Transactions on Environment, Energy and Earth Sciences
ISSN: 2960-1924, eISSN: 2960-2300 | Volume 3
GRET 2024

Unveiling The Role of The Deep Sea In Mitigating Climate Change

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Abstract. The deep sea, defined as marine areas of more than two hundred meters beneath the ocean surface, is an area full of scientific potential and mysteries. Linking the deep sea to climate change, one of the most significant issues of the current world, this essay examines and casts light on the role of the deep sea as a fundamental, nature-based mitigator of climate change. The results of this paper show that the role of the deep ocean in mitigating climate change remains promising based on the interpretation of its carbon sequestration, nutrient cycling and heat storage functions. The article focuses on the in-depth analysis and conclusions of the three major roles of the deep sea in mitigating climate warming. The resources and functions of the deep sea are extremely important to human society, and the national and international communities should pay more attention to the implementation of climate change mitigation methods through the use of the deep sea while raising awareness of the need to cultivate a sustainable and mutually beneficial relationship between human beings and the oceans.

Keywords: The deep sea; Climate change; Carbon sequestration; Nutrient cycling; Heat storage.

1. Introduction

The deep sea is the largest single ecosystem on earth, yet it remains not fully understood due to the difficulties in its exploration [1]. The exploration of the deep sea began in the nineteenth century when emerging discoveries about life at great depths fueled further explorations and discoveries [2]. One of the milestones of the early exploration of the deep sea was set by professor Wyville Thomson at Edinburgh University, who helped and took the lead in the organization of the pioneering voyage of H.M.S 'Challenger' from 1872 to 1876 [2]. This voyage hugely improved upon the early infant science of oceanography as animal life was found 5.5 kilometers below the ocean surface using dredgings [2]. Importantly, such scientific discoveries broke the theory that the deep ocean was a lifeless and slow system [3]. The 1950s saw the rise of scientific investigations of the deep sea by Russian biologists; the deep-sea exploration between the 1960s and 1970s was dominated by scientists from the US; and the period between the 1970s and 1980s was a time of international proliferation in scientific research [2]. As the deep sea continues to be explored, its connection with global issues has become increasingly strong. In the modern age, scientists have begun to unravel the potentials of the deep sea in mitigating climate change, a globally wide environmental problem that poses significant risks to human and natural systems.

Yet, the deep sea and its connections to the mitigation of climate change are relatively under-explored due to many reasons. The difficulty in reaching the deep ocean results in the lack of sufficient scientific knowledge about the deep sea [4]. The current technological developments have not enabled scientists to gain a holistic understanding of the deep sea [4]. Moreover, few studies and research have been carried out to outline and suggest the role of the deep sea in reducing the impacts of climate change. As a result, a mature framework for the deep-sea mitigation of climate change is not completed at the current stage. However, this essay aims at building upon the existing scientific knowledge about the deep sea and bringing attention to the application of the deep sea in mitigating climatic warming. The essay will delve into three crucial roles of the deep sea, namely carbon sequestration, nutrient cycling and heat storage. Then, the value and justifiability of utilizing the deep sea as a mitigator of climate change will be considered and discussed.

2. Deep-Sea Mitigation of Climate Change

2.1. Carbon Sequestration

Climate change and carbon are closely related. The amount of carbon dioxide on earth has been on the rise since the Industrial Revolution, mainly due to anthropogenic activities [5]. Carbon dioxide directly impacts the global carbon cycle and contributes to climate warming [6]. This allows the understanding of the importance of the deep sea in mitigating climate change. Both the conditions and the living organisms in the deep sea play essential roles in carbon storage, transport, and sequestration. Due to the low temperature and high pressure of the deep sea, gas forms of carbon can be captured as gas or buoyant fluid in the deep waters [7]. Inorganic and anthropogenic carbon is transferred from the surface ocean into the deep sea in a process known as the biological pump [4]. Organic carbon resulting from the natural remains of dead organisms engages in the process of naturally sinking into deep waters [4]. Once sunk, organic carbon can either be remineralized by microbes and animals or buried as sediments in deep waters for a prolonged period [4]. It is worthwhile to note that remineralization does not always lead to a release back into the atmosphere and remineralized carbon may still remain sequestered for thousands of years [8]. In addition, microbes and animals precipitate carbonates to sequester carbon. In specific, animals oxidize methane, store carbon and bury carbon through bioturbation [9].

Due to the notable potential and capacity of the deep sea in storing and sequestering carbon, the possibility of direct injection of anthropogenic carbon dioxide into the deep sea is considered by many scientists. While oceanic carbon sequestration may not have the ability to shift the world from the current situation into a carbon-free economy, it has several profound advantages including its high practicality and convenience in implementation [10]. It is also concluded that large-scale carbon dioxide sequestration in the deep sea below three thousand meters is technologically viable [11].

