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Climate-smart fisheries production in Pakistan: A policy brief and way forward for decision-makers

Amina Shahzadi[1*], Sweara Kainat[2], Sumbal Ammara[3]

[1]*Department of Environmental science, University of Veterinary and Animal Sciences, Lahore, Pakistan*
[2]*CMH Institute of Medical Sciences, Bahawalpur, Pakistan*
[3]*Department of Environmental science, International Islamic University Islamabad, Pakistan*

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ABSTRACT

This study seeks to examine the contribution of fisheries to poverty reduction and food security, and portray the potential impacts of climate change on the already strained resources in Pakistan. Fish is a major source of food for the majority of poor and vulnerable communities in Pakistan. The sector also provides jobs to many men and women and is one of the most traded food commodities in the region. Fish trade supports economic growth in many developing countries in general and most in Pakistan, in particular by providing an important source of cash revenue to service international debt and importing food for domestic consumption, thus contributing to national food security and diversification of diets. However, the benefits gained from the sector are often overlooked in national economic planning. This study provides a review of the potential physical and biological impacts of climate change on fisheries by giving specific examples from Pakistan. It is clear that the higher the production level and per capita food supply from fishery products, the lower the prevalence of hunger. Nonetheless, the fisheries sector continues to lack sufficient attention by policymakers. It is recommended that increased and sustained investments in market development, fisheries governance, and provision of economic incentive mechanisms are crucial to minimize the potential impacts of climate change on fisheries and food security and increase the resilience of many poor fishers' communities in Pakistan.

Introduction

In this world, water is vital for all life forms. From all freshwater resources of the earth, only a very minute quantity is available to human beings, due to unplanned urbanization, use of chemicals, rapid industrialization, which causes varying levels of heavy pollution in aquatic organisms and deterioration of water quality of aquatic fauna including fish (Hadyait et al. 2020; Shelton 2014b). The life quality of any population is directly related to water quality and availability (Mirza et al. 2012). In recent years, the increased population growth and industrial activities have contributed to the worsening of the environmental problems mainly related to surface waters (Mehmood et al. 2020b). Any characteristic of water which affects the growth, reproduction, survival, production of aquaculture species are considered as water quality variable (Hadyait et al. 2020; Shelton 2014b)

Fishing is an important source for the food and country economy, it is also a source of livelihood for the coastal population of Pakistan (Siddiqi 1992). Fish is the cheap and most important source of animal protein for human beings (Ali et al. 2020). Catch from the wild (marine and freshwater) and aquaculture is the origin for fish and fishery products (Kartika 2014). With the increase in the human population, the demand for the food supply has increased. Fisheries is one of the best supporting sectors after agriculture for coastal societies and those inhabiting near inland water bodies, therefore domestic people are directly or indirectly dependent on the fisheries sector for their livelihood (Mehmood et al. 2020a). The majority of people inhabiting near coastal, rivers, dams, lakes, and reservoirs areas are carrying out varied occupations, for instance, capturing fish, fish netting, gear preparation and repairing, small-scale fish business, diesel provisions, loading or unloading fishing boats, processing, packaging, marketing, trading, aquaculture related industries and others services (Shah et al. 2019a).

Fish is one of the most traded food commodities in the region (Akpaniteaku et al. 2005). Fish trade supports economic growth processes by providing an important source of cash revenue to service international debt, funding the operations of national governments, and importing food for domestic consumption, thus contributing to national food security and diversification of diets (Shah et al. 2016). However, the benefits gained from the sector are often ignored or understated in national economic planning (Hutchings 2000). While the importance of fisheries is often understated, the implications of climate change for these sectors and coastal and riparian communities, in general, are difficult to ignore (Barange and Perry 2009).

Fisheries and aquaculture depend on aquatic ecosystems (freshwater, coastal, and marine) (Bellwood et al. 2003). These ecosystems are already feeling the impact of climate change due to their high sensitivity to changes in temperature, salinity, and acidity. As a result, livelihoods dependent on fisheries and aquaculture are expected to be among the first to be significantly impacted by climate change (Ali et al. 2009). Particularly vulnerable are the livelihoods of small-scale fish farmers and fishers on a small island (Bell et al. 2013). Climate change poses significant threats to fisheries on top of many other concurrent pressures such as overfishing, habitat degradation, pollution, the introduction of new species, and so on (Brander 2010).

** Corresponding Author: Amina Shahzadi*
E-mail Address: ali.ahmad0451797@gmail.com
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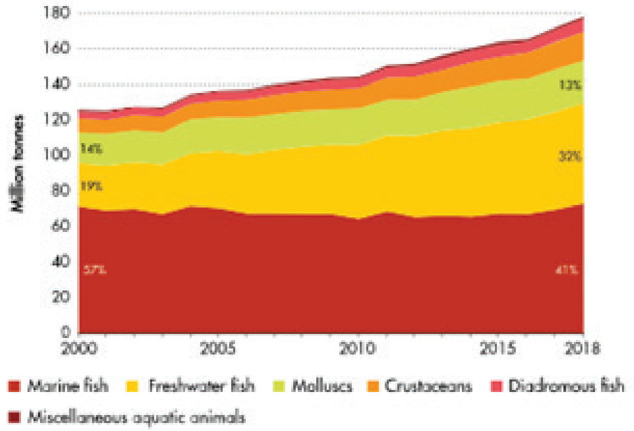

Figure 1-World capture fisheries and aquaculture production by species group, from FAO's Statistical Yearbook 2020

