and the United States of America. PICES' goals are to (1) advance scientific knowledge and capacity available for the member countries, including information on human activities affecting, and affected by marine ecosystems, and (2) provide a mechanism for collaboration among scientists in addressing timely and critical scientific questions about the North Pacific. In the 28 years since its establishment, PICES has become a major forum for the discussion and sharing of marine science in the North Pacific. Information on the Organization and its activities is available on the PICES website at http://www.pices.int.

SCOR and PICES have developed cooperative methods that have made it possible for an international non-governmental organization and a regional intergovernmental organization to share their strengths. Continuing and expanding collaboration between PICES and SCOR is based on the recognition that PICES can play an important role in bringing a North Pacific perspective to the global activities of SCOR, and that by participating in and implementing these activities in the region, PICES can advance its own scientific agenda. PICES contributes scientific expertise to SCOR-sponsored international large-scale ocean research projects (HABS [GlobalHAB], IMBeR, SOLAS, GACS [Global Alliance of Continuous Plankton Recorder Surveys]), to ocean carbon activities (IOCCP [International Ocean Carbon Coordination Project]) supported by SCOR, and to several SCOR Working Groups. SCOR working groups supported by PICES have included WG125 (Global Comparisons of Zooplankton Time Series), WG134 (The Microbial Carbon Pump in the Ocean), WG137 (Patterns of Phytoplankton Dynamics in Coastal Ecosystems: Comparative Analysis of Time Series Observation), WG146 (Radioactivity in the Ocean, 5 decades later), WG149 (Changing Ocean Biological Systems (COBS): how will biota respond to a changing Ocean), WG154 (Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS), and WG155 (Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change). **In addition to the above, PICES and SCOR are both strong proponents of capacity building.**

To discuss on-going and future collaborations, SCOR and PICES continue to irregularly exchange observers to the others annual/executive meetings. In recent years, SCOR was represented by Dr. Sinjae Yoo (Korea) at the PICES-2014 annual meeting in Yeosu, Korea, Dr. Sun Song, Vice-president of SCOR at the PICES-2015 annual meeting in Qingdao, China, and Edward Urban at the PICES-2016 meeting in San Diego, USA. Dr. Harold Batchelder (PICES Deputy Executive Secretary, liaison member of SCOR Capacity Building Committee) attended the 2013 SCOR Executive Committee Meeting (Wellington, New Zealand), the 2014 SCOR meeting (Bremen, Germany), the 2015 meeting in Goa, India, the 2016 meeting in Sopot, Poland, the 2018 meeting in Plymouth, UK, and the 2019 meeting in

Toyama, Japan. A written report and presentation of PICES activities in 2017 was prepared by PICES and presented by Song Sun (China) on behalf of PICES at the 2017 SCOR meeting in Cape Town, South Africa. According to our records, SCOR was not represented at PICES-2017 in Vladivostok nor PICES-2018 in Yokohama, Japan. Sinjae Yoo officially represented SCOR at the PICES-2019 annual meeting in Victoria, BC, Canada (16-27 Oct 2019).

This report provides an update on PICES-SCOR collaborations since the 2019 SCOR Meeting in Toyama—a period that includes the PICES Annual Meeting, which was held in Victoria, BC, Canada (Oct 16 – 27, 2019). The MSEAS (Marine Socio-Ecological Systems) International Meeting scheduled for May 2019 was postponed for a year due to the COVID-19 pandemic and the inability of many of the participants to obtain travel permission early in 2020 given the pandemic. It is currently scheduled to be held in Yokohama in 2021, but that remains uncertain until more is known about the ongoing severity of the COVID-19 pandemic. **The PICES Annual Meeting in October 2020 will be a virtual meeting.**

PICES is greatly appreciative of SCOR's long standing financial support, since it is difficult for PICES to fund participants from non-PICES countries to our annual meetings and sponsored international activities.

Examples of such sponsored international activities in the recent past are:

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

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

(3) SCOR provided $5200 USD to PICES on behalf of SOLAS to support international travel of scientists from developing countries to attend the 4th Effects of Climate Change on the World's Oceans Symposium (ECCWO-4) in Washington, DC, 2-9 June 2018.

For the PICES 2019 Annual Meeting in Victoria, BC in October, SCOR provided substantial funding ($10,000 USD) from the GlobalHAB program budget to support a 2.5 day Workshop (17-19 October 2019) titled "**W18:** ***GlobalHAB: Evaluating, Reducing and Mitigating the Cost of Harmful Algal Blooms: a Compendium of Case Studies***", which is cosponsored by SCOR, ISSHA, NOWPAP, Greig Seafood Ltd., IOC UNESCO, GlobalHAB, and AXA XL Insurance). Efforts are underway to produce a series of papers to be published and archived on the PICES web page.

Workshop (W18) Description: Over the last 2 decades, several reports have compiled what is known about the economic effects of harmful algal blooms. Most coastal regions have neither conducted economic analyses of HABs nor collected data that can be used to generate reliable quantitative estimates of net economic losses and economic impacts. Better estimates of the economic impacts of HABs will require coordination among HAB scientists and economists. This 2.5 day international workshop brought together expertise in the science of HABs and economics to review and analyze case studies for the study of economic impacts of HABs on fisheries and aquaculture. The workshop structure was:

Day 1 (1/2 day): Overview of Economics and HABs, Analysis of U.S. west coast impacts. *The discussion were focused on types of economic assessment that will guide our discussions of case studies on workshop day 2.*
Day 2 (full day): Case studies: examples of HAB impacts to wild fisheries, recreational fisheries and aquaculture worldwide. *The discussions were focused on what economic studies can be done in the future and where the data gaps are.*
Day 3 (full day): Mitigation strategies, Value of Information. *The discussions were focused on the value of HAB forecasts. Wrap up and writing assignments.*
The output of this workshop is a compendium of examples describing economic approaches used to estimate the costs of HABs and their mitigation, focusing on establishing connections between HAB scientists and economists. A shorter version of the compendium may be prepared for submission to a journal. In addition, the workshop will (1) propose priorities for research and effective management in the future, (2) develop partnerships between economists and HAB researchers to develop transdisciplinary projects, and (3) attract resources to the field. There are currently 6 chapters and an appendix with definitions of concepts and terminology. These chapters will be published as a PICES Special Publication by late summer 2020 and will be posted on both the PICES and GlobalHAB websites.

CHAPTER 1: GlobalHAB Workshop: Evaluating, Reducing and Mitigating the Cost of Harmful Algal Blooms, a Compendium of Case Studies

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CHAPTER 2: Evaluating the economic impacts of harmful algal blooms: Issues, methods, and examples

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CHAPTER 3: Economic Impacts and Management of Cochlodinium in Korea

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CHAPTER 4: An Economic Assessment of Ciguatera Fish Poisoning Outbreaks—An Island Model

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CHAPTER 5: Estimating and mitigating the economic costs of harmful algal blooms on commercial and recreational shellfish harvesters

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CHAPTER 6: The economic impacts of harmful algal blooms on salmon cage aquaculture

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CHAPTER 7: Conclusions and Recommendations

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APPENDIX 1. Definition of Economic Concepts and Terminology

Benefits: the benefits people get from something are equal to the maximum amount they are willing to pay for it.
Consumer surplus: the difference between the price that consumers pay and the price that they are willing to pay.
Cost-benefit analysis: measuring changes in economic value associated with a project, policy, or event.
Costs: the costs of something are all expenditures of productive resources or inputs required to produce it.
Counterfactual analysis: in the case understanding the impacts of a harmful algal bloom (HAB), a counterfactual analysis compares observed outcomes to a counterfactual, or what would have happened without the HAB.
Economic impact analysis: measuring changes in economic outcomes, such as income and employment.
Economic value: economic value, also referred to as economic welfare, is the sum of consumer and producer surplus and any external costs and benefits.
External benefits: benefits generated with the production or consumption of a good that are not considered by the producer or consumer, because they are not compensated for these benefits.
External costs: costs generated with the production or consumption of a good that are not considered by the producer or consumer, because they do not pay for the costs.
Externalities: any external benefits and costs.
Market demand curve: aggregates the quantity demanded by all consumers in the market for each price.
Market supply curve: aggregates the quantity supplied by all firms in the market for each price.
Markets: institutions in which buyers and sellers of goods and services carry out mutually agreed-upon exchanges.
Opportunity costs: the maximum value we give up by doing one thing instead of something else.
Private goods: must be bought in order to be consumed and whose ownership is restricted to the group or individual that purchased the good.
Producer surplus: the difference between the price that producers receive and the price that they are willing to accept.
Race to fish: harvesters compete with each other to capture the fish first.
Variable costs: costs that change when the quantity produced changes.
Willingness to accept (WTA): the minimum amount a producer would sell their product for.
Willingness to pay (WTP): the maximum amount a consumer would pay for a good.

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HARMFUL ALGAL BLOOM ACTIVITIES SUPPORTED BY SCOR

Co-sponsored symposia/conferences/workshops
PICES partnered with GEOHAB (with ICES and NOAA as other sponsors) in organizing and funding the workshop on "*Harmful algal blooms in a changing world*" (March 18–22, 2013, Friday Harbor, WA, U.S.A.) to assess the state of knowledge on HABs and climate change, and to identify the most critical research needs that can realistically be addressed over the next 5–10 years. The findings were published in the peer-reviewed journal *Harmful Algae*. Wells, M.L., V. L. Trainer, T. J. Smayda, B.S.O. Karlson, C.G. Trick, R.M. Kudela, A. Ishikawa, S. Bernard, A. Wulff, D. M. Anderson, W.P. Cochlan. 2015, Harmful algal blooms and climate change: Learning from the past and present to forecast the future. Harmful Algae, 49 (2015), 68–9.
SCOR generously provided $10,000 USD to support a 2.5 day Workshop at PICES-2019 (17-19 October 2019) titled "*GlobalHAB: Evaluating, Reducing and Mitigating the Cost of Harmful Algal Blooms: a Compendium of Case Studies*". More details about this workshop and SCOR's participation is in earlier text of this document.

Under GlobalHAB Theme 12. Climate Change
• **Economic Impacts of HABs workshop** – held in October 2019 in conjunction with the PICES Annual Meeting in Victoria, BC (this is described above W18).

• • **Special issue in *Harmful Algae*** (information from Chris Gobler). This special issue is complete and papers are listed below.
• • **Best-practices Manual** (information from Marina) – The first meeting was held in Napoli on 26 Feb.-1 March 2018. They discussed interactions with SCOR WG 149 (COBS). The idea is not to build a manual for all possible scenarios. This item has not been updated since last year's annual meeting, so may be dated.

Climate Change and HABs: Special Issue of Harmful Algae (Final)
1. Climate Change and Harmful Algal Blooms: Insights and perspective

Christopher J. Gobler
2. Pelagic harmful algal blooms and climate change: Lessons from nature's experiments with extremes

Vera L.Trainer, [a]Stephanie K.Moore, [a]GustaafHallegraeff, [b]Raphael M.Kudela, [c]Alejandro Clement, [d]Jorge I.Mardones, [e]William P.Cochlan[f]
3. Perspective: Advancing the research agenda for improving understanding of cyanobacteria in a future of global change
M.A Burford, C.C Carey, D.P. Hamilton, J. Huisman, A. Wulff
4. Climate change and harmful benthic microalgae
Patricia A. Tester, R. Wayne Litaker, Elisa Berdalet
5. Cyst-forming dinoflagellates in a warming climate
Michael L. Brosnahan, Alexis D. Fischer, Cary B. Lopez, Stephanie K. Moore, Donald M. Anderson
6. Basin-specific changes in filamentous cyanobacteria community composition across four decades in the Baltic Sea
Malin Olofsson, Sanna Suikkanen, Justyna Kobos, Norbert Wasmund, Bengt Karlson
7. Dynamic CO_2 and pH levels in coastal, estuarine, and inland waters: Theoretical and observed effects on harmful algal blooms
John A. Raven, Christopher J. Gobler, Per Juel Hansen
8. Harmful algae at the complex nexus of eutrophication and climate change

Patricia M. Glibert
9. Harmful algal blooms: A climate change co-stressor in marine and freshwater ecosystems
Andrew W. Griffith, Christopher J. Gobler
10. Progress and promise of omics for predicting the impacts of climate change on harmful algal blooms

Gwenn M.M. Hennon, Sonya T. Dyhrman
11. Modelling HABs in a changing climate

David K Ralston and Stephanie K. Moore.
12. The Future of HAB Science: Directions and challenges in a changing climate, Mark Wells, Bengt Karlson, Angela Wulff, Raphe Kudela, Charles Trick, Valentina Asnaghi, Elisa Berdalet, William Cochlan, Keith Davidson, Maarten De Rijcke, Stephanie Dutkiewicz, Gustaaf Hallegraeff, Kevin J. Flynn, Catherine Legrand, Hans Paerl, Joe Silke, Sanna Suikkanen, Peter Thompson, Vera L. Trainer

OCEAN CARBON ACTIVITIES SUPPORTED BY SCOR

Communication/coordination

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

Scientific Activities

✦ Ocean acidification has been proceeding for a century, at an accelerating rate, and its impacts are beginning to be felt in many corners of the North Pacific. A workshop on "*Acidification of the North Pacific Ocean: a basin-wide assessment*" was held on November 3, 2016 at the PICES Annual Meeting in San Diego, CA. It was well attended, and brought together scientists from all of the PICES countries to synthesize observations and projections of acidification processes and impacts in our respective countries' waters and adjacent international waters. The workshop is the culmination of a two-year long process of collation of relevant information, and synthesis of data collected in each of the countries of the North Pacific basin. The workshop proceedings will form the basis for subsequent assessments, with improved understanding of which ocean regions are most vulnerable to acidification impacts, and how additional resources might best be deployed to predict or detect changes likely to produce significant impacts. There were several topical presentations, as well as individual national updates and extensive discussion of the contents of the proposed assessment and strategies for completing it.

