

The Effect of Climate Change on Waterborne Diseases: A Geographical Analysis

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Abstract:

Global warming has emerged as one of the most critical environmental challenges affecting freshwater ecosystems and biodiversity worldwide. Native small fish species are particularly vulnerable to climate-induced environmental changes because of their limited mobility, specialized habitat requirements, and sensitivity to variations in water quality and temperature. Dindori district of Madhya Pradesh, located within the upper Narmada River basin, possesses diverse freshwater resources, including rivers, streams, ponds, and wetlands that support a rich variety of indigenous fish species. This conceptual study examines the impact of global warming on native small fish biodiversity in Dindori district through a comprehensive review of existing literature. The study explores the effects of rising water temperatures, altered rainfall patterns, habitat degradation, shrinking aquatic habitats, changes in species distribution, disease outbreaks, and invasive species on freshwater fish communities. Findings from the reviewed literature indicate that climate change significantly affects fish growth, survival, reproduction, and ecosystem functioning. The study further identifies anthropogenic pressures such as overfishing, pollution, deforestation, and sand mining as additional threats that intensify the vulnerability of native fish populations.

Keywords: Global Warming, Native Small Fish Biodiversity, Freshwater Ecosystems, Climate Change, Dindori District.

Introduction:

Global Warming has become a major Environmental problem facing the World Today. The term "Global Warming" refers to the Long-Term Increase in Earth's Average Temperature due to primarily the Greenhouse Gases (such as CO₂, Methane & Nitrous Oxide) in the Atmosphere. Industrialization, Deforestation, Urbanization, and Burning Fossil Fuels have increased the Greenhouse Effect substantially causing Significant Changes in Global Climate Patterns. The Climatic Changes can be observed through Rising Temperatures, Unpredictable Rainfall, Prolonged Droughts, Floods and Other Extreme Weather Events. These Climatic Changes will have Substantial Implications on

Natural Ecosystems and Biodiversity. Aquatic Freshwater Ecosystems are among the Most Vulnerable Ecological Systems Affected by Climate Change. Rivers, Lakes, Streams, Wetlands and Ponds provide Essential Habitat for Aquatic Organisms. They Provide Numerous Ecological Functions Such as Nutrient Cycling, Water Purification and Maintenance of Biodiversity. Fish Species Constitutes Important Component of Freshwater Ecosystems. They are Used as Indicators of Environmental Health. Any Alteration in Water Quality, Temperature and Hydrological Conditions Affects Fish Populations and Overall Aquatic Biodiversity.

Freshwater Biodiversity in Dindori District

The Dindori District is found at the Eastern end of Madhya Pradesh within the Narmada river Basin. Water Resources are very much present in this area due to many water bodies such as rivers, streams, Ponds, Reservoirs and Seasonal Wetlands. The Aquatic Ecosystems from these water bodies provide home to many Native Fish Species which form a large part of the Biodiversity of this Area along with being Important to Ecosystem Functioning. This region provides Breeding Sites, Feeding Areas & Shelters to Many Other types of Aquatic Organisms. In addition to providing food for larger fish, birds and other Aquatic Animals through being eaten by them; they help control Populations of Insects & Plankton.

Global Warming and Threats to Fish Biodiversity

Climate Change has become one of the largest threats to freshwater biodiversity globally. The warmer climates have resulted in a reduction in water quality and an increase in the amount of dissolved oxygen in water. Water temperature also affects aquatic production which is related to the ability for plants and animals to produce energy. Ectothermism refers to how some living things (fish) regulate their internal biological functions through an external source (environmental). Because of this, only minor changes in the water temperature could be able to significantly alter fish growth, reproduction, metabolism, and mortality. In addition to altering temperatures; irregular precipitation will add additional stressors on already stressed fish populations. Extreme weather events and/or excessive rain may result in loss of or damage to fish habitats as well as disruption to breeding cycles. Due to the fact that small indigenous fish species typically have limited adaptations to changing environments and require very specific habitats they are extremely vulnerable to these types of climate-related changes. The combination of climate change with other human impacts including pollution, overfishing, deforestation, and habitat destruction all contribute to increasing the susceptibility of freshwater ecosystems. Many native fish species have declined due to reductions in population numbers, habitat fragmentation, and increased risk of local extinction.