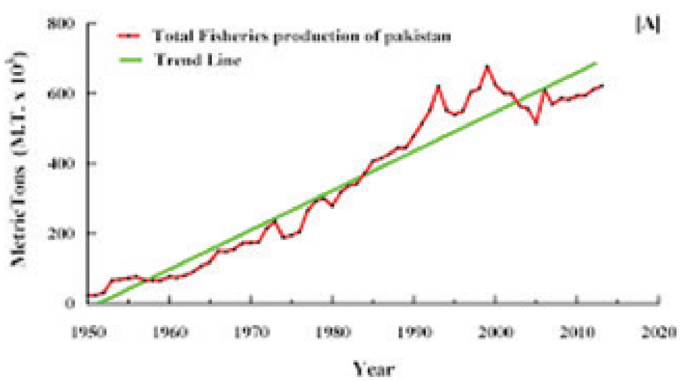

Figure 2- Total fish production in Pakistan

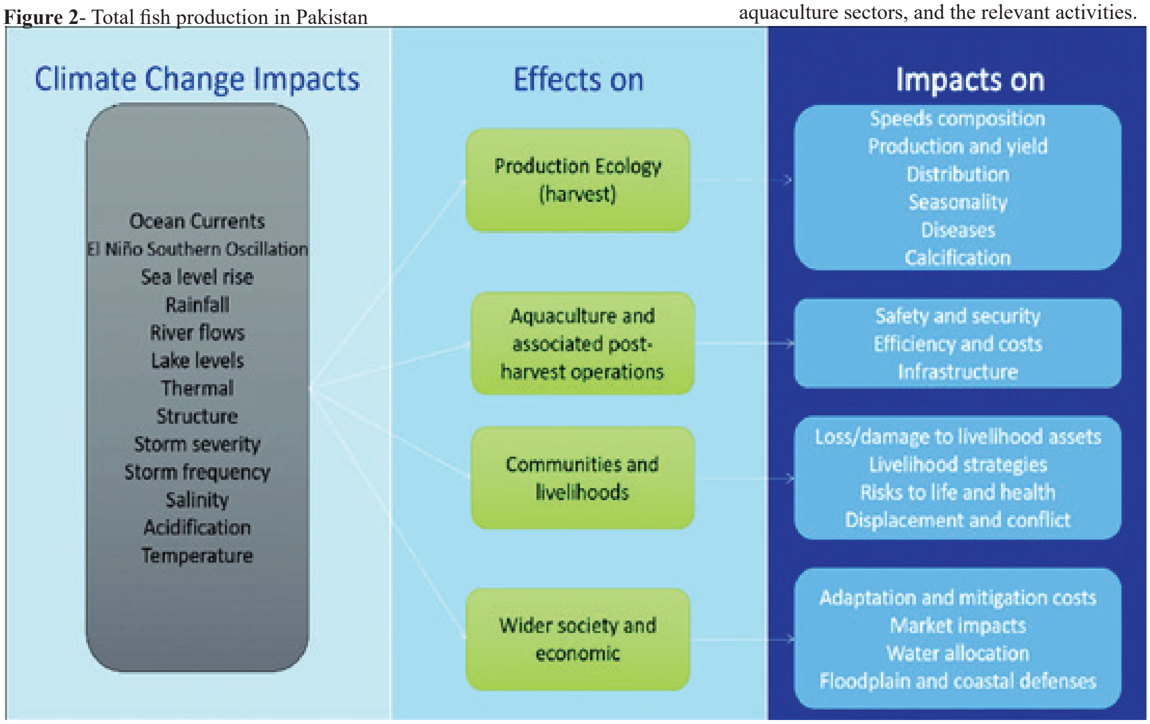

Figure 3- Climate change impact on fisheries and aquaculture

Changes in biophysical characteristics of the aquatic environment and frequent occurrence of extreme events will have significant effects on the ecosystems that support fish. This will affect food security in multiple ways (Moazzam 2013).

Pakistan, the less impacted by an increase in sea level and it resulted in damage of mangrove forests that are the major food and fuelwood source for breeding sites and residents for 90%of Pakistan's main exporter of fisheries (Mehmood et al. 2020b). Firstly, the extinction of some fish species means lower fish production for local consumption. Secondly, the migration of many fish species to aquatic environments with the optimal climatic condition will have a tremendous effect on fishers who are not able to follow fish due to political (borders) and economic reasons (Alam 1991). Finally, since most of the fish harvested for export in many developing countries is supplied by small-scale fisheries this will lead to reduced fish production thus lower earnings from fish export, and consequently reduced capacity to import food and exacerbation of national food insecurity (Mohammed and Uraguchi 2013).

The aquaculture and fisheries sectors are facing many challenges and constraints, both internal from within the sector (overexploitation of resources, discrimination in access to resources, and poor management) and external (competition from other land- and water-use sectors, pollution, and habitat degradation) (Anwar 2018). The sustainability of many fisheries around the world is already under threat from poor management and weak governance, leading to overfishing and environmental degradation; an estimated 30 percent of stocks are currently overexploited and 57.4 percent are fully exploited (Baset et al. 2020a; Siyal et al. 2013). Poorly planned aquaculture development has led to serious damage to freshwater and marine ecosystems, disease outbreaks, and human health scares (Moazzam and Nawaz 2014). In addition to these existing challenges, the broad impacts of climate change across ecosystems, societies, and economies are a compounding threat to the sustainability of fisheries and aquaculture (Allison et al. 2009).

