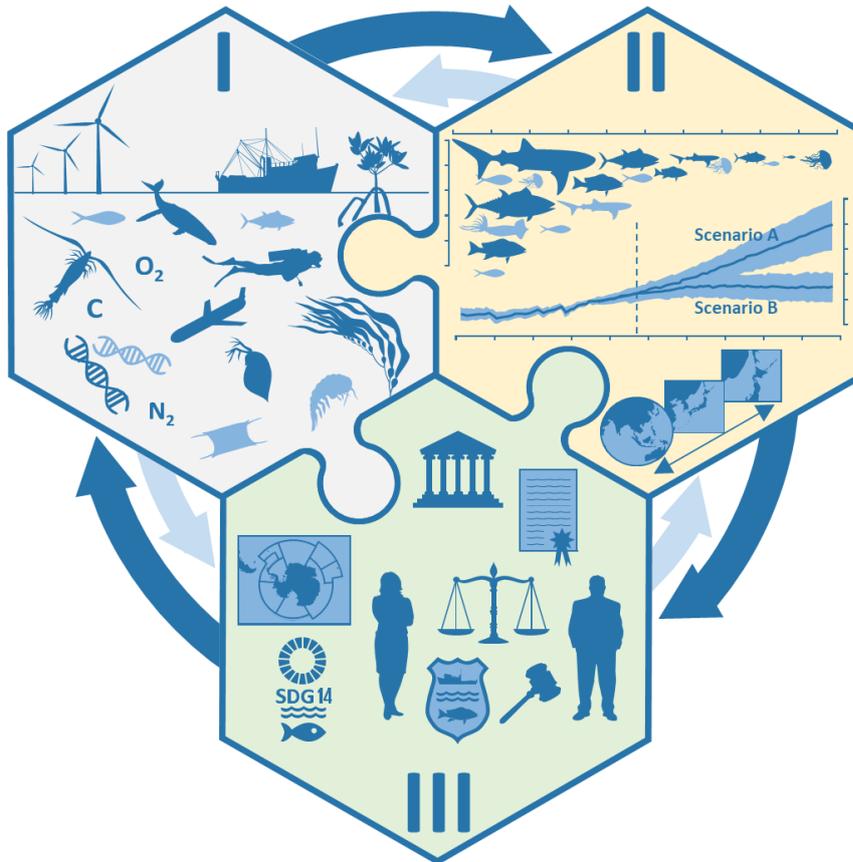


Annual Report to SCOR



2021 - 2022

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

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A. IMBeR STRUCTURE and OPERATIONS

Integrated Marine Biosphere Research (IMBeR) is an international research project with a vision towards *Ocean sustainability under global change for the benefit of society*. IMBeR is co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and Future Earth.

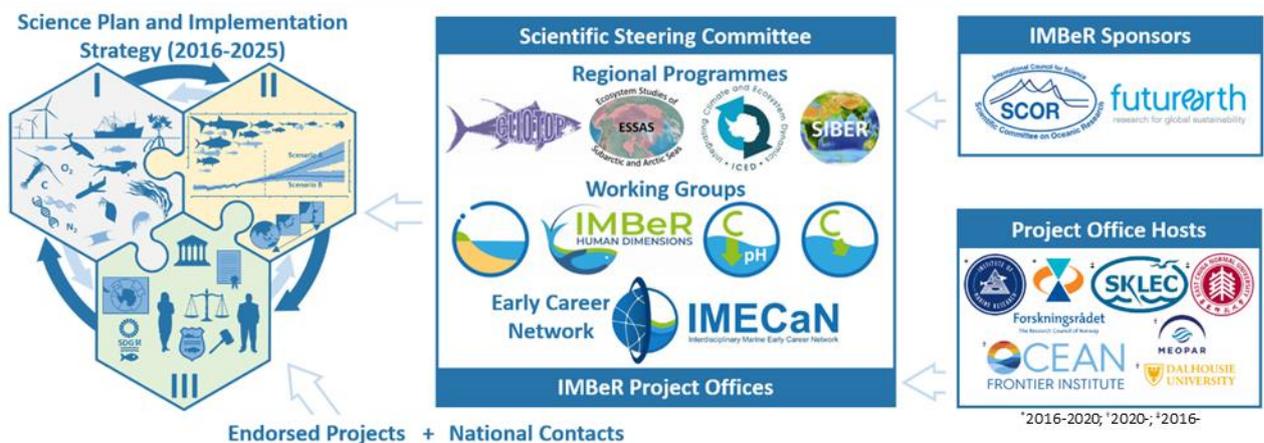


Figure 1. Schematic overview of IMBeR's structure and operations.

All the research and events undertaken by IMBeR are directed towards implementing the IMBeR **Science Plan and Implementation Strategy 2016-2025 (SPIS)**. The SPIS is structured around three **Grand Challenges (GCs)**. Three **Priority Research Objectives** focus the research for each of the GCs for the time remaining to complete the current SPIS (2022-2025):

- **Grand Challenge I:** 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. ([GCI Fact Sheet 2021](#))
Priority Research Objectives:

1. Cumulative effect of multiple stressors
 2. Integration of climate change and climate variability
 3. Impacts on society – preparation for a changed future
- **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. ([GCII Fact Sheet 2021](#))
Priority Research Objectives:
 4. Integration of data systems and approaches for predictions and projections
 5. Development of predictive models and projections for use at regional scales
 6. Development of alternative scenarios to bridge the gap between physical climate sciences and humanities
 - **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. ([GCIII Fact Sheet 2021](#))
Priority Research Objectives:
 7. Develop knowledge on best practices for multilevel governance approaches to ocean climate adaptation and mitigation
 8. Develop understanding on key ingredients for transformation towards more sustainable, equitable and inclusive governance approaches to fisheries and aquaculture
 9. Support implementation of post-2020 biodiversity targets for marine spatial planning, marine protected areas

In addition to the GCs, **Innovation Challenges (ICs)** focus on research topics that can be addressed within three to five years, and thereafter mainstreamed into the GCs once deliverables have been completed. There are currently four ICs:

- **Innovation Challenge 3:** advancing understanding of ecological feedbacks in the Earth System;
- **Innovation Challenge 4:** advancing and improving the use of social science data for ocean management, decision making and policy development;
- **Innovation Challenge 5:** interventions to change the course of climate impacts;
- **Innovation Challenge 6:** sustainable management of Blue Carbon ecosystems.
(ICs 1 and 2 were mainstreamed into the GCs in 2019)

The science outlined in the SPIS is advanced via:

four **Regional Programmes:**

- **Climate Impacts on Oceanic Top Predators** ([CLIOTOP](#)) and its [task teams](#);
- **Ecosystem Studies of Subarctic and Arctic Seas** ([ESSAS](#); and see [factsheet](#)) and its [working groups](#), [national](#) and [multinational programmes](#), and [endorsed projects](#);
- **Integrating Climate and Ecosystem Dynamics** ([ICED](#); and see [factsheet](#)), co-sponsored by the Scientific Committee on Antarctic Research ([SCAR](#)); and
- **Sustained Indian Ocean Biogeochemistry and Ecosystem Research** ([SIBER](#)), co-sponsored by the Indian Ocean Global Ocean Observing System ([IOGOOS](#));

four **Working Groups:**

- **Continental Margins Working Group** ([CMWG](#)), a joint working group with [Future Earth Coasts](#);
- **Human Dimensions Working Group** ([HDWG](#));

- **Integrated Ocean Carbon Research (IOC-R)**, a joint working group involving IMBeR, the Intergovernmental Oceanic Commission of the United Nations Educational, Scientific and Cultural Organization ([IOC-UNESCO](#)), the Intergovernmental Oceanic Commission – International Ocean Carbon Coordination Project ([IOCCP](#)), the World Climate Research Programme ([WCRP](#))/Climate and Ocean - Variability, Predictability, and Change ([CLIVAR](#)), the Surface Ocean – Lower Atmosphere Study ([SOLAS](#)), and the Global Carbon Project ([GCP](#));
- **SOLAS-IMBeR Ocean Acidification (SIOA)**, a joint working group with SOLAS;

eleven **Endorsed Projects**

- **Atlantic Meridional Transect (AMT)**; 2012-)
- **Collaborative Research and Education Project in Southeast Asia for Sustainable Use of Marine Ecosystems (CREPSUM)**; 2021-)
- **Gulf of Trieste – Time-series (GoTTs)**; 2021-)
- **Integrated Arctic Observation System (INTAROS)**; 2016-2021)
- **Mechanisms of Marine Carbon Storage and Coupled Carbon, Nitrogen and Sulphur cycles in response to global change (MCS-CNS)**; 2016-2021)
- **Marine Ecosystem-based Management Progress Evaluation Group: tracking the global progress of EBM (MEBM-PEG)**; 2020-)
- **Negotiating Ocean Conflicts among Rivals for Sustainable and Equitable Solutions (NoCRISES)**; 2021-)
- **Importance of Physico-Chemical Cycling of Nutrients and Carbon in Marine Transitional Zones (NUTS&BOLTS)**; 2020-)
- **Processes and Approaches of Coastal Ecosystem Carbon Sequestration (PACECS)**; 2016-2021)
- **The Study of Kuroshio Ecosystem Dynamics for Sustainable Fisheries (SKED)**; 2014-2021)
- **Ocean Acidification and Biogeochemistry: Variability, Trends and Vulnerability (VOCAB)**; 2017-2021)

and the **Interdisciplinary Marine Early Career Network (IMECaN)**, with around 850 members from almost 90 countries.

IMBeR has two **International Project Offices (IPOs)**, one in Halifax, Canada, hosted by the [Ocean Frontier Institute, Dalhousie University](#), and [MEOPAR](#), and the other in Shanghai, China, at the [State Key Laboratory of Estuarine and Coastal Research \(SKLEC\), East China Normal University \(ECNU\)](#). The IPOs are responsible for all the administrative and logistical aspects of the project, as well as communicating with the IMBeR community via the [website](#), the biweekly [IMBeR eNews](#) bulletin, and a monthly [IMBeR newsletter](#) that is published in English and Chinese, Twitter ([@imber_ipo](#) with 2000 followers) and [IMBeR WeChat](#) (with 434 subscribers and over 24,000 post reads).

