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RIVER RENAISSANCE: SAVING THE ORIENTAL MAHSEER FROM CLIMATE CHAOS

Shahid Mahmood

Department of Zoology, University of Gujrat, Gujrat 50700, Pakistan

shahid.mahmood@gmail.com

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Corresponding Author: *
Shahid Mahmood

Abstract
Climate change is an emerging global threat affecting all forms of life. In recent years, rapid and drastic climate shifts have severely impacted ecosystems and species, including the Mahseer – an important endemic fish species in India. Valued for its size, taste, and economic potential, the Mahseer is facing serious challenges such as habitat degradation, reduced growth, disrupted breeding patterns, altered migration routes, and declining population. These effects are pushing the species toward critical endangerment. To prevent further loss of biodiversity, effective and sustainable conservation strategies are essential. Protecting the Mahseer not only preserves ecological balance but also offers economic benefits to the regions where it naturally occurs.

INTRODUCTION

Mahseer is considerably important as being flagship specie in Asian fresh water fishes due to its recreational and economical impacts that virtually because of its taste, size and specie specific aspects (Baruah and Sarma 2018). The declining in the population diversity of the mahseer is going on drastically due to anthropogenic activities which basically destroying their habitats (Sarkar, Mahapatra et al. 2015). The prediction shows about the global change leads to majorly effecting the biodiversity at local to regional and also global levels (Sala, Stuart Chapin et al. 2000), which is due to certain anthropogenic effect like as alternation in land usage, deposition of nitrogen, exotic species invasion, which create about recent important directions toward climate change (Parmesan 2006).Climate change is one of the drastic problem of the century, that is evidential in the observational study, which showing about change in air quality, water temperature, increasingly melting of ice and snow reservoir which leads to ultimately increase in sea level (Change 2007). The increasing strategy of the average temperature of reservoir leads to diverting of freshwater fauna diversity, their distribution along with abundance (Perry, Low et al. 2005). Climate change mostly take place by millennial and seasonal time scales, but the unexpected warming observation in theses decades threatening the functioning of the natural proceeding of ecosystem, specifically when the anthropogenic activities combines with theses water subjected changes (Malmqvist and Information 2008).

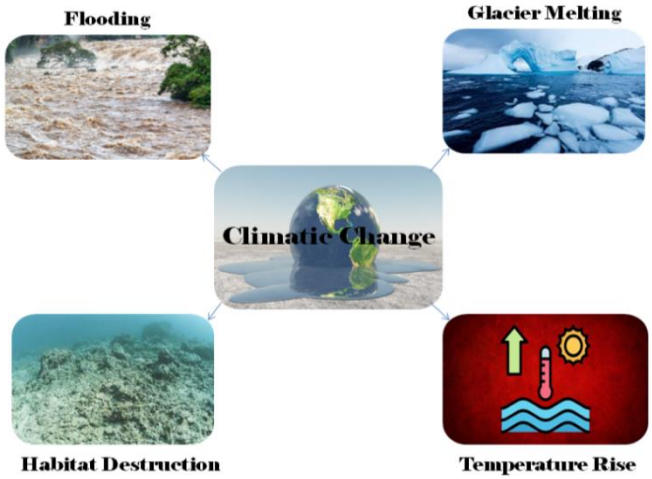
Biology and Ecology of Mahseer

The mahseer fish including almost 16 known species in recent literature which includes, *Tor ater, Tor barakae, Tor dongnaiensis, Tor khudree, Tor kulkarnii, Tor*

laterivittatus, Tor malabaricus, Tor mosal, Tor polylepis, Tor putitora, Tor remadevii, Tor sinensis, Tor tambra, Tor tambroides, Tor tor and Tor yingjiangensis (Malmqvist and Information 2008). Mahseer species are most commonly found in Laos, India, Vietnam, China, Pakistan, Myanmar, Nepal, Bangladesh and Indonesia but majority of species found in India (Mani, Kumar et al. 2009). Mahseer preferred habitat that having richness of dissolved oxygen with fast flow of fresh water and also the rocky substrate where the deep pool and clearness of water playing important role (Nale, Pakhale et al. 2024). The lifecycle include the spawning period where they spawn in the upstream of their habitat having the rock consisting substrate then moves toward juveniles stages where they grow in the fast flowing water and then migrate and their next habitat is deeper water zone where they have to feed on crustaceans, insects and plant material so on (Sarma, Mohan et al. 2022).The migration phenomenon take place because of the seasonal variation and spawning condition which showing about the migration is only within habitat like as between up streams and down streams (Nautiyal, Bahuguna et al. 2001). Mahseer being important and under interest of study due to its key role in the predator prey relationship and also the nutrient recycling in the cold fresh water habitat (Baruah 2024). Mahseer is also as important species because it act as an indicator of water clarity, as a gaming specie that attracting tourism and beneficial source of food (Everard, Pinder et al. 2021).