✦ During the past two years a group led by the co-chairs (James Christian (CAN) & Tsuneo Ono (Japan)) of the PICES Section on Carbon and Climate (S-CC), worked with other contributing authors to complete the document. **It was published as PICES Special Publication No. 5, and titled "*Ocean Acidification and Deoxygenation in the North Pacific Ocean*"**.

SCOR WORKING GROUPS

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

✦ PICES currently supports Associated Members for three SCOR Working Group: o WG 149 on *Changing Ocean Biological Systems: how will biota respond to a changing ocean? (COBS)* (Dr. Uta Passow, USA, Assoc. Member) – This WG was approved in late 2015, so should be completing its tasks in 2019.

o WG 154 on *Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)* (Dr. Sonia Batten, Canada, Assoc. Member)—This WG was approved in late 2017, and is holding their third meeting in September 2019.

o WG 155 on *Eastern Boundary Upwelling Systems: Diversity, Coupled Dynamics and Sensitivity to Climate Change (EBUS)* (Dr. Ryan Rykaczewski (USA); Note also that Dr. Enrique Curchitser (USA) is a full member of EBUS and the Vice Chair of PICES.—This WG was also approved in late 2017, and met for the first time in Washington DC immediately prior to the ECCWO-4 Symposium. I am unsure if there has been a second meeting, as there is not information about other meetings on the website.

✦ PICES provided partial support to Sonia Batten to participate in the first P-OBS meeting immediately prior to the AGU Ocean Sciences meeting in Portland, OR in February 2018, and partial support to Ryan Rykaczewski to participate in a 2-day meeting of EBUS immediately prior to the 4th Symposium on the Effects of Climate Change on the World's Oceans, held in Washington, DC in early June 2018.

CAPACITY BUILDING

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

✦ SCOR provides travel support for scientists from countries with "economies in transition" to participate in SCOR-relevant sessions/workshops at PICES Annual Meetings, international symposia and capacity building events led/co-organized by PICES. For this reporting period, funding from the SCOR/NSF fund was provided/committed for the following event, and there is one other request pending with SCOR (see below):

✦ $5,000 USD (~6,650 CAD) for the PICES-2019 Annual Meeting "*Connecting Science and Communities in a Changing North Pacific*", which occured from 16-27 October 2019 in Victoria, BC, Canada. The scientists to be offered partial travel support from SCOR are Samuel Akande (Nigeria; 1200 CAD), Basheer Ahamedd KK (India; 1000 CAD), Pengbin Wang (China; 1000 CAD), Maria Shulgina (Russia; 1000 CAD), Jianchao Li (China; 1000 CAD), Gloria S. Duran (Peru; 1000 CAD), and Baolan Wu (China; 450 CAD).

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

Past PENDING REQUEST for Consideration by SCOR
(IGNORE THIS: NO DECISION BY SCOR): Travel support in the amount of $5000 USD has been requested from SCOR for scientists from countries with "economies in transition" to attend sessions and workshops at the MSEAS-2020 Symposium that will be held 24-28 May 2020 in Yokohama, Japan. **NOTE: THIS REQUEST WAS NOT ACTED UPON AS IT BECAME CLEAR THAT THE MAY 2020 MSEAS WOULD BE POSTPONED TO MAY 2021 DUE TO THE COVID-19 ACTIVITY.**
CURRENT REQUEST for Consideration by SCOR
(**PENDING WITH SCOR**): Travel support in the amount of $5000 USD has been requested from SCOR for scientists from countries with "economies in transition" **to attend sessions and workshops at the MSEAS-2021 Symposium that will be held ca. 24-28 May 2021 in Yokohama, Japan.**

GESAMP WORKING GROUP 38

THE ATMOSPHERIC INPUT OF CHEMICALS TO THE OCEANS

Annual Report to SCOR by the Co-Chairmen of GESAMP Working Group 38

http://www.gesamp.org/

Robert Duce and Timothy Jickells

July, 2020

During the past year GESAMP WG 38 has focused its attention in three areas: 1) Development of a workshop on the ocean management and policy implications of the air/sea exchange of chemicals; 2) Development of a workshop on the atmospheric transport of microplastics to the ocean; and 3) Completion of the peer-reviewed publications arising from the 2017 workshop "The impact of the changing acidity of the ocean and atmosphere on the air/sea exchange of chemicals", as well as from other WG 38 activities.

Development of a workshop on the ocean management and policy implications of the air/sea exchange of chemicals

Plans have been developed, funds have been obtained from several UN agencies and from SOLAS, and individuals have been invited for a workshop which was to be held in October, 2020 at Nelson Mandela University, Port Elizabeth, South Africa, entitled **"What is the potential role of atmospheric deposition in driving ocean productivity in the Madagascar Channel and Southwest Indian Ocean – an adaptive-dynamic management approach within Large Marine Ecosystems".** Unfortunately, due to COVID-19, this in-person workshop has now been postponed, likely until October, 2021. This workshop, which would include international scientists, managers, and policymakers, would evaluate the atmospheric inputs and impacts of nutrients from biomass burning and industrial emissions, with the following objectives:

- To evaluate the current knowledge of the atmospheric inputs into the southwest Indian Ocean and scientific evidence for the factors that control algal blooms in this region, including the potential role of atmospheric deposition, and the confidence in our understanding of these factors.
- To debate the associated potential impacts and management implications with a broader group of stakeholders/experts (including social scientists and economists)
- To present this information to decision-makers at the senior management and policy level for their response and advice on adaptive management steps
- To identify the feasibility of institutionalising such an adaptive/dynamic management process at the regional level and linking it into national management processes.

- In parallel with this process, to introduce young and emerging scientists to the debate and the science involved and to build capacity for this dialogue within the region.

The workshop will bring together leading scientists who are recognized experts in their field (atmospheric chemists, oceanographers, etc.) to confirm the status of knowledge and its 'confidence' and to identify any emerging trends that may need further resolution. We had already invited a group of senior scientists who had responded very enthusiastically to this workshop plan. This group have also understood the need for a postponement and indicated they still wish to be involved when the workshop is rescheduled. The workshop will also bring in other expertise from the fisheries sector (private and public) as well as socio-economists and environmental managers to elaborate on the implications and discuss potential 'next steps'.

It will also include senior managers and decision-makers (i.e., Permanent Secretaries, Directors-General, Ministers) for their consideration of the management implications and the reality of being able to respond in an adaptive and dynamic manner within their national and/or regional needs and priorities. At the Capacity Building level, the audience will be young undergraduates with science or management majors, graduate students, and early career scientists from Africa with a focus on those having interest/expertise in marine systems and who will hopefully go on to work in this field of science or become managers themselves.

The Workshop has a set of expected Outputs to be delivered both within and beyond the attendees:

- A clearer understanding of the role of atmospheric nutrient input within the southwest Indian Ocean and its possible role as a 'driving' mechanisms for phytoplanktonic blooms and associated food chains
- Positive demonstration to scientists, managers and policy-makers of how a Trends Analysis and 'weight-of-evidence' approach can be used for the furtherance of adaptive/dynamic management to their mutual advantage
- Identification of a process whereby such an adaptive/dynamic management approach could be adopted and used at both the national and regional level.
- Furthermore, if we have sufficient information and an effective 4-day process, we are also considering a 'Special Issue' of papers covering the workshop's results. This special edition would include the relevant new scientific knowledge as presented during the workshop and would lead into a final paper or papers describing the dynamic ecosystem management process.

Development of a workshop on the atmospheric transport of microplastics to and from the ocean

WG 38 has been developing, in cooperation with GESAMP WG 40 (Plastics and Microplastics in the Ocean), a virtual workshop entitled **"The Atmospheric Transport of Microplastics to and from the Ocean"**. We believe that atmospheric transport of microplastics to the ocean may be a quantitatively important and under-studied aspect of the broader issue of oceanic microplastic pollution. Thus WG 38 and WG 40 are proposing a joint activity - a virtual workshop, with two main goals:

1. Identification of our current understanding and quantitative estimations of the major sources and types of atmospheric microplastics, their atmospheric transport paths, and their inputs to and from the global ocean; and

2. Identification of an appropriate future atmospheric (and marine) sampling and measurement strategy to enable more accurate estimations of the above to be made.

We hope this workshop can help set the research agenda and provide advice to relevant national and international agencies. We are currently identifying a group of approximately 20 individuals to invite to this virtual workshop. Included would be individuals with expertise in the formation and physical form of atmospheric microplastics; atmospheric measurement of microplastics; long range atmospheric transport modelling; dry and wet deposition processes, calculations, and modelling; sea-to-air transport processes of substances (recycling); and possible atmospheric global and regional monitoring sites.

WMO strongly supports this proposed virtual workshop, and we expect it to take place sometime before the end of 2020 and report in early 2021.

Recent publications of WG 38

Smith, S.R., G. Alory, A. Andersson, W. Asher, A. Baker, et al. 2019, "Ship-based contributions to global ocean, weather, and climate observing systems, Frontiers in Marine Science, 6, 434, 10.3389/fmars.2019.00434..

Ito, A., S. Myriokefalalitakis, M. Kanakidou, et al., 2019, “Pyrogenic iron: The missing link to high iron solubility in aerosols”, Science Advances, **5**: eaau7671.

Hopkins, F.E., P. Suntharalingam, M. Gehlen, O. Andrews, *et al*., 2020, ”The impacts of ocean acidification on marine trace gases and the implications for atmospheric chemistry and climate. Proceeding of the Royal Society A, **476**: 20190769. http://dx.doi.org/10.1098/rspa.2019.0769.

Liss, P.S.,2020, “Microplastics: All up in the air?”, Marine Pollution Bulletin, **153,** https://doi.org/10.1016/j.marpolbul.2020.110952.

POGO – Partnership for Observation of the Global Ocean

Partnership for Observation of the Global Ocean (POGO)
Report to SCOR Annual General Meeting 2020

Introduction

POGO was established in 1999 by a group of directors of marine research institutions who met to discuss ways in which they could work together more effectively in support of global oceanography, and in particular ocean observations. Members value POGO as a forum in which they can meet their peer-directors at least annually, in well-attended meetings, to discuss matters of common interest.

POGO's vision is to have by 2030, world-wide cooperation for a sustainable, state-of-the-art global ocean observing system that serves the needs of science and society.

POGO's mission is to:
1. Lead innovation and development of the crucial components of the ocean observing system.
2. Identify and contribute to the development of the key skills, capabilities and capacities needed to achieve the vision.
3. Work with governments, foundations and industry, to articulate the benefits to society and required funding to build and sustain the system.

More information on POGO can be found at www.ocean-partners.org.

Collaboration with SCOR

SCOR is the leading international organisation in the marine science arena, and POGO has always enjoyed good relations with it. Examples of joint activities include the following:
POGO funds jointly with SCOR a Visiting Fellowship programme that enables early-career scientists from developing countries to study for up to three months in a major oceanographic institution of their choice. The programme is now in its 20th year, and a total of 172 fellowships have taken pace to date (see statistics on gender, geography etc in Fig. 1). The programme is administered by the POGO Secretariat. Candidates are selected by a committee in which both POGO and SCOR are represented. SCOR also runs a Visiting Professorship modelled on the POGO one, and on several occasions the two programmes have complemented one another (for example, in Southern Africa).
POGO and SCOR have collaborated in assessing capacity building in marine science at the global level and coordinate their respective capacity-building programmes. This was conducted initially through a series of workshops convened and funded by SCOR, and more recently, SCOR and POGO Secretariats have been working on impact evaluation questionnaires sent to past trainees and trainers of their respective and joint programmes. They have been analysing the data obtained for inclusion in joint publications on the POGO-SCOR fellowship and professorship programmes, the latter of which has been submitted to *Oceanography*.

SCOR established, jointly with POGO, the International Quiet Ocean Experiment (IQOE). This is a programme aimed at the acoustic background in the ocean, including its anthropogenic and natural components. The Science Plan was published in 2015. The Sloan Foundation was instrumental in starting up this initiative, and in providing seed funding for coordination. POGO funded a Working Group to support the IQOE, which was instrumental in getting an Acoustic Essential Ocean Variable (EOV) accepted by GOOS. POGO has also earmarked funds for an Acoustic EOV Implementation Workshop, which was due to take place in 2020 (plans are being reviewed in light of COVID-19). POGO also encouraged its members to consider hosting an International Project Office (IPO) for the programme, which led to the Alfred Wegener Institute recruiting 2 data managers to support IQOE and its Data Working Group in 2019/20. A special issue of ECO Magazine on ocean sound was co-sponsored by SCOR and POGO in 2019, which featured an overview article on IQOE, as well as many contributions from the IQOE community.

