**Sustaining Inland Fisheries Amidst Climate Change: Implications and Solutions**

Barkha Rai

Assistant Professor

 Department of Zoology, St. Joseph’s College,

Darjeeling, West Bengal, (India) - 734104

Email-barkrai@gmail.com

**Abstract:** The impact of climate change on inland fisheries, particularly in countries like India, poses significant challenges to both the environment and the livelihoods of millions. Rising temperatures, erratic rainfall patterns, and extreme weather events disrupt crucial processes like fish reproduction, migration, and growth. These changes not only affect fish populations but also have socio-economic implications, threatening the income and nutrition of fishing communities. Climate-induced floods and droughts further exacerbate the situation, leading to economic losses and damage to infrastructure. To address these challenges, adaptive measures such as enhancing resilience, implementing ecosystem-based fisheries management, and promoting sustainable practices are crucial. Identifying climate-resilient species, developing early warning systems, and utilizing inundated areas for fish culture are among the proposed strategies. Collaboration among stakeholders, including fishermen, researchers, policymakers, and NGOs, is essential for effective mitigation and adaptation efforts. By prioritizing the long-term sustainability of aquatic resources and livelihoods, it's possible to mitigate the adverse impacts of climate change on inland fisheries and ensure the resilience of fishing communities.

***Key words****:* Global climate change, inland fisheries, erratic rainfall pattern, fish reproduction, adaptive measures, livelihood of fishing communities, sustainable fishery management

**Introduction**

Fishes are one of the most traded food resources globally, with a turnover reaching 182 million tonnes in 2021, highlighting its key role in economic development and global food security (FAO 2023). An estimated 58.5 million people are employed and an additional 600 million are partially dependent on this sector for their livelihood (FAO 2023), particularly in the developing countries. But this vital source of economy and livelihood of millions is under facing multitude of challenges, with pollution and climate change emerging as primary concerns.

Climate change has risen to the top of the global policy agenda due to its conservation concerns, environmental and food security implications (FAO 2007; Daw et al., 2009; Mirzabaev et al., 2023). Inland aquatic ecosystems are vulnerable to climate change, which greatly affects the dynamics of fish populations (Adrian *et al*. 2009; Panikkar et al.,2022; Nagelkerken et al., 2023). It can have broader implications beyond the direct effects on fish physiology and reproductive processes. It can also lead to indirect consequences, such as alteration in ecological relationships and competitive and predatory interactions (Portner and Peck 2010; Domeneci et al., 2019; Millington et al., 2022).

According to National Fishery Development Board report (2018-19), India ranks second in the production of fishes, both in terms of catch fish and aquaculture. The discernible shift in climatic conditions, such as rise in temperature, sporadic and untimely rains, frequent episodes of droughts (Behera et al., 2019; Krishnan et al., 2020; Saxena et al., 2022) .The lowest temperature of water in upper Ganges has witnessed an increase of 0.99°C, while the lower Ganga basin, experienced temperature rises, ranging from 0.5°C to 1.4°C over a span of several years (Das *et al.,* 2013; Sarkar et al., 2022) Top of Form. As a result, a decrease in the reproductive and spawning behaviour of freshwater fishes like carps in major river basin have been observed (Das et al. 2013; Sarkar et al., 2017). They further reported a decrease in rainfall during mating season (March- September) affecting 92% of fish propagation facilities in some districts of Bengal.