Objectives of the Study

The study has been undertaken with the following objectives:

1. To examine the impact of global warming on freshwater ecosystems and fish biodiversity.
2. To review the ecological significance of native small fish species in Dindori district.
3. To identify climate-related threats affecting indigenous fish populations.
4. To suggest conservation and management strategies for protecting fish biodiversity under changing climatic conditions.

Significance of the Study

The study adds to the expanding area of research concerning the effects of climate change and its implications for preserving freshwater biodiversity. The results show that a variety of native small fish species are ecologically important as well as how important it is to develop new ways to manage these fish species which will be resilient to future climatic changes. These results can aid researchers, policy makers, fisheries managers, and organizations working towards the preservation of freshwater ecosystems and maintaining biodiversity in areas like Dindori district where water resources have been negatively impacted by climate related issues.

Literature Review

Climate Change has been identified globally as one of the most serious environmental issues that can affect the world's biodiversity and functioning of all ecosystems. Due to their high sensitivity to changes in temperature, precipitation, and water flow, freshwater systems are considered at great risk from climate change. The diversity of fish (especially small native fish) is being threatened by both global warming and other man-made impacts. There have been numerous research papers examining the relationship between climate change and the loss of biodiversity in aquatic systems; therefore, there is an urgent need for conservation efforts to be implemented. This chapter will provide a review of the current literature regarding global warming, freshwater ecosystems, the biodiversity of fish, and how indigenous fish populations are affected by climate change.

Global Warming and Freshwater Ecosystems

The Intergovernmental Panel on Climate Change (IPCC) states that global warming will continue to cause an ongoing rise in the world's mean temperature as a result of increased greenhouse gases being released into the atmosphere. Due to the rising global temperatures, the hydrologic cycle has been

affected causing many areas to be experiencing reduced amounts of freshwater, which is greatly impacting freshwater ecosystems. Freshwater systems around the globe have been ranked as one of the most endangered ecosystems globally; primarily due to climate-related changes including water temperatures, flow rates and quality of habitats (Dudgeon et al., 2006).

Impact of Rising Temperature on Fish Biodiversity

Environmental conditions that surround a fish influence how it behaves physiologically. Since fish are ectotherms, they rely entirely upon environmental conditions for both their physiological functions as well as their body temperature. As stated by Ficke et al. (2007) water temperature increases have direct impacts on fish growth rates, feeding habits, reproduction, and survival. Due to small thermal tolerances of many native fish species this warming trend will likely result in population declines along with changes in species composition. These changes will likely lead to decreases in diversity as well as changes to the way ecosystem's function.

Habitat Degradation and Species Distribution

Climate change is an additional factor that degrades habitat as a result of increasing evaporation, decreasing available water and altering the hydrologic cycle. Xenopoulos et al. (2005) found that decreasing water levels results in habitat fragmentation and isolation of aquatic ecosystems from one another. These limitations reduce fish movements and hinder their ability to move freely throughout their food sources and reproductive habitats. The same changes in habitat typically cause a redistribution of species. Species will continue to shift ranges due to less-than-optimal environmental conditions until they find locations with suitable temperature and adequate water availability for survival.

Research Methodology

Research methodology provides the general structure of how research can be done methodically and based on scientific principles. The methodology will outline the processes that will be followed when gathering, processing, and drawing conclusions from information related to the research question. As this study is both conceptual and review-orientated, all of the information collected will come from secondary sources, therefore there will be no need to collect primary data. The methodology was created with a view to reviewing/ synthesizing all of the relevant literature regarding the influence of global warming on native small fish biodiversity in the Dindori District of Madhya Pradesh. This chapter will detail the design of the research, sources of the data, methods of data collection, selection criteria and the overall analysis of the study.

Sources of Data

The study is based entirely on secondary data sources. Information has been collected from a variety of reliable and authentic sources to ensure the comprehensiveness and credibility of the research. The major sources of data include: Research Articles, Books and Reference Materials, Government Reports.

