Impact of Climate Change on South Asia: Shifting Marine Ecosystems in Pakistan

Syed Haider Ali and Zakir Hussain

Abstract

One of the existential threats facing all species on planet earth is global warming. Its impact has already been felt in many parts of the world, but more severely in coastal areas containing marine ecosystems. The effects of climate change are adversely affecting the marine ecosystems of South Asia, posing considerable threats to biodiversity, fisheries, and the economic systems of the region. There is a significant shift in biodiversity, productivity, and functionality of these marine ecosystems due to increased sea temperatures, ocean acidification, and sea level rise. As a result of climate change, the region has been experiencing ecological changes, which have prompted an analysis of the resulting ecological alterations, including coral reef bleaching, changes to marine species migration patterns, and a decrease in fish populations. As a result of global warming, Pakistan has significant concerns regarding the persistence of marine life, which is crucial to its exports, and is also a significant part of its labour force. To mitigate this threat, several strategies are recommended, which address the government's weak policies and emphasize the support of international organizations. Taking precautions, it is now imperative to combat global warming's negative effects on marine life. This study highlights climate change as an imminent non-traditional threat with significant consequences for South Asia's marine biodiversity and marine life.

Keywords: Biodiversity, livelihood, global warming, climate change, marine life.

Introduction

Climate change is real. It is happening right now; it is the most urgent threat facing our entire species and we need to work collectively together and stop procrastinating it.[1]

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[1] Statement by UN Messenger of Peace for Climate Action Leonardo DiCaprio on his acceptance speech of Best Actor at the 88th Academy Award Oscars, Los Angeles, 28 February 2016.

Humanity has utilized natural resources in various ways throughout history, harnessing natural phenomena like geysers' hot springs in one region and melting snow to generate hydropower in another. However, the increasing global population and advancements in science have led to rising temperatures and shifts in weather patterns worldwide. These changes are collectively referred to as climate change and global warming. Nature has provided warnings through past ice ages, but the current situation represents an enduring and unprecedented shift in weather patterns.

Both developed and developing countries have grown increasingly concerned about these phenomena in recent years, prompting the allocation of funds for research aimed at mitigating their effects. According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures could increase by up to 3°C by the end of the century if significant measures are not taken to curb greenhouse gas emissions.[2] This scenario would have severe consequences for human health, biodiversity, and socioeconomic systems.

To understand global warming and climate change, it is essential to define and explain several key concepts, including greenhouse gases, the greenhouse effect, carbon footprints, climate mitigation, and adaptation. Greenhouse gases, such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), trap heat in the atmosphere, intensifying global warming. They achieve this by absorbing and re-emitting infrared radiation, leading to the greenhouse effect.

In the context of climate change, a carbon footprint is a measurement of the greenhouse gases emitted by an entity, organization, or product. Climate change mitigation involves taking measures to reduce greenhouse gas emissions, while adaptation focuses on countering the effects of climate change.[3] It is already causing adverse effects across the globe, including more frequent droughts in some regions and increased rainfall in others. Additionally, rising sea levels have begun to threaten the lives of people in countries like Sri Lanka, Australia, and Myanmar. In vulnerable areas such as sub-Saharan Africa, South Asia, and small island developing countries, these phenomena could jeopardize decades of

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[2] IPCC, 'Climate Change 2021: The Physical Science Basis' (Cambridge University Press, 2021).

[3] IPCC, 'Climate Change 2014: The Climate Change. Impacts, adaptation and vulnerability' (Cambridge University Press, 2014); Kashif Majeed Salik et.al., 'Climate change vulnerability and adaptation strategies for the coastal communities of Pakistan,' Ocean & Coastal Management, Vol. 114, 2015, pp. 61-73, https://www.sciencedirect.com/science/article/abs/pii/S0964569115001209

progress in poverty reduction and human well-being improvement.[4] South Asia, a region bordered by the Himalayas to the north and the Indian Ocean to the south, is experiencing the ravages of climate change with greater intensity and a wider range of threats compared to many other parts of the world. This region, covering just 3.5 per cent of the world's land area, is home to a staggering one-quarter of the global population, making it the most densely populated part of our planet.

Comprising eight countries — Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka — South Asia is particularly vulnerable to climate change due to its tropical and subtropical location. Many of its residents inhabit regions prone to natural disasters, including floodplains and coastal zones.

The impacts of climate change and global warming in this region are already profound, manifesting as increased summer rainfall in Pakistan, droughts in Bangladesh and India, and a range of other calamities. These effects include rising temperatures, more frequent heatwaves, unpredictable monsoon rainfall patterns, sea-level rise, and an increase in the intensity and frequency of extreme weather events.

