

## REPORTING FORM 2023

Please return completed form to [imber@dal.ca](mailto:imber@dal.ca) by **10<sup>th</sup> March** (in order to give everyone enough time to collate and read all the reports before the April SSC meeting)

**REPORTING PERIOD: WHAT YOU HAVE DONE** since the annual report submitted for the SSC meeting held virtually in August 2022 ([Link to past annual reports](#))

and **PLANNED ACTIVITIES** over the next year (and beyond if details available)

**N.B.** The form focuses reporting on the research objectives (2022-2025) of the Grand Challenges (in order to align with how we are addressing IMBeR's commitments defined in the 5-year review process to SCOR and Future Earth)

**Thank you.**

*Integrated Ocean Carbon Research*

*Co-chairs: Christopher Sabine, Carol Robinson*

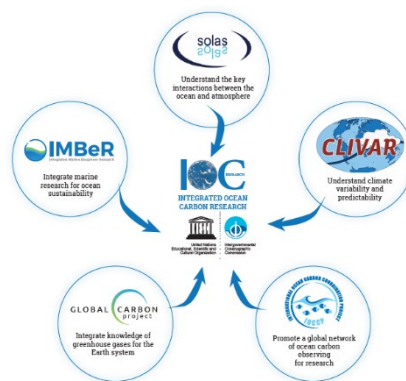
*Steering Committee member representing IMBeR : Nina Bednarsek*

### 1. Ongoing activities, in line with the IMBeR Grand and Innovation Challenges

*(Among other uses, information will be used to update the Grand Challenge Factsheets)*

Integrated Ocean Carbon Research ([IOC-R](#)) is a formal expert working group of the Intergovernmental Oceanic Commission of the United Nations Educational, Scientific and Cultural Organization ([IOC-UNESCO](#)) consisting of a partnership between IMBeR, 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](#)). The co-Chairs of IOC-R are Chris Sabine (University of Hawaii, USA) and Carol Robinson (University of East Anglia, UK). The steering committee consists of a

representative from each of the partner organisations and is co-ordinated through the IOC (Kirsten Isensee and Henrik Enevoldsen). Nina Bednarsek is the IMBeR representative on the IOC-R steering committee. Established in 2018, IOC-R aims to review, prioritise and fill knowledge gaps by designing and promoting future integrated ocean carbon research. In 2019 IOC-R reviewed the literature and collated the opinions of the global ocean carbon community to produce a summary document outlining gaps in our understanding and a vision for co-ordinated ocean carbon research and observations for the next decade. This review and vision contributes to the ocean carbon science elements of the Implementation Plan of the UN Decade and is framed within four themes:



*Will the ocean uptake of anthropogenic CO<sub>2</sub> continue as primarily an abiotic process?*

*What is the role of biology in the ocean carbon cycle and how is it changing?  
What are the exchanges of carbon between the land-ocean-ice continuum?  
How are humans altering the ocean carbon cycle and resulting feedbacks?*

Several members of the IMBeR community contributed to and co-authored this vision document, and several subquestions within these themes align with topics within the IMBeR Grand Challenges. The document has been used in various policy discussions and has formed the basis for several national and regional research programmes.

The IOC-R steering committee meets virtually about twice a year, sometimes with representatives from other networks, to ensure collaboration within the UN Decade and with other ocean carbon communities e.g. G7 Future of the Seas and Oceans Initiative (FSOI).

In December 2022, IOC-R convened a virtual meeting to discuss progress and remaining knowledge gaps in ocean carbon science with a view to updating the 2019 IOC-R vision document. The specific objectives of the meeting were :

- I. To gather the ocean carbon community, to appraise everyone of new and existing ocean carbon projects, programmes and initiatives within and outside of the Ocean Decade framework,
- II. To provide a platform to discuss knowledge gaps and emerging ocean carbon questions,
- III. To start a review of the IOC-R vision document,
- IV. To scope and plan an in-person workshop to, for example, help to develop an updated version of the 2021 [IOC-R review and vision document](#), and
- V. To establish an [Ocean Decade Community of Practice](#) focussing on ocean carbon.

The draft report of the meeting is currently with the 48 attendees (including Nina Bednarsek, Niki Gruber and Ingrid van Putten who could represent IMBeR Grand Challenges 1, 2 and 3 respectively), for comment. Several invitees who could not attend the meeting (including carbon experts who have previously been IMBeR SSC members such as Jean-Pierre Gattuso, Laurent Bopp, and Masao Ishii) contributed comments and will hopefully be able to attend the next meeting. The results of an expert online survey to re-evaluate the 2019 research questions and identify any additional experts to be included are currently being collated, and an in-person meeting is planned for May in Brussels, hosted by the G7 FSOI.