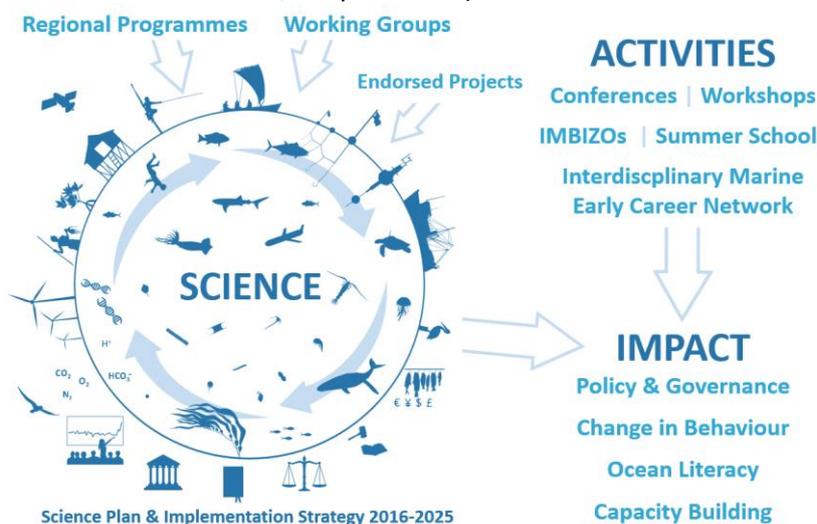


Figure 2. Contribution of the Regional Programmes, Working Groups, Endorsed Projects, Interdisciplinary Marine Early Career Network, and IMBeR activities towards addressing the Grand and Innovation Challenges.

B. SELECTED SCIENCE HIGHLIGHTS in 2021-2022

Possible future scenarios in the gateways to the Arctic for Subarctic and Arctic marine systems: II. Prey Resources, Food Webs, Fish, and Fisheries ([Mueter et al., 2021a](#))

Climate change impacts are pronounced at high latitudes, where warming, reduced sea-ice-cover, and ocean acidification affect marine ecosystems. This paper reviews climate change impacts on two major gateways to the Arctic: the Bering and Chukchi Seas in the Pacific and the Barents Sea and Fram Strait in the Atlantic. They present scenarios of how changes in the physical environment and prey resources may affect commercial fish populations and fisheries in these high-latitude systems to help managers and stakeholders think about possible futures. Predicted impacts include shifts in the spatial distribution of boreal species, a shift from larger, lipid-rich zooplankton to smaller, less nutritious prey that would have detrimental effects on fishes that depend on high-lipid prey for overwinter survival, shifts from benthic- to pelagic-dominated food webs with implications for upper trophic levels, and reduced survival of commercially important shellfish in waters that are increasingly acidic. Predicted changes are expected to result in disruptions to existing fisheries, the emergence of new fisheries, new challenges for managing transboundary stocks, and possible conflicts among resource users. Some impacts may be irreversible, more severe, or occur more frequently under anthropogenic climate change than impacts associated with natural variability, posing additional management challenges.

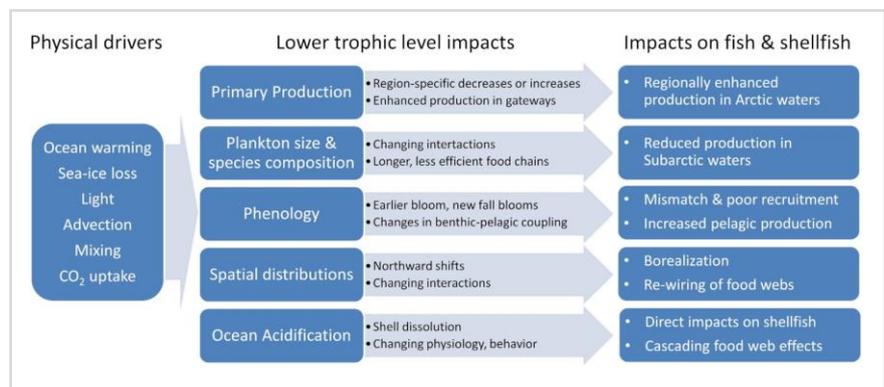


Figure 3. Schematic of main drivers and some anticipated responses of lower trophic levels and fish to increasing atmospheric CO₂ levels in the major Arctic gateways. (Mueter et al., 2021a)

Status, Change, and Futures of Zooplankton in the Southern Ocean ([Johnston et al., 2021](#))

In the Southern Ocean, several zooplankton taxonomic groups (euphausiids, copepods, salps and pteropods), are notable because of their biomass and abundance and their roles in maintaining food webs and ecosystem structure and function, including providing globally important ecosystem services. These groups consume microbes, primary and secondary producers, and are prey for fishes, cephalopods, seabirds, and marine mammals. In providing the link between microbes, primary production, and higher trophic levels these taxa influence energy flows, biological production and biomass, biogeochemical cycles, carbon flux and food web interactions, thereby modulating the structure and functioning of ecosystems. Additionally, Antarctic krill (*Euphausia superba*) and various fish species are harvested by international fisheries. Global and local drivers of change are expected to affect the dynamics of key zooplankton species, which may have potentially profound and wide-ranging implications for Southern Ocean ecosystems and the services they provide. Johnston et al. assess the current understanding of the dominant metazoan zooplankton within the Southern Ocean, including Antarctic krill and other key euphausiid, copepod, salp and pteropod species. The study provides a systematic overview of observed and potential future responses of these taxa to a changing Southern Ocean and the functional relationships by which drivers may impact them. To support future ecosystem assessments and conservation and management strategies, the authors also identify priorities for Southern Ocean zooplankton research.

Table 1. Assessment of the potential impacts of key ecological drivers of change on the distribution and abundance of key Southern Ocean zooplankton taxa. U = unknown/influence varies greatly according to species, L (blue) = low influence, M (orange) = medium influence, H (red) = high influence.

Taxa	Prey populations		Predator populations		Fisheries
	Microbiota (sea ice and sea floor)	Primary production	Predator populations	Recovery of historically harvested species (e.g., whales, seals)	
Antarctic krill 	M	H	H	H	L
Other euphausiids 	H	H	H	H	L
Copepods 	U	H	M	U	L
Salps 	U	H	U	U	U
Pteropods 	U	H	U	U	U

Low Temperature Sensitivity of Picophytoplankton P:B Ratios and Growth Rates Across a Natural 10°C Temperature Gradient in the Oligotrophic Indian Ocean (Landry et al., 2021)

Most models and predictions of the oceans under climate warming assume relatively high temperature sensitivities of phytoplankton growth, derived mainly from laboratory studies. Such assumptions are questionable under nutrient limitation, and mortality (loss) factors must also be considered for nutrient-poor waters, where production, nutrient cycling, and biomass turnover need to balance. Landry et al.'s investigation of picophytoplankton biomass (B), production (P), and growth along a natural 10°C

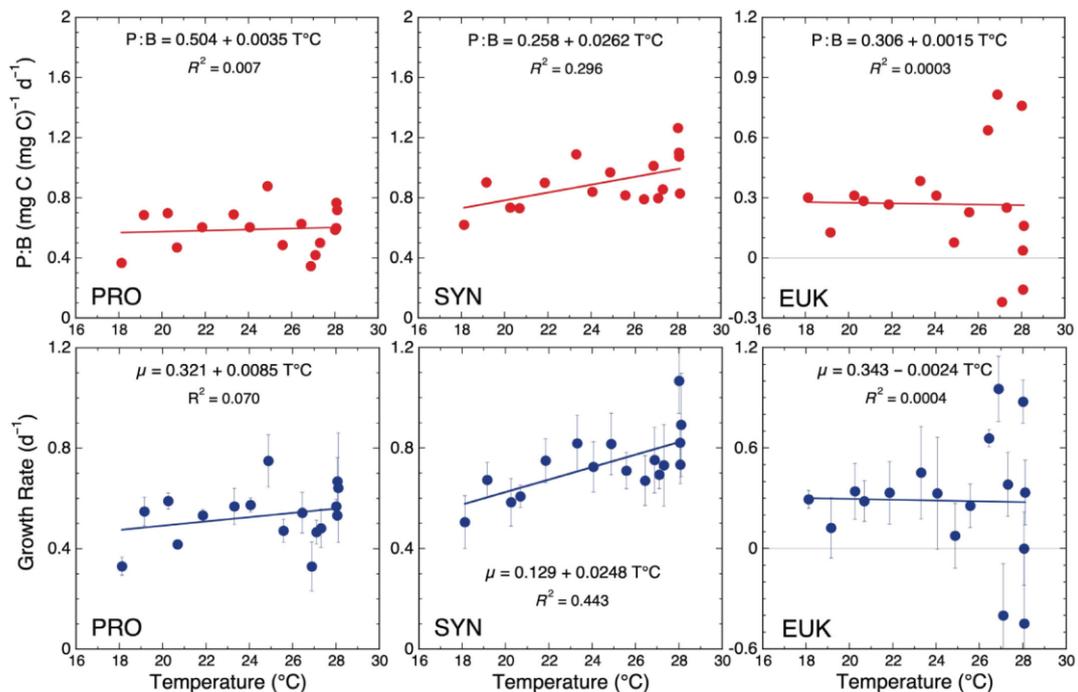


Figure 4. Production:biomass (P:B) ratios and growth rates for *Prochlorococcus* (PRO), *Synechococcus* (SYN), and photosynthetic eukaryotes (EUK) along a 10°C gradient in environmental temperature in the oligotrophic eastern Indian Ocean. Upper panels (red symbols and lines) are the ratios of depth-integrated carbon biomass and production from the surface to the depth penetration of 7.6% daily incident solar light. Lower panels (blue symbols and lines) are corresponding mean instantaneous growth rates at four light depths from 76% to 7.6 % incident light. Uncertainties are standard errors of mean rates. (Landry et al., 2021)

temperature gradient in the oligotrophic eastern Indian Ocean reveals low temperature sensitivities of P:B and growth rates, especially for *Prochlorococcus*, the biomass dominant. From documented variability in cell surface properties of *Prochlorococcus* and their effectiveness in reducing grazing vulnerability, the authors hypothesize that the selection for mortality defenses could be important for understanding microbial adaptations to a warming ocean. They also highlight natural environmental gradients that bridge future conditions in the contemporary ocean as major resources for investigating microbial physiological, genetic, and ecological adaptations and testing hypotheses.

A Typology for Reef Passages (Breckwoldt et al., 2022)

Coral reefs host exceptionally diverse and abundant marine life. Connecting coasts and sheltered lagoons to the open ocean, reef passages are important yet poorly studied components of these ecosystems. Abiotic and biotic elements ‘pass’ through these reef passages, supporting critical ecological processes (e.g., fish spawning). Reef passages provide multiple social and ecological benefits for islands and their peoples, but are so far neither characterized nor recognized for their multifaceted significance. This study investigated 113 reef passages across nine Pacific islands (in Fiji, New Caledonia, Vanuatu). GIS-based visual interpretations of satellite imagery were used to develop criteria to define three distinct types of reef passages, mainly based on distance to coastline and the presence or absence of an enclosed water body. The discussion identifies ways to refine and augment this preliminary typology as part of a research agenda for reef passages. This typology will be extended to other regions to better document reef passages and their various roles, supporting biodiversity conservation and sustainable fisheries management.

