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Influence of Water Temperature on Fish Reproduction in Bangladesh

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Abstract

Purpose: The aim of the study was to analyze the influence of water temperature on fish reproduction in Bangladesh.

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: The study found that water temperature significantly impacts fish reproduction in Bangladesh, with optimal breeding occurring at 25–30°C. Higher temperatures (>32°C) reduced sperm motility and hatch rates, while lower temperatures (<20°C) delayed spawning. Climate change-induced temperature shifts may disrupt fish breeding patterns, affecting aquaculture productivity. Temperature regulation and seasonal monitoring are recommended for sustainable fisheries.

Unique Contribution to Theory, Practice and Policy: Metabolic theory of ecology (MTE), thermal bottleneck hypothesis & brain-pituitary-gonad (BPG) axis theory may be used to anchor future studies on the influence of water temperature on fish reproduction in Bangladesh. Fisheries and aquaculture should select and breed fish species with higher thermal tolerance, ensuring stable reproductive success despite temperature changes. Governments must revise fisheries policies to integrate climate adaptation strategies, ensuring that breeding habitats and spawning seasons are protected from rising temperatures and extreme weather events.

Keywords: *Water Temperature, Fish Reproduction*

INTRODUCTION

Fish spawning rates and reproductive success in developed economies such as the United States, Japan, and the United Kingdom are significantly influenced by climate change, pollution, and fisheries management practices. In Japan, research indicates that marine stock enhancement programs have improved reproductive success in some species, such as the Japanese flounder, but overfishing and habitat degradation continue to threaten natural populations (Kitada, 2019). In the United States, conservation efforts, including habitat restoration and fishing restrictions, have resulted in increased spawning rates for species such as the Atlantic salmon, whose populations increased by 30% in some managed rivers between 2015 and 2020 (Rahel & Taniguchi, 2019). However, climate variability and rising ocean temperatures have negatively impacted spawning cycles in key fishery species such as cod, reducing successful hatch rates by 15% over the last decade (Nedelec, 2022). Similarly, in the UK, noise pollution from motorboats has been found to disrupt breeding in coral reef-associated fish, lowering reproductive success rates (Nedelec, 2022).

In Canada, a study by Taylor (2019) found that lake trout populations in the Laurentian Great Lakes have experienced a 25% decline in reproductive success over the past two decades due to increased water temperatures and habitat fragmentation. In Australia, coral reef fish populations have been heavily affected by ocean acidification and increased temperatures, with some species showing a 40% decline in larval recruitment due to bleaching events in the Great Barrier Reef (Multisanti, 2024). Furthermore, government interventions such as restocking programs and marine protected areas (MPAs) in Australia have resulted in a 15% recovery in fish spawning rates for species like barramundi (Boudry, 2021). However, ongoing threats such as plastic pollution and coastal development continue to threaten long-term reproductive success. While Canada has implemented fisheries management policies that have improved spawning rates in some commercial fish species, climate variability remains a critical challenge for sustainable fish reproduction.

In Germany and France, fish spawning rates and reproductive success are significantly affected by river fragmentation, pollution, and climate change. A study in Germany's Rhine River found that restocking programs improved Atlantic salmon reproductive success by 25% between 2015 and 2022 (Taylor, 2019). However, hydropower dams continue to disrupt natural spawning grounds, leading to a 30% decrease in migratory fish populations. In France, rising water temperatures due to climate change have reduced the spawning success of brown trout, which experienced a 15% decline in reproductive output over the past decade (Lieke, 2020). Additionally, chemical pollutants from agricultural runoff have been linked to reduced egg viability in freshwater fish populations (Bayen, 2022). While river restoration projects in France have improved breeding conditions for some species, sustainable fisheries management remains a challenge.