POGO contributed to the establishment, and continues to support the development of the SCOR-SCAR Southern Ocean Observing System (SOOS). For example, POGO provided funding to support a workshop on "Observing and understanding the ocean below the Antarctic sea ice and ice shelves" (OASIIS) in 2016.

Both POGO and SCOR support the Global Alliance of Continuous Plankton Recorder Surveys (GACS). In 2019, POGO provided support for a Workshop on "eDNA Tools for the CPR Survey" and also for training 2 scientists (from South Africa and Brazil) on "Continuous Plankton Recorder silk analysis methods, from cutting the silk to statistical data analysis and interpretation". Both events were held in Australia in Dec 2019.

POGO has an interest in contributing to the activities planned under the International Indian Ocean Expedition 50th anniversary (IIOE-2), an initiative of SCOR and IOC.

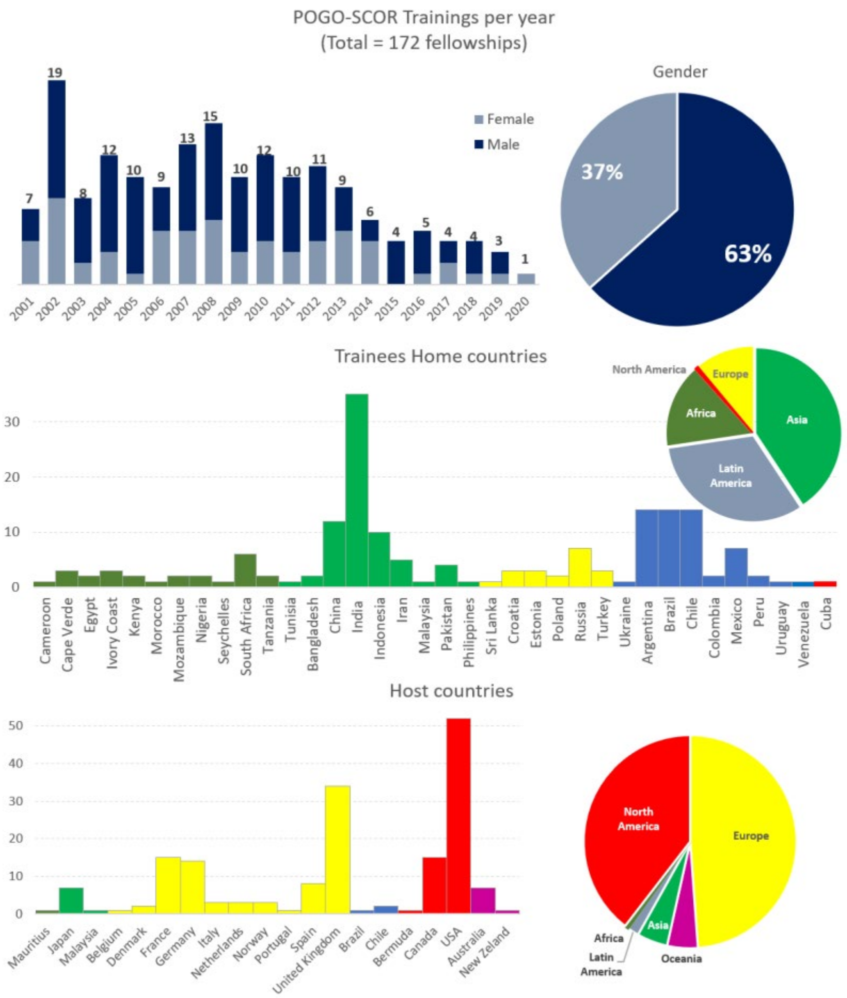

Fig. 1. Statistics relating to the POGO-SCOR Visiting Fellowships funded since 2001.Note: the 2020 figure does not include fellowships agreed for 2020/21 that have not yet taken place.

Current POGO activities

Capacity development

Over the last 20 years, POGO has provided training in ocean observations to over 900 early-career scientists, mostly from developing countries. The main capacity development programmes are:

The Nippon Foundation-POGO Centre of Excellence, a ten-month graduate-level training programme in observational oceanography, hosted by the AWI since 2013, and previously hosted by BIOS in Bermuda (2008-2012); associated with this is a Regional Training Programme of 2-3 weeks duration, held annually (usually in a developing country);

A shipboard training programme, which has its origins in the Atlantic Meridional Transect (AMT) Visiting Fellowship on-board a research cruise (initially co-funded by SCOR?); the programme, now funded by NF, provides opportunities for any cruise PI to offer a spare berth for training, and POGO provides a “match-making” service between potential fellows and suitable shipboard training opportunities; shipboard training cruises have also been funded through this programme, providing hands-on training to over 20 students each, notably the North-South Atlantic Training transects (NoSoAT, 2015 and 2016)) and South-North Atlantic Training transect (SoNoAT, 2019), on-board the German ice-breaker *RV Polarstern*, and which also comprised a substantial shipboard outreach element involving schools in Brazil, Germany, Ireland, Japan and UK;

The NF-POGO Alumni Network for Oceans (NANO), which is made up of all the alumni from past NF-POGO training programmes, and offers further support and opportunities for those alumni, ranging from the communication/sharing of training, conference and job opportunities via the NANO website and social media, to the opportunity to publish articles in, and serve on the Editorial Board of the NANO newsletter, to possible involvement in the collaborative NANO global projects;

The POGO-SCOR Visiting Fellowship Programme (mentioned above);

Training Initiatives organised by POGO members, who are successful in applying for partial funding from POGO (those selected for 2020/21 are listed below).

Projects and Working Groups

OpenMODs:

In 2017, POGO issued a call to its members for a collaborative ocean observing project to be funded to the level of 50K USD. The successful proposal was “Open Access Marine Observation Devices (OpenMODs). The goal of this project is to conceive an “easy-to-use" flexible and affordable oceanographic class of equipment and to prepare an international realization programme through a series of concerted workshops. The proposal is to start from the experiences and expertise brought in by the members of the consortium but to be underpinned and enhanced by interaction with potential users (to be found also among POGO Alumni) and private companies/consortia (e.g. 4H-JENA engineering GmbH) and organisations (e.g. UNESCO/ICTP) interested in this activity. The proposed approach will be cost-effective, flexible and modular and the equipment will be tailored to meet with diverse user needs and deployment purpose. Two workshops were held in 2018 and 2019 to assess the state-of-the-art in low-cost ocean observing technology, agree on priority applications and parameters that would need to be measured and on a few “pilot” locations for testing the system, engaging with local stakeholders and so on. Some preliminary ideas for the system design were also discussed, and a manuscript on the subject is being published. The next step is a workshop bringing together engineers and technology developers from various POGO member institutions to discuss further the design specifications and start working on some prototypes. Again, the workshop has been delayed by COVID-19.

Biological Observations WG:

This WG has set an agenda for collaboration, and has ensured that POGO is informed on the state of development of ocean biological observing systems. This group has worked on behalf of POGO to partner with other organizations to foster workshops and other activities and works to ensure that POGO is represented in international discussion of ocean biological observing capabilities and systems, with the aim of enabling the community to move from ocean biological observation to ecosystem understanding.

In May 2019 a workshop was held on Machine Learning and Artificial Intelligence (ML/AI) in Biological Oceanographic Observations, funded by the Lounsbery Foundation and hosted by the POGO member institute, Flanders Marine Institute, to educate the POGO community about AI/ML as it is currently being applied in biological oceanography and jump start analysis efforts with new machine learning and artificial intelligence tools. This type of capacity building is critical as ML/AI techniques become more pervasive. Moreover, the WG views ML/AI approaches to data analysis as a necessary building block for future biological observations as hardware tools collect even larger data sets. The workshop covered state-of-the-art analysis techniques applied to acoustics, imaging and genomics, and included hands-on tutorials with a focus on data pre-processing and organisation. The workshop concluded with discussions on the direction of ocean observation in the age of big data. Plans are being discussed for replicating this workshop in the future, possibly in different regions, and also for sharing the tutorials via OceanTeacher.
The WG held a 1-day meeting in Honolulu, Hawaii, after the OceanObs'19 conference, to discuss the outcomes of the ML/AI workshop and future directions for the WG and for POGO.

Some residual funds left over from the AI/ML workshop have been ear-marked for a workshop on eDNA, which was originally to be held jointly with SCOR. Since the workshop did not take place during the financial year for which SCOR had ear-marked the funds, and subsequently COVID-19 made it impossible to hold the workshop in-person in 2020, the workshop is now being held virtually in late 2020. The landscape for eDNA methods and applications has been evolving rapidly since POGO's Biological Observations Working Group original suggestion for a workshop on eDNA. On May 11 2020 an eDNA Workshop Science Advisory Group met to provide information and advice to the WG regarding how to frame a useful and successful workshop given the many activities related to eDNA that are taking place and proposed. Efforts related to using eDNA for both science and management fall into three general categories: development of measurement protocols, bioinformatics/taxonomy, and development of science/management strategies and products. The measurement category includes issues related to sampling, laboratory processing and sequencing of eDNA. The eDNA community has organized to synthesize ideas related to these methodological issues and a virtual workshop planned for late summer by the Alliance for Coastal Technologies in coordination with US IOOS and MBON. In addition, GLOMICON is undertaking an intercalibration-based study of methodological issues. By fall these efforts will have advanced the measurement issues regarding eDNA substantially. The bioinformatics/taxonomy category is developing from the activities of registries like GenBank and the efforts to get taxonomic information into databases like OBIS and INSTG. The third category is one that is very important to POGO. It focuses on how to generate useable products from eDNA studies (whether for science purposes or for management purposes) and how to use the results of these initial eDNA studies to design effective field campaigns (again, for both scientific or management purposes). For example, nations that are aware of the potential power of eDNA are asking scientists to develop field studies that will answer important societal questions related to water quality (e.g., HAB prediction), fishery management (e.g., new ways to conduct stock assessment), MPA management (establishing baselines and studies of change) and other topics. Scientists are excited about the potential of eDNA to answer longstanding questions related to biodiversity, climate impacts, etc. The Bio Obs WG proposed that POGO focus its eDNA workshop on the third category of issues, and this was agreed by the POGO Board in June 2020.
Other future directions for the POGO Bio Obs WG, and thus for POGO, include (1) inexpensive technologies for biological observing (also linked to OpenMODs topic above), (2) data archaeology

for critical marine biodiversity observations, (3) interoperability of marine biological data, and (4) capacity development for biological observing.

Initiatives funded by POGO for 2020-21

Working Groups:
WG on "Women in Science: ERIKA (Empowerment /Employment of female researchers in Key Assignments", led by Karen Wiltshire, Alfred Wegener Institute for Polar and Marine Research, Germany.

Projects:
Acquisition of Oceanographic Data for Sustainable Resources Management in the Gulf of Guinea, led by NIOMR, Nigeria;
Building Capac**I**ty in **O**cean Acidifica**T**ion Moni**T**oring in the Gulf of Guine**A** (BIOTTA), led by the University of Ghana.

Training initiatives:
Training on Subsurface Mooring Design, Recovery and Deployment, organised by IOCAS, China;
Support for SOLAS Summer School.

ISC – International Science Council

The International Science Council (ISC)
Çompiled by Arno De Marchi

These are extracts from the ISC upcoming Annual Report for 2019, namely:
Message from Heide and Daya (this is a good introduction to what happened in 2019)
Brief update on Action Plan (just an introduction with links to more information)
Ocean Decade
Governance: New committees appointed

Message from CEO and President (taken from Annual Report 2019)
The International Science Council's first full year of operation has been a period of intense activity, with the aim of positioning the ISC as a distinctive and effective global voice for science. We put in place the Council's new governance system and launched our first three-year action plan, setting out an ambitious programme of priority projects. We took stock of progress to date, working to consolidate existing partnerships and scientific initiatives. And we extended our global reach, appointing the Council's first patrons and a Special Envoy for Science in Global Policy.

The Council has expanded its networks and spheres of influence throughout 2019, working to enhance the visibility and voice of international scientific research and scholarship on issues of major concern to science and society. We have acted to increase the integration of science and evidence-informed understanding in major international policy processes. In June 2019, the Council appointed its inaugural patrons: Mary Robinson, former President of Ireland and United Nations (UN) High Commissioner for Human Rights, Chair of the Elders and leading defender of climate justice; and Ismail Serageldin, Emeritus Librarian of the Library of Alexandria in Egypt. These patrons are using their international standing and influence to assist the Council in advocating for the social, political, economic and cultural value of science to policy-makers and the public. In addition, the appointment of Flavia Schlegel as Special Envoy for Science in Global Policy has bolstered our presence in, and engagement with, the UN and other global policy fora.

In line with our statutes, we have appointed four advisory committees on the basis of nominations from our members: Science Planning; Freedom and Responsibility in Science; Outreach and Engagement; and Finance and Fundraising. Together, these committees bring together considerable scientific expertise and experience from differing sectors and settings, and will be crucial in taking forward our Action Plan 2019–2021 and shaping the next few years for the International Science Council.