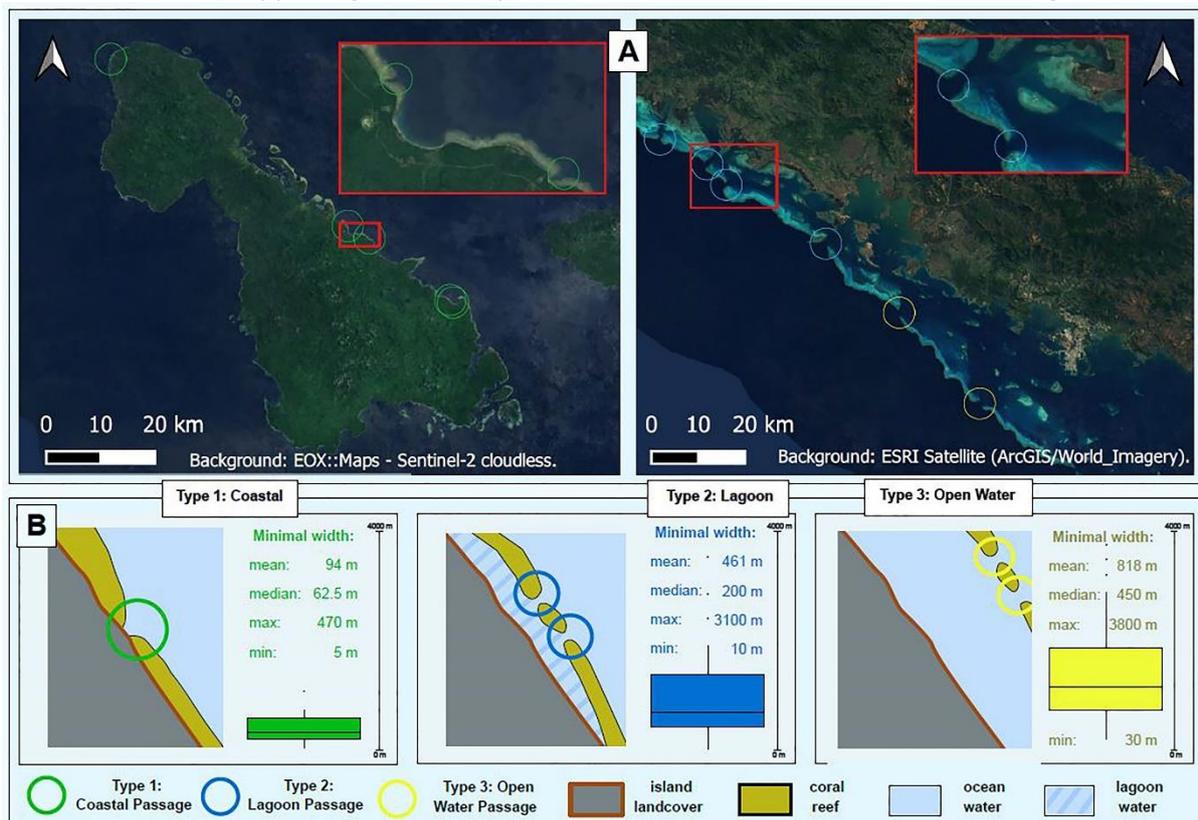


Figure 5. (A) Satellite images of examples of reef passages from the study sites. (B) Conceptual image of the three types of reef passages proposed in the study. (Breckwoldt et al., 2021)

Equity in Science: Advocating for a Triple-blind Review System (Brodie et al., 2021)

There is increasing recognition that a lack of diversity in the publication process may result in biases that undermine equity in scientific publishing. Indeed, geographic, gender, and language biases at the editorial and peer-review stages can impact manuscript acceptance rates and negatively influence under-represented researchers. The publication process involves many steps in communication between editors, reviewers and authors which allow conscious and unconscious biases to affect decisions. These biases help to perpetuate a scientific publishing forum that is dominated by a fairly homogeneous group – mostly male, originating from or based in rich and developed countries or institutions, native English speakers or with strong fluency in English, and primarily white. In addition, when the identity of authors is known it can favour well-established rather than early career researchers. Brodie et al. propose ‘triple-blind review’ for peer-reviewed journals – a process that keeps author identities and affiliations blind to manuscript editors until after first appraisal. Blinded appraisal will help to reduce biases that negatively affect under-represented and minority scientists, ultimately better supporting equity in scientific publishing.

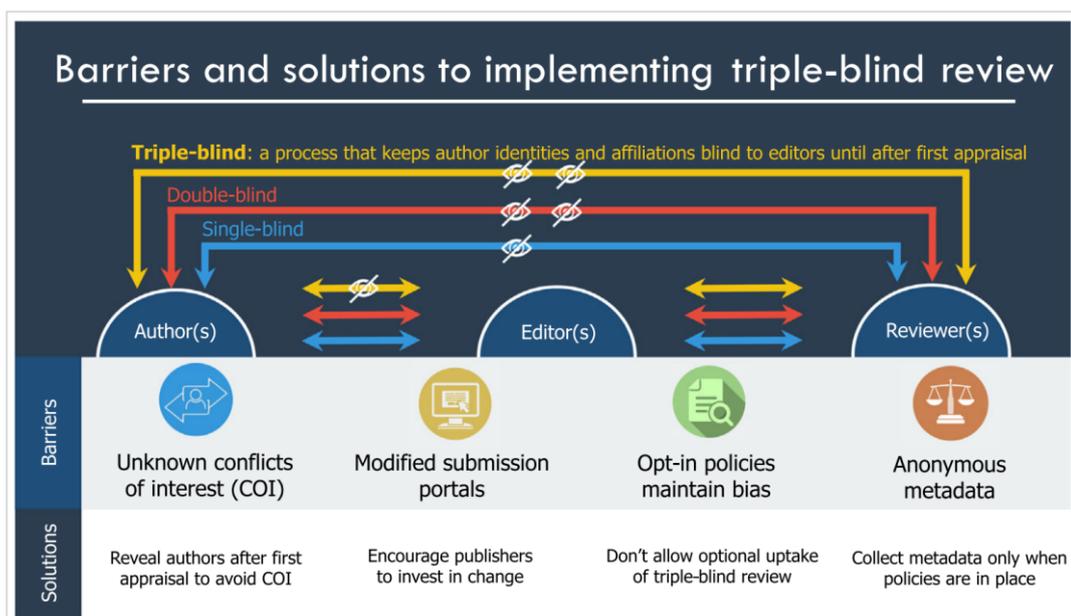


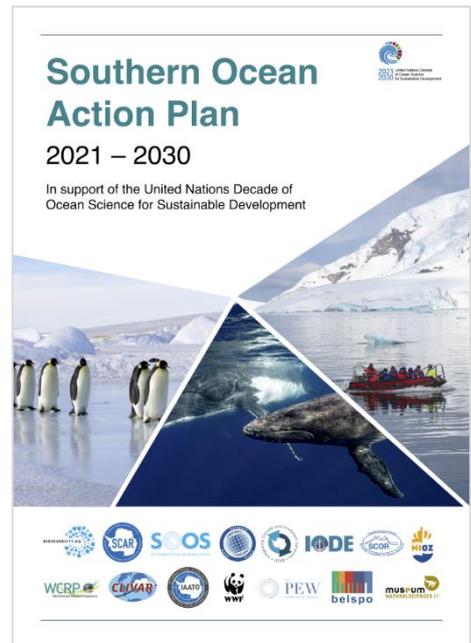
Figure 6. Conceptual summary of the barrier to implementing triple-blind review. Arrows highlight the pathways in which authors, editors, and reviewers interact in scientific peer-review systems. Eye icons indicate whether a pathway is anonymous. (Brodie et al., 2021)

The Southern Ocean Action Plan (2021-2030) (Janssen et al., 2022) *formal submission to UNDOCS*

As a member of the Southern Ocean Task Force, ICED co-authored the Southern Ocean Action Plan which was developed through a stakeholder-oriented process. The process engaged the scientific research community, business and industry sectors, and governance and management bodies. The process identified the needs of the Southern Ocean community to address the challenges related to the unique environmental characteristics and governance structure of the Southern Ocean. Synergies were also identified within the different sectors of the Southern Ocean community and beyond, to produce an Action Plan that provides a framework for Southern Ocean stakeholders to formulate and develop tangible actions and deliverables that support the UNDOCS vision. Through the publication of the Action Plan, the Southern Ocean Task Force aims to mobilise the Southern Ocean community and inspire all stakeholders to participate and leverage

opportunities to deliver innovative solutions to maintain and foster the unique conditions of the Southern Ocean. This framework provides an initial roadmap to strengthen links between science, industry and policy, as well as to encourage internationally collaborative activities to address existing gaps in knowledge and data coverage.

Figure 7. Cover of Southern Ocean Action Plan.



The Global Pandemic Has Shown We Need an Action Plan for the Ocean ([Murphy et al., 2021](#))

Murphy et al. (2021) discuss how the COVID-19 pandemic is the first serious test of how science can inform decision-making in the face of an immediate global threat, yielding important lessons on how science, society and policy interact. The global societal and economic impact of COVID-19 has shown that we need to assess, plan and prepare for potential future changes. These insights are particularly important for the ocean science community because of the global connectivity of the ocean and its crucial role in the Earth's climate system and in supporting all life on Earth. Murphy et al. outline how lessons from the COVID-19 pandemic can inform sustainable ocean governance and how IMBeR, along with the UNDOCS, can serve as platforms to help achieve this.

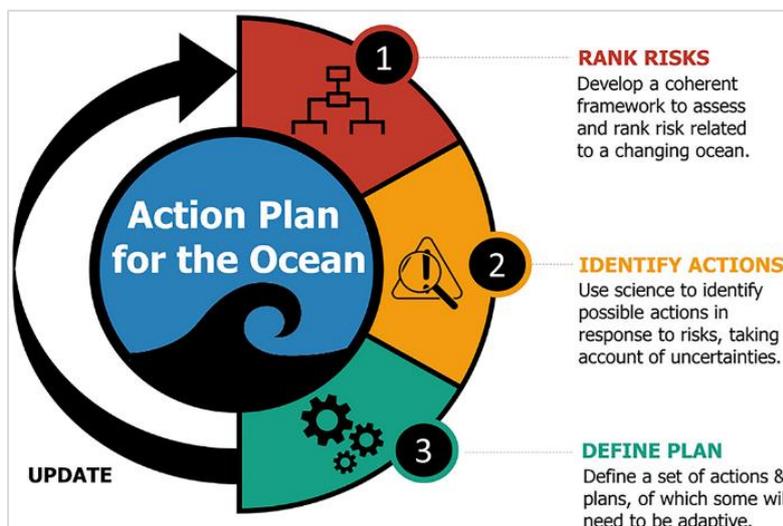


Figure 8. Iterative process for developing an 'Action plan for the ocean' (from Murphy et al. 2021)

C. SELECTED SCIENCE ACTIVITIES 2021-2022

IMBeR ClimEco7 Summer School – Interdisciplinary Ocean Science for Sustainable Development 9-13 August 2021, *UNDOS-endorsed activity* ([link](#))

The virtual ClimEco7 summer school included lectures dealing with the impacts of climate change, a range of modelling approaches and linking science-policy-society. The number of participants was limited to 60 Masters and PhD students and postdocs from 38 countries. Smaller training sessions took a more hands-on approach on how to write a good academic paper or grant proposal, and how to create quality social media content. The summer school also provided networking opportunities: small groups with different participants each day, met for informal discussions facilitated by a lecturer, so that by the end of the week, all the participants had met each other. In addition, there were participant-driven interactions and meet-ups organised using the summer school WHOVA app. Videos of the lectures are available [here](#).