Global Warming and Freshwater Ecosystems

Concept of Global Warming

Global warming is a long-term increase in the average atmospheric and oceanic temperatures of earth caused by an increased greenhouse gas. It is one of the most important environmental issues for humans on earth today and has impacted many different ecosystems and human populations all over earth. The causes of global warming are largely related to human activity. They include industrialization, urbanization, deforestation, and the heavy usage of fossil fuel. As a result, there is an increase in the amount of greenhouse gas that exists in the air, which can lead to changes in climate and other environmental factors.

Greenhouse Gases

The primary greenhouse gases that cause an increase in temperature are carbon dioxide (CO₂), methane (CH₄), nitrogen oxide (N₂O), and fluorinated gases. These gases contribute to a global increase in temperature by trapping heat that is being radiated by the earth's surface. The main sources of CO₂ include; deforestation, fossil fuel consumption, and manufacturing. Methane is produced through agricultural practices including raising livestock and through landfill waste. Nitrogen oxides are created primarily through fertilizer use and through industrial processes. The earth's natural "greenhouse" allows for the retention of enough heat so that the planet remains warm. An overabundance of these gases can disrupt the natural energy balance of the earth which contributes to climate change. According to scientific data, since the industrial revolution there has been a substantial increase in the concentration of all greenhouse gases contributing to unusual patterns of warming worldwide.

Rising Global Temperatures

One of the most noticeable impacts of the build-up of greenhouse gases is an increase in the earth's overall temperature. The world has experienced an unusually large rise in its average surface temperature over the last hundred years. It has also seen some of the largest increases in the last few decades. As the world sees higher temperatures it will be felt through atmospheric flow and

precipitation patterns. This can have an impact on all forms of nature and its biodiversity. Glaciers are melting at rates that were previously unseen. Sea levels are increasing due to ice being lost from glaciers. There is also evidence to suggest that there are more frequent and longer lasting heat waves than there used to be. In addition, changing weather patterns during different seasons have become more common as well. Since, temperature has a direct effect on the quality of water, the level of dissolved oxygen and biological activity within freshwater systems, these systems are especially sensitive to global warming. Therefore, freshwater based organisms such as fish, amphibians and other species are threatened by the effects of global warming.

Water Temperature Increase

The impact that climate change has had on aquatic environments is mostly due to increased levels of water temperature. The regulation of a variety of biological and ecological functions (metabolism, reproduction, etc.) of aquatic organisms are all influenced by water temperature. As the atmosphere gets warmer, so do freshwater bodies. A result of an elevated water temperature can be reduced dissolved oxygen in freshwater which creates stress to many aquatic species. A large number of freshwater species require a particular range of water temperatures. Changes from this will negatively affect the physiological performance of those species. Indigenous small fish species are especially sensitive as they typically have limited ranges for acceptable temperatures. An increase in water temperature can also create changes to a food web's composition (abundance and location) through its effect upon plankton, aquatic vegetation and invertebrates. This disruption could create unbalances in the ecology of freshwater systems, with ultimately less biodiversity than was present before.

Habitat Fragmentation

Habitat fragmentation is the process by which aquatic habitats are separated as a result of reduced water availability, modified flow patterns, or physical barriers. Droughts caused by climate change, as well as decreasing water levels, have been responsible for separating rivers, streams, and wetlands and thus reducing their interconnectedness. The isolation of aquatic habitats restricts the migration of fish and other aquatic species to breeding sites, feeding sites, and refuge sites. The reduced interconnectivity among fragmented habitats may reduce genetic diversity among populations and make them more vulnerable to changing environments.

Altered Ecological Processes

Climate change influences numerous ecological processes within freshwater ecosystems. Rising temperatures, changing water chemistry, and altered hydrological patterns affect nutrient cycling,

primary productivity, and species interactions. These changes can disrupt food webs and ecological balance.

Species Migration and Extinction Risks

Many species migrate to areas that have better environments as environmental factors change. But some types of freshwater organisms do not have the same opportunity to move from one area to another. Because small, indigenous fish cannot easily move through fragmented habitats, their populations decline in size and there is an increased risk of extinction. Those species that are climate-sensitive will be at a higher risk than other species, due to their dependence upon very specific environmental conditions in order to reproduce and survive. Loss of native species can also decrease biodiversity, lower the resiliency of ecosystems and impact how well those systems' function.

