Climate Change Impacts: Adaptation and Mitigation in Fisheries and Aquaculture

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Abstract

The role of fisheries in alleviating poverty and ensuring food security, while illustrating how climate change could further strain Pakistan's already limited resources. Most of Pakistan's impoverished and vulnerable populations rely on fish as a staple meal. The region's most traded food commodity is also a significant employer for both men and women. Pakistan, a developing nation, benefits economically from the fish trade paying off foreign debt and imports food for local consumption, improving food security and encouraging people to eat various foods but the advantages derived from the sector are frequently disregarded in the context of national economic planning. This analysis offers an overview of the possible impacts of climate change on fisheries, illustrated with some examples from Pakistan. The evidence suggests a direct correlation: as production levels and food supply from fishery products on a per capita basis increase, the extent of hunger decreases. Despite this, the sector of fisheries remains insufficiently prioritized by policymakers. Increased and ongoing investments in market development, fisheries governance, and the supply of economic incentive mechanisms are required to minimize the potential implications of climate change on fisheries and food security, while also enhancing the endurance of numerous impoverished fishing communities in Pakistan.

Keywords: Fisheries, Climate change, Food security, Climate-smart aquaculture, Ecosystem-based management

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Introduction

Since the onset of the Industrial Revolution, human development has been growing exponentially, but this progress has come at a cost. Anthropogenic interventions have driven significant modifications in land utilization, elevated greenhouse gas (GHG) emissions levels, and consequently intensified climate change (Lamichhane et al., 2019). Over the period from 1880 to 2012, according to the Intergovernmental Panel on Climate Change (IPCC), an increase in global mean temperature and changes in patterns of precipitation affected the hydrological and runoff characteristics (Ghaderpour et al., 2021).

The 15th edition of the Global Risks Report 2020, which the World Economic Forum compiled, comprehensively presented a variety of climate realities, identifying regions that are significantly impacted. The risks encompassed the potential for the loss of life as a result of health hazards and natural disasters, as well as the excessive stress placed on ecosystems, particularly aquatic and marine systems. Food and water security are two other areas that are greatly affected. Extreme weather, disasters, and higher sea levels are all expected to cause more people to move. When countries try to get resources along land and water borders, conflicts may arise. The study also talks about how rising systematic risks affect capital markets financially (WEF, 2020).

At the twenty-first UNFCCC conference of the parties (COP-21) in Paris in 2015, the Paris Agreement was adopted and came into effect in 2016. The Paris Agreement included additional objectives, commitments, improved compliance and reporting rules, along with support mechanisms to the current climate change mitigation framework. The primary aim of the accord is to restrict the global temperature rise to 2 °C by 2100 and to strive for a limit of 1.5 °C. The agreement seeks to achieve global peak greenhouse gas emissions at the earliest opportunity to establish equilibrium between anthropogenic emission sources and greenhouse gas sinks and reservoirs between 2050 and 2100. The agreement established additional binding obligations, requiring all parties to provide nationally specified contributions and to implement national measures to fulfil and strive to surpass these commitments. The agreement promotes increased openness, compliance, and explicit reporting and communication. Moreover, the agreement promotes voluntary collaboration among parties in addition to obligatory measures. The agreement also calls for poor countries to get financial and technological help, as well as programs that build their skills. Parties from developed countries are required to promote sustainable development and make sure that vulnerable countries have the right tools to help them deal with climate change and adjust to it. Adaptation and building up people's ability to respond to changes in temperature is one of the most important goals set out in the agreement (UN, 2015).

Article 6 of the agreement included two international market mechanisms: cooperative approaches and the sustainable development mechanism. All parties are to employ these channels to fulfil their nationally specified contributions. Cooperative approaches provide a framework for parties to employ internationally transferred mitigation outcomes (ITMOs) to achieve nationally specified contribution objectives and promote sustainable development. The sustainable development mechanism is an innovative strategy that fosters mitigation and sustainable development and is regarded as the successor of the clean development mechanism. Debate and negotiations regarding these systems continue (Gao et al., 2019).