Climate Change

Climate change can be referred as a multidimensional factor that affects the flora, fauna and overall system in different ways (Change 2016). The term "climate change" denotes the long term change in the temperature, atmospheric conditions and precipitation (Romm 2022). Climate change causes divided in to two categories, which are Natural causes and Anthropogenic causes. The natural causes includes volcanic eruption, solar activity, change in earth orbits, plates tectonics and spreading of sea floor, while the human induced causes includes burning of fossil fuels, industrialization, pollution, change in land use, deforestation and oceanic acidification (Hegerl, Brönnimann et al. 2019). The key factor in all the phenomenon of climate change is ultimately green house gases, which includes methane, carbon dioxide and nitrous oxide (Jeffry, Ong et al. 2021). The green house gases exclusively play role in the increase of atmospheric temperature which leads to the basic climatic change pattern (Kweku, Bismark et al. 2018). Climate change leads to increase in temperature which effect in different ways, like melting of glaciers, sea level rise, change in season pattern, precipitational changes and also change in biology and habitat of living organism due to change in their surrounding environment temperature (Dawson and Spannagle 2009). Climate change effect the living organism by change in their environmental regarding factors and also change in temperature can effect vegetation, feeding habitat and sources, optimal function temperature rang and seasonal linked cycles (Hardy 2003). The climate change can be lemmatized by making decisions like, use the renewable energy source, improvement of energy efficiency, protection of ecosystem, reforestation, sustainable transport usage, reduction in agricultural carbon emission, reduces waste, global cooperation, different government policies and awareness among the people about the drastic effect of climate change (Margeta, Glasnovic et al. 2021).



Effect of Climate Change on Mahseer

Increase in water temperature

The temperature is one of the key factor that effecting the fishes in different aspects in different ways of responding. At the temperature of 28, Mahseer showing the shortest GET (Gastric Emptying Time) that showing about better food assimilation and faster food digestion (Das, Noor et al. 2018). The maximum BGW (body weight gain) and SGR (sustainable growth rate) is observed at the temperature of 26, which is showing about the maximum growth of the mahseer. But if temperature increase or decrease from the optimal ranges (26-28), it will ultimately results in decreasing of growth (Iskandar, Noor et al. 2024). Critical thermal maxima and lethal thermal maxima having more chances to increase with increase in environmental temperature, as along the rising of temperature the activity of different metabolic and maintaining enzymes will increase but until it reaches to the optimum temperature, after which it going on decrease (Akhtar, Pal et al. 2013). The Mahseer having higher metabolic activity in the season of higher temperature like as summer, which is basically influenced by the higher blood composition (e.g, RBCs & WBCs) that playing role in immune response and also aiding in the transport of oxygen (Gupta, Sachar et al. 2013). The best hatching take place at the temperature of 23, because the lower temperature (17) will slow down the development and higher temperature (26) having risk on larval survival (Dash, Tandel et al. 2021). As the climate change will ultimately leads to the rise in temperature, which can cause the melting of glaciers and ice in that region and thus it will effects the fauna of that region along with effecting their native species like mahseer in different aspects as survival rate, migration of fishes, spawning, the reproductive efficiency, the food availability along with habitat degradation (Pande and Posti 2023). The breeding season shifted from 15 to 20 days earlier due the change in climate and also if temperature rise in the surrounding environment of fishes, it will effect gonadal development and spawning migration is also effected by pattern of erratic monsoon, also temperature increase can effects negatively on fecundity and maturation of eggs (Joshi, Das et al. 2018). The temperature become warmer, this will increasing the metabolic rates but it will also decreasing the feed efficiency and in the same way, cooler the temperature, thus lowering the metabolic rate and all of this conclude about to maintain the temperature within optimal ranges (Subagja, Imamudin et al. 2021).