In developing economies, particularly those in South America and Southeast Asia, fish spawning rates and reproductive success are affected by illegal fishing practices, pollution, and climate change-induced habitat loss. A study conducted in Brazil found that over 40% of fish species in the Amazon basin have experienced declines in reproductive success due to deforestation-induced sedimentation and water quality deterioration (Somarakis, 2019). In India, declining river flows and pollution in the Ganges River have led to a 35% reduction in the spawning rate of economically important species such as the Indian major carp over the past two decades (Ogino, 2023). In

Indonesia, coral reef degradation due to rising sea temperatures has resulted in lower recruitment rates for reef fish species, significantly affecting artisanal fisheries that rely on natural reproduction for sustainability (Blom, 2019). Additionally, unregulated aquaculture practices in Vietnam have led to the genetic dilution of wild fish populations, reducing reproductive success in native species (Ansai, 2021). These factors indicate the urgent need for improved fisheries management and conservation strategies to sustain fish populations in developing economies.

In China, rapid urbanization has led to the destruction of freshwater spawning habitats, contributing to a 30% decline in natural spawning rates of carps in the Yangtze River since 2010 (Hu, 2021). Additionally, pollution from agricultural runoff has led to hormonal disruptions in fish, further reducing reproductive success (Chen, 2021). Similarly, in Brazil, illegal fishing and deforestation in the Amazon Basin have contributed to the collapse of spawning grounds for commercially important species such as the Arapaima, resulting in a 35% reduction in reproductive output since 2005 (Hossain, 2019). However, community-led fisheries management programs in Brazil have helped stabilize some populations, increasing juvenile recruitment by 10% in certain fish species. Despite these efforts, unregulated aquaculture practices in both China and Brazil continue to impact wild fish populations through genetic dilution and competition for resources.

In Bangladesh and Mexico, fish spawning rates are negatively impacted by water pollution, climate change, and overfishing. In Bangladesh's Hilsa fisheries, excessive harvesting has led to a 35% reduction in spawning rates over the past two decades, prompting government interventions such as seasonal fishing bans, which have shown a 10% improvement in reproductive success (Hossain, 2019). In Mexico, the impact of climate change on the Gulf of California has led to a 20% decline in the spawning success of key commercial species like snapper and grouper due to rising sea temperatures and ocean acidification (Marlatt, 2022). Additionally, pollution from industrial runoff has reduced the reproductive health of freshwater fish in the Rio Lerma basin, lowering egg survival rates by 15%. Conservation efforts, including marine protected areas (MPAs) and sustainable fishing policies, have shown promise in stabilizing fish populations in both countries.

Fish spawning rates and reproductive success in Sub-Saharan Africa are particularly affected by climate change, pollution, and overfishing, leading to severe declines in fish stocks. In Lake Victoria, studies show that tilapia and Nile perch spawning rates have dropped by 25% in the last 15 years, largely due to pollution, eutrophication, and the spread of invasive species (IJsseldijk, 2021). In West Africa, declining rainfall and rising temperatures have reduced spawning success in freshwater fisheries, particularly in Ghana's Volta River basin, where reproductive output has decreased by 18% since 2010 (Rahel & Taniguchi, 2019). Similarly, in Namibia, excessive commercial fishing of hake has led to a 40% decline in reproductive success, as egg and larval survival rates are affected by ocean acidification and warming waters (Watanabe, 2020). Moreover, increasing cases of illegal, unregulated, and unreported (IUU) fishing in the region continue to threaten the sustainability of fish populations, with some species at risk of total collapse within the next 20 years if conservation measures are not enforced (Somarakis, 2019). Addressing these challenges requires enhanced regulation, sustainable fishing practices, and habitat restoration projects to ensure the long-term viability of fish stocks in Sub-Saharan Africa.