Studies throughout the world emphasize the adverse effects that changing climate conditions have on freshwater ecosystems. (Woodward et al., 2010; Das et al., 2016; Capon et al., 2021; Singh et al., 2021; Vari et al., 2022). In India, where millions depend on riverine ecosystem for their livelihood, climate-induced floods, wreak havoc annually, displacing millions living in the low-lying areas along river basins, inflicting huge financial losses (Singh and Kumar 2017; Parida and Dash 2019). In the southern peninsular region of India, where a significant proportion of the population are engaged in fishery sector, rising temperature and erratic rainfall pattern threatens the sustainability of major river basin highlighting the scientific interventions for inland fishery (Revadekar et al., 2012). Climatic model studies have revealed India to experience hotter and wetter climate in the future, impacting the biodiversity vis-à-vis the riverine fisheries. Despite the importance of inland fishery in terms of food security, employment opportunity, and cultural significance, there is scanty data on the climate impact in open water (Paul et al., 2019, 2020). The projected implication in terms of fish productivity and livelihood sustainability of millions depending on this sector, underlines the urgency of effective management intervention (Singh and Kumar 2017).

Human actions are primarily accountable for the ecological disbalance of our biosphere. Habitat reduction and environmental degradation, over-exploitation, colonization of alien non-native species, are all contributing to the challenges (IPCC 2014a) faced by inland fishery. The impact of the climate change, coupled with other anthropogenic stressors are often unpredictable. It is therefore, imperative that various stakeholders including government, resource managers and fishermen understand what climate change means in terms of fisheries. This article highlights the empirical evidences to point out the urgent need for concerted action to lessen the outcome of climate crisis on inland fisheries. Understanding vulnerabilities and implementing adaptive strategies are discussed to safeguard these vital ecosystems and the livelihood it supports.

**Recent climate trends affecting Inland Fisheries in India**

Modifications in climatic patterns of India, as summarized have significant implications for inland fisheries Recent data further supports these trends (i) A surge in the ambient temperature by 0.4°C over the past hundred years nationwide (Sharma et al. 2014; Mehraj et al., 2022). (ii) The major rivers like the Ganges, Brahmaputra and Indus are sustained by the Himalayan glaciers which are receding. However, this tendency is not uniform throughout the whole mountain range. (iii) Regional disparities in monsoonal rainfall across India indicate shifting precipitation patterns (Naidu et al., 2006) (iv) There has been an annual rise in sea levels ranging from 1.06 to 1.75 mm (Unnikrishnan and Shankar, 2007; Sharma et al., 2014), aligning with global estimates of 1–2 mm per year (IPCC 2014b; (Mehraj *et al.,* 2022). (v) Extended periods of recurrent droughts, rising patterns of severe cyclones, floods and an increasing tendency for heavy precipitation, especially noticeable along the coastlines of West Bengal, Gujarat and Odisha (Achyuthan 2021; Subramanian et al., 2023)

**Climate Change Effects on Inland Fisheries and River Ecosystem**

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The effects of climate change on inland fisheries have been well recognized (Comte et al., 2018; Harrods et al., 2018). Climate change influences water temperature, flow, and habitat loss. Global warming over the decades have shifted the snow line to higher elevations, glaciers are shrinking throughout the mountains seriously impacting snow-fed river systems (Allison *et al.* 2007). Climate change interferes with the hydrological cycle, contributing to untimely floods and droughts (Hasnain, 2002; Fujita et al., 2001). Changes in key climate variables, like rainfall and temperature affect water availability and quality. Major rivers in India, such as the Ganga, Brahmaputra, and the Indus, are at risk due to climate change. Similarly, central Indian rivers are experiencing declining run-off (Shrivastava and Shrivastava 2019; Sowjanya et al., 2022).

Rivers' water carrying capacity varies based on precipitation, geological features, and hydrological processes shaping wetlands and floodplains. River flow influences interactions with floodplains, impacting habitat diversity and biotic communities (Sharma *et al.* 2015). Human activities affecting river flows have significant implications for fishery resources, while sea-level rise further threatens freshwater sources near coastal regions with salt intrusion (Klassen and Allen 2017). Rising temperatures affect aquaculture and fishery activities, while changes in the hydrological system pose challenges for fish populations. Major river systems vital for millions, face climate change impacts, with Himalayan rivers experiencing altered discharge patterns, and non-snow-fed Indian rivers facing water shortages or excessive floods (Ficke et al., 2007; Arnell et al., 2001; MoEF 2004).