Alteration in flow of river and hydrology

The pattern of rainfall is effected by the climatic change which ultimately effecting the flow of river and also when the temperature rise and melting phenomenon of glacier take place more rapidly, which leads to more water in early summer and more water flow but ultimately shortening of water take place in remaining time of summer season (Nurbatsina, Salavatova et al. 2025). In warmer season, there will be increase in evaporation and also the snowing phenomenon will be slow down which reducing the snow packing water availability for river and thus ultimately this unusual pattern will effects the river

flow and leading to effecting the flora and fauna of river (Bibi, Shafique et al. 2025). The increase of dam will effect the availability and flowing of water in river which leads to decreasing the population diversity of the Maseer in the river also (Jeeva, Kumar et al. 2011). Mahseer prefer to live in habit having faster flow of water with well oxygenation and deeper areas but dams and climatic changes will effect negatively on these suitable factors and thus effect negatively on population of fishes (Kumar). The river flow may be much faster and it will not be ultimately suitable for the spawning of Mahseer and this results in decrease of the male ratio in the river Ganga which can be due to lose of habitat or migratory phenomenon (Bhatt, Nautiyal et al. 2004). Young Mahseer prefer to live in the fast moving water but the older mahseer suitably live in deeper water and in this way, when the climate changing pattern will effects the river efficiencies and thus the juvenile stages of Mahseer will be threatened (Dhawan, Sivakumar et al. 2023). The change in the water flow may be suitable for invasive fish species and thus these fishes will compete with the Mahseer in different aspects and ultimately leads to limitations in food resources (Gupta, Everard et al. 2020). As we know, the recreational activity will depend upon the river flow and if the river flow is unusual, then the population of Mahseer will effect and in this way the ecotourism is negatively impacted (Baruah and Sarma 2018).

Destruction of habitat and the Fragmentation

Mahseer considerably prefer to habitat having richness of oxygen and rocky area with deep pool of water which also having the property of fast flowing of water but the spawn in the shallow tributes (Nale, Pakhale et al. 2024). The nutritional profile of Mahseer also shows about the better food content in fishes, those live in fast flowing water (SHAPAWI, BASRI et al. 2025). The population of Mahseer in threatened due to changing in their habitat, as like construction of dams effect the flow of water in the rivers, which will ultimately effect the fishes because Mahseer prefer in fast flowing water (Mohanty, Badapanda et al.). The pollution factor and different hydropower projects effects the movement and habitat sustainability for the Mahseer living in fast moving rivers areas (Dhawan, Sivakumar et al. 2024). Deforestation is one of the common problem in the recent years which is going on increase day by day and also leads to pollution factors in different ways which effecting the population of blue Mahseer in the region of Thailand (Pongsanarm, Panthum et al. 2025). Nowadays, sand mining is trending activity for construction purpose, for crude oil mining and for bridging, which can ultimately affect the breeding sites of Mahseer (CONSER, RINE et al. 2024).

Ecosystem Disruption and Food Availability

Mahseer species are highly sensitive to change in their ecosystem and leads to critically danger zone due to change in their habitat, which may be due to climatic change or pollution factor causes by human activities (Akhtar and Ciji 2024). The increase in sedimentation and altered flow regimes can affect the population of aquatic insects and algae which are primary source of food in aquatic ecosystem that ultimately effect the population of Mahseer (Pinder, Britton et al. 2019). The increase in temperature also effects the aquatic fauna that is importantly require for the proper growth and metabolism of Mahseer (Rana, Tarafdar et al. 2022). The increase in temperature leads to favorable environment for invasive species of fishes, which causes food competition stress for Mahseer and reduction in food availability to their species (Gupta, Everard et al. 2020). The changing in climate results in decreasing availability of plankton and larvae, which causes food stress in Mahseer developmental stages and causes growth retardation (Jamwal, Phulia et al. 2024). The nutritional value decreases due to uneven rainfall pattern and precipitation mechanism which will affect the primary producers availability in the ecosystem and thus effect feeding strategies (Wangchuk and Wangmo 2022).