Notably, Pakistan's marine ecosystem, encompassing the Arabian Sea and 1,046 kilometers of coastline, faces severe threats from global warming and climate change. These encompass rising temperatures, higher sea levels, ocean acidification, and shifts in ocean currents. These factors have profound implications for marine life and the communities that depend on it.[5] This diverse marine ecosystem, renowned for its biodiversity, includes vital habitats such as mangroves, seagrass meadows, and coral reefs. These areas serve as breeding grounds for various marine organisms and provide essential ecological services to local communities and the environment.[6]

Mangrove forests along the coast are of paramount importance to preserve due to their role in supporting various marine species, including fish, crustaceans, mollusks, turtles, dolphins, and whales. Pakistan's waters are renowned as a hotspot for marine biodiversity. The Indus Delta, situated in the south-eastern part of Pakistan, boasts one of the world's largest and most diverse mangrove ecosystems. Many

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[4] IPCC, 'Climate Change 2018: Global warming of 1.5C' (Cambridge University Press, 2018).

[5] Muhammad Naseem, 'Impacts of Climate Change on Marine Fisheries of Pakistan,' *International Journal of Agriculture and Environmental Research*, Vol. 6, No. 4, July/August 2020, p. 111.

[6] Muhammad Ahmed and Muhammad Bilal, 'Mangroves of Pakistan: A review,' *Wetlands Ecology and Management*, Vol. 27, No. 6, December 2019, p. 843.

commercially valuable fish species breed in these mangrove ecosystems, which not only serve as carbon sinks but also act as a natural buffer against coastal erosion.

Astola Island in Balochistan stands as one of Pakistan's most crucial coral reefs. It not only sustains marine life but also provides a habitat for migratory bird species, making it ecologically vital to protect not only marine but also avian biodiversity. Coral reefs play an additional role in safeguarding coastal areas by attenuating wave energy and preventing shoreline erosion through their diverse coral species, fish, and invertebrates.[7]

Urgent attention and concerted efforts are imperative to mitigate the adverse effects of global warming on Pakistan's marine life. Beyond the escalating ocean temperatures caused by human-induced climate change, these effects pose multifaceted threats to the delicate ecosystem of Pakistani waters. The rising ocean temperatures are depleting crucial marine resources, disturbing intricate ecological balances. Coral reefs, known for their biodiversity and support for numerous species, face particular jeopardy due to increasing water temperatures. Stress-induced coral bleaching is resulting in severe compromises to countless marine organisms, ultimately leading to ecosystem collapse.

The livelihoods of millions of Pakistanis depends on the fisheries industry. Pakistan's marine ecosystem, with its biological diversity and economic significance, is a cornerstone of the nation's wellbeing. Within Pakistan's fisheries industry, both artisanal and commercial fishers target various species for local consumption and export. Moreover, the marine ecosystem underpins a range of economic activities, including tourism, aquaculture, and shipping, further underscoring its importance to the nation's economy.

Climate change poses a significant threat to marine life in South Asia, necessitating immediate action and comprehensive strategies to combat it. These strategies must include a reduction in greenhouse gas emissions, enhanced marine conservation efforts, and the promotion of sustainable fishing practices to safeguard the delicate marine ecosystems. Collaboration among international organizations, government entities, scientific communities, and local stakeholders is imperative to raise

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[7] A. Adil, M. A. Khan, and H. Zahoor (eds.),'Climate Change and its Impact with Special Focus in Pakistan,' *Pakistan Engineering Congress*, 2018; Muhammad Khan and Hina, 'Biodiversity and ecology of coral reefs in Astola Island, Balochistan, Pakistan' *Russian Journal of Marine Biology*, Vol. 43, No. 4, July 2017, p. 257.

awareness, develop effective policies, and preserve marine biodiversity for future generations. Furthermore, it is pertinent for the South Asian Association for Regional Cooperation (SAARC) to play a highly effective and practical role in formulating regional policies.

Climate change and global warming have created a multitude of challenges for marine life in Pakistan, which is one of the largest markets in this domain. This paper proposes a new mitigation and adaptation strategy to address the issues Pakistan faces in this context. The research is qualitative in nature and utilizes both primary and secondary sources. It provides a comprehensive description of available data for analysis, encompassing causal factors, effects, and recommended actions. The primary aim of this research is to highlight the major causes and effects of climate change in South Asia, emphasizing the significance of marine life in Pakistan and the reasons why Pakistan underutilizes the benefits of marine resources.

This study seeks to assist coastal communities in the region in adapting to climate change, with the ultimate goal of achieving a more sustainable and climate resilient future for the nation. By examining the impacts of global warming on marine resources, this research underscores the vital need to protect communities dependent on marine ecosystems for their livelihoods and food security. Given the global concern about climate change, this study contributes to our understanding of how climate change affects marine life.

Climate catastrophe in South Asia

Over the past few years, South Asia has experienced several devastating events resulting from the rapid increase in climate change. These events include a rise in extreme weather events, increasing temperatures, and sea-level rise over the past few decades, all of which have exacerbated socio-economic and health vulnerabilities in the region. Following are the major events damaging the livelihoods of the entire South Asian region.