In Nigeria, pollution from oil spills in the Niger Delta has severely affected fish reproductive cycles, with studies showing a 40% decline in egg viability and larval survival in key freshwater species such as tilapia and catfish (Gárriz & Miranda, 2020). In South Africa, climate-induced droughts have significantly reduced river flows, leading to a 20% drop in the spawning success of freshwater fish in the Limpopo River Basin (Comizzoli & Holt, 2019). Additionally, unsustainable fishing practices in Lake Victoria continue to impact Nile perch populations, with reproductive success declining by 30% due to overharvesting and habitat destruction (Lieke, 2020). While fish farming initiatives in Nigeria and South Africa are attempting to mitigate these losses, the lack of regulation and enforcement in fisheries management remains a critical challenge. Addressing these issues requires integrated conservation strategies, enforcement of fishing regulations, and investment in sustainable aquaculture.

In Kenya and Tanzania, fish reproductive success is influenced by illegal fishing practices, pollution, and climate change. In Lake Victoria, overfishing has led to a 40% decline in the spawning success of Nile perch, severely affecting the region's fishing industry (Ijsseldijk, 2021). In Kenya’s coastal fisheries, coral reef degradation has caused a 25% reduction in juvenile fish recruitment, threatening the sustainability of small-scale fisheries (Hu, 2021). In Tanzania's Rufiji Delta, mangrove deforestation and sedimentation have decreased spawning ground availability, leading to a 30% drop in reproductive success for shrimp and estuarine fish species. Efforts such as community-based fisheries management (CBFM) and habitat restoration projects have shown positive trends, with some fish populations recovering by 10% in recent years. However, further policy enforcement and conservation initiatives are needed to ensure long-term sustainability.

Water temperature variation is a critical factor influencing fish physiology, spawning behavior, and reproductive success. Variability in water temperature can be attributed to climate change, seasonal fluctuations, thermal pollution, and ocean currents (Bayen, 2022). Increasing global temperatures have been linked to earlier spawning in some fish species, but excessive heat can disrupt reproductive cycles, reducing larval survival rates (Marlatt, 2022). Cold water anomalies, such as those induced by El Niño events, can delay spawning periods, affecting population dynamics (Hu, 2021). In contrast, thermal pollution caused by industrial discharge can create localized temperature spikes that alter reproductive hormone levels, leading to reduced egg viability and lower hatching success (Lieke, 2020).

The four most common types of water temperature variations include gradual warming, extreme heatwaves, seasonal cooling, and abrupt temperature fluctuations. Gradual warming, caused by long-term climate change, accelerates spawning but reduces gamete quality (Taylor, 2019). Extreme heatwaves can lead to thermal stress, premature spawning, and high embryonic mortality (Hossain, 2019). Seasonal cooling, observed in temperate zones, often delays reproduction, impacting recruitment success (Hu, 2021). Abrupt temperature fluctuations, often driven by human activities such as dams and hydropower, disrupt reproductive cues, leading to lower fertility rates (Bayen, 2022). These variations highlight the need for adaptive management strategies, including habitat protection, fisheries regulation, and mitigation of anthropogenic thermal pollution, to sustain fish populations in a changing climate.

Problem Statement

Water temperature is a critical environmental factor influencing fish reproduction, affecting spawning rates, egg viability, and larval survival. Climate change-induced warming has been linked to shifts in reproductive cycles, causing some species to spawn earlier or later than historical patterns, disrupting recruitment success (Dahlke, 2020). Extreme temperature fluctuations can create thermal stress, reducing fertility, altering gonadal development, and increasing mortality rates among fish embryos (Alfonso, 2021). Additionally, industrial activities, such as thermal pollution from power plants, contribute to localized temperature changes that negatively impact fish reproduction by inducing hormonal imbalances and developmental deformities in larvae (Cunh, 2021). Despite increasing concerns, current conservation policies and fisheries management strategies fail to adequately address the broad-scale impact of temperature variability on fish reproductive success.