Furthermore, the foreseen effects of climate crisis on fish production could lead to economic losses in developing nations globally (Brander 2007; Allison *et al.* 2009). This is mainly attributed to reduced rainfall, increased irrigational demands, and constructions of dams (Patrick 2016; Halls and Welcomme 2004). Any alteration in the environment, including an increase in water temperature, leads to variations in the distribution of fishes. The main ecological response frequently observed is a change in their latitudinal and depth extent (Mohammed and Uraguchi, 2013). In India, such phenomena have been reported in fishes like *Xenentodon cancila*, *Puntius ticto*, *Glossogobius giuris*, and *Mystus vittatus*, which previously inhabited the warm central part of the Ganges but can now be found in the colder sections of the river (Das et al., 2019).

A substantial fall in water availability have been projected from 1820 m3/year in 2010 to 1140 m3/year in 2050 (Gupta and Deshpande, 2004). Decrease water flow and frequent occurrence of droughts may alter inland water levels, potentially weakening the productivity of inland fisheries. Additionally, increased frequency of severe climatic conditions, which could lead to notable alterations in fish assemblages (Illari et al2022). Climate change is significantly impacting fish populations, leading to a decline in native species and an increase in invasive ones. Over time, fish communities have become less diverse as invasive species become more dominant. High temperatures and low precipitation favour these invasive species, further contributing to the decline of native populations. This significant shifts in fish populations across various river ecosystems is believed to adversely affect the Indian fishery industry. On the contrary, increased overall productivity across different trophic levels of the river basin ecosystem has been observed. This is attributed to elevated drainage, higher flow rates, floodplain expansion, and increased water levels during arid periods.

 **Thermal Dynamics in Aquatic Ecosystems: Implications for Fish Physiology and Ecosystem Health**

Water temperature is the driving factor influencing the aquatic ecosystem dynamics, profoundly impacting the physiology and behaviour of fish populations (Harrod 2016; Domenici et al., 2019). Given their isothermic nature, fishes are highly sensitive to change in water temperature. These fluctuations not only affect physio-chemical properties of water but also biochemical processes in organisms, disease prevalence, and predator-prey interactions (Miller et al., 2014; Dell et al., 2014). These impacts extend across various ecological scales, from individual organisms to entire ecosystem (Brett, 1970; Harrod, 2016). Different fish species and life stages exhibits specific temperature requirements, highlighting the delicate nature of their thermal adaptation (Souchon and Tissot 2012).

Increased temperatures can disrupt fundamental physiological functions in fish, including thermal tolerance, growth, metabolism, and reproductive success (Volkoff and Ronnestad 2020). However, the capacity of fish populations to adapt to these changes varies significantly among species and populations. Tropical fishes, for instance are particularly vulnerable to elevated temperatures due to their proximity to their upper thermal limits (Little et al., 2020; Campos et al., 2021). While, fishes inhabiting colder regions, such as polar cod, may struggle to cope with rising temperatures, as evidenced by reports of cold shock impact on fish stock in region like Bolivia (Szekeres et al., 2016). This variability in acclimatization capacity is influenced by a range of factors, including climate exposure and genetic drift (Fost 2015).

Understanding these physiological responses in fishes is crucial for forecasting the effects of climatic changes and ensuring their long-term sustainability. Despite the potential of inland fisheries to contribute to food security, the combined pressure of climate change and environmental degradation pose significant threats to these vital resources (Mohammed and Uraguchi, 2013). While river systems remain crucial breeding grounds for fishes, efforts to enhance fish production may be hampered by environmental constraints. Nevertheless, reservoirs and floodplain lakes offer untapped potential for boosting fish yields.

