Blue Carbon: Navigating Risks and Responsibilities in Geoengineering Solutions

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BlueRemediomics

BIOcean5D

SUMMARY

In the last few decades, blue carbon ecosystems – including mangroves, seagrass meadows, and salt marshes – have been recognised for their natural capacity to capture and store atmospheric carbon in biomass and marine sediments. In this policy brief, we navigate the challenging intersection of science, ethics, and governance around marine carbon removal to contribute to ongoing debates in national, regional, EU, and international policy-making. We discuss the potential impacts of marine geoengineering approaches, such as Carbon Dioxide Removal (CDR) techniques, on marine biodiversity. Focusing specifically on marine geoengineering, we advocate for the application of the precautionary principle, and we reflect on the ethical imperatives to manage marine ecosystems in the face of ongoing anthropogenic climate change. We attempt to outline key recommendations toward responsible and equitable decisions around marine geoengineering that preserve both the integrity of the ocean and the wellbeing of future generations.

The inclusion of planktonic ecosystems within the blue carbon scope represents a key paradigm shift. Plankton, including phytoplankton and zooplankton, are a cornerstone of marine food webs and play an important role in regulating global carbon cycles. While this "*invisible majority of the ocean*" has been overlooked in discussions around carbon sequestration, planktonic organisms are now recognised as major carbon sinks, capable of sequestering significant quantities of carbon dioxide (CO_2) through photosynthesis and export to the deep ocean.

This broader perception of blue carbon has expanded the scope of marine Carbon Dioxide Removal (mCDR) initiatives, with more and more researchers and policymakers considering the potential to leverage planktonic ecosystems for advanced carbon removal from the atmosphere through large scale marine geoengineering. From iron fertilisation to ocean alkalinity enhancement, a diverse range of techniques are being investigated to maximise the carbon sequestration potential of the ocean and mitigate the impacts of anthropogenic carbon emissions.