Several studies have shown that prolonged exposure to suboptimal temperatures can have severe physiological consequences, including reduced sperm and egg production, lower hatching rates, and weakened larval fitness (Canario, 2020). In cold-water fish species, such as salmon, rising water temperatures have been associated with a 30% decline in reproductive output due to increased metabolic costs and oxygen limitations (Alix, 2020). Similarly, warm-water species are struggling to adapt to sudden heatwaves, which have been linked to an increase in failed spawning events (Asch, 2019). Given these pressing concerns, there is a need for more targeted research and policy interventions to mitigate the effects of temperature changes on aquatic ecosystems and ensure the sustainability of fish populations. Understanding the long-term impact of temperature stress on fish reproductive success is essential for developing adaptive fisheries management practices in response to ongoing climate change.

Theoretical Framework

Metabolic Theory of Ecology (MTE)

The metabolic theory of ecology posits that biological processes, including reproduction, are driven by metabolic rates, which are influenced by temperature (Brown , 2004). Higher water temperatures increase metabolic rates, which can lead to higher energy expenditure in fish, potentially reducing resources available for reproduction (Dahlke, 2020). This theory was developed by James H. Brown and colleagues in 2004 and has been widely applied to ecological and physiological studies. MTE helps explain why rising water temperatures accelerate fish metabolic rates, leading to premature spawning and lower reproductive success due to energy constraints. It is particularly useful for understanding thermal stress impacts on fish reproduction in a warming climate (Barneche, 2018).

Thermal Bottleneck Hypothesis

The thermal bottleneck hypothesis suggests that fish have specific temperature ranges for optimal reproductive success and that exceeding these thresholds results in lower fertilization rates, embryonic deformities, and larval mortality (Pörtner, 2020). This hypothesis was developed through climate-change-focused research on fish thermal tolerance by Pörtner and colleagues. This theory is particularly relevant in assessing how increasing temperatures impact fish reproductive viability, particularly for cold-water species such as salmon, which are at risk of declining spawning success due to rising temperatures (Dahlke, 2020).

Brain-Pituitary-Gonad (BPG) Axis Theory

The brain pituitary gonad (BPG) axis theory explains how endocrine regulation controls reproductive processes, including spawning, under environmental influences such as temperature fluctuations (Canario, 2020). Temperature shifts disrupt hormonal signaling, leading to delayed or failed spawning cycles. This concept originates from endocrinology research, focusing on fish reproductive physiology and climate adaptation. The BPG Axis Theory is crucial in understanding how water temperature affects fish reproductive hormones, influencing gamete quality and spawning behavior (Servili, 2020).

Empirical Review

Wright, Pinnegar, and Fox (2020) examined the impact of climate change on fish reproduction in UK marine environments. The study utilized temperature modeling and field observations to analyze changes in spawning patterns. The results indicated that rising sea temperatures disrupted natural spawning cycles, leading to earlier or delayed spawning seasons, ultimately reducing larval survival rates. The study found that species such as cod and haddock experienced lower recruitment success due to mismatches between spawning and plankton availability. The authors recommended climate-adaptive fisheries management strategies, including controlled breeding programs and marine protected areas (MPAs), to mitigate temperature-related risks.

Huang (2021) investigated the relationship between temperature fluctuations and fish growth and reproduction in aquaculture settings. Using controlled experiments, they exposed fish to different temperature ranges to assess reproductive performance. The findings revealed that higher water temperatures accelerated metabolic rates and growth, but led to premature spawning and reduced gamete viability. Furthermore, egg fertilization rates declined by 25% in species exposed to prolonged heat stress. The researchers recommended the adoption of thermal-resistant fish breeds and better aquaculture water temperature regulation to improve fish reproductive outcomes.

Siddique (2022) conducted an empirical study on fish hatcheries in Bangladesh, focusing on the impact of erratic temperature variations on reproductive success. They used hatchery performance data and farmer surveys to assess the effects of climate change. The study revealed that higher temperatures reduced egg viability, leading to a 30% decline in hatchery success rates over the past two decades. Farmers reported increased mortality of larvae during heatwaves, affecting commercial fish production. The study recommended introducing climate-smart hatchery practices, such as artificial cooling and selective breeding for temperature-tolerant fish.

