

**Annual Report to SCOR
2019 – 2020**



**Ocean Sustainability under Global Change
for the Benefit of Society**

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A. 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>]

B. 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).

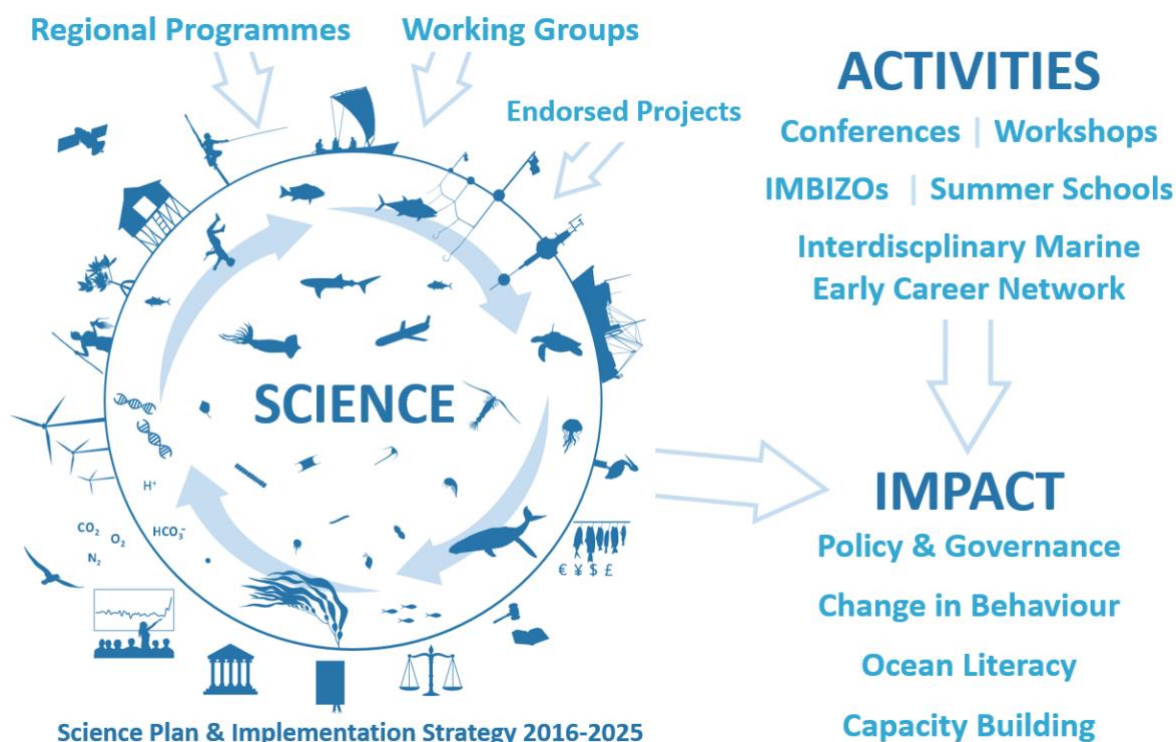


Figure 1. Contribution of the Regional Programmes, Working Groups, Endorsed Projects and IMBeR activities towards addressing the Grand Challenges and Innovation Challenges