Methodology

The literature review was global in scope and based on a desk review of published and grey literature. Data and information were summarized and analyzed to distill best practices.

Objectives

The purpose of this study is to synthesize available knowledge and best practices in climate change adaptation and mitigation in the fisheries and aquaculture sectors. Specifically, the study has the following objectives:

→ To review relevant literature on climate change, the fisheries and aquaculture sectors, and the relevant activities.

→ To identify best practices in climate change adaptation and mitigation in the fisheries and aquaculture sectors.

→ To guide the integration of climate change adaptation and mitigation measures in the fisheries and aquaculture sectors, and enhance the quality of management design, implementation, supervision, and evaluation processes, as well as engagement in policy dialogue.

Worldwide Fisheries Scenario

Globally people get 25% protein from fish and shellfish. In 2004 nearly 75% of global fish was used for straight human utilization (Lauria et al. 2018). However, in 1997 the demand increased to 57% and it will exceed 98.6 % in 2020 (((Mehmood et al. 2020a))). The benefits gained from the development of fisheries are significant (Mehak et al. 2018). From local to global levels, fisheries and aquaculture play important roles in the food supply, income generation, and nutrition (Brander 2007). Globally, some 43.5 million people work directly in the sector, with the great majority in developing countries (Brander 2007). Adding those who work in associated processing, marketing, distribution,

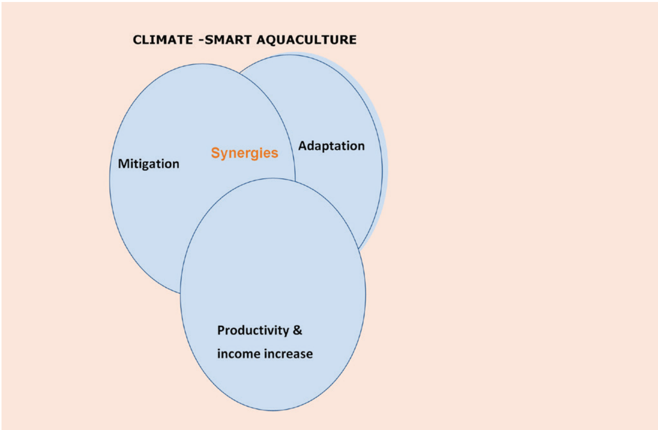

Figure 4- Climate-smart aquaculture

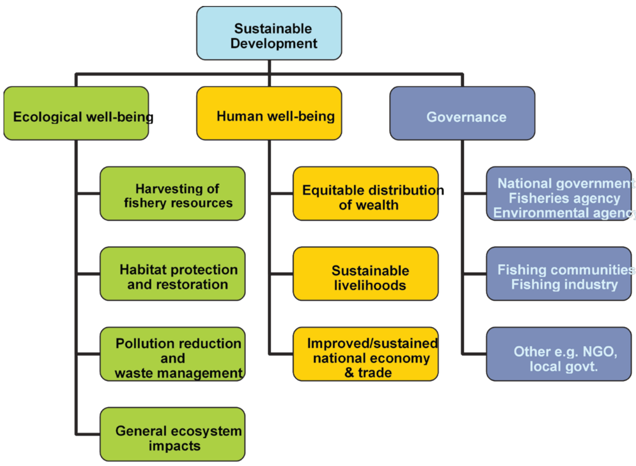

Figure 5-Expanded tree of sustainable development, with subsidiary policy objectives or issues that are relevant to planning under the ecosystem approach to fisheries framework

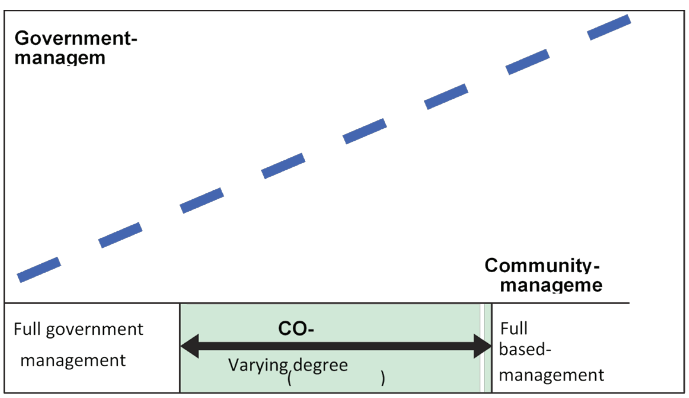

Figure 6- Co-management approach for fisheries management

and supply industries, the sector supports nearly 200 million livelihoods (Cochrane et al. 2009). This sector assures the livelihood of 10-12% of the world population. According to recently published The State of World Fisheries and Agriculture (FAO), the capture fisheries reported as 92.6 Million Tons (MT) in 2015 worldwide, including 81.2 MT by marine and other remained 11.6 MT captured from inland waters (Shah et al. 2019a).

