

Ocean Acidification as an Environmental Concern

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Abstract

Oceans have been essential in protecting Earth from some of the more severe effects of climate change by absorbing around 30% of the carbon dioxide that humans have been responsible for emitting. However, since the industrial era, this has led to a rise in ocean acidity of about 26%. This creates a number of legal challenges in addition to the scientific challenge of tackling the issue of ocean acidification and its effects on marine life. This research work will analyse the impact of Ocean Acidification on marine ecosystem, maritime transport, food security and fisheries from the lens of human rights approach, and other socioeconomic concerns relating to ocean acidification. This study aims to evaluate whether the current global legal structure offers a sufficient basis for tackling these socio-legal complexities.

Keywords: Ocean acidification, environmental impacts, climate change, legal challenges

INTRODUCTION

Ocean Acidification has been aptly described as the ‘evil twin’ of climate change by Hull in his Article [1]. Climate change impacts on marine and coastal ecosystems, such as sea level rise, deoxygenation, coral bleaching, loss of sea ice, and changes in species abundance and distribution, have been fuelled by increasing carbon dioxide (CO₂) emissions. These emissions have also aided in the acidification of the oceans. The ocean is expected to absorb nearly a quarter of total anthropogenic CO₂ emissions with some 525 billion tonnes of CO₂ absorbed since the beginning of the industrial era and about 22 million tonnes sequestered each day [2]. When CO₂ and sea water combine to generate carbonic acid, the pH levels and saturation states of carbonate minerals, such as aragonite and calcite, which are needed by many marine animals to form their shells and skeletons, are both dropped. In the last two centuries, there has been a roughly 30% rise in the average acidity of the ocean's uppermost layers. If current CO₂ emissions persist, it is anticipated that the pH level will further drop by approximately 120% by the close of this century. It is believed that the rate of ocean acidification is higher now than it has been for at least the past 300 million years [3].

The effects of this ocean acidification are extensive and intricate. As stated in the Intergovernmental Panel on Climate Change's 5th Assessment Report (IPCC), the combination of rising ocean temperatures and diminishing oxygen concentrations poses a threat to marine organisms, exposing them to potential harm. Ocean acidification is also accelerating. The Report emphasises how vulnerable arctic habitats and coral reefs are. One of the ecosystems that are most susceptible to ocean acidification may be deep-sea coral reefs. The reduction in aragonite saturation required for calcifying species, like corals, certain plankton, and shellfish, to develop calcium carbonate skeletons is brought on by the rise in carbon dioxide absorption by the oceans. Numerous marine animals that use calcium carbonate to form their shells will be directly impacted by acidification. Polar, subpolar, deep marine, and upwelling regions are particularly susceptible to the loss of critical connections in food chain [4].

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It is still unknown whether the current international legal system provides the necessary framework to address this threat to the oceans or whether it “exists in somewhat of an international legal twilight zone,” as described by Baird *et al.* [5], despite the fact that the risks and effects of ocean acidification continue to increase. For instance, the current legal framework established by the United Nations Framework Convention on Climate Change (UNFCCC) does not only address carbon dioxide emissions, nor does it specifically address the issue of ocean acidification, which is solely a result of elevated levels of atmospheric carbon dioxide [6].

This study seeks to undertake a thorough analysis of both the ecological and socio-legal consequences of ocean acidification. Additionally, it aims to evaluate the effectiveness of the international legal structure concerning human-caused ocean acidification. The study also assesses whether the UNFCCC and the United Nations Convention on the Law of the Sea (UNCLOS), two prominent global frameworks, offer the requisite legal groundwork for addressing the issue of ocean acidification.

OCEAN ACIDIFICATION

Ocean acidification is the term for a long-term, generally decades-long, decrease in the pH of the ocean that is mostly brought on by the absorption of carbon dioxide (CO₂) from the atmosphere, since it is the major source of nitrogen gases, mercury, carbon dioxide, and radioactive isotopes, though it can also be brought on by other chemical additions to or subtractions from the ocean [7]. Also, before ending up in the ocean, some organic chemical contaminants, such as polychlorinated biphenyls (PCBs), can travel across great distances in the air [8]. Further, Fossil fuel combustion releases carbon dioxide into the atmosphere, causing the greenhouse effect, which causes a rise in ocean and atmosphere temperatures because less heat can be reflected away from the earth. The oceans have warmed by around 1°F to a depth of 200 ft over the past century, and the vast majority of scientists agree that rising amounts of greenhouse gases from human activity in the atmosphere are the primary cause [9].