Extreme weather events

It has been noted that climate change has increased the frequency and severity of extreme weather events worldwide, and South Asia is no exception. Over the past three years, particularly up to 2022, the region has witnessed a significant rise in floods, cyclones, and heat waves.[8]

[8] World Meteorological Organization, 'Statement on the State of the Global Climate in 2021' (World Meteorological Organization, 2022).

South Asia is known for its frequent flooding, especially during the monsoon season. The intensification of the monsoon and the associated increase in precipitation have led to destructive floods in recent years. Bangladesh, India, and Nepal have been severely affected by these floods, resulting in numerous casualties and widespread displacements. According to the United Nations, in 2020 alone, floods forced an estimated 4.8 million people to flee their homes, causing significant damage to crops, infrastructure, and livelihoods.[9] These events highlight the substantial economic and social costs associated with extreme weather events, which are exacerbated by climate change.

Climate change has also raised ocean temperatures, providing more energy for the formation and intensification of cyclones, which poses an increased threat to South Asia. Cyclones represent a significant risk to the region, and their frequency and intensity are on the rise. The impact of Cyclone *Fani*, which hit the Bay of Bengal in 2019, affected millions of people in India and Bangladesh, underscoring the growing danger posed by such events. Furthermore, several heatwaves have become more frequent and severe in recent years, characterized by prolonged periods of excessively hot weather. India and Pakistan have particularly experienced the brunt of these heatwaves, resulting in numerous fatalities each year. In 2022, several heatwaves saw temperatures reach 50°C in various parts of these countries.

As these weather events intensify in South Asia, they significantly affect the region's economic and social fabric, leading to immediate loss of life and property, as well as long-term impacts on its socioeconomic development. Repeated occurrences strain resources, disrupt economies, and hinder developmental progress. Moreover, the ability to recover from such disasters varies, with marginalized and impoverished communities bearing the greatest burden due to their disadvantaged conditions. These communities are particularly vulnerable to disasters due to limited access to resources, dependence on climate-sensitive livelihoods, and their proximity to disaster-prone environments.

Lastly, floods and cyclones have significant ecological repercussions. These events can disrupt ecosystems, lead to biodiversity loss, and even permanently alter landscapes. The loss of biodiversity affects ecosystem

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[9] UNDP, 'Adaptation Gap Report 2023: Towards Global Goals through Local Action' (United Nations Development Program, 2023); M. Nadeem et.al., 'Climate Change Vulnerability and Adaptation Strategies for Coastal Communities of Pakistan: A Case Study of Karachi,' *Journal of Political Studies & Public Policy,* Vol. 7, No.2, 2019, pp. 34-49.

services, upon which humans depend for food, water, and other necessities.

Rise in sea levels

The melting polar ice caps and thermal expansion of seawater are primarily responsible for the increase in sea levels experienced in South Asia. This rise in sea levels is a consequence of global warming and poses an imminent threat to the region, particularly to coastal countries and island nations. Throughout South Asia, sea levels have risen rapidly, resulting in severe land erosion, habitat loss, and forced displacement, particularly in low-lying areas.[10]

It is important to note that Bangladesh represents one of the most critical cases in South Asia due to its deltaic geography and proximity to the sea level. With approximately one-third of Bangladesh's population residing along the coast, the sea level rise has had devastating effects on the country. According to the National Oceanic and Atmospheric Administration, an estimated 10 per cent of Bangladesh's land is projected to be submerged by 2050, displacing millions of people and diminishing arable land in the process.[11]

The Maldives, an Island nation, also faces significant risks. It is the world's lowest-lying country, comprised of 26 atolls and over 1,000 coral Islands with an average ground level of just 1.5 metres above sea level. Rising sea levels pose an existential threat to the Maldives, rendering it uninhabitable in the future. Furthermore, the rising sea levels impact mangrove forests in the *Sundarbans*, a stretch of land extending from Bangladesh to India. These mangroves play a crucial role in protecting the coastline from storm surges, cyclones, and coastal erosion. Their loss due to sea level rise exposes these coastal regions to greater risks.

Apart from the loss of homes and livelihoods resulting from sea level rise, the displacement of people leads to increased urban density in already overcrowded cities. Sea level rise has profound socio-economic consequences for the future, as climate migrants face numerous

[10] IPCC, 'The Physical Science Basis: Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change' (Cambridge University Press, 2021).

[11] NOAA, 'National Oceanic and Atmospheric Administration: Global and Regional Sea Level Rise Scenarios for the United States' (National Oceanic and Atmospheric Administration, 2022).

challenges, including limited access to basic amenities, job insecurity, and social marginalization.[12]

Additionally, the rise in sea levels leads to saltwater intrusion into freshwater resources, resulting in water scarcity that adversely impacts agriculture and domestic consumption. Saltwater intrusion can also lead to soil salinization, further hindering agricultural production and threatening food security.