Status of fisheries in Pakistan

Pakistan's fisheries sector comprises marine capture, inland capture, and freshwater aquaculture components (Nazir et al. 2015). The marine capture fishery is targeted by a fleet of bottom trawlers and gillnetters in the Arabian sea, as well as by artisan vessels in coastal waters and the Indus delta (Kaczan and Patil 2020). Total marine production of at least 350,000 tonnes per year is caught by an estimated

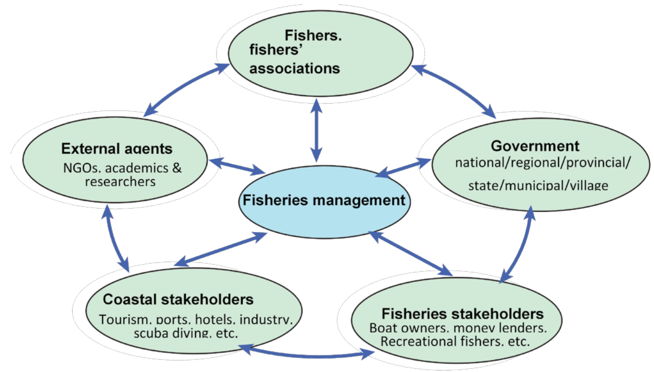

Figure 7- Fisheries management tools

204,000 fishers (Baset et al. 2020b). The Arabian Sea is ranked as one of the most biologically productive in the world (Mohsin et al. 2017b).

An aquaculture sector produces around 150,000 tons of fish per year, dominated by carp but with growing tilapia production, supplemented by trout in hillier areas (Mohsin et al. 2017c). Pakistan has a 1,120 km long area of coastline along with the Sindh and Baluchistan provinces with approximately 50,270 square kilometers (Km2) of the continental shelf and 350 nautical miles virtually (2,900,00 km2) of an exclusive economic zone (EEZ) (Tariq et al. 2020; Shah et al. 2017). On the other hand, thus it almost 3,102,408-hectare area of inland water reserves (Jarwar 2008). It is blessed with plenty of potential fishery resources (Mohsin et al. 2017c).

The significance of commercial marine fish fauna consists of 250 demersal fish species, 15 different kinds of shrimp, 20 large, 15 medium, and 50 small pelagic fish species, 5 lobsters, and 12 cuttlefish/squid/octopus's species (Nazir et al. 2015). Thus, the addition of freshwater fauna particularly comprises more than 235 species, which consist of 200 fish species (admitted 20 commercially valuable) and 35 types of shellfish included prawn and crab (Mohsin et al. 2019). The fisheries sector in Pakistan plays a substantial role in the alleviation of poverty and the accomplishment of food security (Majid 1996). However, considering of county's economy, it has not a very effective role yet, nonetheless, fisheries support various sub-branches of livelihood to relevant folks along with the coastal range and inland areas of the country (Mohsin et al. 2017a). Pakistan has enormous potential for aquaculture development which can lead to export-oriented economic growth (Shah et al. 2018a). Among others, human resource development is an important area that is needed to improve to boost fisheries and aquaculture development (Khan 2017).

In countries where aquaculture is practiced on a large scale training programs for the fish farmers play a pivotal role to promote the small-scale business of aquaculture in the coastal and inland areas (Baset et al. 2017). The small-scale business is assured to play a progressively vital role by contributing the most effective outlet by promoting individual employment and increasing employment growth rate. Export of fish from Pakistan is getting pace with time. To meet market demand and earn more profits, fishermen try to catch more and more fish (Shah et al. 2019b). This thirst has resulted in an enormous increase in the number of trawlers. Thus, their number has increased from 3 (1958) to 1631 (1985). According to a report, the recent number of trawlers operating in Pakistan is about 2400 (Panhwar et al. 2011). This happening has seriously threatened commercially important fish species in Pakistan (Mohsin et al. 2020).

In Pakistan, fish is usually consumed throughout winter starting from October till April. Fish consumption in Pakistan is low (Kartika 2014). The major reason for low consumption is the fact that most of the produced fish is exported. According to official information and records, most of the fish caught in Pakistan is from marine sources, which is declared to be 70 percent of the whole fish exports (Rehman et al. 2019). Pakistan exports fish mainly to Europe, US-Japan, and Middle Eastern countries, accounting for only 0.25 percent of world exports (Khan 2018). From the existing natural resources, the total export potential has been estimated to be about 1 billion US dollars (Baset 2020).

Significance of the fisheries sector and its role in economic

Pakistan is a predominantly agricultural country where about two-thirds of its 135 million population is dependent, either directly or indirectly, on agriculture (Noman et al. 2019). Fisheries, a sub-sector of agriculture, plays a significant role in Pakistan's national economy and contributes towards the food security of the country (Mohsin et al. 2017a). Contributing about 1.0 percent to the total GDP, which is equivalent to about 4.0 percent of the GDP of the agriculture sector, it absorbs 1.0 percent of the country's labor force (Nazir et al. 2016). The fisheries sector provides direct employment to about 400,000 fishermen and 600,000 people in ancillary industries (Nazir et al. 2017). With their families, they depend on fishing for their livelihood (Mohsin et al. 2016). The export of fish and fishery products during 1999–2000 reached 92 000 tonnes, this corresponding to a value of $US 139 million (Akhtar 2003). Estimated annual fisheries production is about 0.6MMT (Million metric tons) including 63% marine and 37% inland (Daudpota et al. 2014). Pakistan has about 193 freshwater fish species, and 800 marine species (Amman et al. 2020).

Fish production in Pakistan during 2000 was 654 500 tonnes, of which 474 400 tonnes (about 72 percent) was caught from the sea whereas 180 000 tonnes was obtained from inland waters, 80 percent of which was captured from a network of rivers, irrigation canals, and lakes (Kalhoro et al. 2013). Aquaculture in Pakistan benefits from irrigation, as about 75 percent of the fish ponds in the country are supplied with water by irrigation canals (Akhtar 2003). During 2006-2007 the fisheries sector witnessed a growth of 4.2 percent (Jarwar 2008). In 2013, the Pakistani fisheries sector contributed 62.30 thousand Metric Tons (MT) including 14.81 thousand MT from aquaculture and 47.49 thousand MT from capture (Mohsin et al. 2019). Although, export and import were remained at 11.08 thousand MT and 0.16 thousand MT, respectively, except that value of export earnings was 2.27 million USD and import expenditure 4,313 USD (Kartika 2014).