Nieto et al. (2017) performed a comprehensive systematic examination of the efficacy of the Paris Agreement policies by assessing 161 intended nationally determined contributions (INDCs) from 188 nations. The research examined sector-specific strategies in each of these nations and calculated emissions under their respective INDCs. The analysis determined that the optimal scenario would result in an annual worldwide emission rise of roughly 19.3% by 2030 relative to the baseline period. Conversely, a 31.5% rise in world emissions is anticipated without intervention. It is determined that if the anticipated optimal emissions level is sustained from 2030 to 2050, a temperature rise of no less than 3 °C will occur. Moreover, a 4 °C rise would be guaranteed if annual emissions persist increasing.

Water is essential for the survival of all forms of life on Earth. Unplanned urbanization, chemicals, and fast industrialization have reduced the amount of freshwater that humans can access. Fish and other aquatic animals are especially vulnerable to the pollution and declining water quality caused by these conditions (Danylchuk et al., 2023). Aquaculture species' development, proliferation, and maintenance are all affected by a wide range of water quality variables (Hanifa et al., 2022).

Climate change due to global warming is predicted to affect widely societies, ecosystems and economies, intensifying stress on all food supplies and livelihoods, encompassing the aquaculture sector and fisheries. There is an imperative to better comprehend where climate change is most probably to reduce economic opportunities for fishermen and where there is the key priority to invest in substitute urban and rural enterprises. Approximately in all countries of the world, fish is a vital part of the human diet. It provides the essential nutrients that are absent in the main staple food which prevail in most of the diet of people. Fish is highly nutritious and economical source of animal protein which provides 20% of protein. Fish oils are rich in polyunsaturated fatty acids (PUFA) that are highly nutritious. Besides protein sources, fish is also a rich source of minerals and vitamins (Mohanty & Sahoo, 2010).

Impact of Climate Change

A range of aquatic habitats, from coastal to marine, are vital to fisheries and aquaculture. Because of their extreme sensitivity to changes in temperature, salinity, and acidity, these ecosystems are experiencing the consequences of climate change. The fishing and aquaculture industries are expected to be among the first to feel the severe effects of climate change (Shahzad, 2023). Several aspects of society are vulnerable to the outcomes of climate change on our natural resources (Chandio et al., 2020). A major threat to marine fisheries is the occurrence of climate change (Pauly & Cheung, 2018). Marine fish face a significant threat to their ability to develop and reproduce due to this environmental issue, which reduces their chances of survival in their lifetimes (Clarke et al., 2021). Ocean temperatures have been rising due to climate change, which has both immediate and long-term effects on fish populations. There has been an overwhelming number of studies on this relationship (Gamito et al., 2013).

Climate change represents a significant challenge that the global community is currently confronting, particularly regarding its varied and uncertain effects on water resources as described in Figure 1. In Pakistan, where diverse climate conditions prevail, the impact of climate change may be more pronounced. The economy of Pakistan is fundamentally rooted in agriculture and exhibits a significant reliance on the Indus irrigation system (Shakir & Ehsan, 2010). Water is essential for the sustenance of all life forms in our world. A minimal proportion of the areas is accessible to humans, chiefly due to unregulated urbanization, chemical application, and fast industrialization. These factors lead to substantial contamination of aquatic species and the deterioration of water quality, impacting aquatic fauna, especially fish (Hadyait et al., 2020).