Figure 9. ClimEco7 Flyer.

IMBIZO6: Marine Biosphere Research: Buoyant Solutions for Ocean Sustainability 18-22 October 2021 ([link](#)), *UNDOS-endorsed event*

'IMBIZO' is the Zulu word for 'a gathering'. The virtual IMBeR IMBIZO6 conference on Buoyant Solutions for Ocean Sustainability had 115 attendees from 39 countries. IMBIZOs are comprised of three concurrent workshops interspersed with plenary cross-workshop integration sessions. The workshop topics were:

1. Exploring potential marine options for climate intervention
2. Lighting the Grey Zone. How can we integrate human dimensions in decadal-scale prediction systems?
3. Ocean governance and climate adaptation: comparing responses, charting future courses

Prior to the main conference, IMEcaN convened a workshop on 'Building Capacity for Diversity and Inclusion in Ocean Sciences'. Recordings and presentations are available online [here](#).

Planned outputs from IMBIZO6 include:

1. Roadmap on the governance of climate interventions
2. Perspective paper 'Lighting the Grey Zone: what is needed for decadal-scale prediction to meet decision-making needs for marine socio-ecological systems'
3. 'Ocean Governance and Climate Adaptation: Comparing Responses, Charting Future Courses' Research Topic in *Frontiers in Marine Science* ([open for submissions](#))

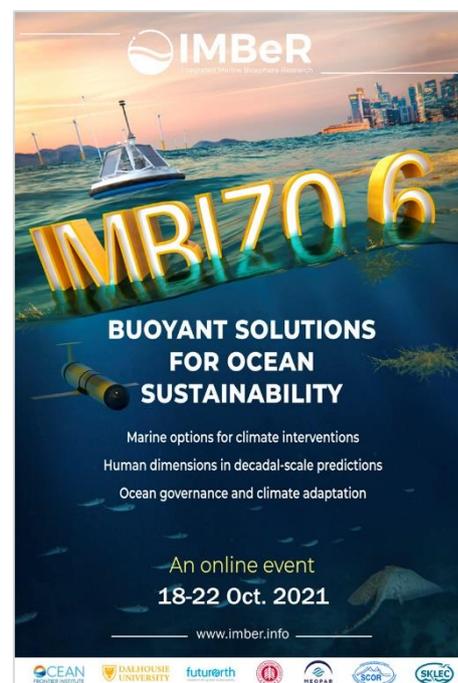


Figure 10. IMBIZO6 Flyer.

IMBeR West Pacific Symposium: Changing West Pacific Ocean: Science and Sustainability 22-25 November 2021 ([link](#)), UNDOS-endorsed event

Following the success of IMBeR's [China-Japan-Korea Symposia series](#), and responding to the series' expanding geographical reach, IMBeR held its first [West Pacific Symposium](#) in 2021 which was attended virtually by over 900 participants from 70 countries. The conference had eight sessions, including an ECR-led ICED-CLIOTOP joint session 'Connectivity of the West Pacific and Southern Ocean: the Importance of Oceanic Top Predators'. The symposium resulted in a two-volume special issue in Deep-Sea Research Part II: Topical Studies in Oceanography ([call for papers](#)). In addition, two focused study groups were established to undertake region-wide collaborative research:

1. Ocean Colour-based Plant species identification and Carbon flux in the Indo-Pacific oceans study group (IMBeR OC-PC);
2. Indo-Pacific Region: marine biogeochemistry, biodiversity, sustainability study group (IMBeR IPR).

Recordings of plenary sessions and keynote talks are available [here](#).



Figure 11. IMBeR West Pacific Symposium 2021 Flyer.

ESSAS Annual Science Meeting 20-23 June 2022, Seattle, USA ([link](#))

The 2022 ESSAS Annual Science Meeting was held in June in Seattle, WA, USA, with 79 participants including 25 ECRs attending either in-person or virtually. The meeting brought together researchers from seven countries with links to the Arctic to discuss recent advances in understanding of the past and future of high-latitude marine socio-ecological systems. (see [full conference program](#)). A joint session with the [Oceans Past Initiative](#) aimed to foster interactions and future collaborations. Several publications are expected from the gadid workshop that formed part of the meeting.



Figure 12. ESSAS Annual Science Meeting booklet front cover.

Solving Complex Ocean Challenges Through Interdisciplinary Research: Advances from Early Career Marine Scientists

Frontiers Research Topic led by IMECaN ([Brodie et al. eds](#))

IMECaN produced a 42-article Frontiers Research Topic ‘*Solving Complex Ocean Challenges Through Interdisciplinary Research: Advances from Early Career Marine Scientists*’. One of the criteria for inclusion in the special issue was that the first author of each article had to be an ECR. In addition, the research topic editors were all ECRs. Over 200 authors contributed to this special issue that showcases the diversity of research undertaken by early career marine scientists, with original research articles and perspective pieces focused on interdisciplinary marine science. The special issue specifically addresses IMBeR’s three Grand Challenges and includes perspectives on the role of early career researchers in solving ocean challenges. Articles covered topics including biogeochemistry, ecology, fisheries, plastics, restoration, and social-ecological systems.

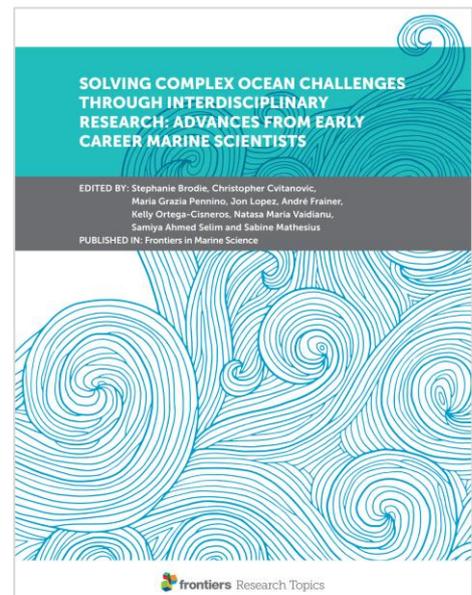


Figure 13. IMECaN Frontiers Research Topic.

The Second International Indian Ocean Expedition (IIOE-2): New Exploration in a Poorly Understood Ocean Basin (volume 4)

Special Issue in Deep-Sea Research Part II ([Hood et al. eds](#))

The fourth volume from SIBER’s collaboration with the IIOE-2 was published in Deep-Sea Research Part II. The special issue highlights the broad range of IIOE-2 research, including: the impact of the Madden-Julian Oscillation (MJO) on the Indonesia throughflow, seasonal sea surface temperature variations of the Somali Current/Undercurrent system, effect of radiant heating on chlorophyll in the southern Bay of Bengal during summer monsoon, long-term chemical changes of sea surface carbonate in the Mozambique Channel, physical and biogeochemical processes that determine chlorophyll-a profiles in the Arabian Sea, microalgal blooms in the northwestern Arabian Sea and Persian Gulf, spatial and temporal variability of export fluxes in the southern Indian Ocean subtropical gyre, and zooplankton assemblages variation in the Bay of Bengal and the southwestern Indian Ocean. The special issue demonstrates the importance of the IIOE-2 in motivating and compiling oceanographic research in the Indian Ocean. Volumes 5 and 6 are under development and will provide more new insights into this complex and poorly understood ocean basin.

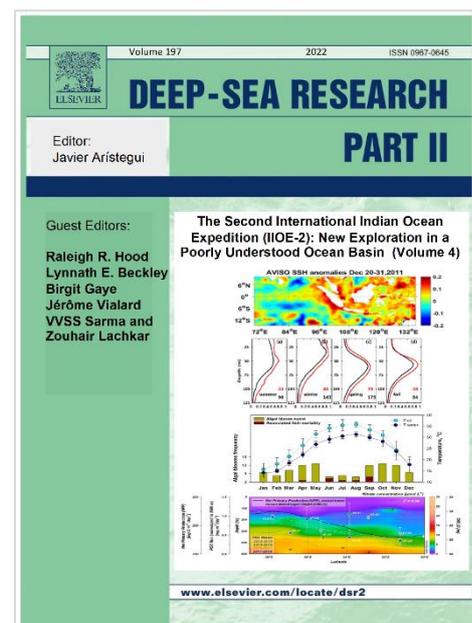


Figure 14. IIOE-2 Special Issue.

Marine Ecosystem Assessment for the Southern Ocean: Meeting the Challenge for Conserving Earth Ecosystems in the Long Term
Frontiers Research Topic ([Constable et al., eds](#))

Over 175 authors from 19 contributed to this 20 article Frontiers Research Topic addressing the Marine Ecosystem Assessment for the Southern Ocean (MEASO), a core project of IMBeR's ICED regional programme. The articles fall under several MEASO themes: (i) global and local drivers of change in Southern Ocean ecosystems; (ii) status and trends of marine biota in Antarctica and the Southern Ocean, including details of their critical limits and relationships (attribution of change) to key drivers, such as habitats; (iii) spatial differentiation and trends in Southern Ocean food webs; (iv) challenges for policy makers, including ecosystem services, changing habitats and coastal and shelf systems, and sentinels of change; (v) lessons, methods, gaps, and future priorities from MEASO-1 and other environmental assessments; and (vi) foundations and extensions of MEASO.

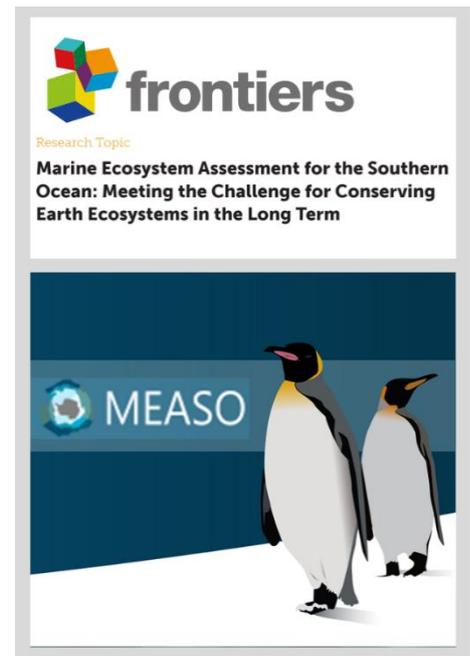


Figure 15. MEASO Frontiers Research Topic.