The fishing sector contributes 3.25 percent growth in Agriculture for the year 2015-2016 and 5.75 percent growth for the year 2014-2015 are shown in figure 2 (((Mehmood et al. 2020a))). Therefore, the fishery plays a major role in the economy of the country and some common fishermen (Mohsin et al. 2018). In the year 2016-17, the country's Gross Domestic Product (GDP) was 5.3 %, as compared to previous years additional 0.8 %, by the year 2015-16, economic expansion was 4.5 %11,12. In 2017, 19.53 % of the share in GDP was contributed by the agriculture sector with the support of is four major sub-sectors viz. crops, livestock, fisheries, and forestry (Khan 2017). The share of fisheries in agriculture was 2.12 % and its share in GDP accounted for 0.41 %, respectively. However, the revenues and costs are the main components to determine the economic performance of fishing operations (Tariq et al. 2020).

The export of seafood from Pakistan was enhanced to 16,991 tons and the value was 49.82 million USD in 2014 (Shah et al. 2018b). Furthermore, it is reported, that in the year 2015, Pakistan fisheries had produced 643164 MT, including 491990 MT from capture fishery and the rest 151174 MT contributed through aquaculture17,18 (Khan and Khan 2011). The progress of total fisheries production was more prominent with an increase to 19707 MT, including 16914 MT increase in capture and 2793 MT from aquaculture as compared to the previous year 2014 17,18 (Noman et al. 2018). The exports of fish and fish preparations in the first half of Fiscal Year (FY) (Dec 2016-July 2017), fishery exports and preparations had earned as US$ 183.5 million, which depicts an increase of more than 10 % as compared to the US$ 166 million for the FY 2015-2016 (Shah et al. 2019a).

Shrimp fisheries are an important fisheries resource in Pakistan. This fisheries resource has played a vital role in revenue generation through its export. The capture production of shrimps was just 2900 t in 1950. This quantity has increased manifolds and according to reported data in 2015 about 18981 t of various types of shrimps were captured in Pakistan. Unfortunately, recent statistics indicate that capture production of this fisheries resource is decreasing because of overexploitation (Memon et al. 2015). In contrast, to capture production, aquaculture production of shrimps is getting pace, from 1988 (40 t) to 2015 (119 t) it increased considerably, but the growth rate is very low. The export quantity of shrimp fisheries from Pakistan is increasing and has reached 21155 t (75519000 USD) in 2015. However, the market composition is changed now (Mahmood 2013).

China is the biggest emerging export market for shrimp fisheries from Pakistan. About 75 % of shrimp products are sent to China. The export potential of this fisheries resource is immense and can be increased further by augmenting production and implementing trade promoting policies (Mehak et al. 2020). In Pakistan, different laws, regulations are made for the protection and export of fisheries and aquaculture products. These include the fisheries act 1897, fisheries development board, marine fisheries department. In Pakistan, the first comprehensive fishery policy was announced in 2007. Our Policies must have to facilitate flexibility, such as diversification of access to fisheries and alternative livelihoods. It should provide better assets, such as the enhancement of fisheries technology and capacity.

Climate change impacts on fisheries and aquaculture

Climate change impacts the fisheries sector in direct and indirect ways, resulting from processes in aquatic ecological systems, as well as through political, economic, and social dynamics. Capture fisheries depend entirely on the productivity of the natural ecosystems on which they are based (Free et al. 2020). They are, therefore, extremely vulnerable to changes in primary production and how much production is transferred through the aquatic food chain. They are also vulnerable to changes in the physical and chemical parameters of the ecosystems, including temperature, salinity, acidity, and water levels and flows. Aquaculture is also exposed to direct and indirect impacts of climatic change are shown in figure 3, although fewer features and consequences of climate change affect this sector due to a greater level of human control (Chandio et al. 2020).

The vulnerability of aquaculture-based communities is primarily a function of their exposure to extreme weather events, as well as the impact of climate change on the natural resources required to undertake aquaculture, such as quality water, land, seed, feed, and energy (De Silva and Soto 2009). This will require adaptation and improvement of aquaculture systems and species, as well as greater disaster preparedness. It is important to remember that it is difficult to establish a unique causal chain between particular climate change effects and the impacts on fisheries and aquaculture. Rather, it is the cumulative effects of climate change and human responses that count (Salik et al. 2015). The impacts of climate change on fish stocks in Pakistan can be classified as physical and biological changes. Physical changes include sea surface temperature rise, sea-level rise, changes in salinity, and ocean acidification (Solomon 2007). Biological changes include changes in primary production, and fish stock distribution. These factors when combined will have adverse impacts on the already strained resource (Taylor et al. 2016). There are the following impacts of climate change on fisheries;

Physical Changes

Warming of oceans and other water bodies

Changes in ocean fish productivity are expected due to changes in ocean conditions, including the timing of plankton blooms and hence food availability, alterations in predator-prey relationships, and fish stock dynamics. productivity will likely reduce at lower latitudes due to rising temperatures and sea warming (Daw et al. 2009b). The effect on fisheries is uncertain, though the disruption to ecosystems is likely to result in overall declines in fish production in the medium term. Extinction of some species has been predicted if the maximum tolerable heat threshold of the species is crossed and there is no possibility of migration (for example, in inland water bodies) (Cochrane et al. 2009). Increased incidence of toxic algal blooms and shellfish poisoning caused by rising temperatures can disrupt market access if monitoring and testing services fail to identify products that do not meet export requirements (Mcleod et al. 2011).