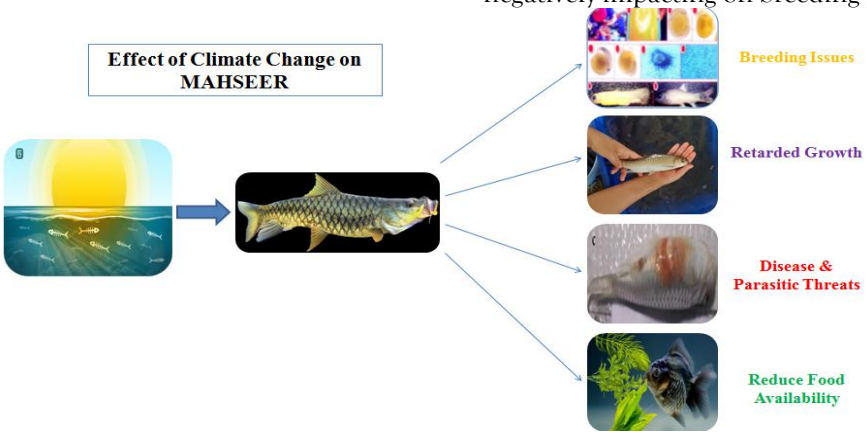
Increase Parasitic and Disease Chances

Climatic change influences the chances of diseases in organism. The evolution of pathogen is increasing due to change in climate and suitable temperature for them which cause the outbreak of disease causing agents in aquatic medium and causes higher mortality rate (Prakoso, Gustiano et al. 2020). As with the increase in temperature, the parasitic prevalence also increases which leads to cause different diseases in Mahseer (Abass, Shah et al. 2024). Temperature rise leads to parasitic load on Mahseer which leads to

weaken immune system and ultimately reduction in their growth. Also in warmer water, Mahseer shows higher indicator of stress because of helminthes and protozoan (Sumiati, Taukhid et al. 2022). The warmer water is much suitable for the bacterial and pathogenic fungi growth, which cause disease in Mahseer and leads to reduction in their reproductive success (Jamwal, Phulia et al. 2024). When temperature rises in surrounding environment, it leads to increase in temperature of water bodies and with the aid of organic polluted matter, it leads to fungal infection in Mahseer and causes their mortality (Mallik, Shahi et al. 2020). Mahseer immunity altered by the climatic change, so in these situations, here is increase the chances of parasitic and fungal infections in these species and makes difficult for them to survive (Byers 2021). In cold water fishes like Mahseer, the rise in temperature creates more vulnerability to diseases like columnaris and gill rot disease due to emergence of parasites and reduction in fish immunity (Bhat, Mallik et al. 2023). The metabolic activity of Mahseer also reduces due to climatic change which causes to reduce the resistance against pathogen and disease risk increase (Pande and Posti 2023).

Effect on breeding and Reproductive success

Mahseer is significantly affected by the change in climate due to its multiple direct and indirect effects on the environment where it has to survive and perform further life activities. The climate induced shift in habitat leads to threatening conditions for the breeding of Mahseer (Awasthi). The reproductive pattern is negatively affected by the change in the surrounding temperature due to specified temperature conditions for the developmental stages (Sarma, Chandra et al. 2024). The reproduction of Mahseer is effected by rise in temperature and in severe conditions, it leads to larval death (Pongsanarm, Panthum et al. 2025). The breeding seasons shifting take place because of temperature rise which shows significant Mahseer population decline in India and Sri Lanka (Sharma, Naskar et al. 2014). The muscle composition of Mahseer is effecting on gonad health, which is adversely affected due to climatic change and rising in surrounding temperature (Sharma, Sarma et al. 2024). The egg laying and hatching capacity is also associated with the riverbed, which is disturbed due to unfavorable warming environment (Abass, Shah et al. 2024). In shortly, climate change leads to change in breeding pattern, water flow, habitat destruction, temperature fluctuation and migration routes, which ultimately negatively impacting on breeding pattern (Viswanath).



Current Efforts and Future Conservation Strategies:

River Management and Habitat Restoration:

The sudden change in Mahseer population leads to decline in the availability of this important species in future and the one of the effecting feature about this aspect is because of habitat destruction due to multiple factors, which needs to conserve and manage properly (Naik, Mahata et al. 2024). Immediately conservation strategies should be performed for the control of pollution decline in the targeted habitat, because it affect the gene flow among the population of Mahseer and leads to diversity loss (Pongsanarm, Panthum et al. 2025). The one of sustainable and practical tool for the conservation of endangered

Mahseer is the catch-and-release strategy, which includes the proper handling; capturing, releasing and angling techniques and it contribute more than 90% improvement in conservation (Gupta, Nautiyal et al. 2016). Monitoring programs to analyze the population status and challenges for their survival should be introduced and make it maximizes to ensure the least human caused disturbance to Mahseer habitat (Rana, Singh et al. 2025). Hydropower project and sand mining also needs to control to reduce the habitat destruction of Mahseer in its major population cites (Negi 2017). The directly throwing of pollution causing agent and deforestation managed in way to control sudden decline in population and control of habitat destruction (Pinder, Britton et al. 2019). The local people awareness and different ecto-tourism rules and regulation will be key helping factors for the conservation management (Abass, Shah et al. 2024).