### **1.a. Grand Challenge I**

*Understanding and quantifying the state and variability of marine ecosystems - with focus on Research Objectives 1 to 3:*

**Research Objective 1.** *Evaluate and predict the cumulative effect of multiple stressors*

**Research Objective 2.** *Integration of climate change and climate variability*

**Research Objective 3.** *Impacts on society – preparation for a changed future*

*Several subquestions within IOC-R themes 1,2,3 and 4 contribute to GC1. See full list at end of document – examples include:*

1. What is the cumulative impact of multiple stressors on the biological (carbon) pump and feedback?
2. How can we enhance linkages between biogeochemistry and ecology as they pertain to the ocean carbon cycle?

3. What are the important natural and human anthropogenic factors that impact the biological carbon cycle and ocean health?
4. What are the trends of ocean acidification within polar regions (Arctic/Antarctic) and what is the impact on high latitude biota and global biogeochemical cycles?
5. What is the combination of stressors and cumulative impacts across various ecosystems, specifically in the coastal regions and Eastern Boundary Upwelling Systems?
6. How can we maintain and enhance sustained high-quality ocean carbon observations critical for quantifying the strength and variability of the ocean carbon sink?
7. How can we support best practices in measurements and data sharing to quantify uncertainty?
8. How can multiple stressors (e.g. warming, deoxygenation, acidification) on the ocean carbon system be incorporated in assessing and synthesizing observations and model results?
9. How will carbon cycling on the shelves and lateral carbon export to open ocean areas change?
10. How does effluent, such as sewage and runoff, from large coastal cities influence lateral organic and inorganic carbon input and the resulting coastal air-sea carbon fluxes?

### **1.b. Grand Challenge II**

*Improving scenarios, predictions and projections of future ocean-human systems at multiple scales - with focus on Research Objectives 4 to 6:*

***Research Objective 4.** Development of integrated data systems and approaches for predictions and projections*

***Research Objective 5.** Development of predictive models and projections for use at regional scales*

***Research Objective 6.** Development of alternative scenarios to bridge the gap between physical climate sciences and humanities*

*Several subquestions within IOC-R themes 1,2,3 and 4 contribute to GC2. See full list at end of document – examples include:*

1. How can we support best practices in measurements and data sharing to quantify uncertainty?
2. How can we build reliable and comprehensive ocean carbon biogeochemistry and biological forecasting systems through enhanced synthesis products, modeling and model-data fusion activities?
3. How can we integrate the land-ocean continuum more fully into global carbon cycle assessments and earth system models?
4. What are the important natural and human anthropogenic factors that impact the biological carbon cycle and ocean health?
5. How can multiple stressors (e.g. warming, deoxygenation, acidification) on the ocean carbon system be incorporated in assessing observations and model results?
6. How can we close important gaps in our knowledge through laboratory and field-based process studies, including properly scaled geoengineering studies, to elucidate mechanisms and contribute to model parameterization?

### **1.c. Grand Challenge III**

*Improving and achieving sustainable ocean governance - with focus on Research Objectives 7 to 9:*

*Research Objective 7. Develop knowledge on best practices for multilevel governance approaches to ocean climate adaptation and mitigation*

*Research Objective 8. Develop understanding on key ingredients for transformation towards more sustainable, equitable and inclusive governance approaches to fisheries and aquaculture*

*Research Objective 9. Support implementation of post-2020 biodiversity targets for marine spatial planning and marine protected areas*

*Several subquestions within IOC-R themes 1,2,3 and 4 contribute to GC3. See full list at end of document – examples include:*

1. What are the combined socio-economic impacts of changes in ocean carbon chemistry, and climate change driven by ocean warming and sea level rise?
2. How should marine management strategies in estuaries and shelf seas be improved to support fisheries, aquaculture, tourism, carbon storage and other marine activities?
3. How will mesopelagic fishing, seabed mining, and the discharge of mine tailings from land to the ocean affect the biological carbon cycle?
4. How can we assess, prioritize and implement adaptation, mitigation and remediation activities based on a knowledge of the past and current state of the affected marine environment?