Potentially, this will cause ecological disaster throughout the oceans in the world. The majority of life on Earth is sensitive to even modest pH fluctuations. For instance, in humans, a shift in blood pH outside of a relatively small healthy range (7.35 to 7.45) causes disease (acidosis [10] when blood pH drops below 7.4, and alkalosis [11] when it increases over 7.45). Humans would die if the ocean pH shift predictions (0.3 to 0.4 pH units on average by the end of the century) were applied to human blood chemistry [12].

Also, one of the major reasons for higher atmospheric carbon dioxide concentrations is maritime transport. The literature and policy agenda have largely ignored the link between maritime transport and ocean acidification. This gap is not unexpected given that ocean acidification as an environmental issue receives little attention from the general public, from international, regional, or national law and policy makers, and from legal academics. Since anthropogenic carbon dioxide (CO₂) emissions are the primary cause of global ocean acidification, CO₂ emission reduction and limitation policies are the most effective strategy to address the issue of climate change and the ensuing ocean acidification. Examining the economic areas that are currently lacking in substantial regulation is crucial in this context. A clear example is the global maritime transport industry. International shipping generates so many greenhouse gas emissions that if it were a nation, it would rank among the top 10 emitters globally and have the greatest rate of emission growth, with emissions expected to rise by 50 to 250% by 2050 [13].

Numerous scientific questions remain regarding the effects of ocean acidification, in part because it is challenging to comprehend the interplay between various stressors and the capacity of different marine species to adapt. Nevertheless, a wide range of effects have been noted. Among them are the challenges faced by marine species that build shells, such as oysters, mussels, clams, urchins, and starfish; the potential decline in calcifying zooplankton and phytoplankton species and the resulting disruption of the food web; the restriction of coral growth; the increased toxicity and abundance of harmful algae blooms; the alteration of sensory systems and avoidance of predator behaviour in some fish; and the decline in some fish populations [14].

Ocean acidification can also be conceptualized as the lesser-acknowledged counterpart of climate change. Ocean acidification has received less emphasis in the public and political discourse than climate change and other environmental issues like plastic pollution in the ocean. Keeping the global atmospheric temperature under control is a key goal of the Paris Agreement [15], which addresses climate change mitigation, adaptation, and loss and damage [16]. The objective is to restrain the rise in global average temperature to significantly less than a 2°C increase from pre-industrial levels, while actively striving to cap the temperature escalation at 1.5°C above those same pre-industrial benchmarks. Ocean acidification has gotten very little attention, despite the fact that numerous organisations and projects have tried to increase awareness of it within the framework of climate change.

It is difficult to grasp the legal and policy aspects of combating ocean acidification. Although a specific ocean acidification agreement has been proposed [17], no comprehensive and integrative worldwide agreement has been enacted to address the issue. Instead, a patchwork of international agreements and projects have come into existence, with climate change accords serving as the foundation for both ocean acidification mitigation and adaptation [18]. Responses to climate change and ocean acidification by regional sea programmes and regional fisheries management organisations (RFMOs) are in varying phases. At the national level, nations respond to ocean acidification in very different ways, with legislative fragmentation, once more a significant issue, particularly in federated states [19].

Regarding national and international law and policy responses thus far, one thing is evident. With phrases like “lagging law and policy solutions” and “falling between the cracks of and the, UNCLOS and the UNFCCC”, they have not been up to the challenge of addressing the mounting concerns of ocean acidification. With their nationally determined contributions (NDCs) to mitigate emissions being found to be insufficient and indicating a temperature increase of at least 3°C by the end of the century, parties to the Paris Agreement have not yet committed to taking appropriate mitigation measures. Even after the COVID-19 crisis, it is unclear how quickly nations will transition to low-carbon economies and how quickly the global populace will adopt low-carbon lifestyles [20].