Hatcheries and Captive breeding programs for Mahseer

The species of Mahseer which are critically endangered, can be repopulated and maintain at normal diversity level with the help of hatcheries. Different advances in captive maturation, which includes the introduction of hormones, the optimal hatchery conditions and ensuring optimal nutritional availability for better production of Mahseer and ultimately also leading to post releasing optimal survival chances for the species (Akhtar and Ciji 2024). The water quality management, feed with Ab libitum, and low densities in the culturing ponds plays a crucial role in the improvement and better production of hatcheries which leads to better availability and diversity of Mahseer to introduce in their concern habitat (Indra, Dewi et al. 2024). Cryoprotectants can be used for long term sperm survival and maximal reproduction rate of Mahseer in stocking sites for huge variety availability to introduce in wild repopulation programs by simply using the phenomenon of milt improvement (Singh, Sharma et al. 2024). For the strong Mahseer population, it is inhibited to perform inbreeding for the obtaining of better genetic diversity that having more ability to survive in the less favorable condition and can adopt themselves according to environment (Sarma, Haldar et al. 2010).

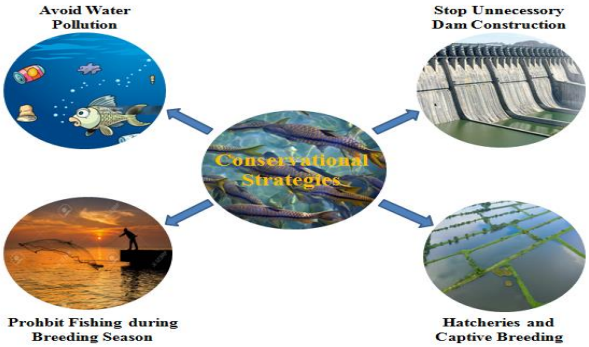
Climatic Effect Mitigation for Conservation

The effect of climate change on Mahseer should be observe and examine for a period of time and tracking system for evaluating the impact and responses of fishes against that change (Awasthi). Climatic change if favoring the non native species in the Mahseer habitat, so proper restriction on the introduction of these species in the concern environment (Gupta, Everard et al. 2020). Mahseer species, that are growing in hatcheries, will be under consideration, weather climatic change effecting it or not, and if there is any possibility of negative impact, than different techniques should be employed to encounter that effect (Mishra). Awareness among the people about effect of climate change on Mahseer and importance of that species in economic aspects is also a helping factor to conserve the Mahseer population (Sarma, Akhtar et al. 2018). The long term studies about climatic change and adjustment in seasonal breeding pattern with the help of fisheries management program can be significant roller in conserving aspect (Iskandar, Noor et al. 2024). There should be gene level study and genetically modified species introduction that can tolerate to climatic change with maximal level (Iskandar, Noor et al. 2024). The introduction of temperature controlled program for Mahseer hatcheries can also help in population conservation (Pinder, Raghavan et al. 2020). The prediction models can also be introduced about Mahseer growth at different climatic condition to further study about adjusting the environment (Sarkar, Das et al. 2021).

Policy Recommendations

The strong rule and regulation should be implicated for the conservation of Mahseer to ensure sustainable environment for survival. Habitat conservation and pollution avoidance rules established for the survival of species and also eco friendly zones around the Mahseer habitats (Pinder, Britton et al. 2019). The catch and release strategies can also be introduces and people should be encouraged and guided for its performance and implications (Everard, Pinder et al. 2021). The prohibiting on fishing during breeding season, check about proper mesh size to avoid javelins capturing and specific quota allowance for fisher to capture can be effective in conserving aspect (Renjithkumar and Roshni 2024). The promotion of

ecto-tourism is encouraged with respect to the conservational driven resources and proposes community driven programs for the conservation of endangered species (Sarma, Akhtar et al. 2018). The genetic study for the hybridization analysis is implicated to avoid it and introduction of species with better genetic diversity that can tolerate different environmental threats (Yadav, Kumar et al. 2020).



Conclusion

Climatic change effecting negatively on the biology and overall system of Mahseer. Mahseer habitat is disturbed due to sudden climatic changes and other climate change driven factors. The sudden pathogen attack and immunity susceptibility can be caused by temperature fluctuation in the environment. Reproductive capacity and breeding seasonal linked pattern also got affected by habitat thermal fluctuations. The ultimate effect is on the population size of the certain species and their abundance. Different survival strategies are invested for the normal habitat conditions provision to the threatened species, for the achievement of optimal growing results. The physical practices implicated along with different policies for better results.

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