#### **1.d. Innovation Challenge 3**

*To advance understanding of ecological feedbacks in the Earth System*

*Subquestions within IOC-R themes 1,2,3 and 4 contribute to IC3. See full list at end of document – examples include:*

1. Are the twilight zone food webs changing, and what effect will this have on the evolution of the ocean carbon cycle?
2. Is the changing partitioning between PIC and POC affecting the inorganic carbon cycle, its transport, and fluxes?
3. Is the dissolved organic carbon pool changing, and what are its impacts on climate and environmental change?

#### **1.e. Innovation Challenge 4**

*To advance and improve the use of social science data for ocean management, decision making and policy development*

N/A

#### **1.f. Innovation Challenge 5**

*Interventions to change the course of climate impacts*

*Subquestions within IOC-R themes 1,2,3 and 4 contribute to IC3. See full list at end of document – one example is:*

1. How can we assess, prioritize and implement adaptation and remediation activities based on a knowledge of the past and current state of the affected marine environment?
2. Determine environmental thresholds that will initiate or enhance actions across scales
3. How should marine management strategies in estuaries and shelf seas be improved to support fisheries, aquaculture, tourism, carbon storage and other marine activities?

4. How can we close important gaps in our knowledge through laboratory and field based process studies, including properly scaled geoengineering studies, to elucidate mechanisms and contribute to model parameterization?

### **1.g. Innovation Challenge 6**

#### *Sustainable management of Blue Carbon ecosystems*

*Subquestions within IOC-R themes 1,2,3 and 4 contribute to IC3. See full list at end of document – examples include:*

1. How should marine management strategies in estuaries and shelf seas be improved to support fisheries, aquaculture, tourism, carbon storage and other marine activities?
2. How can we assess, prioritize and implement adaptation, mitigation and remediation activities based on a knowledge of the past and current state of the affected marine environment?
3. Can we safely enhance sequestration and storage of carbon by the ocean?
4. How is carbon burial storage in key reservoirs of the land-ocean continuum changing?

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## **2. Selected highlights**

### **2.a. Selected scientific highlights since last report (1-5)**

*Last report was submitted to SSC meeting, August 2022*

*A community workshop held in December 2022.*

### **2.b. Publications since last report**

*Please add all publications since last report to the table below (see notes for details on “Class” and “Activity” fields).*

*There have been no IOC-R publications in 2022. The report of the workshop held in December 2022 is available as a pdf attached to this report.*

### **2.c. Events, Meetings, and Workshops**

*List all international and national events, meetings and workshops. Describe the level of participation: e.g. chairing session/workshop, organising meeting. Include Regional Programme / Working Group committee meetings and workshops.*

*Format: Title of event. Date. Location. Description of participation. Any other pertinent details.*

*The co-chairs and IOC have met several times to plan activities for the year. The steering committee met in November and the community workshop with ~ 50 participants occurred in December.*

*Information on IOC-R was included in a number of keynote presentations by the co-Chairs e.g. at the Gordon Research Conference on Ocean Biogeochemistry in May 2022 and the UK Challenger Conference in September 2022.*

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### 3. International collaboration and links

*IOC-R is an IOC working group in partnership with IMBeR, SOLAS, IOCCP, CLIVAR and GCP. It contributes to the UN Ocean Decade and has links with a range of international ocean carbon science communities e.g. G7 FSOI.*

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### 4. Input to management, policy and SOCIETY\* over the last year

*Add anything that is not covered under “1.c. Grand Challenge III”*

*\*As previous reporting forms requested ‘input to management and policy’ only, please add any ‘input to society’ not captured in previous reports*

*The 2019 vision document formed the basis of a number of successful research proposals to the EU and UK so arguably has created employment for several early career and established ocean carbon researchers.*

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### 5. Education, Outreach and Capacity Development

*See above*

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### 6. Planned activities

#### 6.a. Activities and Outreach and how they link to the Challenges (including, but not limited to convening sessions, meetings, summer schools, workshops, etc)

*Community workshop in May 2023*

#### 6.b. Upcoming papers (Community-Position-Review-etc)

*Update to 2019 review and vision document on integrated ocean carbon research*

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### 7. Funding

#### 7.a. Funding from external sources

*IOCR is supported by the IOC secretariat in Paris. Limited funding for the workshop in May will be partly provided by partners and associated projects.*

#### 7.b. Funding proposals in progress or planned

*See above*

#### 7.c. Funding requested from IMBeR for 2023-2024

*Include a brief budget and justify requests*

*Travel and subsistence for the IMBeR steering committee member Nina Bednarsek and other IMBeR representatives to attend the community workshop in May in Brussels.*

IMBeR has previously allocated up to USD 2000 for T&S for IMBeR ocean carbon experts to attend the in-person meetings – potentially for 2023: Niki Gruber, Laurent Bopp, Ingrid van Putten.

