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Ocean Fever: Assessing the Impact of Marine Heatwaves on Ocean Environments and Potential Solutions for Ecosystem Restoration

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A B S T R A C T

The long-lasting predicament of climate change has given rise to several issues and concerns that have threatened almost every component of the natural environment. Over the years, it has developed from affecting only those on land to those underwater, extending its threat to the marine ecosystems. As a fundamental resource of energy, the marine environment is under imminent danger due to global warming that has led to the increased frequency of extreme climatic events characterized by abnormally high temperatures in oceans: marine heat waves or MHWs. Recent assessments have shown that over the past century, global ocean temperatures have been undergoing a steady rise, with the intensity and frequency of MHWs increasing on both regional and global scales. Hence, this study aims to further investigate the effects of MHWs particularly on the marine environment, including the ecological disturbances they may have given rise to in different underwater ecosystems, in an effort to provide long-term and effective solutions to mitigate and control the effects of MHWs on both marine life and mankind. In particular, a synthesis of methods and different international laws that should be given more emphasis to successfully curb MHWs was provided along with governmental initiatives for sustainable development. From the stated literature, potential approaches for proactive marine management were concluded to be beneficial in countering this adverse effect of climate change for the primary benefit of the oceans and marine wildlife. Recommendations for the integration of different solutions and improving human adaptation were suggested for future research.

Keywords: Climate change, marine ecosystems, marine environment, marine heatwaves, environmental laws

1. INTRODUCTION

Dominating the 18th to 19th century, the industrial revolution ushered in a groundbreaking transition in the advancement of mankind. Activities entailing the shift to an agrarian to a manufacturing economy, the development of various motor-powered engines, and the growth of machine-based innovations provided higher levels of employment and wages that contributed to newfound economic prosperity among individuals and nations (Chen, 2021). However, notwithstanding the significant impact it incurred on the global population, the increase in the number of activities during this period that demanded high levels of energy consumption and natural resources depletion resulted in adverse effects that soon led to the unprecedented depletion of the ozone layer, ultimately giving rise to the currently rising predicament today of global warming and climate change (Patnaik, 2018). Defined as the global rise in temperatures due to increased concentrations of greenhouse gases (GHGs) in the atmosphere, global warming is one of the several manifestations of climate change, or the long-term measures of atmospheric changes and patterns, in the 21st Century (US Geological Survey, 2019). The variety of extreme weather conditions that both of these have generated has caused widespread and severe changes to the biosphere, lithosphere, hydrosphere, and atmosphere, with documented phenomena such as glacial retreats, sea level rise, increased rainfall, and record-high temperature events (Callery, 2021) exemplifying the scientific evidence of the immense gravity brought about by this man-made environmental problem. Among the most critically affected areas of the global temperature rise have been the oceans, with data from the US National Oceanic and Atmospheric Administration (NOAA) showing that over the past century, average sea temperatures have increased by approximately 0.13°C per decade. Due to this notable alteration in ocean heat content, anomalies in the oceanic climate have resulted in a number of devastating consequences on the foundations of several marine ecosystems and aquatic life - one such anomaly being the growing frequency of marine heat waves (MHWs). Ever since they were first recorded in 1925, marine heatwaves have attracted considerable scientific and public attention because of their rapidly increasing durations and intensities across the global ocean (Oliver et al., 2019). Considered as extreme climatic events, MHWs are prolonged periods of extremely warm ocean temperatures that are mainly caused by the human-induced increase of GHG emissions in the atmosphere. Since then, MHW frequency has doubled and is still projected to rise under continued global warming (Frolicher et al., 2018). What makes MHWs a concern are their life-threatening impacts and implications in the changes of ecosystem structure in underwater environments. The ocean warming they bring causes deoxygenation, or the reduction of dissolved oxygen in the ocean, which further results in unfavorable circumstances such as the sustained loss of kelp forests, coral bleaching, and damage to aquatic breeding grounds. Aside from environmental effects, the phenomenon of MHWs also incurs substantial repercussions on the socio-economic sector, as the affected vegetation for breeding grounds also becomes a gateway for less fish stock and seafood supply, potentially affecting the fisheries market at an unprecedented rate (Pecl et al., 2017). Because of the apparent severity of this environmental problem, different ways of reducing the anthropogenic activities that cause it have been put into action by scientific and governmental institutions and agencies around the world. Federal policies such as those operating under national and sub-national governments have been formulated in an effort to protect coastal communities and effectively build regional ocean resilience, most especially in developing nations that are highly vulnerable to the impact of MHWs (IUCN, 2021). Legislations and treaties such as the Clean Air Act and the Paris Agreement, which were put forth to regulate and reduce overall GHG emissions, have also been given much emphasis since MHWs were declared a widespread issue. As reducing fossil fuels becomes the collective goal, it is essential to adopt nature-based solutions alongside closely monitoring the trends of ocean warming to more proactively prepare for its potential effects. Hence, this paper aims to provide a comprehensive analysis of MHWs as a growing environmental problem for marine ecosystems and human communities alike. By examining the trends of MHWs with respect to their duration, intensity, and environmental impact over the years, methods for controlling their effects will come to light and potentially be adopted to mitigate this consequential issue. In the following sections, in-depth characterizations of the marine environment including the ecosystems and species within it will be provided to impart more knowledge of the natural resources that are threatened due to MHWs. By doing so, mankind's capabilities of understanding and detecting future MHWs may be made possible. Furthermore, this paper also aims to be an instrument for sustainable development by investigating international and national regulations, alongside syntheses of already existing laws and emerging technologies, to suggest potential solutions that can immediately minimize or prevent activities that are positively correlated with the incidence of heatwaves. Through this, the possibility of putting an end to this ocean fever may finally be given the proper consideration it deserves, for the benefit of not only the environment, but the entire human race.