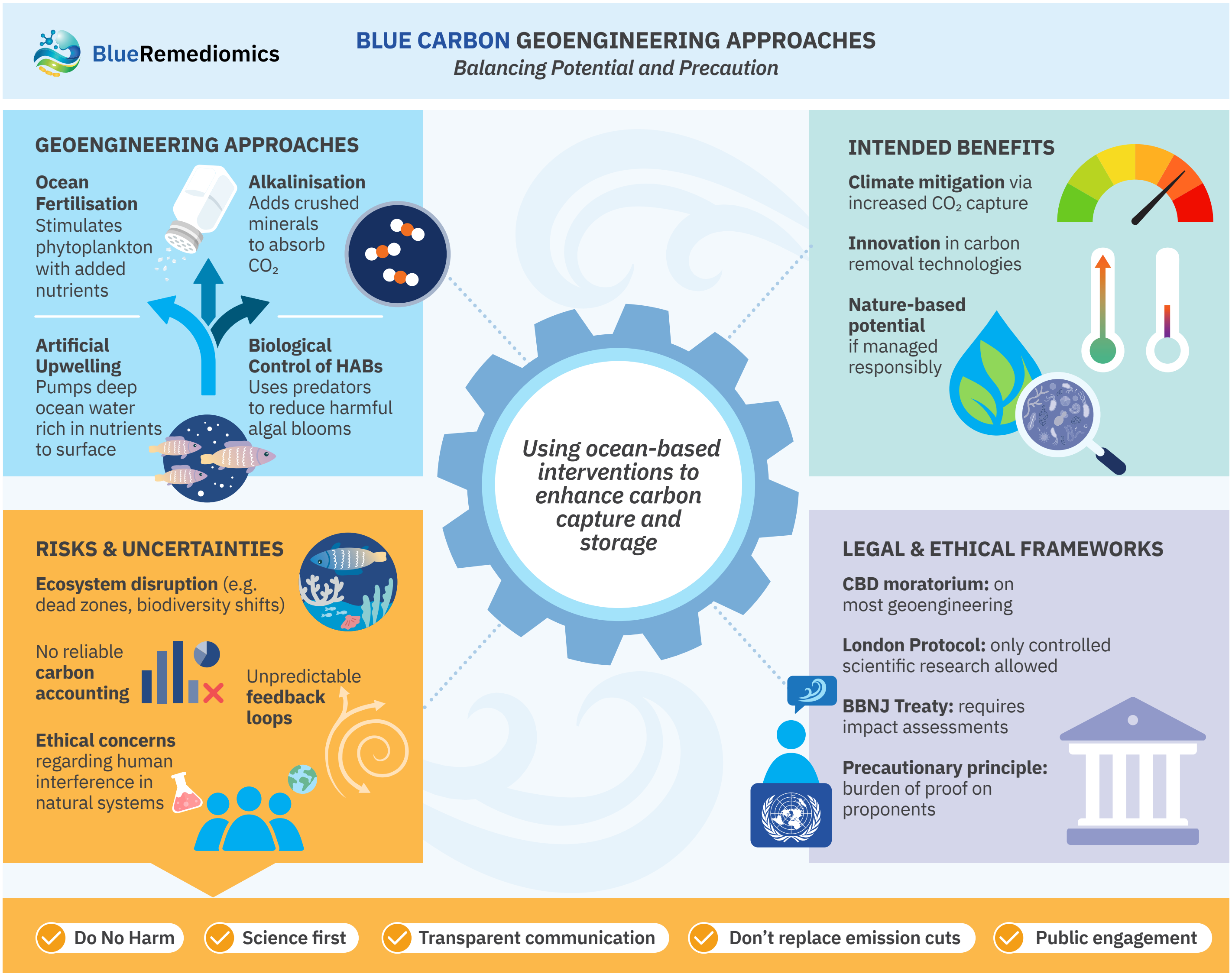


Figure 1. Blue Carbon Geoengineering Approaches

Yet, as we engage into this unexplored field of ecosystem modifications, it is imperative that we proceed with caution and humility. While the promise of leveraging marine ecosystems to address climate change appears attractive, we must acknowledge the inherent uncertainties that come with such projects. Planktonic ecosystems, while formidable carbon sinks, are also sensitive and dynamic environments that abound with life and intricate ecological relationships.

Moreover, we must confront overlooked ethical questions regarding our role as stewards of the marine environment. The development of marine geoengineering for climate targets raises profound ethical considerations about the manipulation of natural systems, the distribution of benefits and burdens, and our obligations to future generations and non-human life forms.

Exploring the Effects of Marine Geoengineering on Marine Life

Recent studies have raised concerns regarding the potential negative effects of geoengineering on marine biodiversity. Activities such as iron fertilisation, which aims to enhance the ocean's capacity to absorb CO_2, have shown unpredictable and potentially harmful impacts on marine ecosystems. Increased nutrient inputs from these activities can disrupt the delicate balance of marine habitats, leading to harmful algal blooms, oxygen depletion creating "dead zones", alteration of nutrient cycles, shifts in species composition, and unintended climate effects. Additionally, the alteration of ocean chemistry through carbon removal techniques may have cascading effects on marine food webs, with important consequences for biodiversity and ecosystem health.

OVERVIEW OF THE DIFFERENT MARINE GEOENGINEERING APPROACHES

- **Ocean Fertilisation:** Adding limiting nutrients (mainly iron, phosphorus, or nitrogen) to the ocean to stimulate phytoplankton growth, which absorbs CO_2 through photosynthesis.

  Objective → Increase phytoplankton biomass, which, upon dying, sinks to the ocean depths, carrying carbon with it.

- **Ocean Alkalinisation:** Adding alkaline minerals (such as crushed limestone or olivine) to increase the ocean's capacity to dissolve CO_2.

  Objective → Neutralise acidity and allow for greater CO_2 absorption by surface waters.

- **Artificial Upwelling (Nutrient Pumping):** Using pumps or other technologies to bring nutrient-rich deep waters to the surface.

  Objective → Stimulate phytoplankton growth at the surface, thereby capturing more CO_2.

- **Direct CO_2 Injection into Ocean Depths:** Capturing CO_2 and injecting it into the deep ocean or underwater geological formations.

  Objective → Permanent carbon sequestration.

- **Enhancement of Carbon Solubility:** Cooling surface water, via microbubble techniques for example, to increase CO_2 solubility.

  Objective → Allow greater CO_2 absorption by the ocean.

IMPACTS OF MARINE GEOENGINEERING METHODS ON MARINE ECOSYSTEMS

Nutrient Imbalance: Some geoengineering methods, such as iron fertilisation, involve adding nutrients to the ocean to stimulate phytoplankton growth and increase carbon uptake. However, this can lead to impoverishment of downstream regions and imbalances in nutrient ratios, potentially causing harmful algal blooms, oxygen depletion, and disruptions to marine food webs.

Ocean Acidification: CO_2 dissolves naturally in seawater according to a natural balance between atmospheric and dissolved CO_2. Geoengineering methods involving the removal of CO_2 from the atmosphere to the ocean can lead to increased uptake of CO_2, resulting in ocean acidification because when dissolved in seawater, CO_2 forms carbonic

acid, which lowers the pH of the water and disrupts marine chemistry. This acidification strongly impacts marine ecosystems by affecting the ability of marine organisms, such as corals, shellfish, and plankton, to build and maintain their calcium carbonate shells and structures.