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## 8. Changes to Organisational Structure (e.g. SSC) of RP / WG / IMECaN

N/A

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## 9. Images / Figures

IOCR has a logo and will produce some consistent text for the webpages of the partner organisations including IMBeR

\*\*\*It is always good to have some recent photos / figures / infographics to create more exposure for the Regional Programmes, Working Groups, etc. These can range from those suitable for a very scientific audience, to those that would engage the general public. IMBeR would use these, on the website (e.g. <http://www.imber.info/> and <http://www.imber.info/en/news>), in tweets (@imber\_ipo), in presentations, etc. In addition, Future Earth (one of our sponsors) regularly asks us to provide high quality images for their glossy reports. These can highlight the activities of IMBeR and their other Global Research Projects (see pdfs of past Future Earth reports here <https://futureearth.org/publications/annual-reports/>)

So, please provide any images that you might think are useful. These can be pasted in this document or emailed as an attachment to [imber@dal.ca](mailto:imber@dal.ca).\*\*\*\*

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## 10. Update on Action Items from 2022 SSC meeting

Please update the [table of Action Items](#)

IOC-R understood it would be invited to join / be represented on the implementation teams for the IMBeR Grand Challenges to facilitate interaction between IOC-R and the IMBeR Science Plan. The Action List suggests this is now unclear?

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## 11. Anything not covered above

See below answers to the separate email from John

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## 12. How to improve this form

Please give suggestions on how to improve this form and make it better next time.

Add text...

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## 13. Appendices

Add appropriate meeting / workshop reports and include URLs (this helps to track where online content is missing)

Dear Carol, Chris and Nina,

We have enjoyed productive meetings with co-chairs of the IMBeR Regional Programmes, Working Groups, and the early career network (IMECaN), and look forward to the meeting with IOC-R now scheduled for March. During these meetings, it has become evident that we should seek broader input/consensus from each group beyond the co-chairs, particularly for the agenda items concerning collaboration and synthesis and also on ideas for the future of IMBeR post-2025. Specifically, Diana would like each Regional Programme, Working Group and IMECaN to consult their respective groups to generate feedback on –

### **Publication and other outcomes or products from your Regional Programme/Working Group/IMECaN**

- What themes would you propose for new publications or syntheses which would progress the IMBeR Science Plan?

- What are your proposals for other types of products connecting IMBeR to society?

The update of the IOC-R vision document in 2023 will synthesise the suggestions of ocean carbon experts across the IOC-R partner organisations (including IMBeR) with those of experts with the UN Decade programmes and international networks such as the Blue Carbon Initiative and G7 FSOI.

### **Synthesis and Collaboration with other RPs, WG and IMECaN**

- How can your Regional Programme/Working Group/IMECaN build better collaboration with the other Regional Programmes, Working Groups, and early career network (IMECaN)?

- Are there synthesis activities that you think could be conducted with the other regional programmes (both regional and thematic syntheses, connecting different challenges, ECRs etc.)?

If there are any other ocean carbon experts in the IMBeR RPs/WGs/IMECaN who wish to be involved in the IOC-R discussions, then please suggest they contact Nina, Chris or Carol.

### **Post-2025 (i.e. 'IMBeR 3.0')**

- Strategy and ideas for IMBeR post-2025 and where your Regional Programme/Working Group/IMECaN fits into this

IOC-R will continue at least for the duration of the UN Decade (to 2030) with potentially updates to the vision document at regular intervals. IOC-R is considering applying to become a Decade Community of Practice. We suggest that the science objectives of IMBeR post-2025 continue to be aligned with the latest IOC-R vision document themes since these are a global synthesis of expert opinions on knowledge gaps and implementation ideas on integrated ocean carbon research (which includes human societies). IOC-R is also aligned with the UN Decade programmes which have an ocean carbon component including Biomolecular Observing Network, Global Ocean Oxygen Decade, One Ocean Network for Deep Observation, An Observing Air Sea interactions strategy, Sustainability, predictability and resilience of marine ecosystems, Deep Ocean Observing Strategy, Digital Twins of the Ocean, CoastPredict, Global Ecosystem for Ocean Solutions, Joint Exploration of the Twilight Zone, Ocean Acidification Research for Sustainability, Global Ocean Negative Carbon Emissions, Global Ocean Decade Programme for Blue Carbon.