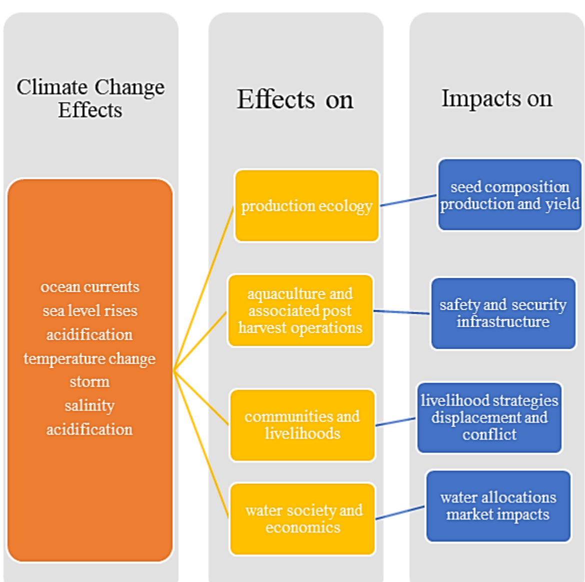

Fig. 1: Climate change Impacts

Ocean conditions, such as changes in the timing of plankton blooms and food supply, as well as changes in predator-prey relationships and the dynamics of fish stocks, are all things that can cause changes in the ocean's fish productivity. Due to rising temperatures and warming seas, lower latitudes are expected to have less productive land (Daw et al., 2009). Though the impact on fisheries is unknown, ecosystem disruption may significantly reduce fish productivity in the medium future.

Some species may go extinct if their maximum acceptable heat threshold is exceeded and they cannot migrate (e.g., in inland water bodies). Rising temperatures can induce toxic algal blooms and shellfish poisoning, which might impede market access if monitoring and testing services fail to identify non-exportable products.

Alteration in DO Levels

Larval survival, fish growth, and migrations may be impaired by diminished levels of dissolved oxygen in the water. The number of regions in which oxygen levels will decrease to extremely low levels (dead zones) will increase, rendering it impossible for fish or invertebrates to survive. It seems likely that the distribution of numerous fish and crustaceans will change as a result of the ongoing warming of the oceans, which will cause marine fish stocks to migrate to higher latitudes (Badjeck et al., 2010). With significant effects on the production and recruitment of fish stocks, such modifications may influence the distribution and timing of fish larval development. Higher temperatures will probably cause some farmed fish species to have possible increases in growth rates, food conversion efficiency, and length of the growing season (Shelton et al., 2014).

Changes in Salinity

Salinity is regarded as critical factor that determines the viability of species in estuarine ecosystems. It can have a direct effect on the organisms or indirectly destroy their habitat, including their breeding and nursery grounds (Abowei, 2010). The osmoregulation of marine animals will be negatively impacted by alterations in salinity. The impacts will be more pronounced for species that can withstand only minimal fluctuations in water salinity, such as zooplankton inhabiting coastal low-lying tidal lakes and wetlands in tropical regions (Schellenberg & Trehub, 2003). This would have serious consequences for the food chain dependent on them and, consequently, the ecological integrity of coastal wetland habitats, significantly affecting local fisheries.

Ocean Acidification

According to DuPont & Thorndyke (2009), an important systemic issue is an effectively irreversible decrease in seawater pH, sometimes known as increased "ocean acidification" resulting from the ocean's uptake of surplus CO_2. Ocean acidification will kill off a lot of coral reefs and reduce shellfish and zooplankton output (Sumaila et al., 2011). Calciferous organisms, which need calcium for shell or skeleton formation, exhibit sensitivity to acidity, since it hinders their capacity to develop robust shells, hence diminishing their resistance to temperature extremes, resulting in increased mortality rates and decreased fertilization success (Le Quesne & Pinnegar, 2012).

Evaluating the consequences of ocean acidification on human communities requires a thorough examination of both the direct and indirect chemical effects on vital marine ecosystem services, such as fisheries (Cooley et al., 2012). Le Quesne & Pinnegar (2012) assert that direct consequences encompass alterations in physiological processes, including otolith formation, diminished development of calcified structures, fertilization and efficacy. These may consequently direct effects at the organismal level, including diminished reproductive and growth success, heightened mortality and predation, changes in eating rates and behaviors, decreased immunological competence, and lowered heat tolerance. Nevertheless, indirect effects encompass modifications to nutrient recycling, changes in the abundance of predators and prey, and effects on coral reefs and other biogenic ecosystems. Although adult fish seem like to survive in low-pH waters or high-CO_2 seawater, their embryo and larval life stages may not be as successful (Petr & Swar, 2002).