A comprehensive, long-term strategy is necessary to address sea level rise. Examples of such strategies include the construction of seawalls and other coastal defenses, the restoration and conservation of coastal ecosystems, and the adoption of sustainable land use practices. Creating climate resilient urban infrastructure is also essential. A robust policy for climate migration, ensuring that climate migrants have the right to resettlement and rehabilitation, is crucial for addressing this issue.

Rising temperatures and heatwaves

Increasing global temperatures, driven by greenhouse gas emissions, have led to more frequent and intense heatwaves worldwide. According to the World Health Organization (WHO), a heatwave is defined as a period of unusually elevated temperatures lasting for five or more consecutive days. Such conditions have had a severe impact on nations like India and Pakistan. In 2022, one of the most severe heatwaves in history occurred, with temperatures soaring to 50°C in parts of India and Pakistan, making it one of the worst events in the region's history.[13]

Rising temperatures in South Asia directly affect several aspects of daily life, particularly human health. A report by Lancet Countdown on climate change and health in India revealed that heat-related death rates for individuals over the age of 65 increased by 53.7 per cent from 2018 to 2022. This report underscores the dangers associated with extreme temperature periods, including heatstroke, dehydration, and various illnesses triggered by extreme heat. Furthermore, rising temperatures have significant economic implications, especially in sectors involving outdoor work, such as agriculture, where labour productivity can be substantially impacted.

The region's energy infrastructure may also come under strain due to rising temperatures, potentially leading to power shortages and

[12] Dasgupta, 'Climate change and the future impacts of storm-surge disasters in developing countries' (Center for Global Development, 2020).
[13] World Meteorological Organization, 'Statement on the State of the Global Climate in 2021' (World Meteorological Organization, 2022).

exacerbating economic challenges in the future. This, in turn, would further drive up the demand for energy in the region.[14]

Heatwaves and rising temperatures also have implications for urban environments, contributing to the phenomenon known as the 'urban heat island effect.' This phenomenon results in urban areas being significantly warmer than rural areas due to human activities and land use changes. The urban heat island effect makes urban populations more susceptible to heat-related health risks and increases the energy required for cooling.

To address these challenges, it is crucial to implement both adaptation and mitigation measures. Establishing early warning systems for heatwaves, setting up public cooling centres, and implementing heat action plans are essential steps to prevent public health problems. Simultaneously, a range of mitigating actions, such as promoting renewable energy, improving energy efficiency, and implementing climate-smart urban planning practices, is necessary.

Ecosystem and biodiversity threats

Biodiversity is the cornerstone of functioning ecosystems, upon which we rely. The threat of climate change, compounded by other human activities, poses a serious existential risk to biodiversity and ecosystems, particularly in biologically rich regions like South Asia.

As the climate undergoes change, numerous species are experiencing shifts in their geographic ranges, population sizes, and life cycle events due to altering conditions, which have been stable for millennia. In biodiversity hotspots like the Himalayas, many species are moving to higher elevations. Rising temperatures in the Himalayas, for example, are shrinking habitats and intensifying competition for species like the snow leopard.[15]

Additionally, coral reefs, vital components of marine biodiversity, are under threat from ocean warming and acidification. The Maldives, home to various coral species, has recently witnessed severe coral bleaching events caused by global warming and acidification. A report by the International Union for Conservation of Nature revealed that 60 per cent

[14] E. Somanathan, Rohini Somanathan et.al., 'The Impact of Temperature on Productivity and Labor Supply: Evidence from Indian Manufacturing,' *Journal of Political Economy*, Vol. 129, No. 6, 2021, p.26.

[15] Mallon, 'Snow leopards and the impact of climate change' (Academic Press, 2021).

of the Maldives' coral reefs bleached in 2023, posing a possible threat to the marine life that relies on them.[16]

Freshwaters ecosystems are also feeling significant impacts. Changes in monsoon patterns, river flows, and increased evaporation rates due to higher temperatures have altered river ecosystems. This, in turn, affects freshwater species, including economically important fish like the Hilsa, crucial to Bangladesh's economy.

Climate changes can favour invasive species over native ones, resulting in shifts in species composition. Such changes can exacerbate the risks posed by invasive species. For instance, India has seen a rise in water hyacinths in water bodies, leading to a significant loss of aquatic biodiversity due to their rapid proliferation.[17]

As biodiversity diminishes and ecosystems degrade, there are profound implications for humanity. Biodiversity is essential as it provides a wide range of ecosystem services, including pollination, climate regulation, water purification, food production, fiber production, and medicinal resources. The loss of biodiversity threatens human well-being, as these services may diminish or disappear, jeopardizing human well-being.