Native Small Fish Biodiversity in Dindori District

Freshwater Resources of Dindori

Dindori district, located in the eastern part of Madhya Pradesh, is known for its rich natural resources and diverse aquatic ecosystems. The district forms an important part of the upper Narmada River basin and possesses a variety of freshwater habitats that support numerous aquatic species, including native fish populations. The availability of rivers, streams, ponds, reservoirs, and wetlands contributes significantly to the ecological richness of the region and provides suitable habitats for freshwater biodiversity.

Rivers and Tributaries

The Narmada River serves as one of the major fresh water bodies in Dindori District. It originates from the Maikal hills near Amarkantak and supplies water to various parts of the area through its tributaries. Seasonal and perennial flows in streams and rivers of the district help maintain the hydrology of the region. The many river systems present in the district supply a variety of ecological functions including nutrient transport, water quality maintenance, and providing habitat for an array of aquatic organisms. Rivers and their tributary have different flow rates, water depth, substrates which allow for the establishment of a large number of species of fish. Many indigenous species of small fish complete their entire life cycle in these riverine ecosystems. They also support local fishing efforts thereby contributing to the socio-economic development of rural communities. Unfortunately, this ecosystem is under increasing pressure from human impacts (such as climate change) as well as sedimentation.

Ponds and Wetlands

Wetlands help protect against flood damage by absorbing heavy rainfall and can be used as a source of drinking water and irrigation. The primary purpose of wetland restoration is to preserve their functions. Restoring or rehabilitating damaged or degraded wetlands is often necessary. In addition to preserving the functions of wetlands, restoring them helps to maintain wildlife populations and stabilize land. Wetlands also filter pollutants out of rainwater before it enters rivers, lakes, and oceans. Wetlands help protect rivers from pollution by filtering pollutants from rain water before it enters into lakes and oceans. Wetland restoration helps to maintain species that live in these ecosystems.

Diversity of Native Small Fish Species

The freshwater ecosystems of Dindori district support a rich diversity of native fish species belonging to different taxonomic groups. Small indigenous fish species form an important component of this biodiversity and contribute significantly to ecosystem stability and productivity.

Taxonomic Composition

Small indigenous species are included among these types of fish; small indigenous species typically include barbs, minnows, loaches, catfishes, snakeheads and many other kinds of freshwater fish that have evolved to survive under local conditions. The degree of morphological variation (i.e., size, shape), feeding habits, preferred habitat(s) and reproductive strategies exhibited by these fish are indicative of their ability to adapt to a variety of ecological niches. This is an important factor allowing for coexistence of a large number of fish species within the same aquatic environment and contributing to high levels of total biological diversity.

Ecological Roles

Freshwater systems contain many native species of small fish that are very important ecologically. Small fish species can be found at all trophic levels and support the dynamic process of feeding within an ecosystem. The diet of some native species consists of plankton, algae, and aquatic plant material. Other species eat insects, larvae, or other invertebrate material. As a result of controlling the population of other aquatic organisms and preventing overpopulation of one particular species, small fish will assist with maintaining the ecological balance of their respective system. Furthermore, small fish will act as an essential food source for large predatory fish (and/or) reptiles, birds, and mammals. Consequently, small fish represent an extremely important connection point between the lower (or primary) and higher (or secondary/tertiary) trophic levels of the aquatic food web.

Importance of Small Indigenous Fish Species

Food Security

The use of small fish species provides both food and nutrition for many people living in rural or tribal areas. They have a very good quality of nutrients such as proteins, vitamins, minerals, calcium, iron and important fatty acids. In addition to providing higher amounts of nutrients than larger fish species when eaten in their entirety (whole), they also are lower cost than other animal-based protein sources. Therefore, small fish help increase access to animal protein, which increases dietary diversity; therefore, contributing to the reduction of nutrient deficiency's, including those related to children and women.

Livelihood Support

Many rural communities depend on small-scale fishing and other fishery related enterprises to generate their income. Local fishing, marketing of small indigenous species, as well as other economic activities (such as tourism) that are dependent upon these fish create a source of household income. In addition, seasonal fisheries in rivers, lakes and wetland areas generate income for many families and help to develop rural economies. Consequently, it is essential to manage fish resources sustainably for both social-economic reasons and the protection of biodiversity. Overfishing can negatively impact community livelihoods and raise economic vulnerabilities.