Changes in the Distribution of Fishes

The alteration in fish distribution is one of the most often documented ecological reactions of marine species (Sumaila et al., 2011). Some fish species may vary their depth and latitude ranges in response to climate change or other environmental factors, such as rising water temperatures. Potentially less fish landings may result from shifts in fish migration patterns prompted by changes in ocean dynamics (Urama & Ozor, 2010). Changes in the distribution of fish stocks have varying effects across different latitudes. In order to locate habitats with optimal water temperatures, certain fish species will migrate northward, potentially increasing the fish harvest in higher latitudes. Consequently, the distribution of benefits and costs in fisheries will be altered as a result of these changes in fish stock distribution, with some individuals benefiting and others suffering (Chandio et al., 2020).

Extreme Shifts in Weather Patterns

Severe storms can raise water levels and wave heights to dangerous levels, and they can also increase the likelihood of flooding, storm damage, significant erosion, and the breakdown of defenses. Tropical and subtropical monsoon regions are particularly at risk from the increasing frequency of storms, cyclones, and floods, which pose a significant threat to aquaculture. Damage to aquaculture facilities and loss of crops are two potential outcomes; escaped fish pose a threat to wild stocks populations through illness and parasite infestation, and they can also harm ecosystems and biodiversity. There is a direct correlation between the frequency of severe weather events and the decline in fishing activity, which in turn reduces revenue. Additionally, there is an increase in the likelihood of accidents involving people and property while at sea. Not having health insurance, having trouble getting a loan, or receiving government assistance all contribute to a person's precarious financial situation. The surge, erosion, and accretion patterns, as well as the orientation of beach plan formations, are all influenced by changes in the wave climate (Mcleod et al., 2011).

Changes in Evaporation Rate and Rainfall Patterns

The effects on freshwater systems will diminish water levels, flow rates, and overall water availability, while worsening water stress, aridity, and drought incidences (Urama & Ozor, 2010). In certain instances, the ecological production and freshwater fish populations of the affected rivers will be at risk due to the reduced river volumes that are a consequence of increased erosion, sedimentation, and rainfall irregularity. Some instances of increased inundation from rivers and lakes will lead to the submersion of land by freshwater and the development of waterlogging (Barange & Perry, 2009). This could potentially have significant socioeconomic consequences, such as the reduction of jobs for numerous fishers who are involved in mollusk farming and the increase in mollusk prices, which may exclude marginal consumers. This might worsen the protein and wealth gaps between the wealthy and the impoverished (Bindoff et al., 2007).

Climate-Smart Fisheries and Aquaculture Practices

Climate-Smart Aquaculture goals to enhance food security by incorporating both the need for adaptation and the potential for mitigation as viewed in Fig. 2. CSA confronts the challenges of creating synergies between the interconnected goals of climate change adaptation,

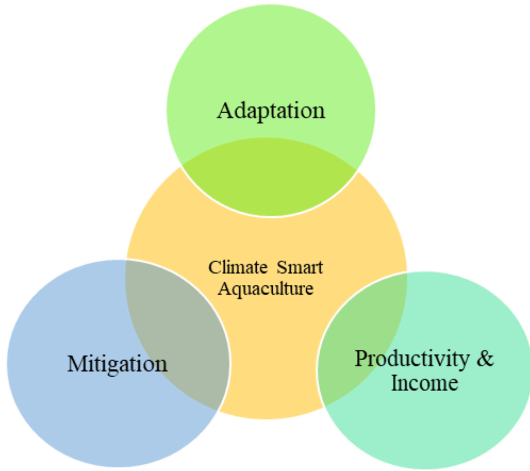

Fig. 2: Climate-smart Fisheries and Aquaculture Practices

mitigation, income growth and productivity while minimizing potential negative tradeoffs (Ahmed & Solomon, 2016).

Climate-smart Aquaculture will Require the Following

Enhancing the efficiency of natural resource utilization for the production of fish and aquatic foods. Preserving the resilience of aquatic ecosystems and the communities are dependent on them enables the sector to persist in fostering sustainable development. Comprehending methods to effectively diminish the susceptibility of individuals most likely to be adversely affected by climate change (Munguti et al., 2023).