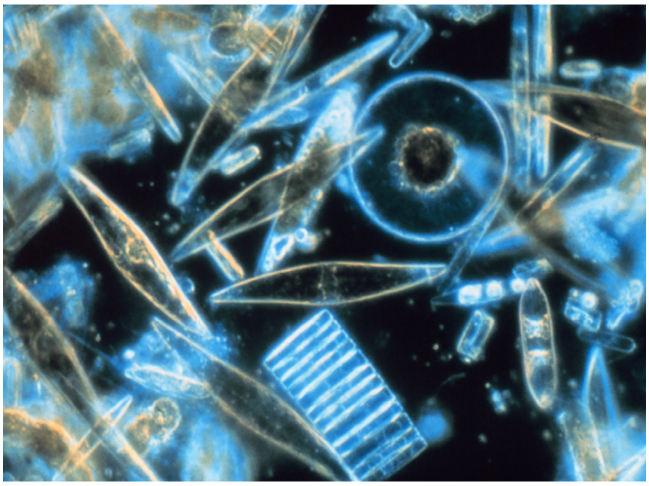
Changes in Marine Biodiversity: Alterations to ocean chemistry and nutrient availability can have cascading effects on marine biodiversity. Changes in primary productivity, species composition, and ecosystem structure may occur, impacting the abundance and distribution of marine organisms, including fish, invertebrates, and marine mammals. Fishing resources could also be strongly impacted. Moreover, the equilibrium of deep-sea ecosystems can also be strongly impacted by the increased quantity of organic matter plunging to the ocean floor.

Risk of Unintended Consequences: Implementing large-scale geoengineering interventions in marine environments carries the risk of unintended consequences. These may include ecosystem shifts, loss of biodiversity, unforeseen ecological feedback loops and unintended effects on climate, which could undermine the effectiveness of mCDR strategies and exacerbate existing environmental challenges.

While marine geoengineering can be viewed as a nature-based solution (NBS) as it relies on natural processes and ecosystems to sequester CO_2, it also presents distinct challenges and considerations that strongly differentiate it from traditional NBS approaches. Balancing the potential benefits of geoengineering with the need to minimise ecological risks and ensure long-term sustainability will be essential in advancing its role as a viable climate mitigation strategy.

Precautionary Approach to Marine Geoengineering

Given the potential risks associated with marine geoengineering methods, it is imperative to apply the precautionary principle. This principle dictates that in the absence of scientific consensus, the burden of proof falls on those advocating for a particular course of action, to establish that this is not harmful. Given the complexity and interconnectedness of marine ecosystems, we must



exercise caution and also prioritise further research to fully understand the potential consequences of deploying technologies at scale. Rushing into large-scale implementation without adequate scientific understanding could lead to irreversible harm to marine biodiversity and undermine the very goals these methods aim to achieve. When more information is available, matters can be further assessed.

EXISTING LEGAL FRAMEWORK ON MARINE GEOENGINEERING

There is actually a complex legal framework surrounding marine geoengineering, climate and the ocean, with mCDR being a key discussion point at important meetings and negotiations.

At the 2010 Conference of the Parties (COP) of the Convention on Biological Diversity (CBD), the parties to the CBD decided to establish a moratorium on most geoengineering activities that could affect biodiversity. This includes ocean fertilisation, except for small-scale scientific research under controlled conditions and according to strict criteria of transparency, impact assessment, and monitoring. mCDR methods, such as ocean fertilisation and ocean alkalinity enhancement, have been subjects of discussion within the CBD's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) and other relevant bodies. The CBD has emphasised the need for precaution and careful consideration of the potential risks and benefits of mCDR initiatives. This includes assessing the potential impacts of marine CDR on marine biodiversity, ecosystem services, and the resilience of marine ecosystems to climate change.

While mCDR has been considered within the broader context of biodiversity conservation and climate change mitigation, specific guidelines or recommendations regarding its implementation may vary depending on the outcomes of CBD meetings and negotiations. As mCDR technologies continue to evolve, ongoing discussions within the CBD and other international fora will likely play a crucial role in shaping policies and guidelines related to their deployment and management in the context of biodiversity conservation and climate change mitigation.