Ecosystem Functioning

Small native fish species in rivers and lakes play a very important role within freshwater ecosystems. Nutrient cycling (the movement of nutrients throughout an ecosystem), energy flow through food webs, and maintaining ecosystem integrity all rely on these species. Small fish also interact with their environment (plants, plankton, insects, etc.) which helps to sustain the overall health and balance of their ecosystems. Having healthy populations of many different fish species can improve an ecosystem's resistance to changes in its environment. Therefore, preserving native fish species will be beneficial to maintaining diversity of species as well as maintaining ecosystem functions.

Impact of Global Warming on Native Small Fish Biodiversity

One of the most important global water quality issues is that of global warming. Since many freshwater systems around the world contain large numbers of local (native) species of small fish which cannot easily move from place to place, have specific habitats in which they live, and can only survive well within a very narrow range of physical conditions; therefore, all such species are at risk due to the effects of climate change. The region of Dindori contains rivers, streams, ponds and wetland areas that provide homes for numerous native fish species. Climate related changes will be detrimental to the diversity of aquatic life in this area. Changes in temperature and rainfall will also

affect how fish reproduce, grow and find food, and ultimately impact how fish distribute themselves throughout an ecosystem. The purpose of this chapter is to describe how global warming is negatively impacting biodiversity among native small fish and discuss the implications for ecosystems.

Rising Water Temperature

Thermal Stress on Fish

One of the most direct impacts of climate change on freshwater environments is increasing water temperatures. Fish are ectotherms; therefore, their bodily temperature, as well as all physiological processes, are controlled by the surrounding environment. Rising atmosphere temperatures warm waters, causing increased thermal stress for fish. Thermal stress has a number of different biological impacts, which include respiration, metabolism, feeding behaviors and immune response. Narrow ranges of thermal tolerance exist in many small indigenous fish species, limiting ability to adapt to rapid and/or longer periods of higher temperature. Higher temperatures can decrease dissolved oxygen in the water, limiting fish survival and growth. The longer fish experience thermal stress, it will weaken them, reducing their susceptibility to disease, predation, and environmental disturbance. Therefore, warmer water temperatures pose a major risk to native fish diversity.

Changes in Growth and Survival Rates

The effects of moderate warming on fish may be positive at first due to an increase in metabolism. However, too much warming generally results in adverse effects. High-temperature environments have a greater requirement for fish to use their energy reserves to maintain their physiological processes. In these environments there is then less energy left over for other biological processes such as growth and reproduction. Decreased rates of growth can result in smaller sizes and decreased reproductive capabilities that can negatively impact population health. Young fish are especially sensitive because they need consistent water quality (a stable environment) in order to grow and develop properly. Losses of eggs, larvae and juvenile fish will also decrease the number of new individuals added to the population and ultimately the sustainability of the population. If the trends associated with climate continue, it could eventually result in a reduction of fish populations, or biodiversity in fresh-water aquatic systems.

Altered Breeding and Reproductive Cycles

Spawning Disruptions

The ability of fish to reproduce is highly dependent upon their environment which includes factors like rainfall, temperature, flow rate and day length. As a result of climate change, many of these

environmental parameters are changing; and therefore, impacting when fish will spawn (and if they will at all). There are several native fish that rely on certain seasonal rains and water temperatures for them to be able to start reproducing. Disruptions caused by changes in rainfall and/or an impact on available water may cause problems with the migration needed for spawning and how fish behave during breeding. Some fish will spawn early/late because of climate change, causing reproductive activity to become out of sync with ideal environmental conditions. Therefore, it could potentially have adverse effects on egg development and larval survival.

Reduced Reproductive Success

Environmental changes due to climate will usually negatively affect the reproductive output of a fish population. High temperatures can prevent or impede the formation of gametes (eggs and sperm), inhibit the process of fertilization, or adversely affect developing embryos. Low levels of available water result in limiting opportunities for individuals to locate appropriate spawning locations; extreme weather can damage or eliminate such sites. The lower number of offspring that survive from one generation to another due to lessened reproductive capacity is associated with a long-term decline of population size.