2. DISCUSSION:

First and foremost, this review is divided into five (5) main sections, which include: The Essence of the Marine Environment, Characteristics and Types of Marine Ecosystems, Climate Change's Growing Significance in the Marine Environment, Marine Heat Waves: Background and History, Environmental Laws and Methods for Sustainability, and The Role of Environmental Laws, Regulations, and Governmental Awareness in Marine Ecosystem Restoration. Thus, this review will include background information on the topic, the study's concept, and additional information for mitigating its effects in an effort to further illustrate and give precedence to the environmental impacts of marine heat waves.

2.1 The Essence of the Marine Environment

According to Soas (2020), the word "environment" is often used for a wide range of connotations. It may simply mean "nature," which encompasses all of its non-human traits, qualities, and processes. While many consider the environment as the natural world consisting of the wilderness and unspoilt landscapes untouched by human activity, others define the environment as an umbrella term that includes human components, such as building inhabitants. Meanwhile, some view all of the Earth's surface, including cities, to be part of the environment, while a few include primarily rural and agricultural areas.

Among all the components of the environment such as the air, landforms, and seas, however, it's the marine environment that encompasses the majority of the Earth, with over 71% of the planet's surface covered with vast ocean bodies (UN Environment Programme, 2016). From deep-sea ocean zones to coastal marine ecosystems, the marine environment is composed of a variety of living and nonliving components that are defined by both biological and physical characteristics. As the primary habitat from which crustaceans originated, the marine sphere continues to sustain the greatest proportion of crustacean species and contain more higher-level biodiversity amongst phyla, classes, orders, families, and genera than other habitats, most likely due to the fact that life originated in the oceans (Reaka-Kudla, 2016). According to Mora et al. (2011), out of the estimated 8.7 million species on Earth, over 2.2 million live in marine environments. Even then, taxonomic inventories of these species remain incomplete to this day, leaving so many species still unknown in its great expanse (UNESCO, 2021). Aside from high levels of dissolved salt, habitats in the marine environment are defined by several other abiotic factors including the amount of oxygen, sunlight, and nutrients found in the water, as well as the area's proximity to land, depth, and temperature. The amount of sunlight ecosystems receives, for one, has divided the marine environment into three main parts: the euphotic or sunlit zone, which is the topmost part of a marine ecosystem that extends as far as 200 meters below the surface and allows photosynthesis to take place; the dysphotic or twilight zone, which only allows minimal light penetration as it extends from 200 to 1000 meters below surface level and where most bioluminescent life forms thrive; and finally, the aphotic or midnight zone, where light is essentially non-existent, water pressure is at its maximum, and temperature is close to freezing. This is also the zone where 90% of ocean life is said to exist, albeit either still unclassified or unknown (National Geographic, 2021).