EFFECTS OF OCEAN ACIDIFICATION ON MARINE ECOSYSTEM

The increasing acidity of the oceans is expected to adversely affect a range of marine organisms, particularly those that possess shells made of calcium, causing potential harm. To make calcium carbonate for shells, many species need calcium and carbonate ions from seawater [21].

Organisms face greater difficulty in accumulating calcium carbonate necessary for constructing their rigid skeletons and shells in conditions of lower pH, as this diminishes the saturation of calcium carbonate. Aragonite and calcite represent two common forms of calcium carbonate minerals. Because aragonite is a more soluble mineral form than calcite, organisms that use it (corals, pteropods, and bivalves) are predicted to be more severely impacted than calcifiers that use calcite (coralline algae, sea urchins) [22]. Acidity hinders the formation of reefs, which could reduce coral resilience and cause erosion. Since a variety of other organisms call coral reefs home, their extinction would have a significant impact on the marine ecosystem as well as on fishing and tourism in the tropics. The protection that coral reefs provide coastal populations against storm surges and hurricanes would be lessened if they were to disappear [23].

Such unheard-of changes in ocean chemistry have serious negative effects on marine life, biodiversity, and ecosystems, especially when paired with other effects of climate change on the ocean, such as rising water temperatures. Of course, different species will respond differently to the acidity of the ocean. Because ocean plants, like plants on land, require carbon dioxide, higher amounts of this gas in saltwater are expected to be beneficial to them [24], which is totally in contrast with the situation of the shelled marine organisms, as mentioned earlier. There are also a lot of unknowns about how marine life will react to ocean acidification, which is made worse by the ongoing dearth of studies on how ocean acidification affects specific species, marine life communities, and ocean ecosystems [25].

The repercussions of ocean acidification on marine ecosystems and human welfare are projected to extend far beyond the effects solely on shell-forming creatures, as indicated by the connections to marine food production mentioned earlier. Recent studies have commenced observing broader reactions to ocean acidification within communities like phytoplankton, bacteria, seagrass, and algae. These responses have the potential to impact interactions among various species, eventually culminating in ecosystem-level changes. Acidosis, the accumulation of carbonic acid in organisms' bodily fluids, is a biological outcome of ocean acidification that can give rise to various additional challenges for creatures such as fish. According to research on marine biochemistry [26], "many important physiological/biochemical events within marine species, spanning from such diverse activities as photosynthesis, nutrient transport, to respiratory metabolism, are connected to the pH gradient across cell membranes [27]." Speaking of physical consequences, declining pH levels reduce the ocean's capacity to absorb sound. As a result, there may be an adverse impact on acoustically sensitive whales and dolphins, possibly impairing their ability to locate and find food. Additionally, as calcium carbonate mineral concentrations decline, light can go farther into the ocean, raising serious concerns about how this would affect organisms that are accustomed to the normally low light levels of the ocean [28].

The potential consequences for the marine ecosystem due to ocean acidification could be substantial, potentially resulting in the depletion of economically important fisheries and the diminished ability of coastal regions to provide protection against storms. This is because marine communities are beginning to respond to ocean acidification and its myriad secondary effects. People may pay a high price in terms of economic and cultural expenses, particularly those living in developing or coastal countries. Ocean acidification is also anticipated to work synergistically with climate change consequences on the ocean, similar to how coral reefs did, to worsen the effects on marine ecosystems [29].

IMPACT ON HUMAN RIGHT OF FOOD SECURITY

About 30% of the anthropogenic carbon dioxide emissions have been absorbed by the ocean, altering its chemistry and causing ocean acidification. The Special Report on the Ocean and Cryosphere in a Changing Climate was issued in 2019 by the Intergovernmental Panel on Climate Change (IPCC). The report's conclusion was [30]:

"The ocean has taken up between 20–30% (very likely) of total anthropogenic CO₂ emissions since the 1980s causing further ocean acidification. Open ocean surface pH has declined by a very likely range of 0.017–0.027 pH units per decade since the late 1980s, with the decline in surface ocean pH very likely to have already emerged from background natural variability for more than 95% of the ocean surface area."