Our regional offices in Africa; Asia and the Pacific; and Latin America and the Caribbean have built new partnerships, in particular through emerging 'open science platforms'. These platforms will convene different interests, ideas and institutions with the aim of mobilizing resources and building and strengthening the expertise required to advance data-intensive, solutions-oriented research in the Global South.

The Council's convening power was perhaps best demonstrated at the Global Forum of Funders hosted by the United States (US) National Academy of Sciences (NAS) in Washington, DC in early July 2019. This event brought together more than 80 science funders, including international development aid agencies, private foundations and national research councils. The Forum resulted in a common call for a decade of global funding action to address the world's most pressing challenges, as captured in the Sustainable Development Goals (SDGs). This statement of shared purpose from research institutions and funders was noted in an article published in *Nature*

Sustainability in September 2019 (*Messerli et al.*), which highlighted the ISC's unique ability to mobilize a diversity of expertise in the context of sustainability science. This exemplifies the kind of globally connected, scientifically impactful organization we want the Council to be.

The development and launch of our first action plan, *Advancing Science as a Global Public Good*, has been a major focus for activity in 2019. This Action Plan 2019–2021 sets out a portfolio of twelve projects, framed by four domains of critical importance for science and society: The 2030 Agenda for Sustainable Development, the digital revolution, science in policy and public discourse, and the evolution of science and science systems. The Action Plan further incorporates activities that address the commitment of the ISC to uphold and advocate for freedom and responsibility in science. It also includes a vision for building the ISC's presence in different regions of the world, for amplifying the voice for science through outreach and engagement, and for strengthening our funding base.

The development of this strategic action plan has depended on the guidance, energy and commitment of our Governing Board, our members and partners, and staff at our headquarters and regional offices. We thank them sincerely for their collaboration and efficiency. Of course, as we implement the projects set out in our plan, and continue to deliver on existing activities, the goals we strive to achieve will require us to continue to scale up, to further consolidate our resources, to seek new partnerships, and to strengthen existing ones.

As we write this introduction to our Annual Report 2019, our world is engulfed in a crisis of almost unimaginable proportions, during which the ISC's power to convene expert minds in the traditional way has been stymied by the SARS-CoV-2 virus. This external threat has forced us to rethink and to find new, equally effective ways to convene our expert communities and deliver on our Action Plan 2019–2021. In this regard, some activities will be expanded and their schedules brought forward; new activities responding to the crisis, within the realms of our four domains of action, will be added; and some activities will have their timelines adjusted to reflect the new reality of our world. In these times of great uncertainty, we can be certain about one thing: that science, and scientific thinking and values, must be central components of responses to global challenges. The International Science Council, with its vision of science as a global public good, stands ready to promote, support and enable the achievement of these goals.
Daya Reddy, President
Heide Hackmann, Chief Executive Officer (CEO)

2019 in review: scientific initiatives
2019 was marked by the development and launch of the ISC's first action plan, Advancing Science as a Global Public Good, which sets out the Council's strategic priorities from 2019 to 2021.
The Action Plan 2019–2021 was developed over the course of 2019, through consultations within the ISC membership and with the broader international science community, and many months of discussions within the ISC Governing Board. It contains an ambitious programme of much-needed initiatives that will position the ISC as an impactful global voice for science. This programme is framed by four 'domains of impact' that reflect urgent priorities for science, in areas in which the ISC can provide leadership through its unique membership and convening power. The Action Plan also sets out a new regional strategy and fundraising plan for the Council, as well as a major project on scientific freedom and responsibility.
The Action Plan identifies twelve solutions-oriented initiatives to address major opportunities and challenges within the four domains. The projects and programmes presented are diverse in their nature, timescale and need for resources. Some are already in progress, building on previous work and existing partnerships, and some have been identified for further development beyond 2019. All work in synergy with the ISC's portfolio of existing activities. The Action Plan is designed to be a living document, with project proposals that will be elaborated in consultation with members and

partners, and flexibility to allow the Council to respond to major external developments, new opportunities and emerging issues.

See our website for more on the Action Plan 2019–2021

For more information see our 2019 Annual Report https://council.science/annual-report-2019/
The Ocean Decade

In 2017, the United Nations proclaimed that 2021 to 2030 would be the 'UN Decade of Ocean Science for Sustainable Development', or the 'Ocean Decade' for short. The Ocean Decade is a major effort to boost ocean science, to share knowledge on the ocean, and to work together to meet Sustainable Development Goal 14 (healthy oceans) and the other SDGs with an ocean dimension. The ISC supports the aims of the Ocean Decade, and in 2019 developed a memorandum of understanding with UNESCO's Intergovernmental Oceanographic Commission (IOC). This MoU sets out a framework of cooperation, include promoting the Ocean Decade among the scientific community, contributing to Ocean Decade preparations, accelerating scientific initiatives, and exploring opportunities for joint fundraising for scientific research. The MoU was signed in early 2020.

One of the main aims of the Ocean Decade is to develop innovative ways to communicate ocean science, and to promote ocean literacy to a broad audience. Towards this aim, in 2019, the ISC and IOC launched a series of blogs. The blogs aim to feature new voices that we need to hear from – across human, natural, social and indigenous science and traditional knowledge – if the Ocean Decade is to be truly inclusive and multidisciplinary.
"Ocean data and information should be considered a 'public good' in the same way that weather observations are."

Martin Visbeck, a member of the Ocean Decade's Executive Planning Group
The MoU developed with UNESCO's IOC is another chapter in a long collaboration between the two organizations. The ISC and IOC helped found, and remain at the helm of, two key international ocean science initiatives: The Global Ocean Observing System, and the Scientific Committee on Oceanic Research. The IOC–ISC partnership on the Ocean Decade illustrates the importance of collaboration between international scientific organizations, which together can mobilize key national, regional and global actors across the science–policy–society nexus to generate knowledge for the benefit of humankind.

Governance
The Governing Board appointed its advisory committees in 2019, on the basis of nominations from ISC members. Each of the committees is chaired and vice-chaired by Governing Board members and includes non-Governing Board members. The committees are:
The Committee for Science Planning, which undertakes strategic scientific planning and reviews, addressing major thematic issues concerned with science for policy and policy for science.

The Committee for Freedom and Responsibility in Science, which safeguards the principle of freedom and responsibility in science and deals with related issues at the global level.

The Committee for Outreach and Engagement, which focuses on membership matters, outreach to external stakeholders, partnerships and strategic communications.

The Committee for Finance and Fundraising, which addresses issues of finance, auditing, resource mobilization and risk management.

SCAR – Scientific Committee Antarctic Research

Report of the Scientific Committee on Antarctic Research to the SCOR 2020 Meeting

Summary
This paper presents the annual report of the Scientific Committee on Antarctic Research (SCAR) to the 2020 meeting of the Scientific Committee on Oceanic Research. The Covid-19 pandemic has had a number of impacts on SCAR including the cancellation of its 2020 Open Science Conference and Delegates meeting in Hobart. However, key elements of the conference are being moved online during the original conference dates 3-7 August. SCAR's current Scientific Research Programs are drawing to a close in 2020 and SCAR is in the process of reviewing proposals for three new proposed Scientific Research Programmes, for consideration by the SCAR Delegates.

Background
The mission of SCAR is to advance research in, from and about Antarctica and the Southern Ocean, and to promote scientific knowledge, understanding and education on any aspect of the Antarctic and Southern Ocean regions. To this end, SCAR is charged with the initiation and international coordination of Antarctic and Southern Ocean research beneficial to global society. SCAR provides independent and objective scientific advice and information to the Antarctic Treaty System and other bodies, and acts as the main international exchange of Antarctic information within the scientific community. Descriptions of SCAR's activities, and the scientific outputs and outcomes facilitated by SCAR are available at: https://www.scar.org/.

SCAR 2019 Highlights
Highlights from 2019 include the XIII International Symposium on Antarctic Earth Sciences (ISAES), held in July 2019 in Incheon, Korea. ISAES expanded its scope in 2019 to include new areas of research such as Antarctic volcanism, remote sensing and climate science. The symposium was attended by over 450 participants from 32 countries.

Also in July, at the Antarctic Treaty Consultative Meeting in Prague (ATCM XLII), SCAR submitted three lead Working Papers (WPs), three co-sponsored WPs, eight lead Information Papers (IPs), eight co-sponsored IPs and one Background Paper (BP). SCAR's contribution to the work of the Antarctic Treaty System was recognised in Resolution 7 of the ATCM XLII on "SCAR's Sixtieth Anniversary and the Role of SCAR in Providing Scientific Advice to Support the Work of the Antarctic Treaty System". SCAR's enduring and crucial role in providing objective and independent scientific advice to support and inform the work of the ATCM and the Committee for Environmental Protection (CEP) was recognised and acknowledged with gratitude. SCAR President Professor Steven L Chown delivered SCAR's 2019 lecture to the ATCM. The subject of the lecture was "*What does the Paris Climate Agreement Mean for Antarctic and Southern Ocean Environmental Protection?*" and was very well received.

Training, support and development of the Antarctic community continue to form a fundamental component of SCAR's work. In 2019, SCAR awarded eight early-career Fellowships and three Visiting Scholar Awards. Fundraising efforts continued in 2019 to increase capacity for Antarctic research internationally.

Also in 2019, SCAR and the International Association of Antarctica Tour Operators (IAATO) commenced a collaborative project to develop a systematic conservation plan (SCP) for the Antarctic Peninsula, aimed at informing the Antarctic community on how to optimally manage biodiversity, science and tourism together in the region, and contribute to the sustainable management of IAATO activities into the future. The project will report in 2021 due to delays caused by the Covid-19 pandemic.

In August 2019 SCAR published a paper outlining progress made since its 2014 Horizon Scan, outlining the science most urgently needed from Antarctica and the Southern Ocean to forge new understanding of what the future holds for both the region and its effects on the planet (https://doi.org/10.1016/j.oneear.2019.08.014).

In September 2019, the SCAR Expert Group on Antarctic Biodiversity Informatics (EG-ABI) partnered with the rOpenSci project and Antarctic Biodiversity Portal to organise a short course on tools for Southern Ocean spatial analysis and modelling using R. The course taught participants how to retrieve, model and interpret species occurrence data from the Southern Ocean using R-tools developed through the Antarctic R community.

September 2019 also saw the release of the IPCC Special Report on Oceans and Cryosphere (SROCC), to which members of the SCAR community contributed significantly.

To mark the 60th anniversary of the Antarctic Treaty on 1 December 1959, SCAR released a series of fact sheets on "*60 Years of Treaty-Supported Antarctic Science*", including one on fish speciation in the Southern Ocean and another on melting ice sheets and sea level rise. The full range of fact sheets is available from https://www.scar.org/library/scar-publications/infographics/.

On 2-3 December 2019, SCAR took part in the first Antarctic Parliamentarians Assembly, involving parliamentarians from 13 of the 54 signatory countries of the Antarctic Treaty. SCAR President Professor Steven Chown presented on "*How will life in the Antarctic survive a changing world?*" showing how invasive species will thrive in a warmer Antarctic. Professor Tim Naish, leader of SCAR's research programme studying the effects of climate change on ice sheets and sea level, presented on "*How is climate change affecting Antarctica and what does it mean for us?*" which focused on the global consequences of future sea level rise from loss of Antarctic ice.

SCAR assisted the International Cryosphere Climate Initiative (ICCI) in organising the first dedicated Cryosphere Pavilion at the UNFCCC meetings at the Convention on Climate Change (COP25) in Madrid in December 2019. As part of the opening ceremony, SCAR Delegates Jerónimo López-Martínez (Spain) and Marcelo Leppe (Chile) presented on the topic of "*Antarctica Past, Present and Future: Sea Level Rise*".

Science Priorities

SCAR's Scientific Research Programs (SRPs) are the main vehicles through which SCAR facilitates and coordinates science in, from and about Antarctica and the Southern Ocean. The current SRPs come to an end this year and the new suite of proposed programs is under review. The results of the review will be considered by the SCAR Delegates. The proposed programs are:

Near-term Variability and Prediction of the Antarctic Climate System (AntClimNow)

AntClimNow will investigate the prediction of near-term conditions in the Antarctic climate system on timescales of years to multiple decades. They will take an integrated approach, looking beyond climate projections of the physical system to consider the Antarctic environment as a whole. A key objective will be to quantify and understand atmospheric and oceanic linkages between Antarctic climate variability and the rest of the planet, with a focus on links with the tropics.

Integrated Science to Support Antarctic and Southern Ocean Conservation (Ant-ICON)
Ant-ICON will answer fundamental science questions (as identified by the SCAR Horizon Scan), relating to the conservation and management of Antarctica and the Southern Ocean, and focus on research to drive and inform international decision-making and policy change. Research themes will broadly cover integrated forecasting of future change, environmental sustainability of human activities in Antarctica, Antarctic conservation in a global context, and socio-ecological approaches to the management and conservation of the Antarctic.