List of themes and subquestions within the 2019 IOC-R vision document :



<b>1) Will the ocean uptake of anthropogenic CO<sub>2</sub> continue primarily as an abiotic process?</b>	
1	Will the oceans continue to act as a sink proportional to the carbon that is being emitted into the atmosphere as a result of human activities?
2	How will global ocean carbon uptake change in the future with decreasing C anthropogenic emissions?
3	Will deep water production and the meridional overturning circulation change in an evolving climate, and what will the consequences be for ocean carbon uptake?
4	What is the historical and future impact of a changing Southern Ocean on the global carbon cycle/budget?
5	What are the trends of ocean acidification within polar regions (Arctic/Antarctic)?
6	What are the causes and magnitude of temporal variability of the Southern Ocean carbon sink?
7	What is the role of western boundary systems as poleward conveyors of carbon, including the role of mesoscale variability (eddies)?
8	How can we maintain and enhance sustained high-quality ocean carbon observations critical for quantifying the strength and variability of the ocean carbon sink?
9	How can we support best practices in measurements and data sharing to quantify uncertainty?
<b>2) What is the (changing) role of biology in the ocean carbon cycle?</b>	
1	What are the important natural and human anthropogenic factors that impact the biological carbon cycle and ocean health?
2	Are the twilight zone food webs changing, and what effect will this have on the evolution of the ocean carbon cycle?
3	Is the changing partitioning between PIC and POC affecting the inorganic carbon cycle, its transport, and fluxes?
4	Is the dissolved organic carbon pool changing, and what are its impacts on climate and environmental change?
5	How can the regional budgeting of carbon sources and sinks be improved over the range of ecosystems?
6	What is the impact of ocean acidification on high latitude biota, and how will the impact affect other global biogeochemical cycles and higher trophic levels?
7	What are the impacts of acidification on marine ecosystems in Eastern Boundary Upwelling Systems?
8	How can we enhance linkages between biogeochemistry and ecology as they pertain to the ocean carbon cycle?
9	How can we build reliable and comprehensive ocean carbon biogeochemistry and biological forecasting systems through enhanced synthesis products, modeling and model-data fusion activities?
<b>3) What are the exchanges of carbon between the land-ocean-ice continuum and how are they evolving over time?</b>	
1	How is carbon burial storage in key reservoirs of the land-ocean continuum changing?
2	What is the impact of (changing) sea ice on the ocean carbon cycle?
3	What is the role of tropical ocean margins in the carbon budget, and is this changing?
4	How will carbon cycling on the shelves and lateral carbon export to open ocean areas change?
5	How can we integrate the land-ocean continuum more fully into global carbon cycle assessments and earth system models?
6	How will the Arctic ocean carbon cycle respond to increasing freshwater input and ocean area due to a reduction in sea ice extent?
7	How will rising sea level change coastal ocean dynamics and carbon cycling?
<b>4) How are humans altering the ocean carbon cycle and what are the resulting feedbacks?</b>	

1	Can we safely enhance sequestration and storage of carbon by the ocean?
2	What is the vulnerability of the ocean to increasing CO <sub>2</sub> levels and what is our ability and need to mitigate increasing CO <sub>2</sub> levels?
3	How can multiple stressors (e.g. warming, deoxygenation, acidification) on the ocean carbon system be incorporated in assessing observations and model results?
4	What is the impact of deoxygenation on ocean carbon cycling?
5	How does effluent, such as sewage and runoff, from large coastal cities influence lateral organic and inorganic carbon input and the resulting coastal air-sea carbon fluxes?
6	What are the combined socio-economic impacts of changes in ocean carbon chemistry, and climate change driven by ocean warming and sea level rise?
7	How should marine management strategies in estuaries and shelf seas be improved to support fisheries, aquaculture, tourism, carbon storage and other marine activities?
8	How can we close important gaps in our knowledge through laboratory and field based process studies, including properly scaled geoengineering studies, to elucidate mechanisms and contribute to model parameterization?
9	How will mesopelagic fishing, seabed mining, and the discharge of mine tailings from land to the ocean affect the biological carbon cycle?
10	How can we assess, prioritize and implement adaptation, mitigation and remediation activities based on a knowledge of the past and current state of the affected marine environment?