Reduced levels of dissolved oxygen in the water can reduce larval survival, impede fish growth, or block migrations. There will be an increase in areas where oxygen levels will decline to very low levels (dead zones), in which no fish or invertebrates can survive. Shifts in the distribution of many fish and shellfish are expected, as the progressive warming of the oceans will push marine fish stocks to migrate toward higher latitudes (Badjeck et al. 2010). Such changes could affect the distribution and phenology of fish larvae, with large impacts on the recruitment and production of fish stocks. Potential increases in growth rates, food conversion efficiency, and duration of the growing season are likely to occur for some farmed fish species due to higher temperatures (Shelton 2014a).

Sea level rise

An increase in inundation, flood, and storm damage is expected, which will affect nursery grounds and fish habitats and accelerate coastal erosion (Bindoff et al. 2007). Saltwater intrusion in deltaic regions could raise water tables, impede drainage, and cause loss and damage to wetlands (Urama and Ozor 2010). On the other hand, inundation and intrusion of saline waters into agricultural land might increase the area available for aquaculture or rice-fish farming with saline-tolerant varieties of rice (Sumaila et al. 2011). Brackish-water aquaculture might also be an attractive alternative in those areas where salinity makes land unsuitable for rice or other crop cultivation. However, this form of aquaculture could lead to local power conflicts, such as the recurrent conflict between poor rice cultivators and powerful shrimp farmers (Marshall and Elliott 1998).

Changes in salinity

Salinity is also considered one of the most important variables determining the survival of organisms in estuarine ecosystems; either by having a direct impact on the organisms or indirectly by destroying their habitat, including their breeding and nursery grounds (Abowei 2010; Marshall and Elliott 1998). Osmoregulation of marine species will be adversely affected by changes in salinity. The effects will be more severe for those species that are tolerant to only small variations in water salinity, such as zooplankton living in coastal low-lying tidal lakes and wetlands in tropical areas (Schallenberg et al. 2003). This would have grave implications for the food chain relying on them and hence the ecological functioning of coastal wetland ecosystems, with huge impacts on local fisheries.

Ocean acidification

Decreased seawater pH (or increased "ocean acidification" resulting from the ocean's absorption of excess CO2) is effectively irreversible in terms shorter than millennia and presents a major systemic threat (Dupont and Thorndyke 2009). Many coral reefs will be destroyed as a direct result of ocean acidification, and the productivity of shellfish and zooplankton is likely to decrease (Sumaila et al. 2011). Calciferous (i.e. animals that use calcium to build their shells or skeletons) are sensitive to acidity, as it impedes their ability to form hard shells and hence reduces their tolerance for high and low temperatures, leading to higher levels of mortality and lower fertilization success (Le Quesne and Pinnegar 2012). Quantifying the effects of ocean acidification on human communities requires assessing the direct and indirect chemical impacts on valuable marine ecosystem services such as fisheries (Cooley et al. 2012). According to Le Quesne and Pinnegar (2012), direct effects include changes in physiological processes such as reduced growth of calcified structures, otolith development, and fertilization success. These may ultimately lead to direct impacts at the whole-organism level, including reduced growth and reproductive output, increased predation and mortality, alteration in feeding rates and behavior, reduction in immune competence, and reduced thermal tolerance. However, Indirect effects include alteration in predator or prey abundance, effects on biogenic habitats such as coral reefs, and changes in nutrient recycling. While adult fish seem well-equipped to deal with low pH waters, or higher levels of CO2 in seawater, their egg, and larval life stages may not be so fortunate (Petr et al. 2002).

Changes in rainfall patterns and evaporation rates

Impacts on freshwater systems will reduce water levels, flow rates, and overall water availability, and increase water stress, aridity, and drought spells (Urama and Ozor 2010). The decreased river flows resulting from increased erosion, sedimentation and increased irregularity of rain will, in some cases, threaten ecological production and freshwater fish populations in the affected rivers. Increased flooding from rivers and lakes will, in some cases, result in increased waterlogging and submersion of land by freshwater (Barange and Perry 2009). This may have tremendous socio-economic effects either by (1) lowering export earnings of net mollusk exporting nations; (2) reducing jobs for many fishers involved in mollusk farming and harvest; or (3) increasing mollusk prices which may exclude marginal consumers – further widening protein and wealth gaps between the rich and poor (Bindoff et al. 2007).

Increase in extreme weather events

Increased storm intensity will cause extreme water levels and wave heights, increased episodic erosion, storm damage, risk of flooding, and defense failure. Aquaculture is very susceptible to storms, cyclones, and floods, which are predicted to occur with greater frequency in the future, especially in tropical and subtropical monsoon regions. Aquaculture facilities could be damaged and the crop lost, while escapees could increase the risk of disease and parasitic infestation of wild stock, as well as impact the environment and biodiversity. An increase in extreme weather events poses increased risks to safety at sea, loss of fishing equipment and physical capital, and loss of revenue from the reduction of fishing activities as a result of the increasing frequency of bad weather. Insecurity and vulnerability are also exacerbated by the lack of any kind of insurance, difficulty in accessing credit or public welfare. Changes in wave climate will cause altered wave conditions (including swell), altered patterns of erosion and accretion, and reorientation of beach plan forms.