As a component of nature, the marine environment offers a vital resource for life on Earth. The different types of marine ecosystems, which are further elaborated below, carry out key functions that include regulating the climate, preventing erosion, accumulating and distributing solar energy, absorbing carbon dioxide, and maintaining biological control. As the habitat of most of the life on Earth, known or unknown, the oceans are a grand treasure trove of genetic information that may be the key in unlocking the mysteries of the origin of life.

2.2 Characteristics and Types of Marine Ecosystems

Gassle (2013) defines marine ecosystems as the major units of ecological function and pathways in the marine environment. As communities of organisms, the structure of marine ecosystems largely depends on the physical, chemical, and geological environment including the distinct assemblages of species that have coevolved over long periods of evolutionary history. Furthermore, they are characterized by several factors including the availability of light as previously mentioned, as well as food, the amount of nutrients, water temperature, depth. salinity, and local topography. All these make up the conditions of each type of marine ecosystem as well as the species of pelagic (algae, bacteria, protozoans, fish) or benthic (crabs, shellfish, seagrass) living in them. The types of marine ecosystems can generally be split into two categories: coastal and open ocean habitats. According to Neal (2019), although only a small percentage (7%) of the ocean's total area is considered coastal habitat, the majority of marine life is located in coastal waters, mainly because they have more sunlight and nutrients available than the open ocean. Among the most common types include estuaries, salt marshes, mangrove forests, coral reefs, the open ocean, and the deep-sea ocean.

Estuaries comprise the coastal zones where oceans meet rivers, allowing the mix of nutrients and salts sourced from different areas. As wetlands with brackish water, estuaries are among the most productive places on Earth for human activities such as fishing and transportation that support an abundance of life-forms. Salt marshes, on the other hand, are the nutrient- and sediment-rich areas where ocean meets land. As they are regularly flooded by high tides, marsh grounds are usually wet, salty, low in oxygen, and filled with decomposing matter. Meanwhile, mangrove forests, which are found in tropical areas, are frequently submerged and flooded with ocean water. The mangroves' root systems are able to filter out salt while being able to stay above the surface to access oxygen. Hence, mangrove ecosystems provide a home for a variety of species, both terrestrial and aquatic. Farther into the marine environment are the coral reef ecosystems located in the bright euphotic zone which are formed by the exoskeletons secreted by coral polyps. Considered the most biologically rich ecosystems on earth, coral reef ecosystems house over 4000 species of fish and 800 species of reef-building coral systems (UN Atlas of the Oceans, 2016), which account for a quarter of the world's entire ocean species.

Contrary to all other ecosystems, the open ocean and the deep ocean ecosystems both vary widely as the ocean's depth changes as well. The open ocean, which mostly consists of all the organisms and their interactions in the euphotic zone, is fairly warm and bright with plenty of oxygen, which is where organisms such as whales, sharks, and dolphins live. Farther away from the land, however, is the deep ocean with darker, colder, and lower-oxygen environments - essentially, the dysphotic and aphotic ocean zones. While some of these organisms have developed unusual adaptations such as large mouths to catch whatever nutrients fall from shallower depths, others utilize different ways to acquire energy such as chemosynthesizing chemicals from deep ocean vents (National Geographic Society, 2020).

