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A Review of Reduced Rainfall Effects on Fisheries and Aquaculture of Madhesh Province, Nepal

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Abstract

Nepal's freshwater fisheries are critically dependent on monsoon driven hydrological cycles. This review explores the impacts of reduced rainfall on fisheries and aquaculture in Madhesh Province, with a focus on understanding the decreased precipitation on fish reproduction, migration patterns, and habitat condition and socio-economic consequences for local fishing communities due to climate change. Madhesh Province, characterized by its warm climate and fertile lowlands, is a key region for freshwater aquaculture, particularly of species such as carp and tilapia. However, declining and erratic rainfall has led to reduced water availability in ponds, rivers, and wetlands, significantly affecting fish growth, breeding cycles, and overall productivity. These climate changes occurs due to rising temperatures and increased evaporation stress on aquatic ecosystems and raise the risk of disease outbreaks, with significant socio-economic impacts on fishing communities who rely heavily on seasonal water availability for their livelihoods. In Madhesh Province, where aquaculture supports food security and income, reduced rainfall exacerbates poverty, reduces employment, and increases vulnerability. This review underscores the urgent need for adaptive management strategies, including improved water resource governance, climate resilient aquaculture practices, and livelihood diversification, to mitigate the impacts of climate variability on fisheries and enhance resilience in the region.

Keywords: climate change, aquaculture, precipitation, breeding cycle

Introduction

Climate change has significantly affected weather patterns in Nepal, leading to prolonged droughts and increasingly unpredictable rainfall (Gurung et al., 2011). Climate change is having a profound impact on Nepal's natural resources, particularly water

availability and biodiversity. Rising temperatures, shifting precipitation patterns, and the retreat of glaciers are reducing the availability of water for essential uses such as drinking, irrigation, and hydropower generation. In parallel, climate change is threatening many endemic species of flora and fauna species that are found only in specific regions of Nepal and are vital to the ecological balance and cultural heritage of the country. Mass deaths of a number of aquatic species, including fish, plants, corals, and animals, have been linked to climate change. Emissions of carbon dioxide are predicted to have at least doubled from their mid-1980s levels by 2050 (Ninawe et al., 2018). Increasing heat, changing rainfall, shrinking habitats, and more severe weather events are putting many species at risk of extinction. The combined impact of shrinking water resources and biodiversity loss is especially harsh on poor and vulnerable communities, who depend directly on natural ecosystems for food, fuel, medicine, and income. These populations often lack the resources to recover, making them increasingly susceptible to poverty, food insecurity, and displacement as climate conditions worsen (Karki et al., 1970). Thus, these climate-related stresses threaten not only their livelihoods but also the broader rural economy that depends on livestock farming (Gurung et al., 2011).

Since 1997, Nepal's mountainous regions have shown an annual warming trend of 0.06 to 0.12°C, raising concerns about climate change on a global scale. The complex interactions between the monsoon system and Nepal's hilly terrain are not well understood, despite the country's hydrology being mostly dependent on the South Asian Monsoon (Basnet et al., 2020). Almost two-thirds of the Earth's surface is made up of aquatic systems (Barange et al., 2018). Nepal is one of the least developed countries, striving to achieve the status of a developing nation and it cannot withstand the consequences of global warming. Over the past 36 years (1975–2010), western Nepal has experienced a rapid temperature rise of 1.2°C per year, nearly double the global average. Overall, Nepal's average temperature increase is about 0.06°C annually. This warming has made hill and high hill regions more vulnerable to climate change, leading to more frequent climate-induced disasters like droughts, floods, and landslides, which have severely affected agriculture (Bista et al., 2018). Nepal’s wetlands are vital ecosystems supporting rich biodiversity and the livelihoods of over 21 ethnic communities. Despite their importance, these areas are rapidly degrading due to the combined pressures of climate change, urbanization, and unplanned development (Timalsina et al., 2025).

Healthy foods like fish are rich in immune-boosting chemicals like taurine, melatonin, and omega-3 fatty acids (Mendivil, 2021). Moreover, fish is essential to the food and nutritional security of many underprivileged and marginalized people worldwide (Kwasek et al., 2020). Women have important roles in small-scale fisheries, particularly in post-harvest and processing, which supply 90% of fisheries jobs and two-thirds of fish for human consumption (Giri, 2018). Nepal’s inland finfish aquaculture is

thriving, leveraging the country's varied climate and geography to boost production. This expansion is a key driver for food security and rural livelihoods, fostering a path toward sustainable economic growth (Gautam & Sapkota, 2023). The environment and fish productivity are seriously threatened by climate change, which is reflected in unpredictable monsoon patterns and decreased rainfall.