Biological changes

Climate change is already affecting the trends of some important biological processes, resulting in changes in primary production and changes in fish distribution (Taucher and Oschlies 2011). Climate-induced changes in primary production and fish stock distribution have negative implications on food security in many tropical coastal states in general and Pakistan in particular (Sumaila et al. 2011).

Changes in Primary Production

The relationship between climate change and future ocean primary production is likely to be a key constraint on fish and fisheries production (Dupont and Thorndyke 2009). The survival of fish larvae during the planktonic stage is thought to depend strongly on the availability of sufficient and suitable food (Brander 2010). Therefore, in addition to the effects of changes in production, climate-induced changes in distribution, and even though multiple factors affect primary production in the aquatic environment, one of the main factors is surface temperature rise. (Pörtner and Peck 2010) suggest that if air temperature increases by about 1.7 degrees, as predicted for the next 80 years, there will be further increases in thermal stability and reductions in productivity in these large lakes. They further warn that the human implications of such faint but progressive environmental changes are potentially dire in this region of the world, where large lakes are essential natural resources for regional economies (Mowla 2016).

Changes in Fish Distribution

Change in fish distribution is among the most commonly reported ecological responses of marine species (Sumaila et al. 2011). Fish species are believed to respond to environmental changes such as warming water temperatures by shifting their latitudinal and depth ranges. Changes in ocean dynamics could lead to changes in migration patterns of fish and possibly reduce fish landings (Urama and Ozor 2010). The effects of changes in fish-stock distribution vary across latitudes. Some fish species will migrate due north in search of habitats with optimal water temperature and thus potentially increasing fish harvest in higher latitudes. Therefore, such changes in fish stock distribution will change the distribution of benefits and costs of fisheries with some winning and some losing (Chandio et al. 2020).

Climate change adaptation and mitigation options for fisheries and aquaculture

Climate-smart aquaculture (CSA)

Climate-Smart Aquaculture aims to support food security taking into account the need for adaptation and the potential for mitigation. CSA addresses the challenges of building synergies between the related objectives of climate change mitigation, adaptation and productivity, and income increase and minimizing their potential negative tradeoffs. Climate-smart aquaculture will require the following:

- Improving efficiency in the use of natural resources to produce fish and aquatic foods.
- Maintaining the resilience of aquatic systems and the communities that rely on them to allow the sector to continue contributing to sustainable development.
- Gaining an understanding of the ways to reduce effectively the vulnerability of those most likely to be negatively impacted by climate change Figure 4.

Mitigation measures to reduce climate change impact on fisheries

Although fisheries and aquaculture do not emit large volumes of GHGs when compared with other industries, industry GHG emissions could be reduced (Harrod 2015). Improving fuel efficiency by switching to more efficient gear types or vessels, switching to sails, or changing fishing practices would reduce emissions from fishing activities. This would also reduce fuel costs, although switching to more efficient vessels and/or gear may only reduce fuel use by 20 percent (Nandy et al. 2018). Product transport is where more sectoral emissions come from, and emission reductions are possible. Using bulk sea freight rather than air freight or non-bulk sea freight, or increasing consumption closer to the source (reducing travel distance) would reduce fuel use (Holsman et al. 2019). Even if international fishing continues to increase, including fish from developing countries traveling to developed country markets, these changes in product transportation can ensure that fishery contributions to GHGs do not increase at the same rate (Mowla 2016).

Adaptation for fisheries and aquaculture sector

Adaptation to climate change is defined in the climate change literature as an adjustment in ecological, social, or economic systems, in response to observed or expected changes in climatic stimuli and their effects and impacts to alleviate adverse impacts of change or take advantage of new opportunities (Caputi et al. 2015). In other words, adaptation is an active set of strategies and actions taken by people in reaction to, or in anticipation of, change to enhance or maintain their well-being (Burgess et al. 2018).

Adaptation can therefore involve both building's adaptive capacity to increase the ability of individuals, groups, or organizations to predict and adapt to changes, as well as implementing adaptation decisions, i.e. transforming that capacity into action (Daw et al. 2009a). Both dimensions of adaptation can be implemented in preparation for, or response to impacts generated by a changing climate. Hence adaptation is a continuous stream of activities, actions, decisions, and attitudes that informs decisions about all aspects of life and that reflects existing social norms and processes (Baset et al. 2020a).

Adaptation can be planned or autonomous (i.e. spontaneous reaction to environmental change or planned action based on climate-induced changes). Autonomous adaptation in fisheries may be changing the timing or locations of fishing as species arrive earlier/later or shift to new areas (Daw et al. 2009b). Planned adaptation in fisheries may be research funding for finding species resistant to salinity and temperature fluctuations for aquaculture. A "no regrets" approach relies on building general resilience without a heavy reliance on specific climate impact projections, which is useful in areas with high impact uncertainty, which include many equatorial areas and developing countries without long-term historical climate data sets (Williams and Rota 2011). Adaptation in fisheries and aquaculture can include a variety of policy and governance actions, specific technical support, or community capacity-building activities that address multiple sectors, not just capture fisheries or aquaculture farmers (Thorpe et al. 2005).