D. ACHIEVEMENTS and ACTIVITIES 2021-2022

--- Implementation of the IMBeR Science Plan and Implementation Strategy

Although COVID-19 made in-person meetings, research cruises, and field work difficult over the period of this report, IMBeR was able to make progress towards achieving the objectives of the Grand and Innovation Challenges. This progress is outlined below:

-- Grand Challenge I: Understanding and quantifying the state and variability of marine ecosystems

ESSAS

- The final report of the **Resilience and Adaptive Capacity of Arctic Marine Ecosystems** ([RACArctic](#)) was submitted to the national funding agencies. Two synthesis papers were published ([Drinkwater et al., 2021](#) and [Mueter et al., 2021a](#)) and another is currently in review.
- The **ESSAS Annual Science Meeting** ([2022](#); see Selected Science Activities 2021-2022)
- Within the **Arctic Challenge for Sustainability II** ([ArCS II](#)) project, ESSAS is developing baseline data and a community analysis of marine fish in the Arctic Ocean using environmental DNA (eDNA). ESSAS aims to develop optimal sampling protocols for eDNA studies in the Arctic. It is anticipated that eDNA data synthesized with oceanographic data will reveal ecological changes in the Arctic region associated with climate change.
- **Arctic Marine Biological Observation Network** ([AMBON](#)) collects year-round eDNA and phytoplankton samples, and passive acoustics to observe vocalizing marine mammals in the Chukchi Sea. Two Essential Ocean Variables (EOVs) - microbes (from eDNA collections) and epibenthic invertebrates, as well as fish and seabirds were added to the spatially expansive sampling program enabling biodiversity observations across time and space. These monitoring and research efforts support Priority Research Objectives 1 and 2 under GC I. Research Objective 3 is supported by partnering with the Joint PICES/ICES Working Group on Integrated Ecosystem Assessment for the Northern Bering Sea - Chukchi Sea (NBS-CS) ([PICES Working Group 44](#)). AMBON also partners with the NOAA-led **US Arctic Observing Network**

([US AON](#)) to link scientific observations to a variety of Arctic stakeholders, such as industry, Indigenous Alaskan communities, management agencies, and the broader Arctic research community. Based on results from the first phase of AMBON, the project recently documented how borealization may be affecting biological communities on the Northeast Chukchi Sea shelf ([Mueter et al., 2021b](#)).

CLIOTOP - ICED joint activity

- **Connectivity of the West Pacific and Southern Ocean: the Importance of Oceanic Top Predators** – ECR-led CLIOTOP-ICED joint session at the IMBeR West Pacific Symposium 2021. The session examined the relationship and relevant lag-times between oceanic processes and predator responses, at scales from foraging behaviour to large-scale demographic trends, and potential future viability under plausible climate scenarios ([further session details](#)).

ICED

- **Marine Ecosystem Assessment of the Southern Ocean** ([MEASO](#)) produced a series of papers on key species and drivers to support scenarios, projections and governance in a [MEASO Special Issue](#). This initiative developed in response to the need to undertake a comprehensive marine ecosystem assessment of the Southern Ocean in support of raising global awareness of the impact of change on these unique ecosystems, understanding their role in Earth System processes and feedbacks, and underpinning policy decisions at the global and Southern Ocean scales. Many papers quantified the state and variables of Southern Ocean ecosystems, and this was presented at both ClimateExpO and COP26 in May and November 2021 (see detail under GC III). This work also addresses GC II and III.
- **ICED multi-year campaign on sea ice ecosystems:** ICED, together with the Scientific Committee on Antarctic Research (SCAR), continues to campaign and plan for a focus on sea ice ecosystems, including a multi-year, multidisciplinary field work effort. This activity will also address GC II.
- **New EU Horizon 2020 programme:** ICED is part of the multi-partner EU Horizon2020 project, led by Norway: **Polar Regions in the Earth System: the Role of Local and Regional Polar Processes in Changing the Polar Climate and the Global Climate System** ([PolarRES, 2021-2026](#)). ICED will use abundance and distribution data of key species in the Southern (and Arctic) Ocean to generate projections of their dynamics using outputs from high resolution physical models of the polar regions. This will input to GCs II and III.
- **Biogeochemical processes and ecosystem function in changing polar systems and their global impacts** ([BIPOLE, 2022-2027](#)) will address a fundamental aspect of the Earth System – how nutrients in polar waters drive the global carbon cycle and primary productivity. Its contribution to GC I includes the way polar ecosystems (particularly zooplankton) process nutrients, and how these are supplied to the rest of the world's oceans. IMBeR (and its regional programmes, particularly ICED) is a key stakeholder in this programme.
- **Joint research interests with other programmes and initiatives:** ICED continues to work with other key initiatives to improve understanding of the state and variability of Southern Ocean ecosystems. These include: CCAMLR and the International Whaling Commission (IWC; see GC III) and SCAR's new Scientific Research Programmes - **Integrated Science to Inform Antarctic and Southern Ocean Conservation** ([Ant-ICON](#)) and **Near-Term Variability and Prediction of the Antarctic Climate System** ([AntClim^{now}](#); see GCIII).
- **Southern Ocean Action Plan (2021-2030):** The Action Plan was developed part of the UNDOS, by ICED, SCAR, and Southern Ocean Task Force members to support several societal outcomes for the Southern Ocean. Activities will address all three GCs. Activities this year include:
 - Virtual kick-off meeting for the Southern Ocean UN Decade, 9 Jul 2021 ([link](#))
 - 2nd Southern Ocean Regional Workshop, 20-22 Sep 2021, online ([link](#))
 - Southern Ocean Decade Update Webinar on the Action Plan Development, Dec 2021 ([link](#))

- UN Decade Lab on Working Group 2: A Healthy and Resilient Ocean, online, 9-11 March, 2022 ([link](#))
- Town Hall, AGU Oceans 2022 Conference to raise awareness of the Action Plan
- Launch of the Southern Ocean Action Plan, online, 12 April 2022 ([link](#))
- **The role of Southern Ocean ecology in the Earth system: integrating across scales, disciplines, and method:** Joint ICED-SCAR Krill Action Group (SKAG) online session at [Ocean Sciences Meeting 2022](#).

SIBER

- **2nd International Indian Ocean Expedition (IIOE-2):** SIBER members continue to be involved in steering committees and working groups, and chairing national IIOE-2 committees. Broader ongoing programmes relating to GCI include the IIOE-2's **Eastern and Western Indian Ocean Upwelling Regime Initiatives** (EIOURI and WIOURI, respectively). The WIOURI programme focuses on nine upwelling regions, with emphasis on climate change and marine food security. In addition to the ongoing **Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosystem research in the Western Indian Ocean (SOLSTICE-WIO)** programme, two new WIOURI projects, focused on the Agulhas current (CYCLOPS) and the Mozambique shelf (ReMoTurb) were launched. Both are multi-disciplinary (physics, biology, biogeochemistry) and address ocean productivity, fisheries and coastal communities.
- **Bluefin Larvae in Oligotrophic Ocean Foodwebs, Investigation of Nutrients to Zooplankton (BLOOFINZ)** is funded by the US National Science Foundation and is an IIOE-2 endorsed project. It started with a cruise off northwestern Australia from January-March 2022. The study investigated the physical, biogeochemical and ecological properties of this ocean ecosystem, the only global spawning area for southern bluefin tuna, as they relate to the habitat quality for larvae of pelagic tunas and their potential vulnerabilities to climate change.
- **Throughflow Indonesian Seas, Upwelling and Mixing Physics** project (**TRIUMPH**): The ongoing multi-disciplinary TRIUMPH project is a key element of the IIOE-2 EIOURI programme. A cruise in 2021 that saw recovery and redeployment of multiple moorings around Indonesia and studies of mixing in the Lombok Strait.
- **Marine Observation System Along Indian Coast** project (**MOSAIC**) – the first two of six multiparameter mooring systems were deployed.
- **Enhancing Knowledge of the Arabian Sea Marine Environment through Science and Advanced Technology (EKAMSAT)** programme was launched in 2021, and will focus on the Arabian Sea and topics including the recurring winter monsoon algal blooms and factors controlling acidification.
- **International Indian Ocean Science Conference 2022 (IIOESC-2022)** 14-18 March 2022 (virtual): SIBER helped organise the conference and contributed to the programme.
- **WIO Regional Benthic Imagery Workshop** 30 August - 2 September 2021 had 266 participants from 20 countries; see [videos](#)
- **Training Workshop on Biological Observations in the Indian Ocean 'From microbes to megafauna'** 8-12 November 2021; 70 participants, 22 countries
- **Coastal Lab in a Box (CoLaB)** is a new collaborative initiative between members of SIBER and the Indian Ocean Research Panel (IORP; IOGOOS/CLIVAR) seeks to create a portable and affordable package of instrumentation and methods for coastal oceanographic studies, alongside protocols and training. An Ocean Best Practices task team is now in place, and CoLaB, that originally targeted western Indian Ocean nations, is now set to become part of the wider UN Decade of Ocean Science for Sustainable Development under the [CoastPredict](#) programme.

CMWG

- **Ecosystem-Social Interactions in the Coastal Sea** – Session at the IMBeR West Pacific Symposium, November 2021, over 100 participants, 2 keynote speakers, 31 oral and poster presentations ([further session details](#))

CREPSUM

- **CREPSUM Planning Meeting** was held on 24 March 2022 ([virtual](#)): more than 70 attendees.
 - **Jellyfish Identification Workshop** 17-18 March 2022 ([virtual](#)): A training workshop on jellyfish identification as part of a CREPSUM educational activity in collaboration with IOC/WESTPAC. More than 60 trainees from 9 countries/regions (Indonesia, Japan, Malaysia, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, Vietnam) attended. High quality microscopic video images were prepared. Lecturers included specialists in jellyfish biology and ecology, medical doctors and health personnel, who lectured on health incidents relating to jellyfish.
- **Grand Challenge II:** Improving scenarios, predictions and projections of future ocean-human systems at multiple scales.

General IMBeR

- **Lighting the 'Grey Zone': How Can We Integrate Human Dimensions in Decadal-scale Prediction Systems?** Workshop at IMBIZO6 ([further workshop details](#))
- **Marine Extreme Events: Impacts, Forecasting, and Risk Management** Session at the IMBeR West Pacific Symposium ([further session details](#))

ESSAS

- The Norwegian Research project on **Arctic Ecosystem Impact Assessment To Oil In Ice** ([ACTION](#)) is a collaboration with US-based ESSAS members. Preliminary results from the project were presented at the 2022 ESSAS Annual Science Meeting.
- Another Norwegian-led research programme, **Winners and losers in the climate casino: Arctic marine resources under climate change** (CASINO) involves researchers from several institutions and Arctic countries. Some of these collaborations were initiated at previous ESSAS meetings.
- ESSAS workshops in 2014 and 2018 on the dynamics of Arctic cod, a key forage species with a circumpolar distribution, led to a number of collaborations. These include in particular the Arctic Research Icebreaker Consortium (ARICE)-funded **Go-West** project, which sampled Arctic cod under newly formed sea ice in the Pacific Arctic and involves researchers from Europe, USA, and Canada.