Specifically, this study seeks to evaluate how declining water availability affects fish production, explores socio-economic impacts on fish farmers, and identifies local adaptation strategies like artificial ponds and water conservation. However, the review faces several limitations, including a lack of region specific data linking rainfall changes directly to fisheries output, difficulty in isolating rainfall effects from other environmental and socio-economic factors, and uneven implementation of adaptation practices across communities. Despite these challenges, the review highlights the need for further localized research and offers insights to support policy-making in water management, climate adaptation, and sustainable rural development.

Results and Discussion

Hydrology and Rainfall Patterns in Nepal

Nepal's Department of Hydrology and Meteorology began in 1962 as a small hydrology unit within the Department of Electricity. It became the Department of Hydrological Survey in 1964 under Acting Director Gokul. Recognizing the global importance of water resource management, international collaboration in hydrology was deemed essential. Meeting growing demands for water requires accurate data and skilled interpretation, particularly of precipitation and evaporation, traditionally handled by meteorological services. With support from the United Nations Development Programme (UNDP) and World Meteorological Organization (WMO), Israeli meteorologist Mordechai Gilead was appointed as a Senior WMO expert to assist in establishing the department (Department of Hydrology and Meteorology of Nepal, 2023).

Nepal experiences four seasons: pre-monsoon (hot, dry, and windy), monsoon (wet with southeasterly winds), post-monsoon (dry and sunny), and winter (cold with snowfall in high mountains). The country's precipitation is largely shaped by the summer southwest monsoon and winter western disturbances. Due to its rugged mountainous landscape, Nepal is prone to extreme weather events such as floods, landslides, and droughts (Karki et al., 2017). Climate change is raising temperatures and altering rainfall patterns, causing rivers to dry more often and reducing water flow between waterways. These changes contribute to global warming and disproportionately affect vulnerable communities, despite their minimal contribution to the problem (Kayes et al., 2025). Nepal's hydrological challenge creates a fundamental water security crisis, characterized by seasonal flooding and water surplus during the monsoon followed by a prolonged, severe dry season with acute water scarcity (Gurung, 2012). Additionally, climate

change, driven by human emissions, disrupts rainfall and glacier melt, threatening water resources and causing disease spread (Upreti, 2013). Similarly, climate change significantly affects the hydrologic cycle, impacting watersheds globally and locally. Therefore, future strategies for flood control, hydropower, irrigation, and ecosystem preservation need to be adjusted accordingly (Teutschbein & Seibert, 2010).

Climate Risks to Aquaculture

Climate change affects fisheries and aquaculture both positively and negatively. Warmer regions like the Terai may benefit from expanded warm-water species and farming areas. However, risks include invasive species, fish diseases, and water quality issues. Cold-water aquaculture, like trout farming, is especially vulnerable to rising temperatures (Wagle et al., 2011). Climate change induced salinity intrusion has both global and local effects on the growth performance and survival of Thai Pangas (*Pangasius hypophthalmus*) in Bangladesh (Mandal et al., 2020). Climate change has disrupted small-scale fisheries in Bangladesh, especially affecting Hilsa fish, by delaying monsoons and altering breeding cycles. It is also changing fish migration, behavior, feeding, reproduction, and catch levels (Giri, 2018). Similarly, thermal habitats of freshwater fish species are changing due to climate change (Xu et al., 2024). This finding brought attention to climate change is increasingly threatening global fish diversity and the sustainability of fisheries, creating significant uncertainty for aquatic ecosystems and the communities that depend on them. Rising temperatures, altered water chemistry, and shifting habitats are directly affecting fish physiology, behavior, and distribution (Huang et al., 2021).