As essential as each one of these ecosystems may be, all of them unfortunately still face the same threat that all other parts of the environment do: human-induced climate change. Hence, tackling these ecosystems' environmental components while addressing the climate change problem would make solutions more effective and beneficial to the marine ecosystem. The following section shall discuss the consequences climate change has posed on the environment and why it is a plight that needs to be faced.

2.3 Climate Change's Growing Significance in the Marine Environment

Understanding climate change caused by humans is critical in the twenty-first century since mankind's combined actions of depleting natural resources have contributed to more evident manifestations of global warming and environmental degradation over the years (Clayton and Brook, 2005). Communities are being displaced as a result of current or future instances of climate change, which forces relocations that may result in mental distress and social disruption. As a result of this ecological calamity, the viability of human society's interaction with nature is jeopardized (Becker et al., 1999). In the late 1960s, the physical environment of human behavior was recognized as critical, as its effects on the oceans began to show during the periods between 1800 and 1994 (Sabine et al. 2004). Climate change, air pollution, noise pollution, and biodiversity loss are all the result of human activity (Vlek and Steg, 2007). As a result, topics such as sustainability and environmental preservation have received more attention in recent years, wherein ways in which environmental concerns and behavior influence these activities are linked to humans' emotional affinity for nature. The impact of climate change on coastal ecosystems have been critical to the planet's survival. Recent studies by Laffoley & Baxter (2016) indicate that rapidly rising greenhouse gas concentrations are pushing ocean systems into conditions that have not been seen in millions of years, raising the threat of irreversible ecological disruption. As temperature changes occur at a greater scale, the metabolism of organisms is heavily influenced while ecological processes such as species interactions are altered. Furthermore, while species begin to adapt to specific ranges of environmental temperatures, geographic distributions of species may also possibly expand or contract, hence giving rise to new species combinations that may interact in unpredictable ways through migration or competition (Center for Climate and Energy Solutions, 2019).

Moreover, anthropogenic climate change has reduced ocean productivity, altered food web dynamics, decreased the quantity of habitat-forming species,

relocated species ranges and raised disease incidence. According to a research by Brierley & Kingsford (2009), climate change is forcing ocean systems into uncharted territory, putting them at danger of ecological catastrophe. Although the full geographical and chronological details are uncertain, there is no doubt that it is altering ocean ecosystems. Globally, and especially in emerging countries, change will continue to create huge issues and costs. As the oceans span approximately 70% of the Earth's surface, their importance to the global ecosystem is obvious. Along with having a significant influence on international heat transmission and precipitation, the seas support a vast spectrum of marine animal species. Humans profit from a wide variety of items and services that they supply, such as food, leisure opportunities, and transportation routes. Hence, current scientific evidence that demonstrates how human-caused greenhouse gas emissions will result in significant global climate change throughout the twenty-first century and into the foreseeable future are important in preserving and conserving existing marine environmental structures. As climate change will most likely exacerbate issues already faced by coastal and marine ecosystems due to human development, land-use change, environmental degradation, and overfishing, among other causes, studying its aspects from different viewpoints is relevant in working towards a sustainable future in the 21st century.

2.4. Marine Heat Waves: Background and History

Ten years ago, a vast swathe of unusually warm water ravaged kelp forests and commercially important marine creatures in the seas of Western Australia, leaving hundreds of dead fish, mussels, and clams washed ashore dead and looking as if they were boiled. This crisis that was labelled as something that looked like a “post-apocalyptic event” (Einhorn, 2021) was, in fact, the world’s first drastically alarming situation of the environmental phenomenon now known as marine heatwaves, which are warm spells in ocean surface waters that last at least five days while reaching a temperature threshold well above the normal range (Viglione, 2021). Caused by a wide range of factors including demonstrations of climate change such as ocean current anomalies and air-sea heat flux, marine heat waves are defined by a set of properties including duration (time from start to end date), intensity (maximum or average temperature anomaly in °C), cumulative intensity (integral of intensity over the event’s duration), annual frequency (count of marine heatwave events in a particular year), and the annual marine heatwave days (days in a year wherein a marine heatwave took place) (Hobday, 2016). For the past ten years, the average temperature of the oceans has increased by 1.5°C with a record-high from the past 10 years. In addition to this, marine heatwaves are expected to become more intense and frequent due to anthropogenic climate change. These rare events have altered species ranges, resulted in local extinctions, and had a negative economic impact on the seafood sector owing to declines in critical fishing species and aquaculture (Valentine, 2019). Although extreme temperatures are increasingly acknowledged as having a significant effect on biological systems, a full characterization is required to synthesize and mechanistically appreciate the role of MHWs in marine ecosystems. Studies have characterized MHWs based on a hierarchy of metrics that enables the identification of MHWs using a variety of data sets (Oliver, n.d.).