The water's carbonate chemistry is changed by the absorbed CO₂, which raises the acidity of saltwater (reduces pH), and lowers the aragonite saturation state. Many marine organisms (including corals that construct reefs and shelled molluscs that use aragonite to build their shells) may experience considerable weakening of their skeletons and shells as a result of these shifting environmental conditions. These consequences could potentially endanger the marine food web and endanger the ability of marine ecosystems to recover, especially corals [31].

Particularly susceptible to the effects of climate change, including acidification, are coral reefs. The highest amount of biodiversity of any ecosystem may be found in coral reefs, which also directly support nearly 500 million people globally. While there are still many unanswered concerns regarding how ocean acidification affects marine life, current research indicates that in addition to having an effect on fisheries and seafood output, acidification may also have an effect on tropical coral reefs, molluscs, and bivalves. According to studies, a variety of marine life will be affected by ocean acidification. This might have significant effects on the world's food supply, particularly for developing nations [32].

Ocean acidification puts in jeopardy the general well-being of the ocean, its aquatic inhabitants, and the countless individuals whose sustenance and livelihoods rely on the ocean. The potential repercussions of ocean acidification on economic decline and the assurance of food security could be

noteworthy. Despite being a worldwide phenomenon, ocean acidification's effects will not be the same everywhere. Particularly vulnerable to the negative effects of ocean acidification are small island developing states (SIDS), whose lives depend on the resources and advantages of the ocean [33]. There are few viable agricultural choices in many SIDS. In 82 developing countries, the subsistence or artisanal fisheries that provide both revenue and protein are primarily dependent on calcifying species [34]. Ocean acidification could influence the cultivation of shellfish and the operations of commercial fishing, yet it also has the potential to imperil the ability of millions of the most economically disadvantaged individuals to obtain protein, ensure food security, and sustain their means of living. Deep and quick reductions in global CO₂ emissions from human activities are required to prevent significant harm to marine life and ocean ecosystems [35].

LEGAL FRAMEWORKS TO MITIGATE OCEAN ACIDIFICATION

With several instruments at the international, regional, and national levels, as well as balancing the interests of various sectors, the current legal framework for the protection of the ocean and its resources is complicated. Ocean acidification and climate change are not immediately addressed by any regional or international instrument.

United Nations Framework Convention on Climate Change (UNFCCC) and The Paris Agreement

The Paris Agreement has been hailed as a major diplomatic achievement that has the potential to spur significant international climate change action. This remains to be seen, though, particularly given that party pledges to decrease emissions are still egregiously below what is required to prevent some of the most devastating effects of climate change [36]. Despite this, the Paris Agreement and the larger climate regime, which includes the UNFCCC [37] and its related legal and policy instruments, such as the Kyoto Protocol [38] and the Paris Agreement, continue to be the main ways that the international community is trying to stabilise atmospheric concentrations of carbon dioxide (CO₂) and other greenhouse gases in response to climate change. This is why the UNFCCC and the Paris Agreement are seen as important legal and regulatory tools for combating ocean acidification, as changing ocean chemistry is brought on by human CO₂ emissions globally, and only their decrease can prevent further change.

In a statement made in 2005 on behalf of the European Community by the United Kingdom, ocean acidification was first mentioned within the auspices of the UNFCCC. This submission mentioned the “potential, considerable impact of ocean acidification on marine biota”. The Subsidiary Body for Scientific and Technological Advice (SBSTA) received this contribution. By providing information on science and technology relevant to the Convention and Kyoto Protocol, SBSTA acts as a bridge between the scientific community and the Parties. Ocean acidification was highlighted at an SBSTA workshop on climate-related risks and extreme events in 2007, and the SBSTA has continued to bring up the subject in subsequent conversations [39]. Since then, study in this field has accelerated, raising awareness of the ramifications for marine animals as well as the ecosystems to which they belong, the biogeochemical processes to which they participate, and the socioeconomic systems they underpin. In the scientific community, ocean acidification is now universally accepted as a serious problem.