Climate Effects on Fish and it's Habitats

Climate change has diverse impacts on aquatic systems, posing significant risks to vulnerable fisher communities. As a highly climate-sensitive sector, fisheries play a vital role in global nutrition, food security, and livelihoods, making them particularly vulnerable to environmental changes (Galappaththi et al., 2022).This aligns with the findings that climate change poses both direct and indirect threats to aquatic ecosystems and fish populations. Direct impacts, such as reduced rainfall, increased evaporation, and elevated water temperatures, disrupt the physiological functions and behavioral patterns of fish. These changes can impair growth, reproduction, and survival of the fish. Indirectly, climate change intensifies water demand for agriculture, reducing reservoir levels and degrading aquatic habitats. These hydrological changes affect food availability, shelter, and overall ecosystem stability, increasing fish vulnerability to predation, disease, and invasive species (Patrick, 2016). Similarly, the diversity and distribution of fish in aquatic environments, as well as their health, are influenced by temperature and dissolved oxygen (DO), along with elevation gradients and seasonal variations (Adhikari et al., 2021).

Ecosystem and Reproductive Stress in Indigenous Fish

Climate change disrupts both global and local environments, harming aquatic ecosystems by shifting species' habitats, disturbing breeding patterns, and breaking down food chains (Ninawe et al., 2018). As water levels decline, aquatic habitats particularly floodplains and shallow lakes shrink, leading to habitat loss for many species. This habitat reduction is especially critical for indigenous fish such as *Tor putitora* and *Channa striata*, which depend on inundated areas for spawning; insufficient rainfall disrupts these breeding cycles and can result in reproductive failure. Additionally, reduced water volumes tend to warm more quickly and hold less dissolved oxygen, placing further stress on fish populations and increasing mortality rates. The disruption continues through the food web, as decreased runoff limits the flow of nutrients into aquatic ecosystems, reducing plankton production and thereby diminishing the food base that supports fish communities.

Carp Culture and Environmental Issues in the Terai

The majority of the "pond" or warm-water fish production takes place in the Terai region, where 94% of the fish ponds are located (Yadav et al., 2023). Similarly, pond culture is the only method of fish breeding on the plains (Farquhar et al., 2018). In Nepal, seven economically valuable carp species are commonly raised using polyculture systems in ponds, lakes, and enclosures. Recently, pangas (*Pangasianodon hypophthalmus*) and Nile tilapia (*Oreochromis niloticus*) have become popular among small-scale and commercial farmers (Wagle, 2016). In Nepal, *Schizothorax moleshowrthii* and *S. progastus* are regarded as delectable fish (Gautam, 2015). The observed trained is the pond culture that is a very popular aquaculture practice with many aquatic species cultured in the pond. Weather conditions like floods, droughts, cold spells, and temperature variations, however, pose a threat to aquaculture. These conditions significantly affect fish survival, growth, and reproduction in pond systems (Paul et al., 2024).

Drought Impacts on Freshwater Life and Aquaculture

Climate change impacts were studied that globally alters the status, processes and dynamics of terrestrial, freshwater, and marine ecosystems (Starck & Wolter, 2024) and also impacts livelihoods, particularly in sectors like agriculture, fisheries, and tourism (Zaman et al., 2025). Other paper examined that drought impacts on freshwater organisms directly by causing mortality and altering physiology in response to high temperatures and desiccation, or more indirectly through changes in inter specific interactions (Cushway et al., 2025).This observation aligns with previous finding that highlights climate change variability in location, timing, and magnitude of rainfall can alter how species respond to the drought and flood disturbances (Hansen et al., 2025).

Aquaculture, especially pond-based and cage fish farming, is increasingly vulnerable to the impacts of reduced rainfall. Water scarcity due to insufficient precipitation limits the availability of water needed to maintain ponds and tanks, threatening the sustainability of these systems. Additionally, elevated temperatures and deteriorating water quality caused by lower water levels create stressful conditions for fish, which can lead to disease outbreaks and significant stock losses. To cope with these challenges, farmers often resort to pumping water or installing aeration systems to maintain adequate oxygen levels measures that significantly raise production costs and strain the economic viability of aquaculture operations.