Mitigation Measures to Reduce Climate Change Impact on Fisheries

Even though fisheries and aquaculture produce relatively low volumes of GHGs compared to other industries, there is still potential to reduce their emission further (Harrod, 2015). Enhancing fuel efficiency through the use of more optimized vessels or gear types, adopting sails, or modifying fishing practices can help lower emissions from fishing practices. This would lead to reduced fuel costs, however, transitioning to more effective gears or vessels may only achieve up to 20 percent reduction in fuel consumption (Nandy & Srivastava, 2018).

A significant portion of emissions in the sector comes from product transport, and there are opportunities for reducing these emissions as discussed in Figure 3. Opting for bulk sea freight instead of other types of sea freight, as well as enhancing local consumption to minimize travel distance, would help minimize fuel consumption (Holsman et al., 2019). Furthermore, suppose international fishing companies continue to flourish. In that case, as well as the transport of fish and fishery products from underdeveloped countries to markets in developed nations, adjustments in the transportation of products can help to confirm that GHG contributions from fisheries do not rise at the same pace (Mohsin et al., 2019).

Adaptation for Fisheries and Aquaculture Sector

In environmental studies, adaptation is interpreted as the process of adjusting in social, ecological, or economic systems concerning anticipated changes in climatic condition and their consequences, to reduce negative impacts or capitalize on new opportunities (Caputi et al., 2015). In simple terms, adaptation involves proactive actions and strategies taken by individuals in response to, or in preparation for, change to improve or sustain their well-being (Burgess et al., 2016).

Adaptation can thus encompass enhancing adaptive capacity, which strengthens the ability of groups or organizations to anticipate and respond to changes, along with putting mitigation plans into action by turning that capacity into practical measures (Daw et al., 2009). Both aspects of adaptation can be applied either in anticipation of or in response to, the impacts of a changing climate. Thus adaptation is an ongoing process involving actions, activities and decisions that guide choice across all areas of life, reflecting prevailing social norms and processes (Waris et al., 2020).

Adaptation can be either planned or autonomous, with the latter referring to an instinctive response to any change in environmental, or measures intended to mitigate climate-related shifts. In fisheries Autonomous adaptation may involve altering the locations or timing of fishing as species come earlier or later, or migrate to new space (Daw et al., 2009). Planned adaptation in fisheries may involve research funding aimed at identifying species that exhibit resistance to salinity and temperature fluctuations for aquaculture purposes. In high-impact uncertainty places like many tropical regions and underdeveloped countries lacking long-term climate data collections, a "no regrets" strategy builds general resilience without relying on specific climate impact estimates (Williams & Rota, 2011). Adaptation in fisheries and aquaculture may encompass diverse policy and governance measures, targeted technical assistance, or community capacity-building initiatives that engage numerous sectors beyond merely capture fisheries or aquaculture producers (Thorpe et al., 2005).

Ecosystem-based Management in Fisheries and Aquaculture

The ecosystem approach to fisheries and aquaculture (EAF and EAA) proposed by FAO is more extensive yet aligns with the broader definition of the concept (Jennings, 2005). An Ecosystem strategy to Fisheries (or Aquaculture) balances multiple societal goals by considering knowledge and uncertainty about biotic, abiotic, and human ecosystem components and their interactions and adopting an integrated strategy within ecologically appropriate boundaries. They can be divided into policy goals and issues (Garcia & Cochrane, 2005). Co-management serves as a mechanism to enhance the participatory nature of Ecosystem-Based Fisheries Management (EBF). The text delineates the spectrum of shared management, from fully community-based management, characterized by the complete devolution of responsibilities to communities and fishers, to central government management, wherein full responsibility is maintained by the government (Zhou et al., 2010). Co-management of fisheries is a collaborative approach in which government entities and fishery resource users jointly assume authority and responsibility for managing fisheries within a designated area. This partnership involves cooperation among the stakeholders, including non-governmental organizations (Schmidt, 2014). The network of stakeholders involved in Ecosystem-Based Fisheries (EBF) is complex due to vertical links (from national to local levels), horizontal linkages (among diverse consumers of natural resources), and geographic coverage. Success relies on an effective system of communication and information transmission. Although adaptation is context-specific, found that many adaptation actions may be used in most fisheries and aquaculture