ICED

- **ICED-MEASO** special issue includes outputs on scenarios and projections (see Selected Science Activities 2021-2022)
- **Southern Ocean Action Plan** (see Selected Science Highlights 2021-2022)
- [Ant-ICON](#) and [AntClim^{now}](#) (see GC I)
- **ICED scenarios and projection:** Further work on developing projections continues with CCAMLR and SCAR, including the SCAR Krill Action Group (SKAG) [Workshop on evaluating change in Antarctic krill populations](#) in April 2021 and the ICED Antarctic krill modelling Workshop in May 2021:
- **ICED krill modelling workshop 2021:** ICED and SCAR scientists and early career researchers (ECRs) organised a virtual [ICED Antarctic Krill Modelling Workshop](#) in May 2021. This aimed to bring together researchers engaged in modelling Antarctic krill and its application to understanding their ecology, links and feedbacks with Southern Ocean and Earth System processes, and input to conservation and management options.
 - Following the workshop, the ECRs (supported by more established ICED researchers) have developed two community papers to progress krill modelling.
- **Ocean Science Meeting 2022.** See GCI
- **SCAR Krill Action Group (SKAG) Annual Workshop 2022:** In March, ICED ECRs involved in the ICED-MEASO initiative and the ICED krill modelling workshop gave a presentation on recent activities.

AMT

Rapid public availability of [AMT data](#) has enabled sophisticated model and machine learning outputs. The use of neural networks has linked AMT and remote sensing observations to project accurate fields of pCO₂ across the sparsely sampled South Atlantic ([Ford et al., 2022](#)).

NUTS&BOLTS

NUTS&BOLTS is a test case for the Marine Institute database to develop a pipeline with QA/QC checks and appropriate metadata for upload onto their database for Ireland. It is hoped that the acquisition of data on key parameters will enable predictive models in cooperation with the Marine Institute (e.g. the newly funded '[Changing Ocean Ireland](#)' project) or other agencies/institutions.

-- **Grand Challenge III:** Improving and achieving sustainable ocean governance

IMBeR's Regional Programmes have worked with a range of stakeholders to ensure that the science under GCI and GCII is relevant to, accessible to, and incorporated into adaptation, mitigation and sustainable management and conservation procedures, by improving communications, facilitating knowledge-exchange and enhancing understanding between science, policy and society.

ESSAS

- The ESSAS Human Dimensions working group has contributed to developing socio-economic scenarios for developing climate-resilient fisheries, most notably through the **Alaska Climate Integrated Modeling** project ([ACLIM](#)) in Alaska.
- The collaborative project **CASINO** (noted above) includes two work packages focusing on international governance of the Arctic.
- Several ESSAS Scientific Steering Committee (SSC) members have been involved in the development of Integrated Ecosystem Assessments for the Central Arctic Ocean, the Chukchi Sea, the Barents Sea, and Norwegian Sea.
- ESSAS endorsed the **Barents Sea Ecosystem and its Services** project ([BarentsRISK](#)). The project seeks to assess the risks of cumulative impacts on the Barents Sea ecosystem and its services and has been developed in direct collaboration with stakeholders and managers. Several members of the ESSAS HDWG are involved.
- Norwegian researchers (including ESSAS SSC members) are developing tools to support integrated ecosystem assessment for the Norwegian Sea within the EU project [Mission Atlantic](#).

SIBER

Relevant activities include the SOLSTICE-WIO programme focused on fisheries and food security in the western Indian Ocean. This combines environmental and socio-economic research with state-of-the art techniques and knowledge transfer, to develop policies for sustainable and resilient fisheries.

ICED

- **Antarctic Treaty System:** ICED continues its work with the Antarctic Treaty Commission via 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 CCAMLR. ICED also works with other international environmental treaties and organisations, conservation groups, and international committees, including the IWC. In April, the Southern Ocean Task Force (of which ICED is part) submitted a paper on the UNDOS Southern Ocean Action Plan to the 2022 Antarctic Treaty Consultative meeting.
- **Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR):** Over the past year, the CCAMLR Working Groups, Scientific Committee and Commission meetings were all virtual. Key topics included krill management strategies and climate change. ICED scientists continue to play an important role taking the inter-sessional science forward in these areas. A paper based on the IPCC

Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) in support of ongoing climate change discussions within CCAMLR, acknowledges the significant contributions of ICED (Cavanagh et al. 2021: CCAMLR WG-EMM 2021/P07). The paper encourages CCAMLR to integrate climate change considerations in advice across its agenda.

- **IWC:** ICED scientists participated in the IWC Climate Change Workshop, Nov-Dec 2021, where the implications of climate change on cetacean species were reviewed, to define and develop the role of the IWC to address this. ICED contributed to a presentation that highlighted common issues between IWC and CCAMLR, and the role of international science programmes (including ICED), in understanding and addressing climate change.
- **SCAR:** [Ant-ICON](#) and [AntClim^{now}](#), see GC I
- **IMBIZO 6: Buoyant Solutions for Ocean Sustainability conference, October 2021:** ICED co-organised the workshop on ocean governance and climate adaptation and integrating human dimensions in decadal-scale prediction systems.
- **UNFCCC Conference Of the Parties 2021 (COP26):** In May 2021 ICED presented at the **COP26 Universities Network Climate Exp0 2021 virtual conference** (under the Adaptation and Resilience theme) on 'International collaborative science to support adaptation and resilience in Southern Ocean ecosystems'.
- **COP26 Conference MEASO Side Event** - The work of ICED-MEASO featured in the **COP26 Conference**, November 2021, in Glasgow, UK. ICED scientists presented on the key outcomes of MEASO and took part in a discussion panel.
- **Science-Policy Initiative between the British Antarctic Survey and the Cambridge Conservation Initiative:** ICED scientists continue to co-lead the science-policy initiative.
- **Climate Change and Southern Ocean Resilience Expert Working Group:** ICED participated in the Climate Change and Southern Ocean Resilience Expert Working Group convened by the Wilson Center Polar Institute and the Pew Charitable Trusts, between March and May 2021. The aim was to inform global policymakers on the importance of Southern Ocean management in the context of climate change, and critical actions that could be taken by CCAMLR. Workshop outputs included a report and a policy brief.
- **Intergovernmental Panel on Climate Change (IPCC):** ICED contributed to the 6th IPCC Assessment Report ([AR6](#)) via their MEASO papers. An ICED scientist was also instrumental in the development of the IPCC's Working Group 2 report on the Polar Regions.

-- **Innovation Challenge 3:** To advance understanding of ecological feedbacks in the Earth System

ICED

See GCI PolarRES and BIOPOLE projects.

-- **Innovation Challenge 4:** To advance and improve the use of social science data for ocean management, decision making and policy development

HDWG

A Decade of Incorporating Social Sciences in the Integrated Marine Biosphere Research Project (IMBeR): Much Done, Much to Do? ([van Putten et al., 2021](#))

ESSAS

- **Integrated Ecosystem Assessments (IEAs):** Several ESSAS members developed IEAs through their involvement in the ICES/PICES/PAME Working Group on Integrated Ecosystem Assessment (IEA) for the Central Arctic Ocean (WGICA) (see 2021 [report](#)), the ICES IEA group for the Norwegian Sea and the Barents Sea, produces annual reports on the ecological status of these regions. Also ICES Integrated

Trend Analysis Working Group and the ICES/PICES Common Ecological Reference Points Working Group. Both groups contribute to providing robust observation data that is tailored to the needs of end-users and managers.

- The ESSAS HDWG Chair is active in multiple national and international efforts to develop better approaches to using economic data to support decision making in fishery management.

NoCRISES

Social science-based methods (e.g., governance mapping, process tracing, cultural consensus analysis) were used to understand marine conflicts and have been applied in six countries that form part of the [NoCRISES](#) project. Four papers that will contribute to social science data for ocean management and policy were presented at a Belmont Forum project session at the [MARE Conference People & the Sea XI 2021](#). They are in review for a Maritime Studies Special Issue: 'Marine conflicts and pathways to sustainability in an era of blue growth and climate change'.

- **Innovation Challenge 5:** Interventions to change the course of climate impacts

General IMBeR

- **Exploring Potential Marine Options for Climate Intervention** workshop at IMBIZO6
- **Ecosystem, Biogeochemistry, and Interventions in the Western Pacific and its Marginal Seas: Beyond the Disciplinary Borders** session at the IMBeR West Pacific Symposium 2021

ICED

See ICED input to the COP26 and the IPCC AR6 detailed in GCI and GCIII.

- **Innovation Challenge 6:** Sustainable management of Blue Carbon ecosystems

- **Coastal Blue Carbon: Measurements, Modeling, and Assessment** session at the IMBeR West Pacific Symposium ([further session details](#))

NUTS&BOLTS

- NUTS&BOLTS provides new data for assessment and sustainable management of Irish Blue Carbon Ecosystems.

- **Capacity Development and Outreach**

IMECaN

- **Building Capacity for Diversity and Inclusion in Ocean Sciences** side event at **IMBIZO6**, 15 October 2021 ([link](#))
- **ClimEco7 Summer School** – Interdisciplinary Ocean Science for Sustainable Development - 9-13 August 2021 (see 'Scientific Highlights' for further details).
- **IMBeR West Pacific Symposium 2021**
- **UNDOS Early Career Ocean Professionals (ECOPs)** – IMECaN continues to engage with ECOPs and other early career networks.

IPO-China

- **Young Scientist Forum** organised by the First Institute of Oceanography, Ministry of Natural Resources in Qingdao, China on 28 September 2021. Fang Zuo delivered an IMBeR presentation (available [here](#))

ICED

- **COP26** side event. See direct ICED input to the UNFCCC Conference Of the Parties 2021 (COP26), the IPCCs AR6, and the UNDOS detailed above

--- **Additional IMBeR activities**

IMECaN

- **Equity in Science: Advocating for a Triple-blind Review System** ([Brodie et al., 2021](#))
See scientific highlights

IPO-Canada

- **IMBeR Ocean Countdown to 2022 ‘Advent Calendar’**
In December 2021, IMBeR launched [Ocean Countdown to 2022](#) as an ocean science alternative to an advent calendar, sharing important, fascinating and inspirational messages about the ocean and ocean science through short videos that were posted daily on Twitter and on the [IMBeR website](#).