C. 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 Lynnaeth 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)

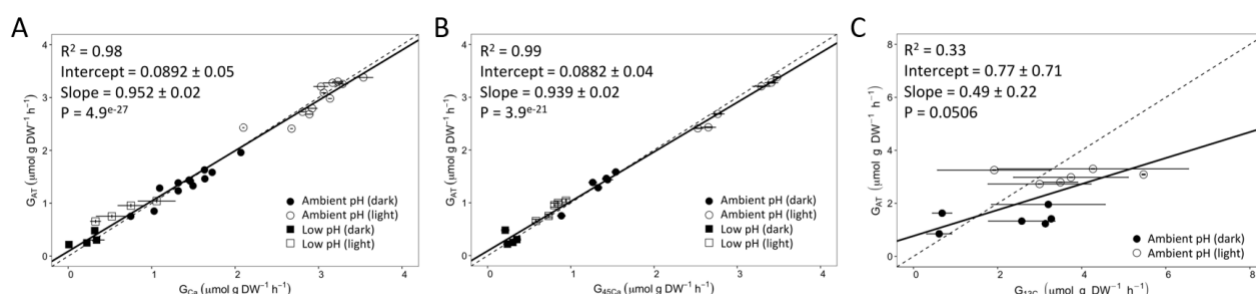


Central place foragers, such as the little penguin (*Eudyptula minor*) rely on areas within a small range of their breeding grounds for chick provisioning ([Evans et al., 2019](#)). Consequently, there is a tight coupling between their breeding success and local bio-physical conditions. The effects of 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}).

D. 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:

1. 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.
2. 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.
3. 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.
4. 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:

1. Modelling Southern Ocean species and ecosystems
2. Projections of ecological change
3. 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:

1. 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.
2. 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.

E. 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:
 1. We all think we are inter- and transdisciplinary – but are we really and what makes it work?
 2. Dynamic ocean governance: Linking environmental variability and local users.
- World Fisheries Congress will now be held in Adelaide, Australia in September 2021.
 1. 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>.

F. 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.

G. 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 CO₂ 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 CO₂ 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:

1. support assessments of current status and trends of Southern Ocean ecosystems, and
2. 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 Pangaia, 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:

1. Regional ocean acidification from observations and CMIP5 models
2. Species and functional group responses to ocean acidification and other stressors
3. Ecological change
4. 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.

H. Other IMBeR activities

Future Oceans₂ Open Science Conference (OSC)

IMBeR held its second Open Science Conference – Future Oceans₂ - 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 Oceans₂

Future Oceans₂, 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-marine#overview>

This research topic was developed by IMBeR's Interdisciplinary Marine Early Career Network (IMECaN, formally launched at Future Oceans₂). 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 Oceans₂ 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 Oceans₂, 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 Oceans₂, 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.

I. 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.



J. 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:

1. Exploring synergies between Regional Programmes and Working Groups
2. IMBeR Future science strategy
3. Mapping IMBeR outputs to the UN Sustainable Development Goals
4. Engagement with IMBeR - how can people get involved?
5. How to improve IMBeR's value to the hosts of the International Project Offices
6. Creating a new Innovation Challenge
7. IMBIZO6 conference
8. Exploring IMBeR's contribution to the UN Decade of Ocean Science for Sustainable Development
9. 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).

K. 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.

1. **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.
2. **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).
3. **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).
4. **GOOS**
SIBER has strong connections with the Global Ocean Observing System in the Indian Ocean – IOGOOS.

5. 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 Oceans₂ 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.

6. 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.

L. 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

- Abreu J, Staniland IJ, Rodrigues CF, Queirós JP, Pereira JM, Xavier JC (2019) Squid in the diet of Antarctic fur seals: potential links to oceanographic conditions and Antarctic krill abundance. *Marine Ecology Progress Series* 628: 211-221. DOI: 10.3354/meps13100
- Asper, VL and Smith, WO. 2019. Variations in the abundance and distribution of aggregates in the Ross Sea, Antarctica. *Elem Sci Anth*, 7: 23. DOI: <https://doi.org/10.1525/elementa.355>
- Atkinson A, Hill S, Pakhomov EA, Siegel V, Reiss CM, Loeb V, Steinberg D, Schmidt K, Tarling GA, Gerrish L, Salliey SF (2019) Krill (*Euphausia superba*) distribution contracts towards the Antarctic continental shelf during rapid regional warming. *Nature Climate Change* 9:142-147 doi:10.1038/s41558-018-0370-z
- Belcher, A, Henson, S, Manno, C, Hill, S, Atkinson, A, Thorpe, S, Fretwell, P, Ireland, L, Tarling, G (2019). Krill faecal pellets drive hidden pulses of particulate organic carbon in the marginal ice zone. *Nature Communications*, 10. 10.1038/s41467-019-08847-1
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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.

N. 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