Increased Disease and Invasive Species Risks

Pathogen Proliferation

Warmer water temperatures create an ideal environment for the development and distribution of pathogens, parasites and other micro-organisms that can lead to infection in fish. Stress from their environment causes a weakening of a fish's natural immunity leaving it open to possible infections. Mortality within affected fish populations is high and as a result of this reduces further still the remaining biodiversity.

Competition with Non-Native Species

Environmental changes allow invasive/non-native species to expand their ranges. Non-native species tend to be more tolerant than native species to environmental variations and are often in competition with native fish for food, habitat and breeding space. The competitive pressure from non-native species can lower the number of native species within a community and lead to an alteration in community structure. This increased interaction likely accelerates biodiversity loss and potentially threatens extinction for the most vulnerable native species.

Climate Change and Anthropogenic Pressures

Overfishing

Overfishing is considered one of the main threats to the world's freshwater fish diversity. Over-harvesting of wild fish due to an increased demand for fish as a source of protein and/or income for many people has resulted in reduced levels of fish populations. Some small indigenous fish are especially vulnerable to over-fishing because they have been caught with smaller meshed nets and unsustainable methods of catching them. Continued removal of fish from the water will result in reduced numbers of reproducing fish and limit the opportunity for fish populations to replenish themselves naturally. The effect of climate on fish can be expected to make it more difficult for fish populations to recover from reduction caused by continued removal.

Pollution

Pollution of freshwater systems has a significant impact on both ecosystems as well as the survival of fish. The primary pollutants are agricultural runoff which contains fertilizers and pesticides, as well as domestic wastewater and solid waste disposal. These activities result in water quality degradation in rivers, ponds and wetland ecosystems. The pollution changes water chemistry, reduces dissolved oxygen levels and introduces harmful compounds into an aquatic ecosystem. Fish that live within these polluted conditions can suffer from physiological distress, have slowed growth, and will die sooner. Additionally, warmer temperatures due to climate impacts create poor conditions for native fish populations.

Deforestation

Removing trees from headwater streams alters the natural characteristics of those streams and can lead to sedimentation and pollution, both of which can have negative effects on aquatic ecosystems. Water quality is affected by sedimentation in two ways: first, as the suspended sediments cloud the water; second, as they are deposited at the bottom of the stream and continue to affect water quality for a long time after they settle. Sedimentation also reduces the number of areas available for reproduction and habitat for many species. Changes in land use or climate will likely exacerbate this effect.

Sand Mining

The uncontrolled removal of sand from riverbeds is becoming an increasingly serious environmental issue throughout much of India. Rivers suffer severe changes to their morphological characteristics due to over-extraction of sand. Additionally, excessive sand extraction results in loss of breeding areas, and alterations to normal water flow in rivers. Turbidity levels in rivers may also be increased

by sand mining, which makes it difficult for native fish populations and other aquatic species to inhabit suitable environments. Fish and other aquatic species require very specific substrate materials for feeding and reproducing; thus, native small fish species are particularly vulnerable. Combined effects of sand mining and climate change will likely result in substantial reductions in the biological integrity of freshwater ecosystems.

Conclusion

There appears to be a substantial risk to the biodiversity of small fish in freshwater systems found within Dindori district due to the threat of global warming. Climate change impacts include rising temperatures, changes in precipitation (rainfall), loss of natural habitats, reduced availability of water sources, increased incidence of disease among fish populations, and the introduction of non-native or exotic species. As a result, many species of small indigenous fish are at a high-risk of extinction as they rely upon specific environmental conditions and natural habitats to survive. Long-term monitoring of biodiversity, assessing the vulnerability of freshwater ecosystems to climate change, and developing adaptive conservation strategies should be priorities for future research. Conservation of the biodiversity of native small fish is vital not only to protect the health of freshwater ecosystems, but it also supports food security and economic stability for rural residents in addition to contributing to the preservation of the ecological function of freshwater ecosystems in Dindori district. Efforts made now to conserve these important aquatic resources will support their continued existence for future generations.

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