The most effective approach to addressing climate change is through the establishment and management of climate-smart protected areas, the restoration of degraded ecosystems, and the adoption of climate-smart conservation practices. Additionally, integrating biodiversity considerations into other sectors such as agriculture, forestry, and fisheries can help to minimize further impacts.

Policies and strategies of climate change in South Asia

Over the past two decades, there has been a substantial increase in the number of policies and initiatives aimed at mitigating and adapting to the effects of climate change in South Asian countries. This progress has been facilitated by the SAARC, which has promoted collaboration on climate change among member countries. SAARC's Action Plan on Climate Change, established in 2008, has continued to evolve, facilitating

[16] IUCN, 'The IUCN Red List of Threatened Species' (International Union for Conservation of Nature, 2022).

[17] David Pimentel, Rodolfo Zuniga and Doug Morrison, 'Update on the environmental and economic costs associated with alien-invasive species in the United States,' *Ecological Economics*, Vol. 52, No. 3, p.273.

initiatives in climate research, technology transfer, and capacity development among member countries.[18]

India, as the largest emitter of greenhouse gases in the region, has adopted the National Action Plan on Climate Change (NAPCC) and launched ambitious programmes to promote renewable energy, particularly solar power, at the national level. India's commitment to the International Solar Alliance aims to mobilize investment in solar energy development, with a goal of achieving 450 gigawatts of renewable energy capacity by 2030.[19]

Pakistan has embraced tree planting as a key strategy for mitigating and adapting to climate change through its National Climate Change Policy. The Billion Tree Tsunami project, initiated in 2015, successfully reached its target by 2020, with goals of increasing carbon sequestration, restoring ecosystems, and providing livelihood opportunities.[20]

Bangladesh, one of the countries most vulnerable to climate change, has taken significant adaptation steps. The Bangladesh Climate Change Strategy and Action Plan (BCCSAP), developed by the government in 2008, has played a crucial role in guiding these efforts. Initiatives include constructing cyclone shelters and early warning systems, implementing climate-resilient agriculture practices, and promoting climate change research.[21]

Bhutan has implemented various policies to maintain its carbon-neutral status while adapting to a changing environment. The Bhutan Carbon Neutral Strategy outlines the country's plans to achieve carbon neutrality and enhance the resilience of its communities and ecosystems.[22]

Maldives, facing the existential threat of sea level rise, has prioritized adaptation strategies. The government's Strategic National Action Plan for Disaster Risk Reduction and Climate Change Adaptation includes

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[18] SAARC, 'SAARC Action Plan on Climate Change' (South Asian Association for Regional Cooperation, 2022).

[19] Government of India, 'National Action Plan on Climate Change' (Ministry of Environment, Forest and Climate Change, 2022).

[20] Government of Pakistan, 'Pakistan's National Climate Change Policy' (Ministry of Climate Change, 2021).

[21] Government of Bangladesh, 'Bangladesh Climate Change Strategy and Action Plan' (Ministry of Environment, Forest and Climate Change, 2023).

[22] Government of Bhutan, 'Bhutan's Carbon Neutral Strategy' (National Environment Commission, 2019).

initiatives like creating climate-resilient infrastructures and improving waste management to reduce negative impacts on the reefs.[23]

While these policies and initiatives represent significant progress, challenges remain. Limited financial and technical resources, along with difficulties in local policy implementation, underscore the need for regional cooperation. Addressing these challenges will require further international support, capacity building, and technology transfer.

Global warming effects on Pakistan's marine environment

Several key factors contribute to the decline of Pakistani marine ecosystems and the overall health of marine organisms due to global warming. In addition to fisheries, coastal regulation, and tourism opportunities, Pakistan's coastline provides an array of marine ecosystems that contribute to its ecological balance and socio-economic prosperity. The Arabian Sea is the longest ocean in Pakistan, but despite its 1,050 km coastline, marine life is facing significant challenges. In addition to coral reefs and mangrove forests, this marine ecosystem consists also of seagrass beds, sandy beaches, and coral reefs. Its marine life contributes greatly to Pakistan's economic and ecological well-being, but human activities and environmental factors pose increasing threats to Pakistan's marine life. Following are the major factors effecting the marine environment of Pakistan.

Rising sea temperatures

Warmer oceans can lead to a change in marine organisms' physiological and behavioural characteristics due to increased sea temperatures. A high-water temperature that disrupts coral growth and reproduction can cause bleaching and eventual death of coral reefs. Increasing sea surface temperatures are adversely affecting coral reef ecosystems, as they are one of the world's most bio diverse ecosystems. Coral obtains essential nutrients and vibrant colors from algae known as zooxanthellae, which are symbiotic organisms. It has been observed that coral bleaching, which occurs when corals expel algae, is increasing along Pakistan's coast, leading to coral degrading and fading.[24]

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[23] Government of Maldives, 'Strategic National Action Plan for Disaster Risk Reduction and Climate Change Adaptation' (Ministry of Environment and Energy, 2022).