INStabilities & Thresholds in ANTarctica (INSTANT)
INSTANT will address a first-order question about Antarctica's contribution to sea level. It encompasses geosciences, physical sciences and biological sciences, of the way in which interactions between the ocean, atmosphere and cryosphere have influenced ice-sheets in the past, and what expectations will be in the future with a special focus on quantifying the contributions to global sea level change. The programme aims to provide greater understanding to decision-makers, enabling them to anticipate and assess the risk in order to manage and adapt to sea-level rise and evaluate mitigation pathways. One of the programme's themes is ocean-ice interactions, to improve understanding of ocean forcing processes of marine-based ice sheet dynamics.

Recent Developments

SCAR notes the excellent relationship with SCOR in delivery of the Southern Ocean Observing System (SOOS) and looks forward to collaborating with SCOR to support both communities' engagement with SOOS over the coming year.

From January 2020, SCAR took over the operation of the Antarctic Environments Portal from the University of Canterbury, New Zealand. The Portal aims to provide easy access to reliable, science-based information on a range of issues relevant to the management of the Antarctic environment. All scientifically-based information available through the Portal is prepared by Antarctic experts and is thoroughly peer-reviewed before being published. The primary objective is to make the best scientific information available to Antarctic policy makers.

In February 2020, prior to the 2020 Ocean Sciences Meeting in San Diego, CA, SCAR co-organised a workshop on the Southern Ocean contribution to the UN Decade of Ocean Science. The 30 participants representing 11 countries included representatives with expertise in ocean sciences, policy, governance and science communication, from all career stages.

SCAR's Open Science Conference and Delegates meeting, which were due to be held in Hobart, Australia in August 2020, have been cancelled due to the pandemic. However, key elements of the OSC will still take place through 'SCAR 2020 Online' (see scar2020.org). The planned plenary presentations will go ahead, as well as highlights of SCAR's concluding scientific research programs and proposed future programs. This will be done through a combination of live-streaming during the week of the original OSC (3rd-7th August 2020) and recorded presentations.

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Future Earth-Ocean

FUTURE EARTH - OCEAN

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Future Earth Secretariat is carrying activities related to ocean science on a regular basis. In addition of liaising with the research projects SOLAS and IMBeR (through funding, sharing of opportunities etc.), Future Earth Secretariat is working in close relation with the Ocean KAN (Knowledge Action Network). More information and Development Team at: https://futureearth.org/networks/knowledge-action-networks/ocean/

Ocean KAN
Co-chaired by Anna Zivian and Mistuo Uematsu the Ocean KAN aims at generating knowledge and facilitating science-to-policy actions in the fields of ocean science (climate change, overfishing, acidification, de-oxygenation, pollution etc.) by bringing together actors from academia, business and civil society.
In this scope, part of the Ocean KAN team attended the 1st Global Planning Meeting for the UN Decade of Ocean Science for Sustainable Development in May 2019. Since then, the Ocean KAN reviewed the Decade implementation plan and attended several other meetings.
At the moment, the Ocean KAN is looking for a host for its International Project Office (IPO). https://futureearth.org/2019/06/12/future-earth-and-the-un-decade-of-ocean-science-for-sustainable-development/
Some members of the Development Team (DT) have recently published an article about the KAn and its role: https://www.tandfonline.com/doi/full/10.1080/08920753.2020.1778426

Virtual Blue COP / Blue Decade
In the Ocean KAN scope, the Virtual Blue COP has been organised in late 2019, aiming to promote inclusive dialogue and focusing on ocean and climate-related themes. Several online events have been organised throughout autumn 2019 https://futureearth.org/2019/12/19/a-virtual-cop-for-a-change/
In 2020, the Virtual Blue COP became Virtual Blue Decade and launched in June a new set of online events about ocean science https://www.virtualbluedecade.org/

The Earth Commission
Future Earth is now hosting the Earth Commission. Its mission is to assess the latest science to underpin the development of science-based targets for systems like land, water (freshwater and oceans), and biodiversity. By setting such targets, companies and cities will be able to contribute to re-stabilizing Earth’s natural systems and work towards ensuring a planet where humans can thrive. https://earthcommission.org/

Collaborative Research Action (CRA) Ocean Sustainability

Future Earth co-branded a Collaborative Research Action on Transdisciplinary Research for Ocean Sustainability with the Belmont Forum and JPI Oceans. This funding supported projects that took integrated, transdisciplinary and cross-sectoral approaches towards the achievement of UN Sustainable Development Goal (SDG) no. 14 to conserve and sustainably use the oceans, seas and marine resources for sustainable development. Thirteen international projects were awarded, with a total of 14,250,000 Euro by funding organizations from 16 countries.

PEGASuS 2: Ocean Sustainability
A partnership between Future Earth, National Center for Ecological Analysis and Synthesis (NCEAS), and Global Biodiversity Center at Colorado State University, this initiative supports two ocean sustainability working groups involving not only researchers, but also innovators in policy, business and civil society to generate research that meets society's needs. One project is aiming to establish a globally coordinated ocean observing system to assess the status of the ocean's biodiversity and ecosystems. A second project is working to help the Government of Palau review existing research and create a portfolio of policy options to support food security and marine resource sustainability in Palau's National Marine Sanctuary.

Ocean Decade Survey
The United Nations has declared 2021-2030 as the United Nations Decade of Ocean Science for Sustainable Development, as an opportunity for global cooperation to take transformative actions toward sustainable oceans. PEGASuS postdocs with Future Earth and NCEAS were involved in the development of a survey for Early Career Professionals, that would include their voices on the Decade preparation process.

Fourth AEON Future Earth Forum
This annual forum held in The University of Tokyo, gathers over 800 participants to educate the public and create a dialogue on environmental issues, choosing a theme from Future Earth's Knowledge-Action Networks. The fourth forum that was held this February was on the theme of "Protecting the Ocean's Environment and Resources". High school students presented on marine plastic pollution, introducing a website that they created with various information and discussing what each of us as individuals can do.
https://futureearth.org/2020/06/08/world-oceans-day-2020-wading-in-marine-plastic/

Science-Based Pathways for Sustainability Initiative – an Ocean workshop in France

In the scope of the Science-Based Pathways for Sustainability Initiative, the French hub of Future Earth as convened a scientific committee to prepare a workshop. This event will focus on marine protected areas and their implementation in France and beyond. A group of students conducted a case study on the topic (https://futureearth.org/2020/02/12/students-build-ground-for-science-based-pathways-workshop-on-marine-protected-areas/) and both the scientific committee and the Paris hub are working on the event, planned for early 2021 in France.
https://futureearth.org/initiatives/earth-targets-initiatives/science-based-pathways/

WCRP – World Climate Research Program

The World Climate Research Programme (WCRP): a Short Update to SCOR-2020

The World Climate Research Programme
"The World Climate Research Programme (WCRP) coordinates and facilitates international climate research to develop, share and apply the climate knowledge that contributes to societal well-being." (WCRP's new Mission)

Like SCOR, WCRP does not fund science directly, but provides resources/platforms to hold meetings and workshops on specific high-priority research topics related to the climate system. Such funds come from its co-sponsors[5] as well as voluntary contributions from various countries and agencies. WCRP has gone almost wholly online since the start of the COVID-19 crisis. Major meeting such as the Joint Scientific Committee meeting were held with over 80 people attending remotely. Currently, WCRP is putting significant effort into implementing its new research strategy (WCRP Strategic Plan 2019-20286) by reviewing its entire structure and improving its functionality, including also its interaction with partners. Major elements of the implementation plan are to strengthen support for core research, and to extend and deepen our engagement with scientific partners at the national and international levels. The full implementation of a new WCRP structure is expected to be complete by the middle of 2022. However, WCRP has begun the process leading to a "soft launch" of its new foci and structure, the endpoint of which we expect will be beneficial to its co-sponsors and nations around the world.

Through its Strategic Plan 2019-2028 WCRP is reorienting itself to ensure that there is the science, knowledge and understanding to target frontier problems, such as disaster risk reduction, climate adaptation, mitigation, and intervention strategies, that need to be solved together with partners for which WCRP's core research continues to be essential for developing answers. The integral role of WCRP in developing knowledge of the climate system will result in an increased understanding of the Earth system, including the complex interactions between the physical environment and human society.
A number of Lighthouse Activities (LHA, ambitious, exciting, and high-profile experiments, projects, and infrastructure building blocks) will be undertaken to advance WCRP's mission and scientific objectives. The activities will be co-designed (with partners and users) and integrative (across the WCRP community) and require diversity. The LHAs are anticipated to start in 2021.
The four WCRP Core Projects will be internally assessed by their Scientific Steering Groups to determine how they might evolve to be fit for the future. They are called 'homes' in the proposed new structure of WCRP, as they are where WCRP's enduring science capacity lives. Two new 'homes' are proposed. One for 'Earth System Modelling and Observational Capabilities' and one for 'Regional Climate Information for Societies'.
A series of regional consultations on the WCRP reform process are being organised, in order to engage communities from all regions of the world, so that the ongoing implementation of the WCRP Strategy and the way in which WCRP evolves lead to outcomes that are useful and useable across the world.
The WCRP Grand Challenges, including the Sea Level GC, will all sunset by the end of 2022. Other projects and activities may also sunset or be revised, as determined by their contributions to WCRP's scientific objectives.

5 World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) and the International Council for Science (ISC)
6 https://www.wcrp-climate.org/wcrp-sp-overview

The WCRP Grand Challenges
http://wcrp-climate.org/grand-challenges
The overarching WCRP Grand Science Challenges (GCs) represent major foci of scientific research, modelling, analysis and observations. Of the Grand Challenges, Regional Sea-Level Change and Coastal Impacts is of most relevant to SCOR, though many others (e.g. decadal climate, carbon feedbacks) have a significant ocean component. The Sea Level GC represents an integrated interdisciplinary program on sea level research reaching from the global to the regional and local scales. The 2019 meeting of the WCRP Grand Challenge on Regional Sea Level and Coastal Impacts was held from 12-15 October 2019 in Orléans, France, with the first two days focused on the links between science and coastal climate services. The workshop, which was organized in association with IOC/GLOSS, WMO and CLIVAR focused on stimulating the uptake of coastal climate services, how they support present days and future coastal resilience, and making recommendations as to the best way forward. A specific research topic on 'Climate Services for Adaptation to Sea-Level Rise' in **Frontiers in Marine Science** is being coordinated by the SL GC. The leadership of the GC has been updated by including the representativeness from user community. The 2nd Sea Level Conference is planned to be held in 2022 in Asia (Singapore), with a large representation from vulnerable Asian coastal areas, and including top world stakeholders, city planners, coastal developers and managers and other relevant stakeholders to focus on the flow of knowledge from sea-level science to strengthen climate change adaptation and disaster resilience in coastal zones. The SL GC will be come to an end after the 2nd SL Conference.

The WCRP Core Projects
WCRP carries out a major part of its activities through its four core projects, CLIVAR (oceans and climate - www.clivar.org), CliC (cryosphere and climate - www.climate-cryosphere.org), GEWEX (water and climate www.gewex.org) and SPARC (upper atmosphere and climate - http://www.sparc-climate.org). Both CLIVAR and CliC are endorsers of the SCAR/SCOR Southern Ocean Observing System (SOOS). Of these core projects the work of CLIVAR is of particular relevance to SCOR.

The CLIVAR Core Project of WCRP
CLIVAR (Climate and Ocean: Variability, Predictability and Change) is one of the four core projects of the WCRP, which is to understand the dynamics, the interaction, and the predictability of the climate system with emphasis on ocean-atmosphere interactions. Many CLIVAR panel and Research Foci members are taking part in the planning for WCRP Lighthouse Activities and the WCRP regional consultation process. Meanwhile, in response to the rapid pace of scientific advances and recognizing the need for the project to be flexible and responsive to new ideas and challenges, a new research foci on Tropical Basin Interactions has been approved by the CLIVAR SSG. COVID-19 has hindered many activities organised by CLIVAR in 2019, however, the CLIVAR community is adapting to the new normality at a fast pace. The planned CLIVAR/FIO summer and ENSO summer schools are postponed to 2021. With the emphasis on connecting observation-modeling-prediction, a pan-CLIVAR workshop on 'From global to coastal: Cultivating new solutions and partnerships for an enhanced Ocean Observing System in a decade of accelerating change' will be organised in May 2021 at ICTP, Italy, in cooperation with IOC-UNESCO, GOOS, and other international partners. CLIVAR is also trying to increase its relevance and contribution to the UN Decade of Ocean Science for Sustainable Development, initiated by IOC-UNESCO. CLIVAR puts emphasis on the regional and gender balance of the membership. In 2020, the ratio of female and male members is about 1:2.

Appendix: Relevant CLIVAR activities, by Panels and RF
Northern Ocean Region Panel (NORP)
The panel has been putting great emphasis on the freshwater storage and exchange. A review paper on Arctic freshwater budget is finished, identifying progress and knowledge gaps on Arctic freshwater distribution, source/sinks, and reanalysis. NORP is planning for a GOOS/GCOS workshop on heat and freshwater transport and storage in models and observations planned for October 2021.

Another workshop on Arctic freshwater will be organized by NORP alongside ASSW2021 in March 2021. The panel is planning on the NORP Bootcamp Summer School tentatively to be held in Helgoland, Germany in Summer 2021.