Figure 7 shows the Sea Surface Temperatures (SST) anomaly during one of three maritime heatwaves addressed based on the study conducted by Oliver et al (2019). The places recorded are Northwest Atlantic in 2012, Northern Mediterranean in 2003, Western Australia in 2011. The graphs demonstrate the prolonged discontinuous abnormally warm water events in these areas that may be classified according to its length, severity, pace of progression, and geographic extent.

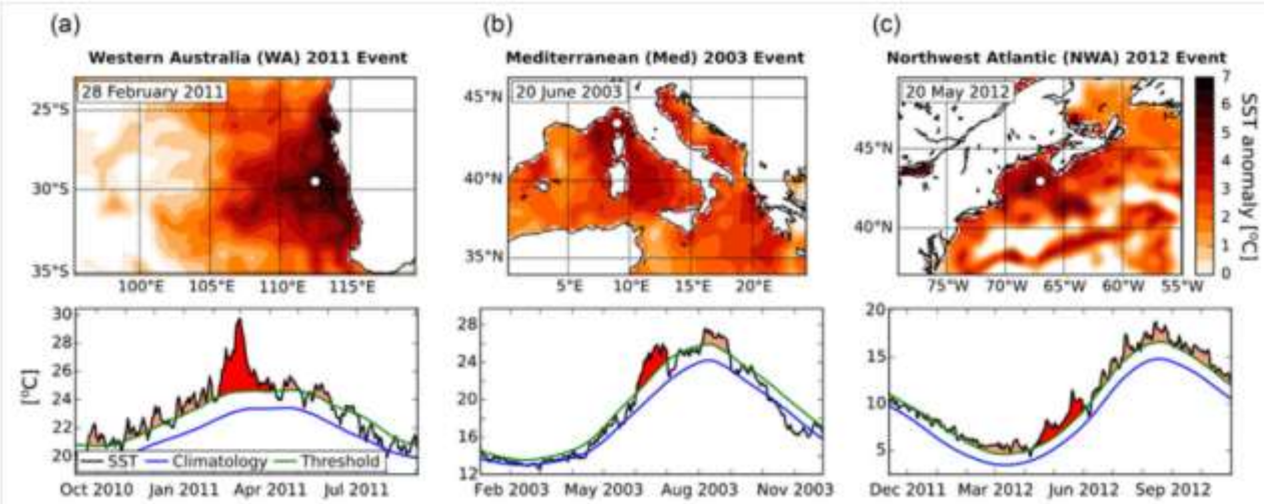

Figure 7. Note image from “Marine Heatwaves” by Eric Oliver entitled “Marine heatwave definition demonstrated for three recent events.”