[24] Marine Science Institute, 'State of Pakistan's Coral Reefs' (Marine Science Institute, 2019); S. Hussain, N. A. Malik, and M. Rafiq (eds.), 'Climate Change and Coastal Vulnerability in Pakistan,' In *Climate Change and Its Impact on Coastal Ecosystems in Pakistan* (Springer, 2022), pp. 587-598.

Rising sea levels

A melted glacier and ice cap negatively impacts coastal ecosystems and species. Increasing sea levels result in erosion, flooding, and loss of mangroves and seagrass as a result of global warming. Marine ecosystems and coastal communities in Pakistan are severely affected by rising sea levels. These habitats act as nursery grounds and feeding grounds for many marine organisms, including fish and crustaceans. Flooding is a major concern during extreme weather events, especially in coastal areas. Inundated coastal habitats can lead to the loss of marine turtle nesting sites, disruption of migratory bird breeding grounds, and displacement of coastal communities when rising water levels threaten coastal habitats. Mangrove forests protect coastal ecosystems from storm surges and erosion, which can reduce the impact of rising sea levels. As the sea level rises, mangrove ecosystems present a threat to coastal habitats and marine life as they reduce wave intensity and stabilize sediments.[25]

Ocean acidification

By absorbing excess carbon dioxide (CO2), oceans become acidified. This results in the pH of seawater decreasing, which adversely affects marine organisms with calcium carbonate skeletons and shells. The acidification of the ocean has negatively impacted Pakistan's coastal waters, preventing coral reefs, shellfish, and other calcifying organisms from growing and developing. Coral reefs, shellfish, and other calcifying organisms have been hindered from growing and developing. Ocean acidification has adversely affected Pakistani coastal waters. Coastal Pakistan has been severely impacted by ocean acidification because coral reefs, shellfish, and other calcifying organisms can't grow and develop.

Altered ocean currents

As a result of climate change, ocean currents are likely to change, and this can have wide-ranging effects on the marine ecosystem. Changes in ocean currents can have a significant impact on plankton abundance, distribution, and abundance as a result of new nutrients being released into the water. Therefore, the whole marine ecosystem is affected as a result of the effect of climate change on fish populations and their predators.

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[25] Mustafa Ahmed, 'Impact of Climate Change on Coastal Erosion along Sindh Coast, Pakistan,' *Pakistan Journal of Marine Sciences*, Vol. 29, No. 1, June 2020, p. 29; Ashraf Hussain et.al., 'Climate Change and its Impacts on Pakistan,' *Journal of Positive School Psychology,* Vol. 6 No. 8, 2022.

Coral reefs

In addition to being among the world's most biologically diverse ecosystems, coral reefs support a number of marine species. However, increasing sea temperatures and ocean acidification are destroying coral reefs along Pakistan's coast. Coral bleaching has led to a reduction of coral cover and a loss of vibrant colors due to elevated SSTs.[26] A coral reef provides essential habitat for invertebrates, algae, and fish. Their decline has a profound effect on the whole ecosystem. Besides providing protection and abundant food, coral reefs serve as nursery grounds for juvenile fish. When coral reefs are destroyed, not only do suitable habitats disappear, but biodiversity hotspots and intricate food chains are disrupted as well.

Fish and marine species

Global warming has multiple impacts on fish populations and marine species. Sea temperature changes can affect fish populations and coastal communities. The migration patterns of certain commercially important fish species along the Pakistan coast have already been altered as a result of rising temperatures. Shellfish and planktonic organisms, which depend on their calcium carbonate structures, are also affected by acidification of seawater. In the event that these organisms are disrupted, the entire food web can be affected, including fish and marine mammals at higher tropic levels.

Coastal communities

The coastal economy of Pakistan is heavily dependent on marine resources for livelihood and sustenance, which includes fishing, aquaculture, and tourism relating to marine ecosystems. The alteration of marine biodiversity and habitats by global warming, however, poses a threat to coastal communities' well-being and socio-economic stability. The loss of coral reefs, coastal erosion, and fish population changes directly affect the income and food security of fishing communities. Reduction in catch yields and loss of productive fishing grounds can result in economic hardships and increased vulnerability. On top of that, sea level rise and erosion pose additional socio-economic challenges to coastal communities.

Overfishing

The overfishing of Pakistan's marine life poses a significant threat. As a result of an increasing demand, fish stocks have been depleted,

[26] Marine Science Institute, op. cit.

destructive fishing gear has been used, and illegal fishing has been conducted. As well as disrupting marine ecosystems, coastal communities may face financial hardship. There are social and economic repercussions associated with the decline of fish populations, including reduced food availability, incomes, and employment opportunities.