Ocean Model Development Panel (OMDP)
Despite the development of ocean (coupled) models, there are still knowledge and technical gaps to be resolved. OMDP has been enhancing the development of an ocean circulation model through identifying the challenges and prospects in ocean circulation models, organizing the Co-ordinated Ocean-Ice Reference Experiments (CORE-I and CORE-II) and the newest variants, the Ocean Model Intercomparison Projects (OMIP-1 and OMIP-2). The panel was involved through the coordinated development of forcing datasets: CORE-I, CORE-II, and now JRA55-do. Since last year, OMDP has built protocols for comparison and comparing ocean-sea ice models at high-resolution and low resolution, and protocols for comparison and comparing ocean model parameterizations. Based on these protocols and previous successes, OMDP will continue leading the role of ocean model community to engage in the model intercomparison on resolution and parameterizations, and other aspects of ocean models. To recognize the role of the ocean on ocean eddies, OMDP organized a workshop on Sources and Sinks of Ocean Mesoscale Eddy Energy in March, 2019 at Florida State University, USA. In January 2020, a CLIVAR/US CLIVAR joint exchanges: A joint special edition on Sources and Sinks of Ocean Mesoscale Eddy Energy was issued. OMDP is planning to organize a workshop on Future Directions in High-resolution Ocean Modelling, postponed to late September.

Southern Ocean Regional Panel (SORP)
SORP serves as a forum for the discussion and communication of scientific advances in the understanding of climate variability and change in the Southern Ocean. SORP successfully organized a session at IGS Sea Ice Symposium in August, 2019 at Winnipeg, Canada. The panel seeks qualified scientists to be the national representatives of Southern Ocean, and asks them to submit the national report to seek the knowledge gaps and cooperation opportunities. In the past three years, representatives from 17 countries submitted the national report. The co-chairs are now working to synthesize them, the impacts of COVID-19 on the Southern Ocean projects of the countries will be included. Due to COVID-19 and the cancellation of SCAR OSC 2020 and associated business meetings, the planned WAMC/YOPP-SH/SOOS/ASPeCt joint workshop was cancelled, the panel is looking for other ways to reorganize it.

Climate Dynamics Panel (CDP)
The frontline problems and techniques described in Collins et al. (2018 NCC) constitute the science topics of the Climate Dynamics Panel, while the “Developing predictive theories of climate dynamics” topic may be considered as an overarching theme. In the past year, CDP (co)organized sessions at IUGG, fall AGU and PICES 2019. Members have organized or lectured at several summer schools to enhance the capability building. The planned workshop on Climate Prediction in the Arctic and North Atlantic sector (5-7th June 2020, Bergen, Norway) has been changed to an online meeting due to the COVID-19; as the main achievement of the workshop, a review paper on uncertainty of the climate prediction will be finished after the workshop. The panel is conceiving another workshop in 2021 for better understanding the climate dynamics.

Atlantic Region Panel (ARP)
The Tropical Atlantic Observing System (TAOS) Review is being finalised by ARP in collaboration with PIRATA. The final draft including science drivers and Essential Ocean Variables (EOV) metrics is now being sought for comments from the TAOS Review Committee, ARP members, and relevant programmes. The final report will be released by the end of 2020. The 2nd CLIVAR-FIO Summer School on Ocean Macroturbulence and Its Role in Earth’s Climate led by ARP originally planned in July 2020 in Qingdao, China, will be postponed to July 2021 due to COVID-19. The CLIVAR ARP endorsed Ocean-Atmosphere component of EUREC^{4}A (EUREC^{4}A-OA, Europe) and Atlantic Tradewind

Ocean-Atmosphere Mesoscale Interaction Campaign (ATOMIC, US) experiment has been conducted in the northwest tropical Atlantic in January-February 2020 with the participation of more than 200 scientists. The team is now validating and calibrating the collected data, writing campaign overviews and data papers, and have started brainstorming collectively to address the scientific analyses of the observations and the parallel modelling effort. Meanwhile, with the sunset of US AMOC Science Team, an AMOC Task Team is being proposed by ARP with prioritising the AMOC activities that can be taken over by the international CLIVAR, with close cooperation with other international partners on AMOC observation and researches.

Pacific Region Panel (PRP)
ENSO remains the focus of researches for PRP. The main activities (e.g. ENSO metrics) of the former CLIVAR ENSO in a Changing Climate Research Foci (ENSO RF) have been integrated into PRP since 2018. A Working Group on ENSO Conceptual Model has been established within PRP and kicked off in July 2020. The WG is to bring experts of ENSO theory, modelling, and observations together to review knowledge on ENSO conceptual models and identify possible avenues for improved conceptual models that can more fully account for ENSO complexity. The PRP also contributed to the AGU monograph on 'ENSO in a Changing Climate', which is to be published in November 2020. The 3rd Summer School on Theory, Mechanisms and Hierarchical Modeling of Climate Dynamics: Tropical Oceans, ENSO and their Teleconnections, co-organised by ICTP and CLIVAR PRP, has been postponed to 2021 due to COVID-19. Meanwhile, PRP continues its effort on Tropical Pacific Decadal Variability (TPDV), by leading the manuscript of 'A review of decadal climate variability in the tropical Pacific: characteristics, causes, predictability and prospects' which has been submitted to Science. A TPDV working group is being proposed within PRP to address the open questions identified in the TPDV article. Moreover, PRP intended to strengthen the cooperation with the biogeochemical groups by co-organising a workshop on 'Climate and Ecosystem Prediction in the North Pacific' alongside the 2019 PICES annual meeting, to synthetize the current state of knowledge on the physical drivers of marine ecosystems variations along the coasts of the North Pacific rim as well as sources of predictability arising from large-scale climate variability. The future work will be focusing on the mechanisms of formation of marine heat waves in the Pacific basin. PRP also actively involved in workshop on 'Atmospheric convection and air-sea interactions in the Tropical Oceans', jointly organised by US and International CLIVAR on May 2019 in Boulder, USA.

CLIVAR/IOC-GOOS Indian Ocean Region Panel (IORP),
The decadal review for the Indian Ocean Observing System (IndOOS) was completed, (see: 'IndOOS-2: A Road map to Sustained Observations of the Indian Ocean for 2020-2030'). This review was sponsored by the Ocean Observations Physics and Climate panel (OOPC), an expert panel of the Global Ocean Observing System (GOOS). It was conducted and written by a group of sixty international scientists, under the guidance of the IORP in partnership with Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) and under the scrutiny of an independent review board appointed through various partners of GOOS. Proactive actions have been taken by IORP, the writing team and partner programmes to advocate the outcomes and recommendations of the IndOOS review, trying to mobilise resources from a broader community to implement the IndOOS-2. The IndOOS Resource Forum (IRF) has been reactivated during 2019, and prioritised recommendations have been conveyed by IORP through the IRF, to national and international representatives of the forum. There were also discussions on how IORP and SIBER can be better coordinated and cooperated. The panel also planned to strengthen the linkage with 2nd International Indian Ocean Expedition (IIOE-2) in the future.

The Eastern Boundary Upwelling Systems (EBUS) Research Focus
The ICTP-CLIVAR Joint Summer School on Oceanic Eastern Boundary Upwelling System was organised by EBUS RF and ICTP in Trieste, Italy from 15-19 July 2019. The school aimed at stimulating

discussion and new ideas concerning the mechanisms that influence the responses of EBUSs to climate variability and change. 37 students and 11 lecturers from 22 countries participated in the summer school. A two-day EBUS RF meeting was organised after the school, with the focused discussion on the cooperation with SCOR working group (WG) 155 on Eastern Boundary Upwelling Ecosystems (EBUE) for the Summer School on 'Changes in coastal upwelling systems and their impact on marine resources', which was originally scheduled from 4-12 May 2020 in Dakar, Senegal, and now postponed to early 2021 due to COVID-19. The structure for the manuscripts for EBUS perspective paper has also been drafted during the EBUS RF meeting in Trieste. EBUS RF is going to be sunset by 2021 after the publication of the EBUS perspective paper.

The GEWEX/CLIVAR Monsoons Panel (MP)
The scientific work of the MP can be summarized under the following topics:
Observational/field studies work;
Engagement with IPCC AR6/CMIP6 and MIPs;
Stakeholder engagement/end users & Climate Services;
Cross-group collaborations;
Climate change detection & attribution (including CORDEX);
Analysis of Sub-seasonal to Seasonal (S2S) simulations

Global Synthesis and Observations Panel (GSOP).
Some of the main activities implemented by the pane during 2019 are:
Organization of a Session on Ocean modeling and data assimilation during OceanObs19
Activities of GSOP were presented by Y. Fujii at OceanPredict
Provision of position comments on the 2nd TPOS2020 report
Participation and outreach of reanalysis inter-comparison activities (North Atlantic ORA-IP and Real-time ORA-IP)
Participation as GSOP to ocean heat content assessment efforts led by K. von Schuckman for the next IPCC report
Endorsement of synthetic profile data activities
GSOP meeting held in WHOI, February 2019
Participation to the IQuOD meetings representing reanalysis requirements and endorsement of IquOD activities

Plans for 2020 and beyond
The panel aims at continuing the participation and dissemination of results regarding reanalysis assessment and in particular participating to the ocean heat content and energy budget studies coordinated by the former group of Clivar Energy budget RF.
The panel aims at continuing supporting IQuOD and other observational activities and in particular representing the requirements from reanalyses.
The panel plans to participate, endorse and promote other activities concerning inter-comparison and assessment of global ocean reanalyses as continuation of ORA-IP (NA ORA-IP, etc.).

Tropical Basin Interaction (TBI)
TBI has starting its activities by several teleconferences during the past 6 months, and plans to organize an online workshop: WCRP-CLIVAR Workshop on Climate Interactions Among The Tropical Basins in early February of 2021, a call for paper will be made in the next few weeks

WCRP and CLIVAR look forward to further exploring collaborations in ocean related activities with SCOR in the future. Please contact Mike Sparrow (WCRP - msparrow@wmo.int) or Jose Santos (CLIVAR - jose.santos@clivar.org) to discuss further.

APPENDIX 11. REPORT ON SCOR CAPACITY DEVELOPMENT ACTIVITIES

CAPACITY-BUILDING ACTIVITIES

SCOR Committee on Capacity Building

<u>Terms of Reference</u>
The primary purpose of the SCOR Committee on Capacity Building is to oversee all of SCOR's capacity-building activities and to help the SCOR Secretariat manage these activities, specifically to

Provide direction for all of SCOR's existing capacity-building activities: participation of scientists from developing countries and countries with economies in transition in SCOR activities, POGO-SCOR Fellowship Program, travel grants, and provision of reports to libraries in developing countries.
Guide and assist SCOR Executive Director in development of new capacity-building activities, particularly the Regional Graduate Schools of Oceanography activity.
Assist SCOR-sponsored projects in developing their capacity-building activities.
Help SCOR arrange funding for existing and new capacity-building activities.
Assist SCOR in interacting with regional and international groups related to capacity building in ocean sciences, such as the ICSU regional centers, START, IOC regional programs, etc.

- Chair: Claudia Benitez-Nelson (USA)

- Other Members: Mary (Missy) Feeley (UK), Vanessa Hatje (Brazil), Venu Ittekkot (Germany), Prasanna Kumar (India), Margareth Kyewalyanga (Tanzania), Sun Song (China-Beijing), Jennifer Verduin (Australia)

- Liaisons: Hal Batchelder (PICES), Jim Costopulos (Global Oceans), Julius Francis (WIOMSA), Peter Pissierssens/Claudia Delgado (IODE/IOC), Eric Raes (IIOE-2 Early Career Scientists Network), and Sophie Seeyave (POGO)

In the past year, the committee reviewed one set of requests for travel support to scientific meetings and also reviewed the 2020 SCOR Visiting Scholar applications. The committee helped compile information on examples of capacity-building activities carried out by SCOR working groups (see https://scor-int.org/work/groups/capacity-dev-examples/).

The committee is also discussing potential new sources of funding for SCOR capacity-building activities.

SCOR Visiting Scholars
SCOR began a program in 2009 to enlist the services of ocean scientists from the SCOR community, from both developed countries and developing countries, both recently retired and active, to teach short courses and to provide more extended on-site education and mentorship at developing country institutions. Some countries and/or individual institutions have requirements for their scientists to retire at a given age, sometimes as early as 60 years of age. Many retired ocean scientists are still interested in teaching and mentoring, and because they are supported by pensions after their retirement, do not need salary support. Some active scientists can also use some of their already-supported work time to work in a developing country.

Hosting visiting scientists, whether retired or active, can have many benefits to host institutions also, such as inspiring, motivating, and informing students and faculty, and leading to future collaborations between the visiting scientist and the host institution.

The program is a partnership, with the host institution providing local accommodation and SCOR finding resources to pay for airfares and other local expenses, as necessary. The participating scientists donate their time. SCOR Visiting Scholars might be onsite for as little as two weeks to as long as visa requirements would allow. Applicants may already have selected a host institution or SCOR will help identify hosts. Information about the program is available at https://scor-int.org/work/capacity/visiting-scholars/.