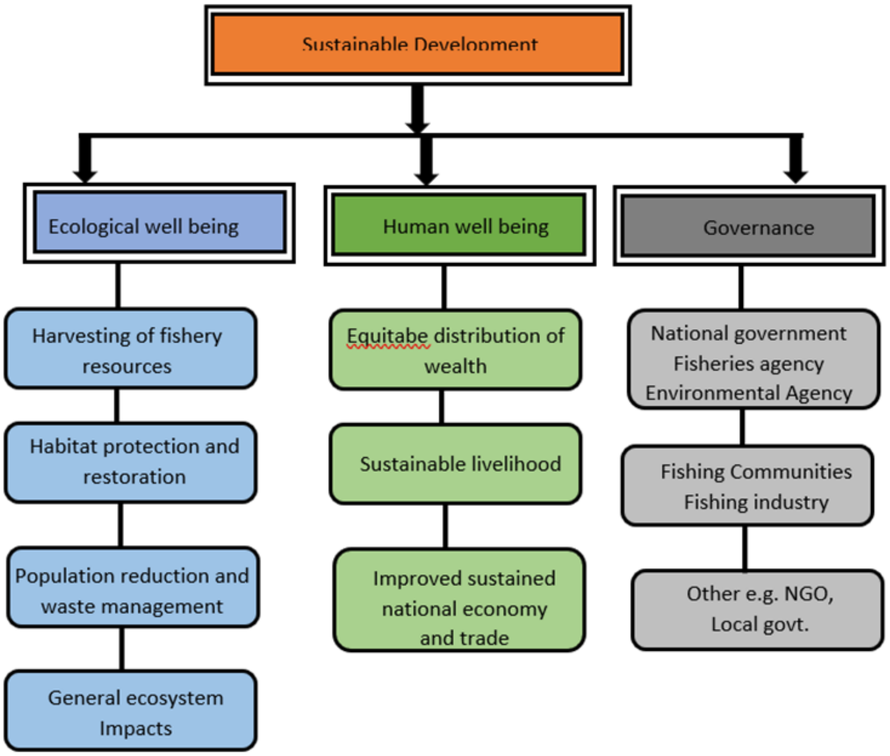

Fig. 3: Sustainable Development

Mitigate External Pressures on Natural Systems

Mitigate terrestrial pollution sources such as urban and agricultural runoff and harmful fishing methods such as explosives and toxins (Muddassir et al., 2019), and the strategies for fisheries management are shown in Figure 4.

Identify and Secure Valuable places

Deep pools in river systems, like the Mekong River, provide essential habitats for fish during dry seasons. They play a crucial role in local fisheries and are important for both upstream and downstream fisheries, often being situated in key spawning areas (Clark, 2006). The impacts of climate change on the hydrologic cycle, along with upstream and downstream activities such as dam construction leading to siltation or basin development causing pollution discharge, will influence these regions.