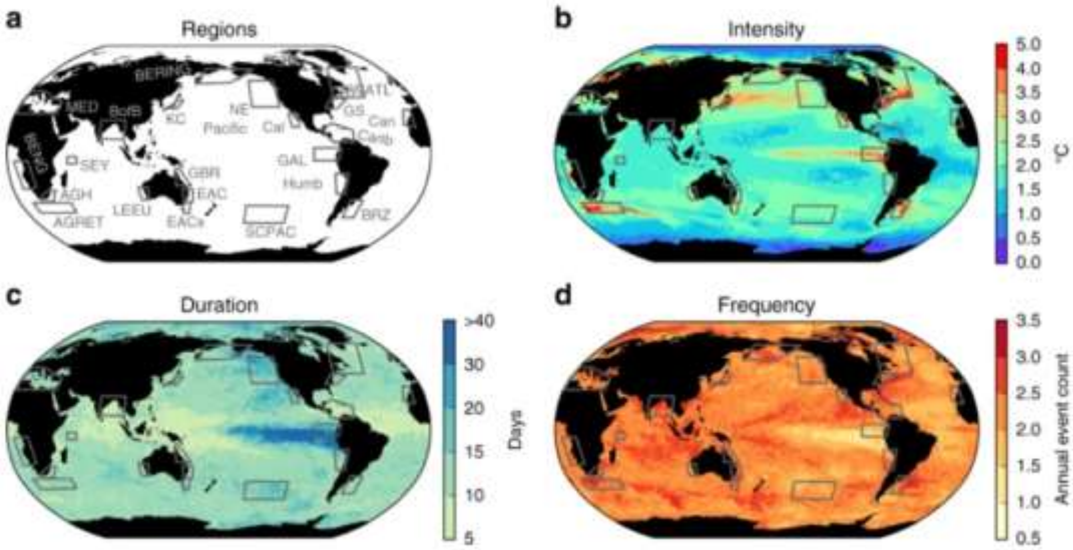

Figure 8. Note from “A global assessment of marine heatwaves and their drivers.” Entitled, “Global MHW characteristics and case-study regions. 34-year (1982–2015) average properties of MHWs based on application of the MHW definition6 to daily sea surface temperatures from the NOAA OI SST V2 dataset across the globe.”

To determine the critical local processes, large-scale climate modes, and teleconnections associated with MHWs regionally, Holbrook et al. (2019) combined a confidence assessment of the historical refereed literature from 1950 to February 2016 with an analysis of MHWs determined from daily satellite sea surface temperatures from 1982–2016. An image is attached above in Figure 8 to visualize the average properties of MHWs. It was concluded that increased or decreased MHW occurrences correspond with main climate modes throughout the majority of the globe, with the exception of western boundary current zones, where MHW events are uncommon and ocean-climate interactions are complex.

Marine heatwaves (MHWs) have the potential to destroy marine life as warmer climates increase the likelihood of marine ecosystems experiencing vulnerability-causing extremes that reduce their tolerance to local temperature rise. The mass mortality of invertebrates has since been exacerbated with the increased risk of deoxygenation and acidification brought upon by MHW occurrences. By encouraging the existence of certain species yet suppressing others, MHWs affect ecosystem structures to a point past their threshold of recovery. In 2011, a marine heatwave shifted ecosystems away from kelp and toward other seaweeds in Western Australia. While lobster numbers surged during a marine heatwave in the Gulf of Maine in 2012, prices plunged, significantly impacting the industry's revenues. Between 2014 and 2016, warm water in the north Pacific prompted fishery closures, massive strandings of marine creatures, and dangerous algae blooms around beaches. It also has an unquestionably detrimental effect on fisheries, aquaculture, and ecotourism. In 2016, a record-breaking marine heatwave in Tasmania resulted in disease outbreaks and hampered growth rates across aquaculture enterprises, exemplifying the profound socio-economic impacts they have, especially on local communities (IUCN, 2016).

Therefore, marine heat waves have a strong link between rising worldwide average sea-surface temperatures and rising marine heatwaves, just as what has been observed with rising global average temperature. As more heat from global warming enters our seas, it seems probable that marine heatwaves will continue to rise. Thus, formulating ways to effectively reduce and control MHWs along with their damaging stressors is now vital for the sake of the living world.