Socio-Economic Impacts on fish farmers and fisher folk

The present study underscores the impacts of climate change on both fisheries ecosystems and livelihoods of fish farmers and fisher folk (Allison et al., 2009). Climate change significantly impacts people, their livelihoods, and ecosystems, posing a serious global challenge especially for the poor in developing countries (Sharma & Neupane, 2025). Furthermore, the Hindu Kush Himalaya region in Nepal is climate-sensitive, with fragile water systems. As a source of major rivers, climate change threatens water supply, affecting millions and their livelihoods (Mudbhari et al., 2022). Aquaculture, along with commercial fishing, provides fundamental support for maintaining worldwide food security and economic progress and nutritional wellness (Abeysinghe et al., 2025). According to research, climate change events had a significant impact on the management of crab points, pond aquaculture, and shrimp farming in enclosures along Bangladesh's southwest coast. They have also had a negative impact on the livelihoods and adaptive challenges of communities that depend on aquatic ecosystems because of storm surges, prolonged floods, salinity increases, sea level rise, droughts, and river bank erosion (Amin et al., 2024).

Furthermore, Bangladesh is highly vulnerable to climate change. Over 11% of its population is involved in the fishing sector, which supplies 60% of the country's animal protein. However, climate change is causing food insecurity and health issues (Alam & Mallick, 2022). Specifically, aquaculture and capture fisheries in Nepal involve about 750,000 people, with rivers contributing nearly 50% of captured fish production (International Journal of Fisheries and Aquatic Studies, 2017). Particularly in landlocked nations and for communities living beside lakes and rivers, fish from inland water capture fisheries represent a significant supply of animal protein. About 90% of the catch is made up of finfish, along with a few crustaceans and mollusks (Welcomme, 2011). These finding highlight the several ethnic communities are traditionally engaged in fishing and related livelihoods in Nepal. In the Koshi region, groups such as the Malaha, Bahardar, Mukhiya, and Sahani are deeply involved in fishing, boating, and fish marketing. Fishermen of Nepal is general have neither land nor asset of their own. They often receive their food and daily goods from the wholesalers, and they pay for this with their

catches. The livelihoods of thousands of Nepalese who depend on inland fisheries are increasingly at risk due to declining fish productivity driven by reduced rainfall. As fish catches decrease, small-scale fishers many of whom have limited alternative income sources face significant economic hardship and job insecurity. This decline also threatens food security, particularly in rural communities where fish serves as a crucial source of protein, and its scarcity can worsen malnutrition. Beyond the economic and nutritional impacts, fishing holds deep cultural significance for several ethnic groups for whom traditional fishing practices are closely tied to their cultural identity. As fish populations dwindle, these communities face not only financial strain but also the erosion of long-standing cultural traditions.

Adaptation and Mitigation Strategies

Climate change adaptation is a key development priority in many developing countries like Nepal, where most people rely on farming (Tiwari et al., 2014). Due to rising climate risks, developing and implementing adaptation (Manandhar et al., 2011). The process of adapting to climate change involves making the necessary adjustments and changes in order to lessen its adverse impacts. To reduce the vulnerability of climate change integration of aquaculture with agriculture irrigation could be substantial to increase the efficiency strategies is essential of water and land use (Gurung, 2012). This study's finding suggests to address the growing challenges facing inland fisheries in Nepal due to reduced rainfall, a comprehensive approach combining technological, ecological, and policy-level interventions is crucial. Promoting water-efficient aquaculture systems, such as re-circulating aquaculture systems (RAS) and integrated fish farming can help optimize water use while sustaining production. At the ecological level, improved watershed management through reforestation and soil conservation can enhance water retention and groundwater recharge, supporting the long-term resilience of aquatic ecosystems. Additionally, the implementation of early warning systems, including real-time monitoring of rainfall and river flows, can enable more adaptive and informed fisheries planning. Equally important is the integration of fisheries management into national climate adaptation policies, ensuring that the sector is supported within broader strategies aimed at building climate resilience.

Technology Innovations in Aquaculture

Recirculating Aquaculture Systems (RAS): A Recirculating Aquaculture System (RAS) is a fish-farming method where water is continuously filtered, cleaned, and reused, allowing fish to grow in controlled tanks with minimal water waste. They provide precise control over water quality and temperature, making fish production resilient to rainfall variability. However, they come with high initial costs and maintenance requirements.

Biofloc Technology (BFT): This microbial-driven system converts ammonia and other waste into microbial biomass, which serves as supplemental feed, reducing water exchange and boosting feed efficiency. It also helps maintain good water quality and can lower disease risks beneficial under constrained water scenarios.