Similarly, the London Convention and its Protocol (London 1972, Protocol 1996) regulate the dumping of waste at sea. In 2013, the parties to these agreements adopted

legally binding amendments prohibiting large-scale marine fertilisation and any other type of marine geoengineering that has not been approved. The only exceptions are legitimate scientific research activities, subject to strict regulation and supervision.

Finally, the upcoming Biodiversity Beyond National Jurisdiction (BBNJ) Agreement will also support the need to address marine geoengineering with a precautionary approach, as it clearly mandates that any activity that could significantly impact marine biodiversity beyond national jurisdiction must undergo an Environmental Impact Assessment (EIA). This requirement could apply to marine geoengineering projects, such as ocean fertilisation, alkalinisation, or artificial upwelling, which could have far-reaching ecological consequences. Before any large-scale geoengineering project can proceed, it would need to be assessed for its potential impacts on marine biodiversity, and if the risks are deemed too high, it could be prohibited or subject to strict conditions. Precaution is also one of the principles and approaches of the BBNJ Agreement as a whole.

This last point is a key element in the consideration of marine geoengineering in today's climate challenges: it is unclear if and how science will be able to measure the real impact of these projects in the years to come. In fact, an ethical question arises: should we authorise large-scale experiments to conclude on the real impact of geoengineering on the global ocean, or should we already acknowledge the fact that they are not a solution but a postponement of a problem that we need to solve through societal rather than technological approaches?

GEOENGINEERING: AN "EXTRAORDINARY OPPORTUNITY" IN CLIMATE COPS

Since the world gathered in Dubai for the Climate Change Conference (COP 28) in 2023, there has been a growing sense of anticipation surrounding the potential role of mCDR as a miraculous immediate solution to the climate crisis. With mounting pressure to achieve ambitious emissions reduction targets and limit global temperature rise, many stakeholders are increasingly looking to the ocean as a vast and untapped reservoir for carbon sequestration. Planktonic ecosystems, once overlooked in climate mitigation discussions, are now being seen as potential saviours, capable of drawing down atmospheric CO_2 and mitigating the impacts of anthropogenic emissions and also removing the need for other societal change.

Both 2024 COPs, to the CBD (October, Cali) and of the United Nations Framework Convention on Climate Change (UNFCC, November, Baku) were critical opportunities for nations to consider collectively the challenges and opportunities presented by mCDR. They also ensured efforts to combat climate change are grounded in scientific rigour, ethical responsibility, and equitable governance frameworks, and consistent with the objectives of the new global biodiversity framework. Nevertheless, faced with the difficulty of identifying the sources of finance needed to achieve climate objectives, the main breakthrough at the Baku COP was in relation to the global carbon markets (Article 6 of the Paris Agreement), when an open approach was adopted on what can be considered as carbon elimination. This approach is worrying, because although it refers to considering the best available scientific data, the financial dimension of marine geoengineering projects could precipitate their implementation even before the conditions for their non-harmfulness to marine ecosystems have been identified.

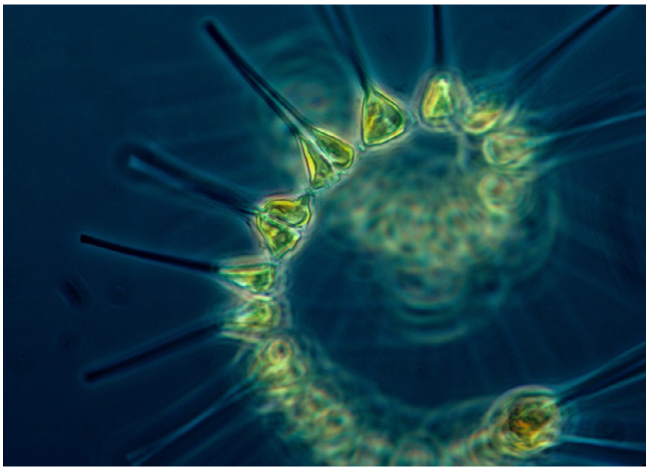
The priority should remain to reduce emissions, not to keep looking for a way to re-absorb them, transfer them or to create a new industrial path. In contrast, the affirmation at Cali of a practical moratorium and a precautionary approach to climate-related geoengineering is welcomed.

LESSONS LEARNED FROM LAND CDR

The current debate on the anticipated contribution of marine geoengineering as a silver bullet solution to climate challenges can also be informed by lessons learned from terrestrial carbon offset projects.

For several decades now, carbon offset projects based on new technologies have been appearing at the UNFCCC COPs, each time announcing that it has identified a protocol for long-term carbon storage. Reforestation, afforestation, soil sequestration or direct capture have been presented as the miracle solutions of their time. What is the situation after several years of implementation? What lessons can we learn from this repetition of history, with the challenge of marine geoengineering?