2.5 Environmental Laws and Methods for Sustainability

Over the years since agencies such as the United Nations have been established, environmental laws have grown to be both well-established with a lengthy past and a bright future ahead. These laws refer to policies, regulations, programs, and court decisions limiting or eliminating human and ecological issues (Environmental Protection Agency, n.d.). Despite the onset of global climate change, environmental limitations established between 1969 and 1980 remain necessary, since their core objectives have been only partly achieved (Biber, 2008). This collection of instructive research includes novel approaches for implementing climate change mitigation and adaptation into the administration of these critical legislative institutions. Two of the most notable international conferences in IEL's history are the Stockholm Conference (1972) and the Rio de Janeiro Earth Summit (1992). The current climate disaster, humanity's most severe environmental problem, enters a new chapter with the signing of the Paris Agreement in 2016 (Greene, 2020). Maintaining the increase in the global average temperature to below 2°C above pre-industrial levels will aid in preventing the irreversible impacts of growing temperatures on ocean ecosystems. Focusing on the marine ecosystems as the rising concern for the state of the maritime environment was one of the most significant developments in the field of international law during the twentieth century. A new, more scientific knowledge of the oceans' environmental and ecological health has supplanted outmoded ideas that the seas were bottomless dumping grounds with boundless absorption capacity and an infinite willingness to sacrifice their resources.

The United Nations is actively promoting the marine environmental regulating process. Adopted in 1982, the United Nations Convention on the Law of the Sea established countries' rights and obligations to protect the marine environment and take efforts to avoid, reduce, and control ocean pollution. In 1992, "Agenda 21" was formed to encourage marine conservation, as well as the responsible use and exploitation of marine resources. In 2016, the United Nations General Assembly approved "The 2030 Agenda for Sustainable Development," which specialized in establishing sustainable development objectives in the marine sector and identifying strategies for the marine industry to flourish in a sustainable manner (Kirchner, 2003).

Aside from the implementation of environmental laws, investing in research that further expands knowledge on MHWs and ways to mitigate them is also a necessary component of building and re-building ocean resilience to warming. In order to do this, agencies and programs aimed at mitigating MHWs must be able to establish a temperature baseline of monitoring that considers the limits of species and combines physical and biological data to implement better forecast systems for predicting future MHWs. Furthermore, to ensure ecosystem restoration, artificial structures such as rock pools can be built in place of MHW-damaged coral reefs to boost the adaptive resilience of species in warmer temperatures.

2.6 The Role of Environmental Laws, Regulations, and Governmental Awareness in Sustainable Development

Rather than living at the cost of nature, as mankind has done for millennia, sustainable development allows humanity to exist in harmony with nature. Despite several environmental and natural resource regulations, sustainability lacks a solid legal foundation. To attain a sustainable society, developing and applying new laws and legal frameworks will be necessary. Considerations for reducing or removing harm include identifying and describing possible hazards, finding the situations or levels of exposure where damage is most likely to occur, and evaluating how the risk of damage varies with exposure levels or conditions. Almost all of these challenges can be addressed with an adequate amount of information in the field of science.

At this period, the importance of science and research cannot be underestimated. Although studies might not perfectly predict what will happen if we do nothing, they can anticipate what will happen if we do something. A policy decision based on an end goal is useless without proof that it will achieve that ultimate goal. Government leaders and scientists view situations from quite diverse angles due to their respective disciplines. However, to make sound decisions for the environment, it is essential to remember that the natural world is dynamic and interconnected. One’s understanding of the natural world has grown in lockstep with ecology, with human activity having an impact on the natural environment. The extent of the effect, its duration, and the ability of the natural world to rebound are all issues that need exploration.

According to Bosselmann (2010), ecological sustainability is a priority among the pillars of sustainable development. He mentions that mankind's ecological footprint is growing in both absolute terms and relative to the number of people in the world. Therefore, it is essential now, more than ever, to create or adjust current regulations that cater to the current conditions of climate change. The durability of environmental laws and nature-based solutions can assist vulnerable populations and ecosystems anticipate, cope with, and avoid devastating phenomena such as MHWs. Hopefully, by doing so, any underlying economic choices made by the governmental and non-governmental sector will always take environmental consequences into account in order to attain complete restoration and protection of the global marine environment.

3. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Every action made in the history of mankind has had its fair share of repercussions on succeeding generations. From the dawn of civilization to modernization, the human race has changed through phases defined by different forms of development, all the while with the world changing alongside us. However, amidst mankind's progress, it is becoming much easier to overlook the other components that constitute Earth. While we become better equipped to fight pandemics and diseases each day, the planet suffers from a deadly plague of its own - one that has worsened with human activity, stripped the Earth of its protective layer, and antagonized the world, including all living beings in it: climate change.

The plight of climate change has resulted in alterations and anomalies that disrupt the normal and healthy balance that co-exists in nature. Amongst its many manifestations that include changing weather patterns and more intense natural disasters, global warming occupies the highest podium as the symptom that has devastated ecosystems the most, predominantly the marine environment. Composed of all the marine creatures and their different ecosystems, marine habitats are essential to nature. They carry out vital environmental roles that sustain essential global cycles and processes and provide a crucial resource to global life. Hence, it is a humanitarian goal to protect the priceless possession of the oceans and ensure that it fulfills its critical roles in maintaining ecological balance.

Unfortunately, however, like all other environmental spheres, the hydrosphere, including the marine environment, has been impacted by the adverse effects of global warming and climate change. Marine heatwaves (MHWs), which are severe, acute thermal events where water temperatures reach anomalous extremes, have become a widespread issue across the world's oceans, garnering international attention due to their increasingly alarming impacts on marine life and biodiversity.

The fact that the worsening predicament of MHWs is due to anthropogenic activities is what makes this environmental phenomenon an absolute terror, as it exemplifies just how far daily human activities like fossil fuel consumption and greenhouse gas emissions can go in terms of destroying the environment and affecting vast quantities of species that are defenseless against extreme heat. High levels of mortality, loss of breeding grounds due to coral bleaching, the spread of invasive alien species, and irregular mass movements as affected species search for more favorable conditions are only some of the many impacts marine heatwaves induce on the marine environment and its ecosystems. Biodiversity and habitat losses, accompanied by increased ocean stressors such as acidification, stratification, and deoxygenation, further make the increasing temperatures brought about by MHWs an evident cause for concern not only for people who are marine biologists, scientists, or environmentalists but also for those individuals who greatly depend on marine ecosystems for their livelihood and survival especially in developing countries.

Any individual concerned for their environment or future would inevitably be distraught after knowing that situations like these are happening without most people knowing. As events like these are often hidden from view under the seas, it is critical to develop sustainable and nature-based methods to end the threat that MHWs possess before it becomes too late. Now is the time for real climate action and justice through the effective implementation and empowerment of environmental rules and regulations that have long been formulated in an effort to curb negative environmental phenomena such as MHWs. Agreements and laws such as the Paris Agreement, the Stockholm Conference, the Rio de Janeiro Earth Summit, and the 1992 United Nations Framework Convention on Climate Change (UNFCCC) must be given the utmost importance and attention today to successfully achieve complete control, awareness, and mitigation of MHWs. Moreover, global endeavors to lessen activities that induce global warming, such as generating power through non-renewable means, manufacturing goods by burning fossil fuels, and immorally consuming resources should be something that is contributed by every individual who has the capacity to participate in the call for climate action as the essential course correction for our planet's rehabilitation. However, to further improve these approaches, it is recommended that methods of improving human adaptation by means of monitoring tools and government policies to keep activities such as fisheries production within sustainable limits be introduced to minimize MHW damage. In accordance with this, appropriate mitigation and adaptation strategies should also be one of the main priorities of scientific research to effectively combat ocean warming.

Considering the situation of our planet today through different lenses such as investigating marine heatwaves only reveals one thing: it is essential to first descend in order to ascend. This means that long-term and effective change can only be achieved if we begin with the smallest components of society first - ourselves. Only by ascending from individuals to communities, and eventually to nations and the world where everyone can engage in the crucial milestone of taking the initiative as the last generation who can do something about climate change. And together, it might just be possible not to find, but rather, be the cure to this challenging plague of the ocean fever.

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