However, different interpretations of Article 2 of the Convention, which outlines the UNFCCC's main goal and provides guidance for its operationalization and that of any implementing agreements (including the Kyoto Protocol and any agreement intended to replace it), are at the core of differing opinions about the applicability of the UNFCCC mandate regarding ocean acidification. Article 2 establishes that the essential goal of the Convention is to “*prevent dangerous anthropogenic interference with the climate system*” via the “*stabilization of greenhouse gas concentrations in the atmosphere* [40]”. One of the Advisory Council on Global Change asserted that the UNFCCC's mission “does undoubtedly imply an obligation to take into account the repercussions of climate change upon the oceans”, which is thought to include ocean acidification, in one of the earliest discussions of this subject in 2006. And this argument was largely based upon the Convention's definition of the climate system as the “totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions [41].”

There is no disagreement around the idea that ocean acidification poses a risk to the climate system. Due to the interplay between the atmosphere and the ocean, which constitutes a segment of the hydrosphere, carbon dioxide emissions discharged into the atmosphere are subsequently conveyed to the ocean. These emissions affect not only the ocean but also marine life and plants, which are both components of the biosphere. Through feedback mechanisms, these emissions also cause changes to biogeochemical processes, which have the potential to influence the composition of the atmosphere. Therefore, in terms of anthropogenic interaction with the climate system, ocean acidification unquestionably falls within the purview of the Convention [42].

Furthermore, the Convention's focus on preserving the climate system, as opposed to solely the atmosphere, partly acknowledged the growing scientific understanding at that time. This understanding was shedding light on the role of the ocean in governing the worldwide carbon cycle and its influence on both the planet's climate patterns and the levels of atmospheric carbon dioxide [43]. It is now generally acknowledged that the ocean plays a significant role in determining the global climate and that, over time scales of millennia, the ocean controls the atmospheric CO₂ concentration. It may therefore be argued that safeguarding the climate system necessitates safeguarding the ocean and the part it plays in regulating the temperature, a part that is disturbed by the rise in ocean acidification [44].

Article 2 also presents three benchmarks for establishing a timeline for achieving the stabilization of greenhouse gases. Additionally, it offers a plan for ensuring the protection of the climate system via stabilization. According to the Article, Parties must take action quickly enough to "allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner [45]". The definition of climate change within the Convention, which focuses solely on a "change in climate," does not readily encompass the concept of ocean acidification. Consequently, even though ocean acidification presents a significant threat to ecosystems, it is challenging to fit it into the first of the three criteria mentioned. However, this does not mean that when determining deadlines for emission reductions to safeguard food supply and economic development, ocean acidification cannot be taken into account. Two systems are under danger because of rising ocean acidity. So, when evaluating stabilising time-lines and trajectories, ocean acidification provides a crucial metric.

The intention behind the Convention's creation is suggested by the aim to safeguard the climate system as opposed to the atmosphere. The Convention views the ocean and atmosphere as integral components of a single, feedback-driven climate system. Inferring that when dealing with the other, the treatment of and effects on the first should be taken into account. Since it is difficult to preserve the climate system without taking ocean acidification into account, as was previously mentioned, it is reasonable to infer that, had the issue been known at the time the Convention was written, it would have been taken into account [46]. The Convention also asks for the preservation of marine, coastal, and ocean ecosystems since they are crucial carbon dioxide sinks and reservoirs. This call for protection could be interpreted as obliging the Parties to safeguard the ocean against ocean acidification as well as marine and coastal ecosystems. Ocean acidification poses a threat to the ability of mangroves, salt marshes, and seagrass meadows to act as sinks and reservoirs for carbon, which is estimated to be considerable. Although it is unknown how well these systems will be able to store carbon, it is anticipated that ocean acidification may cause changes to the systems in the future [47].