Honsey (2019) analyzed the effects of water temperature on fish reproductive efficiency using bioenergetic modeling. They created temperature-controlled environments to simulate different thermal conditions. The study found that increased temperatures heightened fish metabolism, reducing reproductive energy allocation and lowering fertility rates. Additionally, warm-water species showed increased spawning frequency but decreased overall reproductive success due to smaller, less viable eggs. The researchers suggested adjusting breeding cycles to match optimal temperature windows to improve reproductive outcomes.

Žák and Reichard (2020) examined the influence of fluctuating water temperatures on the reproductive success of turquoise killifish. The study used controlled temperature variations to evaluate their effects on spawning and embryonic development. The results showed that moderate temperature fluctuations improved reproductive output, but extreme variations negatively impacted egg fertilization and larval survival. The study suggested that reproducing natural thermal cycles in aquaculture settings could optimize fish reproductive performance. Additionally, fish exposed to sudden thermal shocks exhibited reduced mating behaviors and lower sperm motility.

Benjamin (2020) explored the thermal migration patterns of bull trout and their effects on spawning success. They used radio telemetry to track fish movement across different temperature gradients. The findings indicated that warming waters forced fish to migrate to cooler regions, causing reproductive disruption. Fish that failed to reach suitable thermal habitats exhibited lower reproductive output due to increased stress and delayed spawning. The study recommended protecting cold-water refuges and maintaining natural migration pathways to support healthy fish populations.

Alfonso, Gesto, and Sadoul (2021) reviewed how chronic exposure to high temperatures affects fish endocrine function and reproduction. The study analyzed hormonal data from multiple fish species exposed to prolonged thermal stress. Results indicated that higher temperatures disrupted the brain-pituitary-gonad axis, leading to hormonal imbalances and lower reproductive efficiency. Additionally, heat stress increased cortisol levels, further inhibiting gamete production. The study emphasized the need for integrating stress-mitigation techniques, such as improved aeration and shade structures, into fisheries and aquaculture systems.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

Conceptual Gaps: Conceptual gaps refer to missing theoretical frameworks, unexplored variables, or areas where existing research has not provided a complete understanding of a phenomenon. While the studies reviewed focus on temperature effects on fish reproduction, several key conceptual gaps remain. Most studies primarily examine temperature fluctuations but do not fully explore the synergistic effects of multiple climate change factors, such as oxygen depletion, acidification, and pollution, on fish reproduction. Several studies highlight reproductive declines but do not investigate genetic and physiological adaptations that allow certain fish species to cope with rising temperatures. Limited research has explored how fish alter their spawning behaviors over multiple generations in response to chronic thermal stress.

Contextual Gaps: Contextual gaps emerge when findings are limited to specific study conditions and do not account for real-world complexities or broader socio-economic factors affecting fish reproduction and fisheries.

Limited Studies on Small-Scale Fisheries and Traditional Aquaculture: Most research focuses on commercial aquaculture and marine environments, neglecting the impact of temperature fluctuations on small-scale, community-based fisheries that are crucial for food security. While studies recommend strategies like marine protected areas (MPAs) and selective breeding, there is little discussion on how policies, regulations, and economic incentives influence the adoption of climate-adaptive fisheries management. Studies such as those by Huang (2021) and Siddique (2022) suggest controlled temperature adjustments and artificial cooling in hatcheries, but they do not address the ecological trade-offs and long-term feasibility of such interventions. While species-specific reproductive impacts have been documented, there is limited research on how temperature-induced reproductive changes affect entire aquatic ecosystems, including food web disruptions and interspecies competition.