However, an over-exploitation of the deep sea can engender serious environmental harm in marine ecosystems, such as ocean acidification and deoxygenation [4]. Hence, scientists need to find the balance between utilizing the deep sea in carbon sequestration and conserving the marine environment. One potential, nature-based solution proposed is the formation of carbon dioxide hydrates directed by humans after the injection of carbon into the deep sea [10]. If the injection of carbon dioxide is controlled to occur at a specific location with suitable temperature and pressure (below three hundred meters and eight degrees Celsius), liquid carbon dioxide will change into the form of carbon dioxide hydrates [10]. Solid compounds formed when carbon dioxide molecules are enculturated in crystalline lattices of water molecules, carbon dioxide hydrates are desired products during carbon sequestration as they have high density and stability in the deep sea [12], which creates slower dissolution of carbon dioxide and prevent the rapid release of carbon dioxide into seawater [13]. As a result, the acute damage of anthropogenic carbon sequestration on marine ecosystems can be minimized, as the time available for deep-sea organisms to process and store anthropogenic carbon is largely increased.

2.2. Nutrient Cycling

Nutrient cycling in the deep sea is an indispensable part of the procedure of understanding the full influence of the deep sea on climate change. The foundation for primary production in oceans and nutrients is directly related to many biogeochemical processes in the marine environment [14]. The biogeochemical cycling of nutrients such as nitrogen, carbon, iron and sulfur is carried out in the deep sea. This essay uses nitrification, a key component of the nitrogen cycle, as an example to illustrate the process of nutrient cycling. Nitrification in the deep sea is mainly performed by the ammonia-oxidizing bacteria (AOB) and ammonia-oxidizing archaea (AOA) [15]. AOA and AOB oxidize ammonia into nitrite before nitrite is converted into nitrate by nitrite-oxidizers [15]. This process helps to provide nitrates, which are an important source of nutrients to many living organisms, to deep-sea organisms such as phytoplankton, which promotes their growth [15, 16]. Crucially, the growth of photosynthetic organisms such as many kinds of benthic and planktonic organisms allows more natural carbon storage and uptake in the deep sea, as more atmospheric carbon dioxide can be incorporated into their cells during photosynthesis in the biological pump [4, 16].

Not only living organisms contribute to nutrient cycling. The unique environment of the deep-sea hydrothermal vents is also responsible for enabling nutrient cycling to occur. Hydrothermal vents were first discovered on Equator’s Galapagos Islands in 1976 [7]. Seven hundred and twenty hydrothermal vents have been found since then [7]. Hydrothermal vents are a manifestation of tectonic movements. When trapped sea water below the crust circulates, it may eventually emerge near spreading axes in the deep sea [17]. As hot hydrothermal fluids rise to the seafloor and mix with cold seawater, steep chemical gradients form, supporting the existence of large numbers of hydrogen-oxidizing organisms including an expansive variety of Bacteria and Archaea [18]. These organisms use hydrogen as an energy source to fix inorganic carbon into organic carbon, consequently contributing to the reduction of atmospheric carbon dioxide and the mitigation of climate change [18]. Some notable examples are some members of the order Aquificales, such as Thermovibrio ammonificans or Balnearium lithotrophicum, who use hydrogen as the only energy source for autotrophic growth [18]. In addition to this, many vent animals necessitate dissolved sulfites for living, which are provided by hydrothermal vents in the form of polymetallic sulfide deposits around the sea-floor openings [17]. All of the above living conditions enabled by hydrothermal vent environments promote the growth of living organisms and therefore increase oceanic nutrient cycling and carbon uptake by the deep sea. Nevertheless, it is worth noting that more advanced scientific technologies are required in order for scientists to be able to explain the whole picture, as scientists may have only been focusing on particular nutrients and living organisms that are relatively well-known and well-researched.

2.3. Heat Storage

The capacity and potential of the ocean in global heat storage, with the deep sea playing a significant role in it, have been discussed and debated among scientists for a long period of time. The heat storage capacity of the ocean is supported by the Atlantic meridional overturning circulation, or AMOC in short [19]. AMOC is a cycle of global heat transport containing four branches: the first branch is from the deep sea to the ocean surface, the second branch is from the ocean surface to high latitudes, the third branch is from high latitudes with lighter water to deepwater regions with denser water, and the fourth branch is from regions with denser water to deep currents [19]. The four branches complete the cycle. Importantly, this suggests that heat in oceanic water can be transported from surface oceans to deep currents [19]. Thus, some of the thermal energy in the atmosphere can be absorbed and stored in the deep sea during temporary climatic changes, decreasing the global temperature [19]. Although this effect is not permanent, it may slow down the rate of change of global surface temperatures and hence influence the rate of climate change. Nevertheless, the scientific research about the storage and transport of heat into the deep sea is still incomplete, and much of the current data is based on assumptions of exchange rates and reservoir sizes [19]. As a result, further research is required to present the whole picture.