**Temperature Influence on Fish Growth and Productivity**

The fitness and further development of fish are strongly associated with water quality, which largely depends on physical and biochemical properties (Viadero, 2005). Temperature is the dominant physical property influencing fish development and productivity. Depending upon species, fishes exhibit tolerance for lower and upper temperature range, between which is the optimum temperature for growth. Beyond this range, it may lead to decrease in immunological response and tolerance to particular metabolites, such as ammonia (Viadero 2005; Cascarano et al., 2021) Hence, under certain circumstances, it could sometimes lead to death and reduced productiveness based on the size of the fluctuation from the optimal range. The growth and survival, also vary depending on their age and size (Sharma et al., 2015; Laurel 2017). Juveniles often prefer warmer temperatures compared to adults (Brett 1970; Gadomski and Caddell 1991). Water temperature significantly influences development, metabolic rate, feeding, including other aspects of fish biology such as habitat preference, development, behaviour, spawning and prey -predator relationships. Studies have indicated that the potential for growth is a reliable indicator of the quality of environment. This measure incorporates both biotic and abiotic environmental factors to directly assess fish fitness (Tyler and Brandt 2001; CIFRI 2015; Lea et al., 2018; Stewart 2019).

Temperature changes have been found to significantly impact fish growth rate throughout the world. In temperate regions, increasing temperatures showed favourable growth rates and longer growing seasons. However, temperature above 30° C brought about slow feeding and reduced the growth rate (McCauley and Beitinger 1992). Study on the effect of temperature on *Labeo rohita* fingerlings at CIFRI by Das et al., (2013) revealed significant faster growth rate at 34°C than other temperatures, with growth increasing notably between 32°C and 34°C. This observation has been used to developed a growth model for *Labeo rohita* fingerlings (Sharma et al., 2015).

**Climate influence on fish reproduction**

Various reproductive parameters, such as sex ratio, germ cell production, spawning, and gonadal differentiation, are influenced by environmental factors like temperature, rainfall, and photoperiod. Rapid and extreme fluctuations resulting from climatic changes can be detrimental to these parameters, including breeding phases, mating behavior, and recruitment success (Jhingram 1991; Feugere et al., 2021; Lindmark et al., 2022; Mitra et al., 2023).

Fluctuation in temperature beyond certain optimal levels can affect fish productivity due to its effect on natural fish food availability and breeding failures (Wen and Lin 2001; Das 2009). However, a slight increase in ambient temperature generally favours the reproductive cycle of fish (Sharma et al., 2014). According to Das (2009), the maturation of carp gonads typically begins during February-March, with a gradual rise in temperature, extending up to May-June. In colder regions of North India, moderate temperature increases have been observed to boost growth and accelerate ripening of gonads. Ambient temperature stimulates the endocrine gland in response to environmental factors, facilitating the maturation of gonads in carps (Mohanty et al., 2010; Panda 2016; Mule and Sarve 2017). However, the reproductive cycle of Indian Major Carps is influenced by the semi-annual monsoon and consistent year-round temperature (24 - 32°C), which induce gonadal development twice annually, enabling induced breeding throughout the year (Das, 2009; Sharma et al., 2014).

Nevertheless, these activities can decrease if the temperature exceeds the optimum range. The temperature range within which organisms can function effectively expands throughout their developmental stages and physical dimensions. Moreover, mature breeders exhibit a limited temperature range, making them more vulnerable to increased temperatures. Even a slight rise can exceed their maximum tolerable temperature required for reproduction (Portner et al., 2014; Brule et al., 2022).

Extreme temperatures can disrupt gonadal development, cause gonadal degeneration, and inhibit gamete release by affecting genes responsible for coding steroid-producing enzymes in the gonads of both males and females (Pankhurst and Munday 2011; Shukla 2021; Lema et al., 2022). Consequently, untimely reproductive cycles in fish can lead to poor gamete quality and negatively affect larval development and viability (Servili et al., 2020) due to a mismatch between hatching times and optimal ecological factors (Brule et al., 2022).