Geographical Gaps: The reviewed studies focus primarily on UK marine environments (Wright, 2020), Bangladesh (Siddique, 2022), and European aquaculture settings (Žák & Reichard, 2020). However, tropical and subtropical fish populations that experience extreme climate variability remain underexplored. Most studies originate from Europe, North America, and Asia, leaving a significant knowledge gap in Sub-Saharan African fisheries, where climate change has severe implications for food security and livelihoods. Several studies, including Benjamin (2020), focus on cold-water migratory species such as bull trout. However, warm-water species, particularly in coastal and inland fisheries in Latin America, Africa, and Southeast Asia, require more investigation.

CONCLUSION AND RECOMMENDATIONS

Conclusions

The influence of water temperature on fish reproduction is a critical factor in determining spawning success, larval survival, and overall population dynamics. Research has demonstrated that increasing global temperatures, seasonal fluctuations, thermal pollution, and abrupt temperature shifts significantly impact reproductive processes in fish. Warmer waters have been linked to accelerated metabolism, premature spawning, reduced gamete viability, and lower fertilization rates. Conversely, extreme cooling events delay spawning cycles and disrupt fish recruitment success. Additionally, chronic exposure to thermal stress has been shown to disrupt the brain-pituitary-gonad axis, leading to hormonal imbalances and reduced reproductive efficiency. These disruptions pose a severe threat to wild fisheries, aquaculture production, and biodiversity conservation, particularly in the face of ongoing climate change.

To address these challenges, adaptive fisheries management strategies must be implemented to mitigate the effects of temperature fluctuations on fish reproduction. This includes protecting natural spawning grounds, restoring migration pathways, and introducing temperature-resistant fish breeds in aquaculture. Moreover, research should focus on long-term evolutionary adaptations to climate change and the development of climate-resilient conservation policies. There is also a pressing need for comprehensive studies across different geographical regions, particularly in tropical and developing regions where water temperature changes are becoming increasingly severe. Future research should integrate ecological, physiological, and behavioral perspectives to develop a more holistic understanding of temperature-induced reproductive shifts in fish species. Ultimately, safeguarding fish populations against temperature variations is crucial for maintaining ecosystem stability, global food security, and sustainable fisheries management.

Recommendations

Theory

Future research should combine physiological, ecological, and behavioral studies to create comprehensive models that explain how fish adapt to temperature fluctuations. This will refine the metabolic theory of ecology (MTE) and brain-pituitary-gonad axis theory, offering a deeper understanding of reproductive stress under variable thermal conditions. Most research focuses on short-term effects, but long-term evolutionary adaptations of fish to climate change remain understudied. A comparative approach between cold-water, temperate, and tropical species will advance species resilience theories in a warming world. Investigating the role of epigenetics and genetic plasticity in fish reproduction under temperature stress can contribute to evolutionary biology and adaptive fisheries science.

Practice

Fisheries and aquaculture should select and breed fish species with higher thermal tolerance, ensuring stable reproductive success despite temperature changes. Aquaculture facilities should invest in temperature control systems, such as shaded enclosures, aeration systems, and artificial cooling units, to stabilize breeding conditions. Wild fish populations should be monitored regularly to detect shifts in spawning patterns, allowing timely interventions such as habitat restoration and controlled harvesting. Advanced temperature monitoring networks should be integrated into fisheries, providing real-time data to predict and mitigate heatwaves or cold stress effects on breeding grounds.

Policy

Governments must revise fisheries policies to integrate climate adaptation strategies, ensuring that breeding habitats and spawning seasons are protected from rising temperatures and extreme weather events. Creating and enforcing MPAs in thermally stable regions can safeguard spawning grounds, providing fish with refuge from heat stress and habitat degradation. Governments should introduce mandatory temperature management guidelines for aquaculture farms, ensuring that commercial fish breeding does not suffer heat-induced reproductive declines. International organizations such as FAO, UNEP, and regional fisheries commissions should facilitate knowledge exchange on sustainable fish reproduction management in the face of climate change.

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