

Providing solutions to mitigate, adapt and build resilience to the effects of climate change

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Abstract

This *Quo Vadimus* article is a summary of the Ocean Vision 2030 White Paper - Challenge 5: Unlock Ocean-based solutions to Climate Change (2024). We highlight the obstacles to harnessing the potential of ocean-based solutions to mitigate and adapt to the impacts of climate change. Recommendations to overcome these obstacles include 1) research into marine renewable energy, ways of reducing marine pollution and of expanding vegetated coastal ecosystems, 2) controlled field testing of marine carbon dioxide removal co-designed with invested communities, 3) improved co-designed governance and co-operation as well as capacity development, 4) adaptive governance and management supported by decision support tools for the assessment of vulnerability and risk and 5) prioritisation of fairness and inclusivity in the execution of mitigation and adaptation measures to ensure all stakeholders benefit equitably.

Keywords

UN Decade of Ocean Science for Sustainable Development, ocean-based solutions, climate mitigation and adaptation, nature-based solutions, ocean-climate synergies

Introduction

The 'ocean–climate nexus' explains how the ocean and atmosphere together control and express both the earth's daily weather systems and the long-term changes in planetary climate. The ocean absorbs around 25% of carbon emissions, which together with the uptake of more than 90% of the extra heat, regulates the climate. Unfortunately, conventional carbon emission reduction strategies are insufficient to meet the targets of the Paris Agreement (IPCC, 2021, UNFCCC, 2015), which results in the need for negative emissions. Ocean-based carbon dioxide removal (CDR) approaches such as carbon sequestration through blue carbon ecosystems, a so-called Nature Based Solution, and human derived manipulations of nutrients or ocean alkalinity, if managed properly, could offer innovative avenues to reach these necessary negative emissions (e.g. Duarte et al., 2021).

The Challenge to "Unlock Ocean-Based Solutions to Climate Change" is a pivotal component of the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) which aims to deepen our understanding of the intricate interplay between the ocean and climate, driven by the imperative to mitigate and adapt to climate change.

Harnessing ocean-based solutions to tackle climate change holds immense significance for sustainable development. First, it is crucial for enhancing climate resilience, particularly in the context of vulnerable coastal communities and ecosystems. Strengthening resilience in the regions requires management strategies that account for the interconnectedness of the ocean and climate and that address both mitigation and adaptation (IPCC, 2019; 2021). Second, marine biodiversity is of paramount importance to the functioning of marine ecosystems and the services they provide to society. A thriving ocean ecosystem not only sustains marine life but also plays a key role in climate regulation, ensuring food security, livelihoods, and overall ecological stability. Consequently, safeguarding and effectively managing these ecosystems through the restoration of disturbed and destroyed ecosystems is essential for sustainable development (UN, 2023). Third, addressing this Challenge offers substantial economic potential, especially through the growth of the sustainable blue economy which cuts across several sectors including renewable energy, sustainable fisheries, marine tourism, marine conservation, waste management, and marine biotechnology, in each case integrating environmental, economic and social considerations. These sectors can serve as engines of economic growth while simultaneously reducing CO₂ emissions or building resilience to climate change (World Bank and United Nations Department of Economic and Social Affairs, 2017). Lastly, fostering global partnerships and

interdisciplinary collaboration among stakeholders in the ocean, climate, academic and industrial communities, which are fundamental principles of the Ocean Decade, promotes international cooperation and shared knowledge, contributing to global peace, security, and the advancement of the Sustainable Development Goals (SDGs) (UN, 2023) and enables the economic and social transformation required to implement the Paris Agreement (UNFCCC, 2015).

Obstacles

An over-riding obstacle to meeting this challenge is the lack of adequate financial support and effective implementation of a global socio-political framework, despite 6 IPCC reports and 29 Conferences of the Parties (COPs; IPCC 2022).

The identification of user needs within the ocean-climate nexus is a complex task, as it involves understanding the diverse range of stakeholders, their goals, and how they intersect with both ocean and climate-related issues. There remain significant knowledge gaps in both the physical science and human dimensions of marine mitigation and adaptation approaches which will need to be filled in order to generate durable and just ocean-based solutions to the climate crisis.

Reducing the impacts of climate change will require global agreements which are implemented and tailored to local and regional capabilities and environmental conditions. Such agreements, including the Paris Agreement of the UNFCCC, the Kunming-Montreal Global Biodiversity Framework (GBF) of the Convention on Biological Diversity, and the Agreement on Marine Biodiversity of Areas beyond National Jurisdiction (BBNJ Agreement), currently, or will likely soon, commit governments to obligations which may introduce conflicts among countries, or between the various stakeholders and those implementing the regulations.

Human adaptation comprises an array of measures that reduce harm or exploit opportunities from climate change (Cooley et al., 2022). There is a continued need for improved modelling capabilities at different timescales to aid adaptation, ranging from days for short-term extreme events, to decadal prediction for strategic planning, resource management, and policy development. For areas with operational forecasting systems, it is important that these forecasts are co-developed with end-users, easily accessible and understandable and fit-for-purpose to inform behaviour and decision-making.