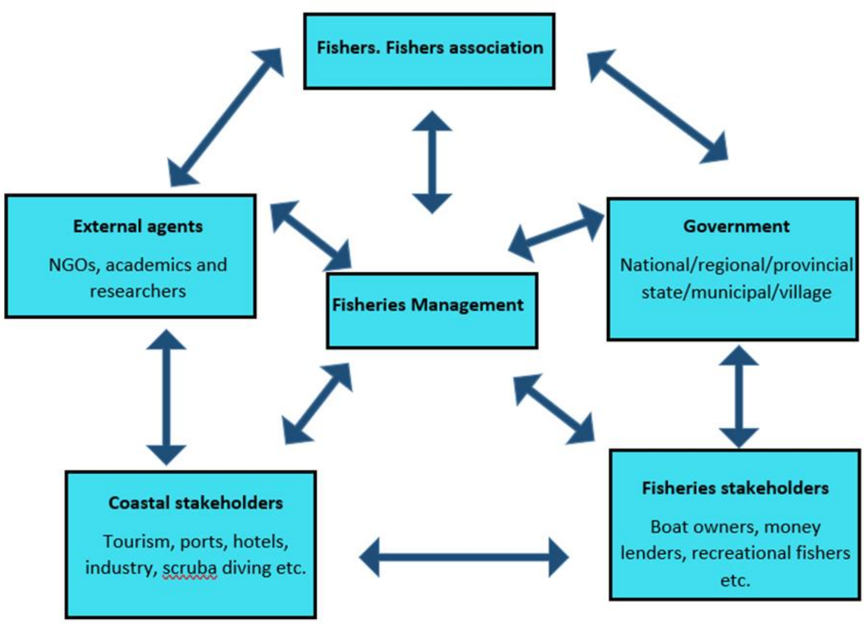

Fig. 4: Fisheries Management

Investments in Reliable Harbors, Landings, and Measures

To enhance the safety of maritime operations by enhancing early warning and forecasting systems for severe and extreme weather patterns and events and reducing the severity of storms (Cowan et al., 2012). Sufficient onshore storage facilities for vessels and cargo can mitigate the risk of loss or damage caused by extreme events and storms (Solomon, 2007).

Mainstreaming

According to Solomon (2007), it is crucial to incorporate the fisheries and aquaculture sectors into national policies for the availability and accessibility of food resources and adaptation to climate change. If such policies do not already exist, they should be drafted and passed. Planning, modifications, and trade-offs with other industries that impact aquaculture and fisheries (such as dams, irrigation infrastructure, and urban and agricultural runoff) will also be required (Shelton et al., 2014).

Capacity Building

Planning for climate change should involve civil society, NGOs, and government organizations as a whole, not simply more technically orientated departments like those dealing with fisheries, the interior, or meteorology (Smith & McCray, 2007). Cochrane et al. (2009) emphasized the importance of public-private partnerships in developing comprehensive adaptation strategies to climate change.

Spatial Planning

Smith & McCray (2007) noted that departments with a technical concentration, such as those dealing with fisheries or the interior, or science and meteorology, should not be the only ones involved in climate change planning; civil society, NGOs, and government organizations should also be included. Cochrane et al. (2009) emphasized the importance of public-private partnerships in developing comprehensive adaptation strategies to climate change.

Monitoring

This data will be used to inform adaptive management and better understand the effects (Mohanty & Sahoo, 2010). Because climate change will cause changes that many people and species will not be able to anticipate, it is critical to gather knowledge on what and when these changes will occur (Gilman et al., 2007). As more is understood and awareness grows, individuals will be better equipped to make decisions that benefit both the aquatic environment and the people who rely on it (Pitcher et al., 2009).

Ghost Fishing

It is probable that an increasing number of gears, including lobster traps, will be lost as storm severity increases. The loss of such equipment can result in habitat degradation and mortality. Nevertheless, certain measures can mitigate their effects (Leiva and Castilla, 2002). In addition to gear retrieval programmers, the specific gear could be engineered to mitigate the effects of loss (Ayub, 2010). For instance, traps may incorporate biodegradable escape panels that decompose within a week, enabling ensnared animals to escape (Mcleod et al., 2011).

Conclusion

Fisheries in Pakistan and other developing nations provide food for deprived communities, generate employment, and contribute to economic growth. The fish trade manages international debt, finances governmental functions, and facilitates local food imports, improving national food security and diet diversification. Climate change poses a significant challenge to Pakistan's fisheries, causing alterations that could lead to decreased fish production, posing risks to vulnerable communities and food security. Therefore, fisheries should be a key focus in policy formulation and sustainable production enhancement.

Increased investments in market development are crucial to mitigate climate change's impact on Pakistan's food security and fisheries. This includes enhancing sustainable enterprises, upgrading infrastructure and strengthening fisheries governance to improve food security and resilience. Pakistan's fisheries contribute to poverty reduction and food security, employing many and reducing foreign debt, but also pose a threat to limited resources due to climate change.

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