Habitant degradation

A loss of coral reefs and mangrove forests has detrimental impacts on the marine life in Pakistan. Coral reefs provide homes, nurseries, and breeding grounds for a variety of marine species. Coral reefs are degrading due to rising sea temperatures, pollution, and destructive fishing practices that result in the disruption of their delicate balance, resulting in a loss of biodiversity and ecosystem services. In coastal areas, erosion, storm surges, and tidal surges are caused by the destruction of mangrove forests and the use of non-sustainable aquaculture practices.

Pollution

It is widely known that Pakistan has a problem with land and marine pollution. Industrial and domestic waste, agricultural runoff, and oil spills contribute a wide range of pollutants to marine ecosystems. Due to this, water is contaminated, habitat is degraded, and marine organisms suffer. In particular, plastic pollution has caused entanglements and ingestions of marine species, disrupting marine food webs, and disrupting marine habitats. As well as affecting marine organisms in a cascading manner, consuming contaminated seafood can also have a cascading effect on human health.

Climate change

In Pakistan, marine ecosystems are experiencing increasingly challenging conditions as a result of climate change. Increasing sea temperatures, increasing acidification, and changing ocean currents have profound impacts on marine ecosystems across the country. Due to increasing sea temperatures, coral bleaching events are causing coral reefs to lose their vitality, disrupting the intricate symbiotic relationships they support, and destroying the coral reefs themselves. As sea levels rise and ocean currents change, they affect marine species distribution and abundance, changing ecological dynamics and the possible collapse of ecosystems. Climate change is expected to have far-reaching effects on biodiversity, fisheries, and coastal communities in the long run.

Findings

In comparison to other parts of the world, the sea level in the South Asia region has been higher than the global average in the coastal regions. As a result, marine ecosystems and coastal communities face a significant threat. Important nesting sites for marine turtles will be destroyed, breeding grounds for migratory birds will be disrupted, and coastal communities may be displaced. The region's coastal erosion is worsened by rising sea levels. The loss of these valuable coastal habitats, such as sand beaches and rocky shorelines, results in the reduction of the availability of suitable nesting places for these marine turtles, affecting the breeding and reproductive patterns of the marine animals.

In addition to altering currents, sediment transport, and nutrient availability, coastal erosion has also significantly affected the health of this marine ecosystem. In South Asia, coral reefs have been severely affected by rising sea temperatures and ocean acidification. Coral bleaching events have caused corals to lose their attractive colors and has reduced the coral cover. This decline in coral cover has severe implications for marine biodiversity, disrupting food chains and reducing habitat availability for numerous species, leading to loss of biodiversity in these areas. Climate change and ocean acidification are greatly affecting fish populations and marine species in Pakistan. Many residents deal in fish farming and trading of fish to earn their livelihood. Changes in sea temperature have led to a change in the distribution and abundance of these fish species in Pakistan, which negatively impacts fisheries and coastal communities' livelihoods.

Ocean acidification threatens the survival of species that rely on calcium carbonate structures, affecting the entire marine food web. Pakistani coastal communities rely on marine resources for their food and livelihood. Coral reef loss, coastal erosion, and changes in fish populations adversely affect the income and food security of these communities, resulting in economic hardships and increased vulnerability. Therefore, to mitigate global warming's impact on Pakistani marine life, effective policymaking is necessary and such frameworks must incorporate climate change considerations. To combat climate change and protect marine biodiversity, international cooperation, collaboration, and financial support are essential. Educating and engaging the local community and public in order to raise awareness play a crucial role in fostering sustainable practices and empowering individuals to make contributions to marine ecosystem conservation.

Since, carbon dioxide (CO_2) is one of the major greenhouse gases, its increasing human emissions are resulting in ocean acidification. As a

result of the absorption of CO2, ocean pH levels decrease, affecting seawater's chemistry. In addition to corals, mollusks, and planktonic organisms, ocean acidification poses a threat to marine organisms with calcium carbonate shells and skeletons. As a result of acidification, these organisms have difficulty building and maintaining their protective structures made up of calcium carbonate, which affects their growth, reproduction, and survival. This impacts the entire marine food web, including species with significant commercial importance.

Changing ocean currents and upwelling patterns have a significant impact on marine ecosystems because of global warming. It is possible for changes in ocean currents to alter marine species' distributions and migration patterns, which could have a significant impact on fishing communities. When upwelling processes are disrupted, nutrients-rich deep waters rise to the surface, reducing primary productivity and affecting the entire food chain. According to the findings, global warming poses a looming crisis for Pakistan's marine life, impacting fish populations and marine ecosystem productivity. Ocean acidification, sea level rise, altered ocean currents, rising sea temperatures, and their cascading impacts on coral reefs, fish populations, and coastal communities require urgent action. Climate change adaptation measures, sustainable fisheries management, conservation of critical habitats, and mitigation strategies are essential to addressing this environmental crisis. A collaborative effort involving government agencies, local communities, researchers, and international partners is crucial to preserving Pakistan's marine ecosystem biodiversity and ensuring its long-term sustainability.