3. The Justifiability of Using the Deep Sea to Mitigate Climate Change

The previous detailed discussions emphasized explaining and analyzing the role of the deep sea in mitigating climate change and how the deep sea has the ability to shape the future of climatic warming. However, this is also an appropriate time and place to switch the perspective and have a deep think about how climate change has shaped and might continue to shape the deep sea.

Both paleo and recent studies have illuminated profound ways in which climate change exerts impacts on the deep sea. As discussed earlier in the essay, the rise of global carbon emissions causes the deep sea to increase its carbon uptake and sequestration due to its massive storage capacity. This raises severe issues at both the individual and ecosystem levels, including the alteration of species distribution, ocean acidification, and the decrease of oxygen solubility [4]. Over the long term, these issues can lead to serious population decline of fish and other marine wildlife, resulting in larger changes in the deep-sea food supply and biodiversity [4].

The full picture can be shown clearer if the causes of climate change, which result in the consequences discussed above, are brought into consideration. Perhaps unsurprisingly, humans accelerated climate change. In fact, humans are considered, almost to scientific consensus, as the direct cause of climate change [20]. Throughout the long period of anthropogenic history, while expanding civilizations, humans have also transformed the world into an industrialized society. With it came an increase in pollution and a sharp rise in global temperatures due to actions such as the distribution of microplastics into oceans, the production of fossil fuels, and the process of agriculture. Acute impacts on the environment, particularly oceans and the deep sea, are subsequent. Humans, consequently, are essentially casting hope on the deep sea in the mitigation of climate change while exacerbating the situation and generating negative environmental impacts on the deep sea.

An ethical dilemma therefore emerges from this discussion. Scientists and biologists may begin to consider and put forward the question of whether it is justifiable and ethically correct in the first place to utilize the deep sea for mitigating climate change. Putting this into different words, whether humans should make the deep sea partially responsible for mitigating climate change is an unresolved question left for scientists to answer.

This essay argues that the approach of using the deep sea as a mitigator for climate change is not valid unless is additional attention given or steps are taken at the same time. Despite various challenges involved in the procedure, humans should strive to strike a balance between exploiting the resources of the deep sea and minimizing potential environmental harm during implementation. As highlighted in the essay, an example that achieves this balance is carbon sequestration. Sequestering and storing carbon in the deep sea can lead to the formation of carbon dioxide hydrates, which can essentially extend the time frame of carbon dioxide release and thereby increase the chance of successful carbon storage. Furthermore, humans should not solely rely on the deep sea for mitigating climate change, but simultaneously grow and promote the awareness of developing sustainability and expanding environmentally friendly approaches in industrial practices. Engaging in such actions can make the effort to protect the natural environment long-lasting and develop a mutual relationship between humans and the environment as a whole.

4. Conclusion

In conclusion, this essay demonstrates that the deep sea holds significant potential as a nature-based mitigator of climate change. Three functions of the deep sea, closely linked to the alleviation of climate change, are reviewed in detail. The deep sea can perform natural carbon sequestration to reduce the amount of atmospheric carbon, by both sequestering anthropogenic carbon in the biological pump and storing organic carbon in the process of natural sinking. The possibility of large-scale purposeful injection of anthropogenic carbon into the deep sea has been proposed, with the potential acute damages to marine ecosystems theoretically minimized by the formation of carbon dioxide hydrates. Moreover, nutrient cycling processes in the deep sea, such as nitrification carried out by AOA and AOB, enhance the natural carbon uptake by microorganisms because of the nutrients supplied by these processes. Specifically, the essay examines the importance of hydrothermal vents in nutrient cycling, highlighting their provision of essential nutrients, like hydrogen and sulfite, to living organisms in hydrothermal vent environments. Thirdly, the deep sea also has the potential to transport and store global heat, thereby decreasing global temperatures and mitigating climate change. This is supported by the AMOC, a transport system in which heat can be transported from the surface ocean to the deep currents in the circulation. The essay then raises the question of the justifiability of using the deep sea as a mitigator of climate change, as humans are meanwhile deteriorating this climatic problem and causing environmental harms on the deep sea, and proposes that humans should grow the awareness of minimizing the environmental impacts during the exploitation of deep-sea resources and be recognizant of the need to develop a more profoundly sustainable society instead of being dependent on the deep-sea, nature-based mitigation of climate change. Nevertheless, due to the scientific and technological limitations, this essay may only represent a small amount of information and insight about the deep sea. More functions of the deep sea and its relationship with climate change should continue to be researched and studied in the future. The focus for future work can also be put on discovering new approaches to minimize the environmental harms engendered when utilizing the deep sea to mitigate climate change.

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