Ecosystem approach to fisheries and aquaculture

FAO's definition of the ecosystem approach to fisheries and aquaculture (EAF and EAA) is longer but reflects the same concept as the more general definition of the ecosystem approach (Jennings 2005): An Ecosystem Approach to Fisheries (or Aquaculture) strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries (Garcia and Cochrane 2005). These areas can be further subdivided into policy objectives and issues which need to be addressed (see Figure 5).

Co-management is the tool to make EAF more participatory. It describes the spectrum of shared management between the extremes of exclusively community-based management (with full devolution of responsibility to communities/fishers) through to central government management (with full responsibility controlled by the government) (Zhou et al. 2010). Fisheries co-management is a partnership approach where government and the fishery resource users share the responsibility and authority for the management of a fishery or fisheries in an area, based on collaboration between themselves and with other stakeholders, especially NGOs (Schmidt 2014).

The network of stakeholders that need to be involved in EAF is complex (Figure 6), both in terms of vertical linkages (national to local), horizontal linkages (between different users of the natural resources), and in terms of geographic coverage. A communication and information exchange network is critical for success (Paukert et al. 2016). Daw et al. (2009b) reported that although adaptation is context-specific, several adaptation activities can be applied in most fisheries and aquaculture contexts as shown in (figure 7). These include:

Reduce external stressors on natural systems

Reduce land-based sources of pollution (e.g. agricultural and urban runoff) and destructive fishing practices (e.g. fishing with explosives and poisons) (Muddassir et al. 2019).

Identify and protect valuable areas

For example, deep pools in river systems, such as the Mekong River, provide sanctuary for fish during dry seasons, are important local fisheries themselves and play an important role in upstream and downstream fisheries as they are also often spawning areas (Clark 2006). These areas will be affected by both climate change impacts on the hydrologic cycle as well as upstream and downstream activities (e.g. dam-building leading to siltation, or basin development leading to pollution runoff).

Investments in safer harbors, landings, and measures

To improve safety at sea due to increased storm severity as well as improved early warning and forecasting systems for severe weather events (Cowan et al. 2012). Adequate onshore storage facilities for boats and gear can prevent loss or damage from storms and extreme events (Solomon 2007).

Mainstreaming

Integrate fisheries and aquaculture sectors fully into climate change adaptation and food security policies at the national level (draft and enact where non-existent) to ensure incorporation into broader development planning (Solomon et al. 2007). This will also involve trade-offs, compromises, and planning with other industries affecting fisheries and aquaculture (e.g. irrigation infrastructure, dams, and urban and agricultural runoff) (Shelton 2014b).

Capacity building

Civil society, non-governmental organizations (NGOs), and government organizations need to be included in climate change planning, not just technically focused departments such as fisheries/interior agencies or science and meteorology departments (Smith et al. 2007). Partnerships between private, public, civil society, and NGO sectors are vital for holistic climate change adaptation planning (Cochrane et al. 2009).

Spatial planning

This comprises marine and terrestrial zoning for siting of aquaculture facilities (subtidal and terrestrial systems) and mangrove areas to balance aquaculture needs with terrestrial development and shoreline protection with rising sea level (Taucher and Oschlies 2011). Besides, the need to think long term about requirements for current coastal activities to shift landwards as shorelines retreat over time (Wasim 2007).

Monitoring

This information will feed into adaptive management as well as contribute to understanding what impacts are occurring (Mohanty et al. 2010). As climate change will introduce changes outside the scope of experience for many people and species, it is important to collect information on what and when these changes are (Gilman et al. 2007). As more is learned and understanding becomes more refined, people will be better able to make decisions that result in benefits for both the aquatic environment and the people who depend on it (Pitcher et al. 2009).

Ghost fishing

As storm severity increases, it is likely that more gear, such as lobster traps, will be lost. Such lost gear can cause mortality and habitat damage. However, some measures can reduce their impacts (Leiva and Castilla 2002). In addition to gear retrieval programmers, the certain gear could be designed to minimize impacts if lost (Ayub 2010). For example, traps could have biodegradable escape panels (e.g. after a week) so trapped animals would be able to escape (Mcleod et al. 2011).

Conclusion

Fisheries are a major source of food for the majority of poor and vulnerable communities in Pakistan and other developing countries. The sector also provides jobs to many men and women and is one of the most traded food commodities in the region. Fish trade supports economic growth processes in developing countries in general and Pakistan in particular, by providing an important source of cash revenue to service international debt, funding the operations of national governments, and importing food for domestic consumption, thus contributing to national food security and diversification of diets.

However, climate change poses a significant threat to fisheries in Pakistan. The potential impacts of climate change on fisheries are categorized as physical and biological changes. These negative effects when combined are going to have adverse impacts on the already strained resource, thereby reducing fish production. Depletion of fish stock and reduction in fish production could threaten the livelihoods of many vulnerable fisher communities and the food security of Pakistan. Therefore, it is argued that fisheries should come at the forefront of the process of adaptive policy formulation, and sufficient investments should be made to boost sustainable fish production in Pakistan.

It is also recommended that to minimize the potential impacts of climate change on fisheries and food security and to increase the resilience of many poor fisher communities in Pakistan, increased and sustained investments are needed in market development through investments that support sustainable artisanal fisheries businesses and market infrastructure, to address post-harvest and income losses; and fisheries governance to provide economic incentive mechanisms. Such investments combined would strengthen the resilience and adaptive capacities of many poor and vulnerable communities and nations, and enhance food security.

Conflict of interest

The authors declare that they have no conflict of interest

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