Marine mitigation approaches based on human-derived interventions cannot be the first-line

solution to climate change; reduction of at least 80% of emissions must be the priority (Ho, 2023). There is high uncertainty about the potential side effects of ocean-based climate solutions and there are little to no regulations on the safety and effectiveness of these approaches (Boyd et al., 2023, Loomis et al., 2022; NASEM, 2022). The monitoring, reporting, and verification (MRV) of ocean CDR is imperative, so the efficacy of these technologies, and any unintended negative consequences must be evaluated and tested through pilot studies before scaling up to larger testing and application (Loomis et al., 2022).

Adaptive governance and management must be supported by decision support tools for vulnerability and risk assessment tailored to coastal communities and marine industries, and for advancing climate change adaptation and mitigation pathways (e.g. Fulton et al., 2020). To navigate this Challenge effectively, researchers and policymakers must employ adaptive and resilient strategies that acknowledge the inherent uncertainties in climate models and projections. This involves continually refining models based on new data, advancements in scientific understanding, and improved computational capabilities, and incorporating the adaptive capacity of coastal communities and marine industries.

Fostering collaboration among scientists, indigenous and traditional knowledge holders, policymakers and industries, is crucial to developing holistic strategies for both adaptation and mitigation that can withstand the uncertainties associated with long-term climate modelling.

What success could look like

By 2030, success for this Ocean Decade Challenge should be marked by a move toward sustainable ocean management and governance (Frazão Santos et al. 2024) and a climate-resilient ocean underpinned by a well-funded, just and equitable socio-political framework including improved collaboration and conflict resolution. Success will include fulfilment of critical science and knowledge gaps alongside the development of the infrastructure, partnerships, capacity and technology required for climate mitigation and adaptation (Hoegh-Guldberg et al., 2023; Morgera et al., 2023; Sabine et al., 2024). Key mitigation approaches include the development of marine renewable energies, decarbonization of maritime shipping, reduction in nutrient and plastic pollution, the successful implementation of blue carbon restoration and conservation projects, and no-negative impact ocean CDR. Adaptation approaches include coastal ecosystem protection and preservation; increased ocean literacy/awareness; co-designed governance and co-operation between ocean users, together with local and indigenous

communities; improved risk assessment and reduction policies (Murphy et al., 2021); and ameliorated predictive capabilities of ocean, climate and weather forecasts (figure 1). Many mitigation actions help to strengthen adaptation by reducing vulnerability, and adaptation approaches can deliver benefits both for mitigation and for reducing climate change impacts (Bindoff et al., 2019).

A cautious, scientifically rigorous approach will have been used for the development of ocean CDR, focusing on inter- and transdisciplinary research, pilot projects, risk assessments, adaptive management and fostering strong connections between the scientific community and policymakers (UNESCO-IOC, 2021). Published codes of conduct and monitoring frameworks for the detection, attribution, and determination of side effects of ocean CDR (Boyd et al., 2023, Loomis et al., 2022, Cooley et al., 2022) will have guided the application of these technologies.

Eight Ocean Decade programmes and 42 projects contribute to this Challenge (UNESCO-IOC, 2023), along with the Decade Coordination Office for Ocean Observing and the Decade Collaborative Centers for Ocean Prediction, Ocean-Climate Solutions, and the Ocean-Climate Nexus. Success in this Challenge will be dependent on supreme co-ordination between these entities, including a focus on knowledge exchange and capacity development.

Despite the obstacles, human society still has the chance to mitigate and adapt to climate change, building upon improved data collection, knowledge generation, and infrastructure and technology development within strengthened partnerships, policy engagement and capacity exchange.

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Acknowledgements

This manuscript is a summary of the discussions documented in the Ocean Vision 2030 White Paper - Challenge 5: Unlock Ocean-based solutions to Climate Change (2024; <https://doi.org/10.25607/kbtq-nm78>) co-authored by Liliana Bastian, Sonia Batten, Richard Bellerby, Robert Blasiak, Sophia Laarissa, Andrea Lira, Courtney McGeachy, Galen McKinley, Jess Melbourne Thomas, Kelly Ortega Cisneros, Fangli Qiao, Dhrubajyoti Samanta, Richard Sanders and V.V.S.S. Sarma. We thank three anonymous reviewers who helped improve the focus of this manuscript.

Author contribution

CR and CS wrote the initial draft of the manuscript, KI proposed the initial draft of the figure. All authors revised and improved the manuscript and figure.

Conflict of interest

The authors have no conflicts of interest to declare.

Data Availability

There are no new data associated with this article.

Figure legend

Figure 1 Relative amounts of sources and sinks of carbon dioxide (CO₂, average 2013-2022) based on Friedlingstein et al. (2023) as well as the consequences of the CO₂ uptake in the ocean, on land and in the atmosphere. The listed consequences are only a subset of current and predicted impacts in the ocean, on land and in the atmosphere (IPCC, 2021). Examples given of mitigation (red) and adaptation (green) activities taking place in the ocean and coastal zones are expected to affect the sources, sinks and consequences in the future.