In 2019, SCOR supported 5 Visiting Scholars:

- Teresa Cerveria Borges from the University of Algarve in Portugal visited the Academia de Pescas e Ciências do Mar do Namibe – APCMN (Academy of Fisheries & Marine Sciences of Namibe, near-future University of Namibe), Angola, from 29th May to 12th June 2019, and contributed to both a workshop and a full course.
- Pere Masqué from the Edith Cowan University in Australia visited the Universidade Federal da Bahia in Brazil from the 22nd of June to the 4th of July 2019, and taught a course on applications of radioisotopes in Marine Sciences and made professional contact for future research collaborations.
- Jorma Kuparinen, professor Emeritus from the University of Helsinki visited the Instituto Oceanografico de la Armada (INOCAR), Guayaquil, Ecuador in October 2019. He worked on developing two project proposals, the first in the Development for scientific collaboration in Marine Biodiversity on the Ecuadorian coast, and the second in human impacts on the biodiversity along the Ecuadorian coast.
- Mridula Srinivasan from the NMFS Office of Science and Technology (NOAA) in the USA visited the University of Mauritius between the 20th of October and the 7th of November 2019, and conducted lectures, theme-based workshops, field trips related to marine science.
- Brian Helmuth from the Northeastern University in the USA visited the Museo Argentino de Ciencias Naturales in Buenos Aires and the Centro Nacional Patagónico in Puerto Madryn, Argentina from the 25th of November to the 5th of December 2019. He lectured on intertidal biophysics and physiological ecology, directed a workshop on how to work with stakeholders on climate issues (strategies for dealing with four different climate hazards - sea level rise, extreme precipitation, extreme heat, and drought), and showed the use of the Gigapan and Kodak 360 in the field to produce stories.

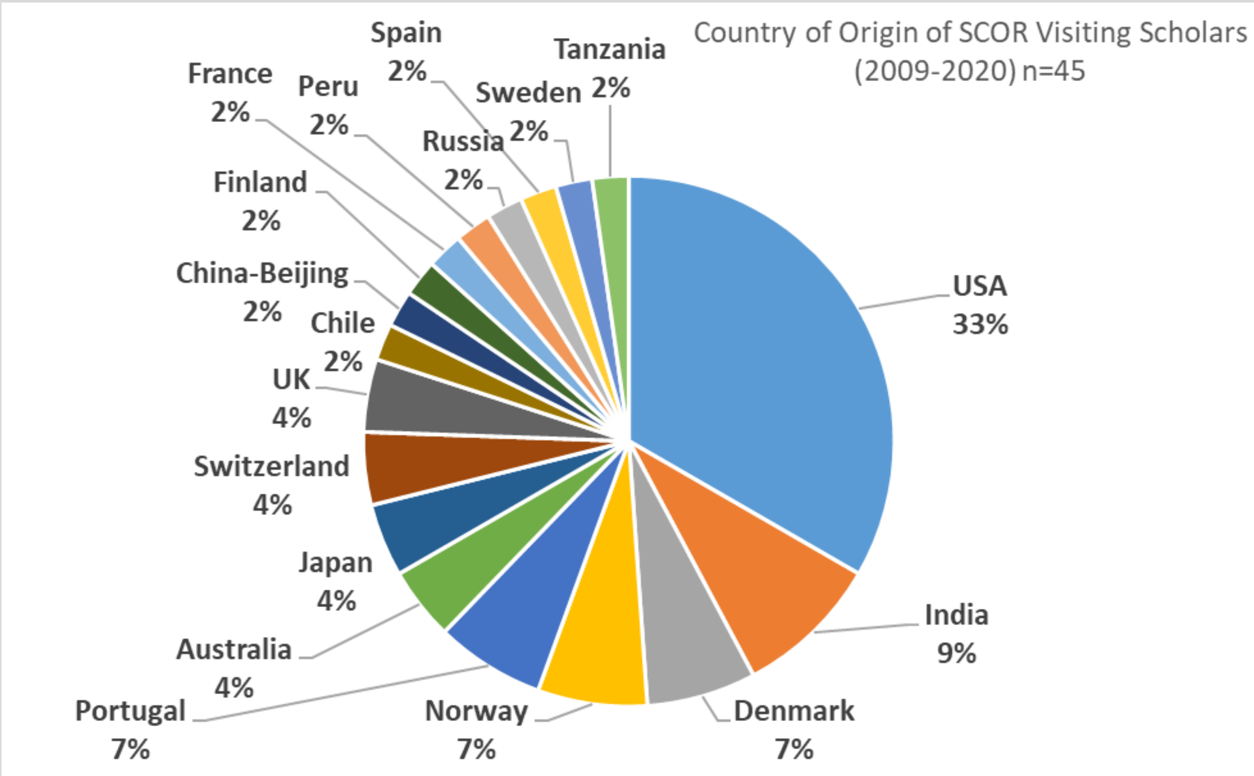
The annual number of Visiting Scholars approved each year has increased from 1 in 2009 to 6 in 2020. The SCOR Visiting Scholars who were approved in 2020 are shown below. The dates of the visits are now unknown because of the COVID-19 pandemic. Later in the year, it will be necessary to decide whether to issue a call for 2021 Fellows or to wait until 2022. James Ditty (see last row below) was approved without a host identified. We had begun to identify a host just prior to the onset of the pandemic, but it has been difficult to complete this process because of the uncertainties faced.

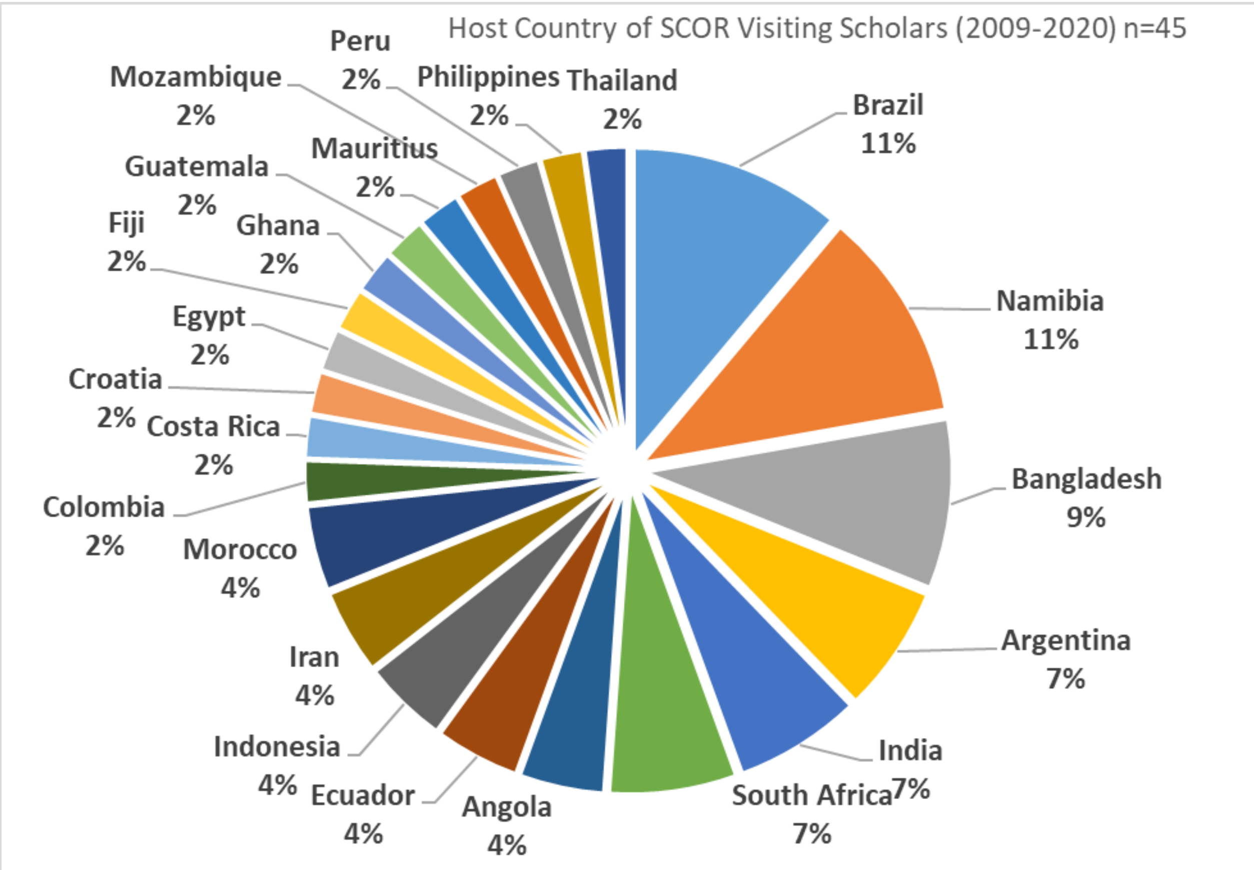
SCOR Visiting Scholars Approved in 2020

Name	Scholar Country	Host Country	Dates of Visit	Topic of Training

Lisa Levin	USA	Fiji		The nexus of climate change, biodiversity and resource extraction in deep waters.
Teresa Cerveira Borges	Portugal	Angola		Marine resources
James Moffett	USA	India		The relationship between the geochemistry of metals such as copper and iron, and the carbon, nitrogen and sulfur cycles
Hailong Liu	China-Beijing	Philippines		Fundamental knowledge of physical oceanography and its applications in polar and tropical regions
Hidenori Kumagai	Japan	India		Marine geology and volcanology including geophysical and geochemical aspects
James Ditty	USA	TBD		identification of early life stages of marine fishes

The 6 SCOR Visiting Scholars approved in 2020 will be supported by the U.S. National Science Foundation and national SCOR committees. This is the first year that SCOR Visiting Scholars will be sent to Fiji and the Philippines, and the first time a Visiting Scholar from China-Beijing has been selected. None of the 2020 Visiting Scholars has been able to do any travel in 2020 due to the COVID19 situation.


Country of Origin of SCOR Visiting Scholars (2009-2020) n=45
USA 33%
India 9%
Denmark 7%
Norway 7%
Portugal 7%
Australia 4%
Japan 4%
Switzerland 4%
UK 4%
Chile 2%
China-Beijing 2%
Finland 2%
France 2%
Peru 2%
Russia 2%
Spain 2%
Sweden 2%
Tanzania 2%


Host Country of SCOR Visiting Scholars (2009-2020) n=45
Brazil 11%
Namibia 11%
Bangladesh 9%
Argentina 7%
India 7%
South Africa 7%
Angola 4%
Ecuador 4%
Indonesia 4%
Iran 4%
Morocco 4%
Colombia 2%
Costa Rica 2%
Croatia 2%
Egypt 2%
Fiji 2%
Ghana 2%
Guatemala 2%
Mauritius 2%
Mozambique 2%
Peru 2%
Philippines 2%
Thailand 2%

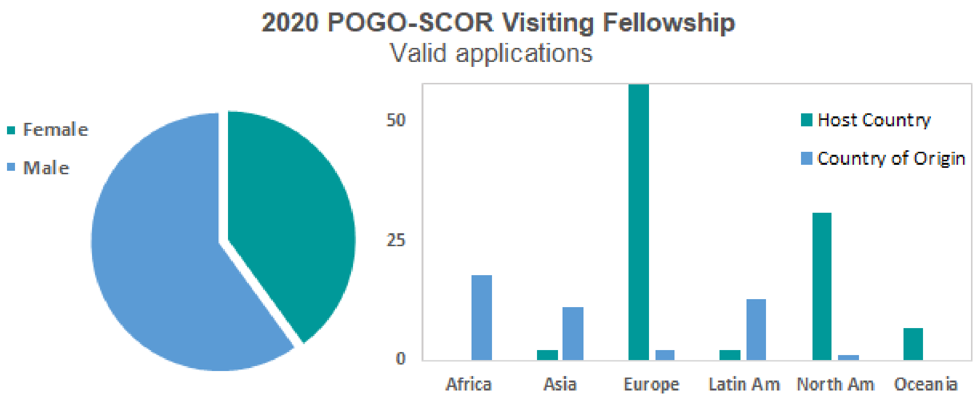
Ed Urban and Sophie Seeyave (POGO Executive Director) submitted an article on the SCOR Visiting Scholar Program and POGO Visiting Professor Program for to *Oceanography* magazine and are now working on revisions to the article.

POGO-SCOR Visiting Fellowships for Oceanographic Observations

2020 Program

This year the twentieth fellowship programme has been launched, jointly supported by POGO and SCOR. As the POGO Members had to be consulted on this year's budget expenditure at the POGO annual meeting at the end of January 2020, the announcement was posted on the 17 February 2020, with a closing date of 31 March 2020, subsequently extended to 30 April 2020 because of the COVID-19 pandemic, which may have impacted prospective host institution's ability to provide acceptance letters and to commit to receiving a foreign visitor.

A total of 45 valid applications were received this year (16 more than last year), 40% of which were from female candidates. Applications were received from 24 countries in all continents, except Oceania. Most of the candidates selected host institutes located in at Europe, followed by North America.



With the combined available budget from POGO and SCOR, 5 candidates were selected from: India, Venezuela, Argentina, Colombia and Morocco.