Integrated Farming Systems

IFCAS (Integrated Floating Cage Aquageoponics System): Developed in Bangladesh and trialed in Nepal, IFCAS integrates fish culture with vegetable production using pond waste as nutrient input. It's especially useful during dry seasons in shallow or shaded ponds. Fish are raised in tanks, and their nutrient-rich water is used to feed plants growing in sand beds. The sand beds act as a natural filter, cleaning the water before it cycles back to the fish tanks.

Integrated Multi-Trophic Aquaculture (IMTA): Doesn't rely solely on one species rather, it combines fish with other organisms (e.g. shellfish, seaweed) that utilize the waste from fish as feed, promoting nutrient recycling and ecosystem balance.

Precision Aquaculture, IoT, and AI Integration: These tools allow real-time tracking and management of water parameters through sensors, combined with machine learning to make dynamic decisions e.g., optimizing feeding, detecting disease early, and regulating environmental conditions.

Climate-Smart Management Practices: Responding to water quality fluctuations (due to heat or rainfall) using lime, aeration, zeolite, pond bottom raking, and added oxygen, along with adjusting feeding schedules. Employ ground water pumping, partial harvesting to reduce stocking density, and delaying stocking to cope with reduced water availability.

Conclusion

Climate change is disrupting inland water bodies through irregular rainfall, changing inflows, and fluctuating water levels. These hydro-climatic changes impact fish communities by affecting their growth, reproduction, behavior, and distribution mainly due to reduced rainfall and increased evaporation. Hence, reduced rainfall, a consequence of changing climate regimes, poses a growing threat to inland fisheries and aquaculture sectors in Madhesh province. Addressing this issue requires a coordinated approach that blends scientific research, community engagement, and policy reform. Immediate action is necessary to safeguard aquatic biodiversity, ensure food security, and protect the livelihoods of thousands who depend on these vital ecosystems.

Recommendations for Madhesh Province (Reduced Rainfall Context)

Adopt Biofloc (BFT): Affordable, reduces water needs, improves feed use.

Combine with Low-Tech Strategies: Use aeration, lime, feeding adjustments during heat or dry spells as immediate risk mitigation steps.

Engage Digital Planning: Even without full digital twins, farm-level maps and condition tracking using mobile tools can help anticipate water and heat stress.

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References

Abeysinghe, K. C., Weerarathne, A. G. P. T., Colonne, D. K. C., & Bellanthudawa, B. K. A. (2025). Sustainable development goals (SDGs), climate change, and the development of aquaculture and fisheries industries. *Environmental Reviews*, *33*, 1–24. https://doi.org/10.1139/er-2024-0136

Adhikari, A., Limbu, J. H., & Pathak, S. (2021). Fish diversity and water quality parameters of Mechi River, Jhapa, province no. 1, Nepal. *Borneo Journal of Resources Science and Technology*, *10*(2), 24–34.

Alam, E., & Mallick, B. (2022). Climate change perceptions, impacts and adaptation practices of fishers in southeast Bangladesh coast. *International Journal of Climate Change Strategies and Management*, *14*(2), 191–211.

Allison, E. H., Perry, A. L., Badjeck, M., Neil Adger, W., Brown, K., Conway, D., Halls, A. S., Pilling, G. M., Reynolds, J. D., Andrew, N. L., & Dulvy, N. K. (2009). Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, *10*(2), 173–196. https://doi.org/10.1111/j.1467-2979.2008.00310.x

Amin, A., Hasan, Z., Ferdous, S. R., & Alam, M. S. (2024). Perceived impacts of climate change on coastal aquaculture in the cyclone prone southwest region of Bangladesh: 10.32526/ennrj/22/20240117. *Environment and Natural Resources Journal*, *22*(6), 535–546.

Barange, M., Bahri, T., Beveridge, M. C., Cochrane, K. L., Funge-Smith, S., & Poulain, F. (2018). Impacts of climate change on fisheries and aquaculture. *United Nations' Food and Agriculture Organization*, *12*(4), 628–635.

Basnet, K., Shrestha, A., Joshi, P. C., & Pokharel, N. (2020). Analysis of climate change trend in the lower Kaski district of Nepal. *Himalayan Journal of Applied Science and Engineering*, *1*(1), 11–22. https://doi.org/10.3126/hijase.v1i1.3353

Bista, R. B., Dahal, K. R., & Gyawali, R. P. (2018). A review of climate change and its effects in the western mountainous water basin of Nepal. *Hydro Nepal: Journal of Water, Energy and Environment*, *23*, 79–85.