The first weakness identified concerns the carbon sequestration versus energy consumption balances of certain technologies, such as direct air capture (DAC) and, carbon capture and storage (CCS). After several years in operation, the usefulness of these projects in the overall carbon balance has yet to be demonstrated. Many CCS projects already underway are collapsing due to the costs involved and the disastrous consequences for the environment.



Similarly, more natural solutions such as carbon sequestered in forests or soils are vulnerable to inversion and leakage. The example of carbon accounting applied to forest reforestation projects and assigning tonnage to linear replanted trees has no ecological basis. Some studies even tend to prove a negative carbon balance. Consequently, no marine project with financial value should be considered without a program of monitoring, robust scientific verification and long-term management of carbon stocks. Measures to protect against reversals and leakage must be implemented, taking into account natural variability, climate impacts and socio-economic factors.

But more than anything else, carbon offset and carbon sequestration projects are no substitute for a massive policy to reduce carbon emissions. CDR technologies can only be seen as a complementary measure to deep and rapid emissions reductions, not as a replacement for them.

Examining Ethical Frameworks for Marine Carbon Dioxide Removal (mCDR)

Beyond the scientific uncertainties, the ethical implications of manipulating marine ecosystems for carbon sequestration must be carefully examined. Intentional large-scale interventions in natural systems to mitigate the impacts of human activities raise profound questions about our relationship with the environment and the boundaries of acceptable intervention. Manipulating life processes to sustain current consumption patterns raises concerns about intergenerational equity, environmental justice, and the rights of non-human species. Different people, bodies and ethical approaches will have different priorities. Before proceeding with widespread implementation of geoengineering strategies, it is essential to engage in a transparent and inclusive dialogue with activists and policymakers, focusing on younger people, older people and the rights of nature (including the ocean itself). Holding digital and in-person community multi-stakeholder events and working with the arts and oral history are also recommended. This wider lens will enable us to develop new paths for questioning these wider aspects of using new technologies and ensure that decision-making processes in the variety of relevant fora are holistic, plural and prioritise the long-term wellbeing of both human and non-human communities.

Acknowledging Our Ignorance: Toward Responsible Ocean Management Through Moratoria

In the face of emerging environmental challenges in the ocean, there is a pressing need for caution and deliberation in our approach to novel ocean interventions. Just as the call by some under the International Seabed Authority for a moratorium on deep-sea mining activities emphasises the importance of fully understanding the ecological and socio-economic impacts before proceeding, so too does the case for a moratorium on large-scale mCDR initiatives. Both deep-sea mining and marine geoengineering represent significant interventions in the ocean environment, with potential implications for marine biodiversity, ecosystem functioning, and ocean health.

Marine geoengineering methods, while offering promise in mitigating climate change, carry uncertainties regarding their ecological impacts, effectiveness, and ethical implications. The manipulation of marine ecosystems for the purpose of carbon removal demands rigorous scientific research, transparent governance frameworks, and inclusive stakeholder engagement to ensure responsible and ethical deployment.

A precautionary approach to mCDR is warranted, recognising the limits of our current knowledge and the importance of prioritising the protection of marine ecosystems and biodiversity. By advocating for maintaining or even strengthening a moratorium on mCDR activities, we emphasise the need for comprehensive research, assessment, and stakeholder engagement processes to inform decision-making and safeguard the integrity of the ocean environment. Balancing the imperative to address climate change with the imperative to protect marine ecosystems requires thoughtful consideration of the potential risks and benefits of human interventions in the ocean realm. As we navigate these challenges, let us prioritise the precautionary principle and uphold our responsibility as stewards of the marine environment for current and future generations.

Key Takeaways for Marine Geoengineering in Policy Forums

- There is **no scientific consensus on the absence of risks associated with the implementation of marine geoengineering activities** in the ocean. On the contrary, many researchers emphasise the immense uncertainty surrounding undesirable effects, potentially on a large spatial and temporal scale, and impacting areas beyond the impacted site.
- There is **no reliable carbon accounting scheme to quantify the excess carbon stored** by these activities, nor the sustainability of this storage.
- As long as there is no scientific consensus on the harmlessness of these practices for biodiversity and marine ecosystems, **the precautionary principle must be applied to all geoengineering activities.**
- Respecting the objectives of the Paris Agreement implies a 40% reduction in greenhouse gas emissions by 2030. **Countries must give priority to reducing emissions at source, before considering any action to offset the remaining emissions.**

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