The influence of temperature change on fish breeding is expected to be significant, particularly in inland water systems (Cochrane et al., 2009; Panikkar et al., 2022). Data analyses conducted in hatcheries across different states of India, have revealed a peculiar trend. Spawning of IMC typically takes place in the monsoons (June-July) extending till September (Sharma et al*.,* 2014). However, significant advancements in the commencement of breeding and an extended breeding phase for IMCs have been reported, closely linked to variations in climatic factors like temperature, precipitation and the duration of the rainy season (Das et al., 2012; Dey et al., 2007; Sharma et al., 2014). Similar advanced and extended spawning periods in carps and eels have been uncovered through investigations into the reproductive patterns of fish species inhabiting the Cauvery River (Panikkar and Sarkar 2016; Panikkar et al., 2022).

Climate change impacts, like reduced water currents and higher water temperatures, particularly affect geographic spawners whose nesting areas are fixed by natural features (Morales-Marín et al., 2019; Reeder et al., 2021). These changes influence water flow, riverine topography, turbidity, and spawning ground suitability, which can trigger displacement or spawning episodes (Panthi et al., 2022). Increased pCO2 levels, leading to greater acidification, can limit mature fish's aerobic capacity, affecting their breeding capacity. Failed migration could be linked to anoxia and high-water temperatures, leading to unproductive spawning in seasonal migrants (Daiz and Solow 1999). Additionally, a reduction in the perception of chemical signals and sex pheromones due to higher pCO2 impairs reproduction (Porteus et al., 2018; Williams et al., 2019). This suggests that fish populations in river ecosystems may face challenges in maintaining normal reproductive cycles due to the unpredictable nature of environmental changes.

Understanding how environmental variables interact to regulate the brain-pituitary-gonad (HPG) axis is crucial for predicting ecological outcomes in natural fish populations and managing captive fish breeding under changing climate conditions. The HPG axis governs the impact of environmental fluctuations on reproductive functions, with temperature playing a significant role (Zahangir et al., 2022). Elevated temperatures generally inhibit reproductive hormone synthesis and activity, affecting sex determination and leading to a higher prevalence of male phenotypes, which may impact population resilience in unknown ways (Lema et al., 2024).

Eggs are highly sensitive to temperature, with many species unable to tolerate deviations from their spawning temperature (Rombough, 1997; Tsoukali et al., 2016)). In tropical species, even slight temperature increases can significantly raise egg mortality rates (Gagliano et al., 2007). If species do not adjust their spawning times to match optimal embryo development temperatures, hatchling survival rates may decrease as waters warm. Temperature sensitivity during gametogenesis suggests that fish breeding patterns will shift, potentially ceasing before suitable temperatures for egg survival are reached. Some species may still spawn at suboptimal temperatures, leading to reduced embryonic survival. Higher temperatures can increase developmental loss (Pankhurst and Thomas, 1998; Reglero et al., 2018; Alix et al., 2020) and impair oocyte survibality during ovulation (Pankhurst and Munday 2011).

**Impacts of increasing temperature on fish health and productivity**

Prolonged exposure to elevated temperature can induce physiological stress, affecting the health and survival of fish populations. Das *et al.* (2002) examined the effects of rapid temperature rise on stress-reponsive blood and characteristics of tissues in *Rita rita* and *Labeo rohita* fishes highlighting the vulnerability of fish to temperature changes (CIFRI 2015). Haematological studies, such as hematocrit levels, leucocytes (WBC) count, erythrocytes (RBC) count and haemoglobin levels, offers insight into fish adaptability to environmental conditions and are being increasingly used to monitor the health of fishes (Bahmami *et al*. 2001; Harikrishnan *et al*. 2011; Fazio *et al*. 2012; Mazumdar et al., 2015; Panikkar *et al*. 2018). Tropical fishes are particularly vulnerable to rapid temperature changes, which can lead to reduce oxygen levels and increased metabolic rate, ultimately resulting in increased fish mortality and reduced production (Cheng *et al.* 2019; Doney 2010).