It is also known that the ocean itself serves as a crucial carbon dioxide storage facility, containing more than 50 times as much dissolved inorganic carbon as the atmosphere does. However, biological and physiological processes, such as photosynthesis and calcification, are changed as ocean acidification advances. Modifications to these processes are probably going to have indirect effects on the climate system and reduce the ocean's capacity to absorb carbon dioxide. As a result, the near-surface ocean's ability to absorb carbon dioxide is currently just 70% of what it was in pre-industrial times and is predicted to drop to 20% by the end of the 21st century [48].

Ocean acidification should not be excluded from the Convention because it was not recognized when it was written. This text was written to develop a dynamic tool that could recognise scientific advancement and react accordingly. This goal is indicated by the Convention's emphasis on sustainable management and conservation. In fact, the Convention mandates that States reassess "the duties of the Party and the institutional arrangements under the Convention" in light of recent scientific advancements. Although the UNFCCC has been sluggish in addressing ocean acidification as a primary concern when setting goals and deadlines for carbon dioxide emission reduction, it should not evade this matter based on perceived restrictions within its mandate's structure.

In the Paris Agreement, parties to the Convention committed to undertake measures to keep the temperature increase to 1.5°C above pre-industrial levels and to hold the increase in the global average temperature to well below 2°C above pre-industrial levels [49]. Parties also committed to "undertake fast reductions" in greenhouse gas emissions in order to "establish a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" in order to accomplish this long-term objective [50].

These objectives effectively establish the foundation for strong and proactive worldwide measures to reduce carbon dioxide emissions. However, there is also the possibility of pursuing less ambitious actions, such as surpassing a 1.5°C increase in global temperatures and attaining a state of net zero emissions by the close of the century. This agreement also makes reference to the employment of (as of yet untested) technologies that would substantially reduce atmospheric carbon dioxide levels later in the century. In the short term, large emissions might persist, and in the long run, atmospheric CO₂ concentrations could drop quickly [51].

While such actions would enable the conditions of this agreement to be fulfilled, ocean acidification would still deteriorate in some sections of the ocean, notably the deep ocean. As a result, "a considerable legacy of anthropogenic CO₂ emissions" will be left for a very long time, creating circumstances that are extremely likely to have an influence on many marine species, ecosystems, and the services they provide. Given these factors, it is difficult to assert that the Paris Agreement possesses sufficient strength to avert unacceptable levels of risk associated with ocean acidification. The motivation to execute the agreement in its strictest version would unquestionably be increased if the effects of ocean acidification were taken into account [52].

The United Nations Convention on Law of The Seas

The main international treaty governing all ocean-related activity is UNCLOS. Part XII of the UNFCCC, which was negotiated in the 1970s and ratified in 1982, was the first comprehensive international instrument for the preservation and protection of the maritime environment. At the time, typical pollution sources like maritime discharges and land-based waste posed the biggest danger to the seas. Ocean acidification is not included in Part XII because it was negotiated before it was clear how climate change would affect the marine ecosystem. As a result, climate change was not one of the risks to the marine environment. It is an open question, however, if, despite this, Part XII still provides a legal foundation upon which ocean acidification can be addressed [53].

Article 1(1)(4) of UNCLOS defines "pollution" as "the introduction by man, directly or indirectly, of substances or energy into the marine environment, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health". Carbon dioxide may fall under this definition. Ocean acidification is a direct result of atmospheric carbon dioxide being absorbed by the ocean, making carbon dioxide a chemical or energy that is either directly or indirectly brought into the marine ecosystem by human activity. More significantly, there is strong scientific proof that the oceans' excessive uptake of atmospheric carbon dioxide caused by human activity has a deleterious impact on marine resources and other marine species [54].

As a result, Article 194(1) mandates that States take all necessary steps, individually or collectively, to stop, mitigate, and manage contamination of the maritime environment from all sources. Such actions must be in accordance with UNCLOS.