E. SCIENTIFIC STEERING COMMITTEE

The 2022 Scientific Steering Committee consists of the chair, in transition from Carol Robinson (F, UK; outgoing chair) to Diana Ruiz-Pino (F, France; incoming chair), three vice-chairs: Marion Gehlen (F, France), Alice Newton (F, Portugal) and Micaela Trimble (F, Uruguay) and 15 members (7 male and 8 female). Seven new members joined the SSC in January 2022: Derek Armitage (M, Canada), Nina Bednaršek (F, Slovenia), Jingling Ren (F, China), Lynne Shannon (F, South Africa), and the early career representative Samiya Selim (F, Bangladesh). Also, ex officio members Dongyan Liu (F, China) and Boris Worm (M, Canada), representing



Figure 16. IMBeR SSC 2022.

the IMBeR International Project Offices’ host institutes, East China Normal University and the Ocean Frontier Institute at Dalhousie University, respectively.

At the end of 2022, one member (Alistair Hobday) will rotate off the SSC and two (Marion Gehlen and Narriman Jiddawi) are up for possible renewal for a second term. The IPOs will survey the remaining SSC members to assess the relevance of their expertise to address the priority research areas of the SPIS, and identify any skills gaps. The 2022 IMBeR SSC will be held virtually on 3 August.

F. COLLABORATIVE PARTNERS

IMBeR science is strengthened, and its impacts extended, through on-going and new partnerships and collaborations with international and national organisations. These include the IMBeR co-sponsors - the Scientific Committee on Oceanic Research (SCOR) and Future Earth. Also, the World Climate Research Programme (WCRP), the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), the Global Ocean Observing System (GOOS) and the International Ocean Carbon Coordination Project (IOCCP). The Scientific Committee on Antarctic Research (SCAR) is a co-sponsor of the ICED regional programme.

IMBeR continues to have long standing collaborations with the SCOR and Future Earth global research projects, SOLAS (e.g. SIOA working group) and Future Earth Coasts (e.g. CMWG).

The IOC-R working group is a joint initiative involving IMBeR, IOC-UNESCO, IOCCP, WCRP, and Climate and Ocean - Variability, Predictability, and Change (CLIVAR), SOLAS, and the Global Carbon Project (GCP).

1. Too Big To Ignore ([TBTI](#))

IMBeR is a partner of the TBTI global research network that focuses on addressing issues and concerns affecting the viability and sustainability of small-scale fisheries. TBTI was originally to finish in 2018, but is still ongoing and hosted the '[4th World Small-Scale Fisheries Congress](#)' and published '[Blue Justice: Small-Scale Fisheries in a Sustainable Ocean Economy](#)' in 2022.

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 supported IMBeR's 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 Integrated Ocean Carbon Research (IOC-R). A letter of cooperation between WCRP and IMBeR was produced in 2022.

4. Global Ocean Observing System ([GOOS](#))

SIBER has strong connections with the Global Ocean Observing System in the Indian Ocean (IOGOOS).

5. Vulnerability to Viability ([V2V](#)): Global Partnership for Building Strong Small-Scale Fisheries Communities

V2V was developed by members of the IMBeR HDWG and IMBeR is a partner in the project. V2V will use the decision support tool IMBeR-ADaPT (Assessment based on Description, responses, and Appraisal for a Typology) which was developed within the IMBeR HDWG. Activities this year include the [V2V Thematic Webinar Series](#).

6. Global Ocean Negative Carbon Emissions ([GlobalONCE](#))

IMBeR is a lead partner on this recently formed UN Decade programme. The programme links with IC5 and aims to provide data, knowledge and best practices to enable society to develop mitigation and adaptation approaches to climate impacts. Global ONCE will establish a network of instrumented marine field stations and research facilities available to evaluate such approaches,

develop the decision rules for initiation and evaluation, undertake and facilitate co-designed interdisciplinary research on key ecosystem carbon processes, build technical and personnel capacity and enhance knowledge exchange between scientists, policy makers, industries, managers and communities. The ONCE approaches span nature-based interventions to optimise organic carbon sequestration capability alongside biodiversity, as well as chemical and engineering technologies. Global ONCE will promote equitable ocean governance of adaptation and mitigation approaches, through enhanced interaction with local, regional and global industries, decision makers and legislators. The programme convened a side event at the UN Ocean Conference to which IMBeR contributed.

G. IMBeR INTERNATIONAL PROJECT OFFICES

International Project Office (IPO) Canada

John Claydon continues as Executive Director, Lisa Maddison as Deputy, and Tracey Woodhouse as the part-time Executive Assistant to the IPO in Canada. In 2022, the IPO started to return to the office, following an extended period of remote working due to COVID-19.

International Project Office (IPO) China

GiHoon Hong continues as Strategy Director, Fang Zuo as Deputy Director, and Kai Qin as Executive Assistant. For most of April and May 2022, the IPO worked remotely due to a COVID-19 lockdown. Two part-time student interns, Min Zhou and Junyue Zhu, joined the IMBeR IPO-China in May 2022 and a full-time Project Officer, Dr. Jing Jing (Inter-regional cooperation expert) has been recruited and will start later in 2022. The [IMBeR IPO-China office webpage](#) has been upgraded to meet the growing regional demand for facilitation of intra-regional cooperation (e.g., the study groups arising from the West Pacific Symposium 2021).

H. PUBLICATION SUMMARY

Since 2016, IMBeR has produced more than 900 publications ([Class 1 and Class 2](#)), and 96 papers were published over the last year (13 Class 1; 84 Class 2). A full list of Class 1 publications (2021-2021) can be found in the Appendices.

IMBeR Publication databases: [since 2016 \(2016-2022\)](#) | [prior to 2016 \(1999-2015\)](#)

I. SUPPORT from SCOR

We greatly appreciate the ongoing support received from SCOR. In particular, we would like to thank the SCOR Executive Director, Patricia Miloslavich, and Financial Officer Ed Urban for their continued help.

J. BUDGET

	Calendar Year	2021	2022	2022	2023	2024	2025
All values USD		Actual	Budgeted	Predicted			
BALANCE from previous year		177,686	164,582	164,582	130,433	100,303	80,173
INCOME							
SCOR (NSF Grants)	(Sept-Aug)	0	50,000	50,000	50,000	50,000	
Future Earth	(from 2021 reduced to Euro 10,000)	0	11,870	11,870	11,870	11,870	11,870
Meetings	IMBeR OSC					365,000	
registration +	ClimEco	400			105,000		
sponsorship	IMBIZO				135,000		
	West Pacific Symposium	2,000			145,000		
Miscellaneous							
Total income		2,400	61,870	61,870	446,870	426,870	11,870
TOTAL AVAILABLE FUNDS		180,086	226,452	226,452	577,303	527,173	92,043
EXPENSES							
Meetings	IMBeR SSC	0	32,000		37,000	37,000	32,000
	OSC 'Future Oceans' (excl. ECR Day)					332,000	
	OSC 'Future Oceans' - IMECaN ECR Day					23,000	
	OSC 'Future Oceans' contingency					53,250	
	ClimEco	500			105,000		
	ClimEco contingency	0			15,750		
	West Pacific Symposium	2,000			135,000		
	West Pacific Symposium contingency				20,250		
	IMBIZO	3,295			145,000		
	IMBIZO contingency	0			21,750		
	GC III session at Future Earth's SRI 2021	0					

Whova App for ClimEco8, IMBIZO7, Future Oceans3, WPS2		8,794					
Constant contact subscription		915					
Subtotal meetings expenses (without contingencies)		15,504	32,000	0	422,000	392,000	32,000
IMECaN		500	3,000		3,000	3,000	3,000
Working Groups	Carbon WG (IOC-R)	0	2,000		2,000	2,000	2,000
	Ocean Acidification (SIOA)	0	7,500	7,500	7,500	7,500	7,500
	Continental Margins WG	0	5,000		5,000	5,000	5,000
	Human Dimensions WG	0	7,500		7,500	7,500	7,500
Regional Progs	CLIOTOP	0	15,500		7,500	7,500	7,500
	ESSAS	0	8,519		7,500	7,500	7,500
	ICED	0	7,500		7,500	7,500	7,500
	SIBER	0	7,500		7,500	7,500	7,500
Subtotal IMECaN, WGs + RPs expenses		0	64,019	7,500	55,000	55,000	55,000
Sponsorship of other projects		0	0	0	0	0	0
Total EXPENSES		15,504	96,019	7,500	477,000	447,000	87,000
BALANCE at end of year	without contingency	164,582	130,433	218,952	100,303	80,173	5,043
	including contingency	164,582	130,433	218,952	42,553	26,923	5,043

K. APPENDICES

Class 1 Publications 2021-2022

The publications listed below are 'Class 1' - 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). Where stated, the activity in question is listed under the publication. Class 2 publications IMBeR Publication databases: [since 2016 \(2016-2022\)](#)

ICED Publications

Janssen, A.R. etc., 2022. Southern Ocean Action Plan (2021-2030) in support of the United Nations Decade of Ocean Science for Sustainable Development.

<https://www.sodecade.org/action-plan/southern-ocean-action-plan/>

Class 1; ICED; SCOR

Caccavo, J.A., Christiansen, H., Constable, A.J., Ghigliotti, L., Trebilco, R., Brooks, C.M., Cotte, C., Desvignes, T., Dornan, T., Jones, C.D., Koubbi, P., Saunders, R.A., Strobel, A., Vacchi, M., van de Putte, A.P., Walters, A., Waluda, C.M., Woods, B.L., Xavier, J.C., 2021. Productivity and Change in Fish and Squid in the Southern Ocean. *Front. Ecol. Evol.* 0. <https://doi.org/10.3389/fevo.2021.624918>

Class 1; ICED; ICED-MEASO

Johnston, N.M., Murphy, E.J., Atkinson, A.A., Constable, A.J., Cotté, C.S., Cox, M., Daly, K., Driscoll, R., Flores, H., Halfter, S., Henschke, N., Hill, S.L., Höfer, J., Hunt, B.P.V., Kawaguchi, S., Lindsay, D.J., Loeb, V., Manno, C., Meyer, B., Pakhomov, E., Pinkerton, M.H., Reiss, C., Richerson, K., Smith, W., Steinberg, D.K., Swadling, K.M., Tarling, G.A., Thorpe, S.E., Veytia, D., Ward, P., Weldrick, C.K., Yang, G., 2021. Status, change and futures of zooplankton in the Southern Ocean. *Front. Ecol. Evol.* 0.

<https://doi.org/10.3389/fevo.2021.624692>

Class 1; ICED; ICED-MEASO

McCormack, S.A., Melbourne-Thomas, J., Trebilco, R., Griffith, G., Hill, S.L., Hoover, C., Johnston, N.M., Marina, T.I., Murphy, E.J., Pakhomov, E.A., Pinkerton, M., Plagányi, É., Saravia, L.A., Subramaniam, R.C., Van de Putte, A.P., Constable, A.J., 2021. Southern Ocean Food Web Modelling: Progress, Prognoses, and Future Priorities for Research and Policy Makers. *Front. Ecol. Evol.* 0.