Recommendations and conclusion

SAARC should make these biodiversity preservation measures a part of its regional policy. This agenda incorporating climate change considerations, specifically those pertaining to marine and coastal environments should be prioritized in the government and cabinet meetings. To safeguard critical habitats, we must develop and implement regulations to reduce greenhouse gas emissions, promote renewable sources of energy production, and create protected areas and marine reserves.

Protecting and restoring critical marine habitats, such as coral reefs and mangrove forests, should be the focus of conservation and restoration efforts. Restoring reefs, managing mangroves sustainably, and developing effective coastal zone management plans are some of the initiatives that can be taken. By enforcing such regulations, setting catch limits, and supporting alternative livelihoods for fishing communities, we can

promote sustainable fishing practices. It is possible to recover fish stocks and ensure long-term sustainability by implementing measures such as fisheries management plans, promoting responsible fishing techniques, and encouraging selective fishing gear.

Resilience in marine ecosystems and coastal communities' adaptability in response to climate change should be strengthened by developing and implementing climate change adaptation and mitigation strategies. Capacity-building programmes, alternative income sources, and incorporating traditional ecological knowledge into decision-making processes may be part of this approach. The participation should be made actively in international climate change and marine conservation agreements and initiatives. Shared responsibility and joint efforts in protecting marine biodiversity with neighbouring countries and regional organizations should be promoted. For climate change adaptation projects and capacity-building initiatives, the international community should provide all types of financial and technical assistance. Public awareness of marine ecosystems, global warming, and individual actions that contribute to conservation efforts is very important.

An educational curriculum that addresses climate change and marine conservation issues, organize workshops and awareness campaigns, and collaborate with the media to spread accurate information. In order to foster environmental responsibility and inspire action, educational initiatives can be targeted at schools, colleges, and local communities. Marine biodiversity, global warming's impacts, and the role individuals can play in conservation efforts must be highlighted through environmental education programmes. Through the inclusion of climate change and marine conservation topics in the curriculum, workshops, and awareness campaigns, this can be accomplished.

Identify the specific impacts of global warming on marine ecosystems in Pakistan and develop targeted conservation and management strategies based on that information. The media can play a significant role in shaping public perception and influencing behaviour. This can include collaborative research projects, monitoring programmes, and long-term data collection initiatives. Various media platforms, such as television, radio, social media, and print media, can be used to disseminate accurate information, raise awareness, and inspire positive actions. Media outlets can be effective in reaching a broader audience by highlighting the impacts of global warming on marine life, conservation efforts, and the importance of sustainable practices.

Coastal communities should be able to adapt better to climate change by building resilience in marine ecosystems. As part of this effort, coral

reefs and mangrove forests need to be conserved and restored, and sustainable fishing practices need to be implemented to promote fish stock recovery. Adaptation efforts can also be effective if community-based initiatives empower local stakeholders and integrate traditional ecological knowledge. In order to limit the long-term impacts of climate change on marine ecosystems, mitigation efforts should focus on reducing greenhouse gas emissions. In order to reduce global warming, it is essential to switch to renewable energy sources, improve energy efficiency, and enact stringent regulations to minimize pollution and unsustainable practices. For global warming to be mitigated and marine biodiversity protected, effective policy frameworks must be developed and implemented.

With particular attention paid to marine and coastal ecosystems, the Pakistan government should prioritize integrating climate change considerations into national policies and strategies. As part of policy initiatives, greenhouse gas emissions should be reduced and renewable energy sources should be promoted. By establishing protected areas and marine reserves, critical habitats, such as coral reefs and mangrove forests, can be conserved and vulnerable species protected. In order to address the impacts of sea level rise, erosion, and pollution on coastal ecosystems, integrated coastal zone management plans are needed. It is also possible to ensure the long-term viability of marine resources by enforcing regulations, setting catch limits, and providing alternative livelihoods to fishing communities.

In conclusion, a multifaceted approach is needed to address the looming crisis of global warming's impact on South Asia's marine life, including robust policy frameworks, international cooperation, and collective action. To mitigate the challenges faced by marine ecosystems and coastal communities, Pakistan must integrate climate change considerations into national policies, implement sustainable practices, and protect critical habitats preserving the biodiversity in these areas. The global nature of climate change and the protection of marine biodiversity require international cooperation and collaboration among nations. Pakistan can contribute to global efforts to combat global warming and preserve marine ecosystems by actively participating in international agreements, advocating stronger climate policies, and obtaining financial and technical assistance. Pakistan can mitigate the challenges posed by global warming by implementing these recommendations, protecting the marine biodiversity and livelihood of coastal communities. In order to address this looming crisis and ensure a sustainable future for marine life in Pakistan, governments, communities, researchers, and international partners must work together in close collaboration to address this emerging global challenge.