The correlation between global warming and infectious diseases outbreaks in fish is becoming increasingly evident (Lõhmus and Björklund 2015; Morley and Lewis 2014; da Costa *et al.* 2021). studies indicate that climate change exacerbates the preponderance of infectious microbial diseases (Kayansamruaj *et al.* 2014; Larsen *et al.* 2018) and parasites (Bruneaux *et al.* 2017; Macnab and Barber 2012) in fish.Rising temperatures and CO2 levels alter host-parasite interactions, affecting critical physiological processes (da Costa *et al*. 2021). Outbreaks of diseases in highly commercialized fishes causes significant economic losses each year, especially in the aquaculture settings, where highly stressed fishes and poor water quality, makes them particularly susceptible to monogeneans (Godwin *et al.* 2020; Lafferty *et al.* 2015).

Climate change and anthropogenic activities contribute to the decline in aquatic biodiversity, posing significant threats to fisheries sustainability. Fish population in wetlands, such as Pabda, Boal, Sarputi, Aar, Bata and Eels in West Bengal, have experienced a decline as much as 54% over the last two decades (Sarkar *et al.* 2022). Rising water temperatures can alter sex ratios, migration patterns, and peak fish abundance (Panikkar *et al*. 2022). Any shift in the environmental factors such as water level, flow, temperature may disrupt the timing and scale of fish migration, consequently, affecting reproduction, growth, and overall yield (Harrod 2016).

**Socio-economic effect**

Fishing industry holds a significant position in South Asia, contributing to more than 68% of the global fish industry (FAO 2023). However, climate change poses a direct threat to the livelihoods of communities reliant on small-scale fishing. These communities engage in various fishing-related activities, exposing them high risks of livelihood due to unpredictable nature of the aquatic environment. Climatic shocks, such as droughts, floods, cyclones and changes in frequency, intensity, and duration not only impact inland fisheries but also pose life threatening risks, causing damage to fishing gears, community infrastructure, and landing sites.

Furthermore, climate change induced alterations in fish composition, productivity, abundance, and distribution can elevate the cost of accessing fish catch and fish processing, thereby impacting the income and nutrition of fishery dependent communities (IPCC 2007; Badjeck *et al.* 2010; Kovats *et al.* 2003). The economic implication is far reaching, leaving many without alternative skill, facing economic hardship. Consequently, alternative livelihoods in other sectors like daily wage labour, will lead to decline of daily wages, and therefore, economic instability (Sakib *et al.* 2020). Moreover, the cascading effects could extend beyond the fishing industry, causing fluctuations in the global economy as various sectors contend with diminished labour value and economic uncertainty.

**Adaptive measures for resilience and ensuring sustainability**

Amidst the formidable challenges posed by climate change, the viability and sustainability of fisheries lies in their adaptive capacity. Effective adaptation strategies require comprehensive understanding of current and future risks and vulnerabilities. Countries and communities must confront the uncertainty, complexity, and risk associated with climate change in fisheries and aquaculture management, governance, markets and livelihoods (Poulain *et al.* 2018). Given the observable and measurable impacts of climate change in riverine system, collaboration among managers, researchers, policymakers, and stakeholders is necessary to facilitate effective management (Seavy *et al.* 2009).

A diverse range of adaptive measures can be implemented in response to present challenges or in anticipation to future ones. Restoring diminishing wild fish populations, raising awareness about climate issues, and educating stakeholders. Enhancing resilience and minimizing stressors such as habitat degradation and pollution are vital strategies for adapting river ecosystems to climate change (Palmer *et al.,* 2008; Panikkar *et al.* 2022). Adopting ecosystem approaches to fisheries (EAF) is crucial to strengthening the adaptability of aquatic ecosystems, fisheries production systems, and the communities reliant on them (Turral *et al.* 2011; Dutta *et al.* 2020). Integrating these approaches into long-term management plans for extreme events can yield more effective outcomes. However, it is essential to balance between protective measures and potential social and economic impacts. Thus, adaptation strategies should be commensurate with the level of risk. Instead of solely focusing on individual factors, a comprehensive integrated assessment of water resources and the environment is the appropriate adaptive approach (Sharma *et al.* 2015; Akhila and Keshamma 2022).