Cushway, K. C., Geist, J., & Schwalb, A. N. (2025). Surviving global change: A review of the impacts of drought and dewatering on freshwater mussels. *Biological Reviews*, *100*(1), 275–307. https://doi.org/10.1111/brv.13142

Farquhar, S. D., Khanal, N., Shrestha, M., Farthing, M., & Bhujel, R. C. (2018). Socio-economic impacts of the Women in Aquaculture (WiA) project in Nepal. *Kasetsart Journal of Social Sciences*. https://doi.org/10.1016/j.kjss.2017.12.014

Galappaththi, E. K., Susarla, V. B., Loutet, S. J. T., Ichien, S. T., Hyman, A. A., & Ford, J. D. (2022). Climate change adaptation in fisheries. *Fish and Fisheries*, *23*(1), 4–21. https://doi.org/10.1111/faf.12595

Gautam, N. (2015). Challenges of freshwater fisheries in Nepal: A short overview. *International Journal of Applied Sciences and Biotechnology*, *3*(4), 579–583.

Gautam, S., & Sapkota, P. (2023). Status and Development Trend of Aquaculture and Fisheries in Nepal. *Nepalese Journal of Aquaculture and Fisheries*, *10*, 1–13.

Giri, S. S. (Ed.). (2018). *Small-scale fisheries in South Asia*. SAARC Agriculture Centre.

Gurung, T. B. (2012). Integrated aquaculture within agriculture irrigation for food security and adaptation to climate change. *Hydro Nepal: Journal of Water, Energy and Environment*, 73–77.

Gurung, T. B., Pokharel, P. K., & Wright, I. (2011). *Climate Change: Livestock Sector Vulnerability and Adaptation in Nepal*. https://doi.org/10.13140/RG.2.1.1548.6887

Hansen, H. H., Bergman, E., Kopf, K., & Lindmark, M. (2025). Resistance of Australian fish communities to drought and flood: Implications for climate change and adaptations. *Ecography*, *2025*(1), e07442. https://doi.org/10.1111/ecog.07442

Huang, M., Ding, L., Wang, J., Ding, C., & Tao, J. (2021). The impacts of climate change on fish growth: A summary of conducted studies and current knowledge. *Ecological Indicators*, *121*, 106976.

Karki, M., Mool, P., & Shrestha, A. (1970). Climate Change and its Increasing Impacts in Nepal. *The Initiation*, *3*, 30–37. https://doi.org/10.3126/init.v3i0.2425

Karki, R., Hasson, S. U., Schickhoff, U., Scholten, T., & Böhner, J. (2017). Rising Precipitation Extremes across Nepal. *Climate*, *5*(1), 4. https://doi.org/10.3390/cli5010004

Kayes, A. N. M., Tabassum, T., & Khan, M. A. M. R. (2025). Assessment of Climate-Induced Vulnerabilities and Poverty Alleviation Potential of Dry Fish Industry: An Ecological and Socio-economic Study in Cox's Bazar District, Bangladesh. *International Journal of Disaster Risk Management*, *7*(1), 461–484.

Kwasek, K., Thorne-Lyman, A. L., & Phillips, M. (2020). Can human nutrition be improved through better fish feeding practices? A review paper. *Critical Reviews in Food Science and Nutrition*, *60*(22), 3822–3835. https://doi.org/10.1080/10408398.2019.1708698

Manandhar, S., Vogt, D. S., Perret, S. R., & Kazama, F. (2011). Adapting cropping systems to climate change in Nepal: A cross-regional study of farmers' perception and practices. *Regional Environmental Change*, *11*(2), 335–348. https://doi.org/10.1007/s10113-010-0137-1

Mandal, S. C., Kadir, S., & Hossain, A. (2020). Effects of Salinity on the Growth, Survival and Proximate Composition of Pangas, Pangasius Hypophthalmus. *Bangladesh Journal of Zoology*, *48*(1), 141–149. https://doi.org/10.3329/bjz.v48i1.47883