Additionally, the phrase "to ensure" imposes a duty of vigilance, as stated by the International Tribunal for the Law of the Sea. For instance, Article 194(2) requires States to take all necessary steps to ensure that activities under their authority or control are carried out in a way that does not harm other States and their environments via pollution. The term "due diligence" refers to the responsibility to enact the necessary laws and regulations, to be vigilant in seeing that they are upheld, and to keep an eye on both private and public operators' operations. Also, there is a responsibility to "deploy appropriate means, to exert best feasible efforts, to accomplish the utmost, to attain..." the desired outcome. The topic of whether states have a duty to use due diligence in preventing excessive emissions of carbon dioxide into the atmosphere from activities under their control is an intriguing one. This likely includes land-based operations and private parties [55]. Boyle argues that States have a duty of care under Article 194 to regulate and manage activities like oil and coal-burning power plants that release carbon dioxide, coal mining, and perhaps deforestation [56].

Further study is certainly required because the scientific data on the effects of ocean acidification are still relatively recent. The obligation to protect rare or fragile ecosystems, the habitat of depleted, threatened, or endangered species, as well as other forms of marine life, is outlined in Article 194(5) of the UNCLOS, which is based on the evidence that fragile ecosystems and habitats like coral reefs are directly impacted. Moreover, without mentioning pollution, Article 192 clearly requires States to safeguard and conserve the maritime environment. The Tribunal offered a thorough interpretation of Article 192 in the recent *South China Sea Arbitral Decision* [57].

Hence, it is logical to deduce that nations are duty-bound under UNCLOS to implement requisite legislations, regulations, and strategies aimed at curbing, mitigating, and managing carbon dioxide emissions from all origins that contribute to ocean acidification. This responsibility emerges from the scientific substantiation of the detrimental effects on the marine environment, particularly vulnerable ecosystems and habitats.

CONCLUSION

Even though the nature and rapid pace of the acidification process are widely acknowledged and anticipated, the precise ramifications of this process remain uncertain. It is generally known that ocean acidification poses serious threats to population dynamics, physiology, and behaviour of organisms ranging from phytoplankton to marine mammals. Increasing acidity prevents shell-forming invertebrates from calcifying, and therefore has the potential to damage marine biota and obstruct oceanic ecological and biogeochemical processes.

The projections indicate the potential for severe consequences on coral reefs and marine organisms with shells, including molluscs and echinoderms. This encompasses krill, a crustacean pivotal in the Antarctic food chain, connecting phytoplankton to higher trophic levels like fish. Additionally, there is the likelihood of an increase in detrimental algal blooms. The specific nature and scope of consequences on marine creatures, however, depend on their physiological capacity to adjust to changing environmental conditions. Furthermore, discerning the distinct biological outcomes of ocean acidification from the concurrent impacts stemming from ocean warming, reduced oxygen levels, and, in polar regions, the decline of sea ice, presents a formidable challenge.

The forecasts suggest that there could be significant adverse outcomes for coral reefs and marine life possessing shells, which includes molluscs and echinoderms. This incorporates krill, a crucial crustacean in the Antarctic food chain that bridges phytoplankton and higher trophic levels such as fish. Furthermore, there's a possibility of heightened occurrences of harmful algal blooms. This can happen

by adopting a mechanism or collective programme that treats forests similarly to how REDD and REDD+ do, or, as some have suggested, by adopting a whole new instrument. The latter option, a new instrument presents a number of challenges, including the possibility that there may not be much political appetite for a new accord given that the Paris Agreement was just completed and the Kyoto Protocol changes have not yet been implemented.

As the comprehensive treaty overseeing global oceans, UNCLOS seems to provide a robust legal structure suitable for dealing with ocean acidification as an outcome of human-induced pollution. It is commonly known that the Parties have a duty to avoid, minimise, and regulate pollution from all sources, including land-based activities. Several verdicts delivered by the International Court of Justice, the International Tribunal for the Law of the Sea, and arbitration panels have refined this obligation, including the importance of exercising due diligence. Nevertheless, UNCLOS alone does not furnish the structure for enacting the united efforts needed to significantly curtail carbon dioxide emissions, which the UNFCCC system accomplishes through decisions made by its Parties. Instead, UNCLOS lays the foundation for individual actions by states. It stands as the sole legal framework that seems better suited for the collaborative endeavours essential to alleviate carbon dioxide emissions leading to ocean acidification.

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