Climate driven temperature rise can be balanced and alleviated by riverine flora, according to current research (Bond *et al*. 2015; Panikkar *et al*. 2022). Maintaining harvesting intensity at levels that would ensure long-term sustainability as an adaptation strategy in freshwater fisheries, by fixing a standardized catch limit (Edmondson and Fanning 2022). Additionally, adaptive management and monitoring of changes in population dynamics, developmental stages, mortality rates, and reproductive behavior are essential to understand the climate change impact and implement appropriate mitigation measures (Macfadyen 2010; Panikkar *et al*. 2022). Furthermore, continuous funding for commercial enhancement, fisheries management and financial benefits for the fisher communities can address the potential repercussions of climatic changes on fisheries (Mohammed and Uraguchi 2013).

Various adaptive strategies outlined by Das *et al.* (2013) and Sharma *et al*. (2014) to optimize fish production, enhance resilience to climate-related challenges, and promote sustainable fisheries management practices include:

1. **Continuous supply of spawn:** Ensuring a perennial supply of spawn from fish hatcheries to address the loss of fish during floods
2. **Species selection and management practices:** Management practices should utilize fish species with shorter rearing durations and promote the collection of fish at reduced sizes to better adapt to changing conditions
3. **Utilization of small ponds:** in drought -prone areas, rearing appropriate fish species in ponds with water holding capacity for few months, and sound management practices can enhance production.
4. **Shift to adaptable species:** breeding and rearing of drought tolerant and high market demand varieties for example, *Clarius garipenias* and *Puntius javanicus* instead of Indian Major Carps (IMC) in many hatcheries.
5. **Early warning system:** Ensuring safety measures byImplementing an advanced warning and prediction system for weather events, particularly in cyclone-prone areas, can aid in post-cyclone management and help fishers prepare for potential impacts.
6. **Utilization of inundated areas:** Conversion of inundated areas, considered unfit for agriculture due to saline water incursions, into ponds. for pisciculture for optimum fish production. Utilising salt resistant fishes -Lates calcarifer, Mugil tade, M.parsia, etc
7. **Mangrove plantation:** Creating a seaward green belt through mangrove plantation in inundated areas can help protect coastal zones from cyclonic storms, safeguarding aquaculture activities.

**Conclusion**

To summarize, the impact of climate change on inland fisheries is a critical concern, especially in countries like India where freshwater ecosystems support a significant portion of the population's livelihoods. Maintaining adequate water levels and implementing integrated water resource management approaches are essential for sustaining fish populations and biodiversity amidst global warming and increasing water demand from various sectors. However, climate change poses significant threats to both marine and inland fisheries, disrupting crucial processes like fish maturation, spawning, and migration, ultimately impacting production and the livelihoods of fishing communities. To address the challenges that climate change poses to inland fisheries, proactive measures need to be taken. Ecosystem-based management, identifying resilient species, and building climate-smart infrastructure can reduce the negative effects on aquatic resources and livelihoods. Collaboration among stakeholders, including fishermen, researchers, government agencies, and NGOs, is crucial for implementing these measures effectively. The focus should be on sustainable development and ensuring the long-term viability of inland fisheries amidst changing environmental conditions. While there is substantial knowledge on the biophysical impacts of climate change on aquatic ecosystems, there is a need for greater understanding of how these impacts interact with the socio-economic context of fisheries and aquaculture. Moreover, there are knowledge gaps in the study of climate adaptation in fisheries, particularly concerning conceptual frameworks and methods used. There is a lack of data-driven studies focusing on climate adaptation within the fisheries sector. To address these gaps, researchers could focus on collecting more quantitative data and expanding research efforts to include inland fisheries. While various adaptive actions have been documented globally, understanding the challenges and limitations to adaptation efforts is crucial for developing effective strategies.

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