The applications were screened independently by a committee of six, with equal representation from SCOR and POGO. In making their selection, the committee considered the following factors:

quality of the application;
relevance of the application to the priority areas identified in the fellowship announcement;
evidence that the training will lead to improved sustained observations in the region, or improved applications of such data;
evidence that the training would lead to capacity-building with potential lasting impact on regional observations; and
the need to maximise regional distribution of the awards.

POGO and SCOR commend the efforts from all the supervisors and colleagues at the various host institutions who agreed to devote time and energy required for the training. The programme would not have been viable without such efforts from prominent scientists and their teams.

Demography of Fellowships for 2020

Parent Institutions:

India	Indian National Centre for Ocean Information Services (INCOIS)
Venezuela	Universidad Simón Bolívar (USB)
Argentina	Universidad de Buenos Aires (UBA/CONICET)
Colombia	Universidad del Norte
Morocco	Hassan II University

Host Institutions:

UK	University of East Anglia
USA	University of South Florida
Belgium	Royal Belgian Institute of Natural Sciences (RBINS)
UK	Plymouth Marine Laboratory (PML)
Spain	Institute of Marine Sciences (ICM/CSIC)

Gender distribution
Male: 3
Female: 2

The report of the performance of the 2019 Fellowships can be accessed at: https://scor-int.org/wp-content/uploads/2020/07/SCOR-POGO-Fellowship_report_2020-including-2019-Fellows.pdf

NSF Travel Support for Developing Country Scientists
SCOR has received support from the U.S. National Science Foundation (NSF) since 1984 to provide funding for SCOR capacity building activities. Most of the funds are used for travel grants for scientific meetings, although a portion are used for SCOR's contribution to the POGO-SCOR Fellowship Program and the SCOR Visiting Scholars program. Travel grants are awarded to ocean students and scientists to enable them to attend international scientific meetings (see https://scor-int.org/wp-content/uploads/2020/03/Eligible_Countries-1April2020.pdf for list of eligible countries).

The current NSF grant that SCOR uses to support these activities has been extended to expire on 31 August 2021, because of the delays in meetings due to COVID-19. So far during the current three-year grant, 181 individuals from 49 countries have received support to assist them in attending a total of 49 different scientific meetings and longer-term training activities. The NSF grant was renewed to start on 1 August 2020 and end on 31 July 2023, and so will overlap with the current grant by one year. The total funding available from each grant is US$225,000.

Over the three-year grant, about 77% of the grant funds are devoted to supporting the travel of scientists from developing countries and countries with economies in transition to ocean science meetings. The SCOR Committee on Capacity Building typically evaluates requests from meeting organizers for such support several times each year. After a meeting is approved, the organizers run a selection process and propose individual recipients for support. The SCOR Executive Director checks the names of proposed recipients to ensure they are from eligible countries and have not received similar support from SCOR for the past two years. Priority is given to applicants who are presenting a paper or poster at the meeting or to those who have some special expertise or regional knowledge to bring to a workshop or working group. Preference is also given to younger scientists. In general, care is taken to ensure that the recipients of SCOR/NSF funds are *active* scientists, and that they have not received similar support from SCOR in the previous two years. All travel grant recipients are informed that their support comes from SCOR and that it is made possible through NSF funding.

Requests come in throughout the year and the SCOR Committee on Capacity Building considers new requests between meetings.

The following requests were approved since the 2019 SCOR Annual Meeting:

Name of Event	Dates	Location	Suggested Amount
5th World Conference on Marine Biodiversity (WCMB 2020)	13-16 December 2020	Auckland, New Zealand	$5000
COSPAR Assembly	28 Jan.-4 Feb. 2021	Sydney, Australia	$3000
15th Pan Ocean Remote Sensing Conference (PORSEC) and Capacity Building Tutorial	2021	Johor Bahru, Malaysia	$3000
WG 150 Summer School	Before April 2021	South Africa	$5000
14th International Conference on Copepoda	6-12 June 2021	Kruger National Park, South Africa	$3000
IMBeR CLIMECO 7	9-13 August 2021	Vancouver, B.C., Canada	$7500
International Conference on Harmful Algae	Fall 2021	La Paz, Mexico	$5000
Gordon Research Conference and Seminar on Ocean Global Change Biology	2021 or 2022	Waterville Valley, USA	$3000
		Total requested	$34,500
		Total available	$47,911

The next review of requests will be conducted by the SCOR Committee on Capacity Building after the SCOR Annual Meeting.

Research Camps at University of Namibia

The 2020 Research Camp was postponed from April to December 2020, and then to 2021 because of the pandemic. For now, it appears that the camp will have access to the Namibian government research vessel at that time, which has become an integral part of the program. This program is supported through grants from the Agouron Institute and the Simons Foundation.

APPENDIX 12. 2019 AUDITED SCOR STATEMENT OF ACTIVITIES

SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH, INC.
STATEMENT OF ACTIVITIES
YEAR ENDED DECEMBER 31, 2019

	Without Donor Restrictions	With Donor Restrictions	Total
SUPPORT AND REVENUE			
Grant and contract revenue	$ 911,876	$ -	$ 911,876
Contribution revenue	800	55,287	56,087
Membership dues	390,805	-	390,805
Meeting registration fees and miscellaneous income	77,333	7,500	84,833
Interest income	3,866	-	3,866
NET ASSETS RELEASED FROM RESTRICTIONS			
Satisfaction of program restrictions	70,482	(70,482)	-
Total support and revenue	1,455,162	(7,695)	1,447,467
EXPENSES			
Program services			
Scientific programs	1,006,024	-	1,006,024
Travel and subsistence programs	82,736	-	82,736
Other conferences and meetings	17,678	-	17,678
Total program services	1,106,438	-	1,106,438
Supporting services			
Management and general	343,659	-	343,659
Total expenses	1,450,097	-	1,450,097
CHANGE IN NET ASSETS	5,065	(7,695)	(2,630)
NET ASSETS			
BEGINNING OF YEAR	173,175	47,091	220,266
END OF YEAR	$ 178,240	$ 39,396	$ 217,636

APPENDIX 13. SCOR RELATED MEETINGS (2020-2021)

SCOR related meetings 2020-2021

Working Group	Meeting mode	Type of meeting	Month	Year	Country
WG159-DeepSeaDecade	Face to face	Working Group meeting	January	2020	Portugal
WG156-Chlorophyll	Face to face	Working Group meeting	February	2020	USA
WG151-FeMIP	Face to face	Working Group meeting	February	2020	USA
WG148-IQuOD	Face to face	Tutorial at conference	February	2020	USA
WG148-IQuOD	Online	Working Group meeting	February	2020	
WG157-MetaZooGene	Face to face	Working Group meeting	February	2020	USA
WG145-MARCHEMSPEC	Face to face	Working Group meeting	February	2020	USA
GEOTRACES	Hybrid	Workshop	February	2020	Russia
GEOTRACES	Face to face	Special session at conference	February	2020	USA
WG154-P-OBS	Face to face	Tutorial at conference	February	2020	USA
WG148-IQuOD	Online	Working Group meeting	March	2020	
WG148-IQuOD	Online	Working Group meeting	April	2020	
WG148-IQuOD	Online	Working Group meeting	April	2020	
WG153-FLOTSAM	Online	Working Group meeting	April	2020	
IIOE-2	Online	Project SSC/SSG	April	2020	Online
WG148-IQuOD	Online	Working Group meeting	May	2020	
SOLAS	Online	Special session at conference	May	2020	
IMBeR	Online	Project SSC/SSG	May	2020	
WG148-IQuOD	Online	Working Group meeting	June	2020	
GEOTRACES	Online	Special session at conference	June	2020	
IMBeR	Online	Project SSC/SSG	June	2020	
WG148-IQuOD	Online	Working Group meeting	August	2020	
WG148-IQuOD	Online	Working Group meeting	August	2020	
WG152-ECV-Ice	Online	Working Group meeting	August	2020	
WG148-IQuOD	Online	Working Group meeting	September	2020	
WG158-C-GRASS	Online	Working Group meeting	September	2020	
WG158-C-GRASS	Online	Working Group meeting	September	2020	
WG158-C-GRASS	Online	Working Group meeting	September	2020	
WG158-C-GRASS	Online	Working Group meeting	September	2020	
WG158-C-GRASS	Online	Working Group meeting	September	2020	
SOLAS	Online	Project SSC/SSG	September	2020	
SOLAS	Online	Workshop	September	2020	
GEOTRACES	Online	Project SSC/SSG	September	2020	
GEOTRACES	Online	Project Technical subgroup	September	2020	
WG154-P-OBS	Online	Working Group meeting	September	2020	
WG156-Chlorophyll	Online	Working Group meeting	October	2020	
WG148-IQuOD	Online	Working Group meeting	October	2020	
WG148-IQuOD	Online	Working Group meeting	October	2020	
WG158-C-GRASS	Online	Working Group meeting	October	2020	
SOLAS	Online	Special session at conference	October	2020	
WG159-DeepSeaDecade	Online	Working Group meeting	October	2020	
WG148-IQuOD	Online	Working Group meeting	November	2020	
WG148-IQuOD	Online	Working Group meeting	November	2020	

WG148-IQuOD	Online	Working Group meeting	November	2020
IOCCP	Online	Project SSC/SSG	November	2020
WG156-Chlorophyll	Online	Working Group meeting	December	2020
WG151-FeMIP	Online	Working Group meeting	December	2020
WG158-C-GRASS	Online	Working Group meeting	December	2020
WG158-C-GRASS	Online	Working Group meeting	December	2020
WG161-ReMO	Online	Working Group meeting	December	2020
WG160-ATOMIX	Online	Working Group meeting	December	2020
SOLAS	Online	Townhall	December	2020
GEOTRACES	Online	Special session at conference	December	2020
GEOTRACES	Online	Project Technical subgroup	Twice per week from August to December	2020
WG158-C-GRASS	Online	Working Group meeting	January	2021
WG161-ReMO	Online	Working Group meeting	January	2021
WG161-ReMO	Online	Working Group meeting	January	2021
WG160-ATOMIX	Online	Working Group meeting	January	2021
SOLAS	Online	Seminar/Webinar	January	2021
GEOTRACES	Online	Special session at conference	January	2021
WG158-C-GRASS	Online	Working Group meeting	February	2021
WG161-ReMO	Online	Working Group meeting	February	2021
WG160-ATOMIX	Online	Working Group meeting	February	2021
WG160-ATOMIX	Online	Working Group meeting	February	2021
WG160-ATOMIX	Online	Working Group meeting	February	2021
WG159-DeepSeaDecade	Online	Working Group meeting	February	2021
WG159-DeepSeaDecade	Online	Townhall	February	2021
WG158-C-GRASS	Online	Working Group meeting	March	2021
WG161-ReMO	Online	Working Group meeting	March	2021
WG160-ATOMIX	Online	Working Group meeting	March	2021
WG156-Chlorophyll	Online	Working Group meeting	April	2021
WG158-C-GRASS	Online	Working Group meeting	April	2021
WG161-ReMO	Online	Working Group meeting	April	2021
WG160-ATOMIX	Online	Working Group meeting	April	2021
WG160-ATOMIX	Online	Working Group meeting	April	2021
WG160-ATOMIX	Online	Working Group meeting	April	2021
SOLAS	Online	Project SSC/SSG	April	2021
SOLAS	Online	Special session at conference	April	2021
IMBeR	Online	Project SSC/SSG	April	2021
WG159-DeepSeaDecade	Online	Workshop	April	2021
WG161-ReMO	Online	Working Group meeting	May	2021
WG160-ATOMIX	Online	Working Group meeting	May	2021
WG153-FLOTSAM	Online	Working Group meeting	May	2021
IMBeR	Online	Project SSC/SSG	May	2021
IQOE	Online	Project SSC/SSG	May	2021
WG157-MetaZooGene	Online	ASLO Aquatic Sciences	June	2021
WG145-MARCHEMSPEC	Online	Working Group meeting	June	2021

WG161-ReMO	Online	Working Group meeting	June	2021	
WG160-ATOMIX	Online	Working Group meeting	June	2021	
WG160-ATOMIX	Online	Working Group meeting	June	2021	
WG160-ATOMIX	Online	Working Group meeting	June	2021	
SOLAS	Online	Special session at conference	June	2021	
GEOTRACES	Online	Special session at conference	June	2021	
SOLAS	Hybrid	Workshop	July	2021	USA
WG159-DeepSeaDecade	Online	Workshop	July	2021	
SOLAS	Online	Workshop	August	2021	
IQOE	Face to face	Project Technical subgroup	August	2021	USA
SOLAS	Online	Special session at conference	September	2021	
SOLAS	Online	Special session at conference	October	2021	
SOLAS	Online	Workshop	October	2021	
SOLAS	Online	Project SSC/SSG	November	2021	
SOLAS	Online	Workshop	November	2021	
SOLAS	Online	Workshop	December	2021	
GEOTRACES	Online	Project Technical subgroup	Twice per week from January to May	2021	
SOLAS	Online	Seminar/Webinar		2021	
SOLAS	Online	Workshop		2021	
SOLAS	Online	Workshop		2021	