Mendivil, C. O. (2021). Dietary Fish, Fish Nutrients, and Immune Function: A Review. *Frontiers in Nutrition*, *7*. https://doi.org/10.3389/fnut.2020.617652

Mudbhari, D., Kansal, M. L., & Kalura, P. (2022). Impact of climate change on water availability in Marsyangdi river basin, Nepal. *Quarterly Journal of the Royal Meteorological Society*, *148*(744), 1407–1423. https://doi.org/10.1002/qj.4267

Ninawe, A. S., Indulkar, S. T., & Amin, A. (2018). Impact of Climate Change on Fisheries. In *Biotechnology for Sustainable Agriculture* (pp. 257–280). Elsevier. https://doi.org/10.1016/B978-0-12-812160-3.00009-X

Patrick, A. E. S. (2016). *Influence of rainfall and water level on inland fisheries production: A review*.

Paul, P., Rahi, M. F., Saiquit, I. H., Sarower, M. G., Rouf, M. A., Parvez, M. S., Aktar, S., Khanom, M., Khan, A. N., & Rahman, M. M. (2024). Climate change effects on the small-scale fisheries in the Northern part of Bangladesh and associated adaptation measures. *Khulna University Studies*, 33–46.

Sharma, S., & Neupane, S. (2025). Exploring Farmers' Resilience: Climate Change and Sustainable Adaptation Strategies in the Agricultural Sector of Nepal. *Turkish Journal of Agriculture-Food Science and Technology*, *13*(2), 504–513.

Starck, S., & Wolter, C. (2024). Resilience Approach for Assessing Fish Recovery after Compound Climate Change Effects on Algal Blooms. *Sustainability*, *16*(14), 5932.

Teutschbein, C., & Seibert, J. (2010). Regional Climate Models for Hydrological Impact Studies at the Catchment Scale: A Review of Recent Modeling Strategies. *Geography Compass*, *4*(7), 834–860. https://doi.org/10.1111/j.1749-8198.2010.00357.x

The Department of Hydrology and Meteorology of Nepal (2023).

Timalsina, R., Maharjan, S., Kandel, S., Awasthi, M. P., Bishwakarma, K., Dhami, U., Thapa, L. B., Singh, V. B., & Pant, R. R. (2025). A Ramsar wetlands in Nepal: Status, uses, challenges, and conservation strategies–a review. *Nepalese Journal of Zoology*, *9*(1), 55–66.

Tiwari, K. R., Rayamajhi, S., Pokharel, R. K., & Balla, M. K. (2014). Determinants of the climate change adaptation in rural farming in Nepal Himalaya. *International Journal of Multidisciplinary and Current Research*, *2*(1), 2321–3124.

Upreti, B. R. (2013). Environmental security: Concepts, issues and problems. *Human Security in Nepal: Concepts, Issues and Challenges*, 211.

Wagle, S. K. (2016). Climate Change Impact on Inland Fisheries and Aquaculture in Nepal. *Climate Change Impact on Coastal Fisheries and Aquaculture in South Asia*, 96.

Wagle, S. K., Gurung, T. B., Pradhan, N., & Raymajhi, A. (2011). Climate change implication for fisheries and aquaculture in Nepal. *Proceedings of Consultative Workshop on Climate Change: Livestock Sector Vulnerability and Adaptation in Nepal*, 94–111.

Welcomme, R. L. (with Food and Agriculture Organization of the United Nations). (2011). *Review of the state of the world fishery resources: Inland fisheries*. Food and Agriculture Organization of the United Nations.

Xu, L., Feiner, Z. S., Frater, P., Hansen, G. J., Ladwig, R., Paukert, C. P., Verhoeven, M., Wszola, L., & Jensen, O. P. (2024). Asymmetric impacts of climate change on thermal habitat suitability for inland lake fishes. *Nature Communications*, *15*(1), 10273.

Yadav, M., Ranjan, R., & Bahadur Shah, T. (2023). Fish farming practices and disease occurrence in the fish farms of Dhanusha district, Nepal. *Malaysian Animal Husbandry Journal*, *3*(1), 15–27. https://doi.org/10.26480/mahj.01.2023.15.27

Zaman, F., Ara, R., & Karim, F. (2025). Vulnerability and climate change. *Bangladesh Journal of Bioethics*, *16*(2), 21–25. https://doi.org/10.62865/bjbio.v16i2.164