<https://doi.org/10.3389/fevo.2021.624763>

Class 1; ICED; ICED-MEASO

Murphy, E.J., Johnston, N.M., Hofmann, E.E., Phillips, R.A., Jackson, J., Constable, A.J., Henley, S.F., Melbourne-Thomas, J., Trebilco, R., Cavanagh, R.D., Tarling, G.A., Saunders, R.A., Barnes, D.K.A., Costa, D.P., Corney, S., Fraser, C.I., Höfer, J., Hughes, K.A., Sands, C.J., Thorpe, S.E., Trathan, P., Xavier, J.C., 2021. Global connectivity of Southern Ocean ecosystems. *Front. Ecol. Evol.* 0.

<https://doi.org/10.3389/fevo.2021.624451>

Class 1; ICED; ICED-MEASO

Van de Putte, A.P., Griffiths, H.J., Brooks, C., Bricher, P., Sweetlove, M., Halfter, S., Raymond, B., 2021. From Data to Marine Ecosystem Assessments of the Southern Ocean: Achievements, Challenges, and Lessons for the Future. *Frontiers in Marine Science* 8.

<https://doi.org/10.3389/fmars.2021.637063>

Class 1; ICED; ICED-MEASO

Human Dimensions Working Group Publications

Brodie, S., Frainer, A., Pennino, M.G., Jiang, S., Kaikkonen, L., Lopez, J., Ortega-Cisneros, K., Peters, C.A., Selim, S.A., Văidianu, N., 2021. Equity in science: advocating for a triple-blind review system. *Trends in Ecology & Evolution* 36, 957–959. <https://doi.org/10.1016/j.tree.2021.07.011>

Class 1; HDWG; IMECaN; SCOR

Pennino, M.G., Brodie, S., Frainer, A., Lopes, P.F.M., Lopez, J., Ortega-Cisneros, K., Selim, S.A., Vaidianu, N.M., 2021. The missing layers: integrating sociocultural values into Marine Spatial Planning. *Frontiers in Marine Science* 8. <https://doi.org/10.3389/fmars.2021.633198>

Class 1; Future Oceans 2; Special issue; HDWG; IMECaN; SCOR

Kitolelei, S., Thaman, R., Veitayaki, J., Breckwoldt, A., Piovano, S., 2021. Na Vuku Makawa ni Qoli: Indigenous Fishing Knowledge (IFK) in Fiji and the Pacific. *Front. Mar. Sci. O.* <https://doi.org/10.3389/fmars.2021.684303>

Class 1; FO2; HDWG

Other publications

Murphy, E.J., Robinson, C., Hobday, A.J., Newton, A., Glaser, M., Evans, K., Dickey-Collas, M., Brodie, S., Gehlen, M., 2021. The Global Pandemic Has Shown We Need an Action Plan for the Ocean. *Frontiers in Marine Science* 8, 1835.

<https://doi.org/10.3389/fmars.2021.760731>

Class 1; SCOR

Calosso, M.C., Claydon, J.A.B., 2022. Social (In)Justice for Small-Scale Fisherfolk in the Turks and Caicos Islands: Struggling to Stay Afloat in a Tax Haven, in: Jentoft, S., Chuenpagdee, R., Bugeja Said, A., Isaacs, M. (Eds.), *Blue Justice: Small-Scale Fisheries in a Sustainable Ocean Economy*, MARE Publication Series. Springer International Publishing, Cham, pp. 55–73.

https://doi.org/10.1007/978-3-030-89624-9_4

Class 1; Activity - IPO

Cui, K., Dong, Y., Sun, X., Zhao, L., Du, H., Liu, J., Wang, C., Liang, C., Zhao, Yicong, Chen, S., Xuan, J., Li, S., Zhao, Yuan, Xiao, T., 2021. Long-term temporal and spatial distribution of coliform bacteria in Jiaozhou Bay associated with human activities and environmental governance. *Front. Mar. Sci. O.*

<https://doi.org/10.3389/fmars.2021.641137>

Class 1; Future Oceans 2

Lundevall-Zara, M., Lundevall-Zara, E., Brüchert, V., 2021. Air-sea interactions of methane in shallow inshore areas of the Baltic Sea. *Front. Mar. Sci. O.* <https://doi.org/10.3389/fmars.2021.657459>

Class 1; Future Oceans 2

Class 2 Publications 2021-2022 – Class 2 publications benefitted from some interaction with IMBeR or IMBeR activities and are listed in the [online database](#).

List of Acronyms

ACLIM	Alaska Climate Integrated Modeling	link
ACTION	Arctic Ecosystem Impact Assessment To Oil In Ice (ACTION)	link
AMBON	Arctic Marine Biological Observation Network	link
AMT	Atlantic Meridional Transect	link
AntClim ^{now}	Near-Term Variability and Prediction of the Antarctic Climate System	link
Ant-ICON	Integrated Science to Inform Antarctic and Southern Ocean Conservation	link
ArCS II	Arctic Challenge for Sustainability II	link
ARICE	Arctic Research Icebreaker Consortium	
BarentsRISK	Barents Sea Ecosystem and its Services	
BIOPOLE	Biogeochemical processes and ecosystem function in changing polar systems and their global impacts	link
BLOOFINZ	Bluefin Larvae in Oligotrophic Ocean Foodwebs, Investigation of Nutrients to Zooplankton	
CASINO	Winners and Losers in the Climate Casino: Arctic Marine Resources Under Climate Change	
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources	link
CEP	Committee for Environmental Protection [Antarctic Treaty]	link
CLIOTOP	Climate Impacts on Oceanic Top Predators	link

CLIVAR	Climate and Ocean - Variability, Predictability, and Change	link
CMWG	Continental Margins Working Group	link
CoLaB	Coastal Lab in a Box	
COP	Conference of Parties	link
CREPSUM	Collaborative Research and Education Project in Southeast Asia for Sustainable Use of Marine Ecosystems	link
DBO	Distributed Biological Observatory	link
ECNU	East China Normal University	link
ECR	Early Career Researcher	
eDNA	environmental deoxyribonucleic acid	
EIOURI	Eastern Indian Ocean Upwelling Regime Initiatives	
EKAMSAT	Enhancing Knowledge of the Arabian Sea Marine Environment through Science and Advanced Technology	
ESSAS	Ecosystem Studies of Sub-arctic and Arctic Seas	link
GCP	Global Carbon Project	link
GoTTs	Gulf of Trieste – Time-series	link
HDWG	Human Dimensions Working Group	link
ICED	Integrating Climate and Ecosystem Dynamics in the Southern Ocean	link
ICES	International Council for the Exploration of the Sea	link
IEA	Integrated Ecosystem Assessment	
IIOE-2	Second International Indian Ocean expedition	link
IIOSC	International Indian Ocean Science Conference	link
IMBeR	Integrated Marine Biosphere Research	link
IMECaN	Interdisciplinary Marine Early Career Network	link
IMOS	Integrated Marine Observing System	link
INDOOS	Indian Ocean Observing System	link
INTAROS	Integrated Arctic Observation System	link
IOCCP	Intergovernmental Oceanic Commission – International Ocean Carbon Coordination Project	link
IOC-R	Integrated Ocean Carbon Research Working Group	link
IOC-UNESCO	Intergovernmental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization	link
IOGOOS	Indian Ocean Global Ocean Observing System	link
IORP	Indian Ocean Research Panel	
IPCC	Intergovernmental Panel on Climate Change	link
IPO	International Project Office	
IPR	Indo-Pacific Region: Marine Biogeochemistry, Biodiversity, Sustainability Study Group	
IWC	International Whaling Commission	link
MCS-CNS	Mechanisms of Marine Carbon Storage and Coupled Carbon, Nitrogen and Sulphur cycles in response to global change	link
MEASO	Marine Ecosystem Assessment of the Southern Ocean	link
MEBM-PEG	Marine Ecosystem-based Management Progress Evaluation Group: tracking the global progress of EBM	link
MEOPAR	Marine Environmental Observation, Prediction and Response Network	link
MOSAIC	Marine Observation System Along Indian Coast	
NoCRISES	Negotiating Ocean Conflicts among Rivals for Sustainable and Equitable Solutions	link
NOAA	National Oceanic and Atmospheric Administration	link
NUTS&BOLTS	Importance of Physico-Chemical cycling of nutrients and carbon in Marine Transitional Zones	link
OC-PC	Ocean Colour Based Plant Species Identification and Carbon Flux in the Indo-Pacific Oceans Study Group	
OFI	Ocean Frontier Institute	link
PAME	Protection of the Arctic Marine Environment	link
PACECS	Processes and Approaches of Coastal Ecosystem Carbon Sequestration	link
PICES	North Pacific Marine Science Organization	link

PolarRES	Polar Regions in the Earth System: the Role of Local and Regional Polar Processes in Changing the Polar Climate and the Global Climate System	link
RACArctic	Resilience and Adaptive Capacity of Arctic Marine Ecosystems	link
ReMoTurb	Marine Research Project of the Continental Shelf of Mozambique	
SCAR	Scientific Committee on Antarctic Research	link
SCOR	Scientific Committee on Oceanic Research	link
SIBER	Sustained Indian Ocean Biogeochemistry and Ecosystem Research	link
SIOA	SOLAS-IMBeR Ocean Acidification	link
SKAG	SCAR Krill Action Group	link
SKED	The Study of Kuroshio Ecosystem Dynamics for Sustainable Fisheries	link
SKLEC	State Key Laboratory of Estuarine and Coastal Research	link
SOLAS	Surface Ocean – Lower Atmosphere Study	link
SOLSTICE-WIO	Sustainable Oceans, Livelihoods and Food Security Through Increased Capacity in Ecosystem Research in the Western Indian Ocean	link
SPIS	[IMBeR] Science Plan and Implementation Strategy 2016-2025	link
SROCC	Special Report on the Ocean and Cryosphere in a Changing Climate	link
SSC	Scientific Steering Committee	
SWIO	Southwestern Indian Ocean	
TRIUMPH	Throughflow Indonesian Seas, Upwelling and Mixing Physics	
UNDOS	United Nations Decade of Ocean Science for Sustainable Development 2021-2030	link
UNFCCC	United Nations Framework Convention on Climate Change	link
US AON	US Arctic Observing Network	link
VOCAB	Ocean Acidification and Biogeochemistry: variability, trends and vulnerability	link
WCRP	World Climate Research Programme	link
WG-EMM	[CCAMLR] Working Group on Ecosystem Monitoring and Management	link
WG-FSA	[CCAMLR] Working Group on Fish Stock Assessment	link
WGICA	Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean	link
WIOURI	Western Indian Ocean Upwelling Regime Initiatives	