Spatio-Temporal Assessment of Physico-Chemical Water Parameters of Govind Sagar Dam, Lalitpur, Uttar Pradesh

Anuradha[1], Vijay Kumar Yadav[2], Kapil Kumar[3]

[1]Department of Zoology, Raghuveer Singh Government P.G. College, Lalitpur, Uttar Pradesh, India
Corresponding Author Email: *prof07a[at]gmail.com*

[2]Department of Zoology, Bipin Bihari College, Jhansi, Uttar Pradesh, India

[3]Department of Zoology, Meerut College, Meerut, Uttar Pradesh, India

Abstract: ***Water quality fluctuations significantly dictate fish behavior, serving as a critical biomarker for physiological health, growth, and ecosystem productivity. This study evaluates key physical, chemical, and anthropogenic parameters across multiple sampling sites at the Govind Sagar Dam in Lalitpur. Parameters analyzed include physical metrics (water temperature and turbidity), chemical variables (dissolved oxygen, salinity, pH, and inorganic nitrogen), and emerging pollutants (microplastics and Agricultural waste). Environmental shifts in these parameters alter fish physiology, metabolic rates, tissue structure, and sensory perception. Consequently, these physiological disturbances impair vital behavioral responses, including swimming performance, schooling dynamics, foraging efficiency, predator avoidance, territorial aggression, mating success, and anxiety-driven threat perceptions.***

Keywords: Dissolved oxygen, pH, Water temperature, Turbidity, Salinity, Inorganic nitrogen

1. Introduction

Over the past five decades, global food production has tripled to sustain rapid population growth, largely enabled by a sevenfold increase in synthetic nitrogen (N) fertilizer application [1,2]. Consequently, nitrogen loading into freshwater ecosystems grew threefold, reaching approximately 120 Tg N/year by 2000 across combined sources: synthetic fertilizers, livestock manure, biological N_2 fixation, and atmospheric deposition. Driven by ongoing demographic expansion and shifting dietary preferences toward higher protein consumption, anthropogenic nitrogen inputs are projected to rise further, posing severe management challenges for global freshwater systems [3-5].

Accelerated demographic growth and economic development in India have precipitated severe natural resource deficits, with freshwater ecosystems experiencing acute strain. Globally, freshwater availability is further constrained by widespread anthropogenic pollution originating from municipal discharge [6, 7], industrial effluents, agricultural runoff, and untreated sewage [8]. These discharge streams load aquatic environments with complex pollutant matrices, including suspended solids, inorganic chemicals, nutrient excesses (N and P), heavy metals, pesticides, and microbial pathogens [9, 10]. Because specific physical, chemical, and biological purity thresholds govern applications in agriculture, industry, aquaculture, and human consumption, systematic water quality monitoring is indispensable. Ultimately, securing potable and high-quality freshwater resources is critical to supporting ecological integrity and achieving national sustainable development goal [12-15,].

Fish growth depends heavily on water quality, with monitoring dissolved oxygen levels being a critical factor [16]. Traditional monitoring methods struggle to provide the up-to-date data needed to optimize production. Smart aquaculture monitoring systems [17] now employ multiple sensors to track parameters such as pH, ammonia nitrogen, dissolved oxygen, and turbidity. These advanced sensors enable farmers to take prompt action to mitigate risks [18-22]. However, the high cost of quality monitoring equipment remains a major challenge, limiting its widespread adoption [23-25].

Poor water conditions adversely affect the health and behavior of fish [26, 27]. These issues can severely impact the productivity of fish farming operations. In 2019, Malaysian fish farms experienced a decline of over 50% in total annual production due to poor water quality. When water quality deteriorates, fish grow more slowly, become susceptible to illness, and experience higher mortality rates [28]. Water temperature plays a significant role in fish metabolism; higher temperatures cause fish to absorb more waterborne pollutants and increase the toxicity of ammonia and nitrite. Fish become stressed and are more prone to inflammation. Furthermore, they fail to convert feed efficiently, resulting in reduced profits [29-32].

Fish farming often involves dealing with multiple water quality issues simultaneously. Dissolved oxygen is the most significant concern; low oxygen levels cause far more fish fatalities than any other problem [33]. Excessive ammonia, resulting from fish waste and uneaten feed, creates toxic conditions that stunt fish growth and damage their gills. pH levels outside the normal range (typically 6.5–8.5) can severely impact fish reproduction and performance. Fish are particularly vulnerable during the breeding season. Eggs and fry are more resilient to adverse conditions than adult fish [34, 35].

Assessing water quality requires a comprehensive evaluation of physico-chemical parameters, heavy metal concentrations, and the overall biotic and abiotic health of aquatic ecosystems. These environments possess vital economic and aesthetic significance, supporting fisheries, agriculture, industrial operations, ecotourism, and scientific research. Consequently, the precise determination of physico-chemical variables and heavy metals is paramount for monitoring environmental degradation and implementing effective pollution control strategies.

2. Materials and Methods

The present study was conducted at the Govind Sagar Dam, a major reservoir constructed on the Shahzad River between 1947 and 1953. Located in the Lalitpur district of southern Uttar Pradesh (24°40'27" N latitude, 78°25'25" E longitude), the reservoir serves as a critical hydrological feature and socioeconomic asset for the region. It supports extensive agricultural irrigation, local capture fisheries, and regional tourism, making its water quality vital to the regional economy and surrounding ecosystems.

2.1. Study Area & Sampling Strategy

Sampling Locations: Water and sediment samples were collected from pre-selected monitoring stations strategically positioned across the target aquatic ecosystem to capture baseline conditions, point-source effluent discharge points, and downstream agricultural or industrial impact zones.

2.2. Sampling Station Profiles

- **Station S1:** Located near the main dam release gate; represents open water body conditions with higher dissolved oxygen and low organic load.
- **Station S2:** Located where the Shahzad River enters the reservoir; reflects baseline inflow water quality from upstream catchments.
- **Station S3:** Located adjacent to surrounding cropland; exhibits elevated nutrient levels (NO_3^- and PO_4^{3-}) from fertilizer leaching.
- **Station S4:** Positioned near local human settlements and fishing docks; shows higher BOD and COD due to anthropogenic runoff.
- **Station S5:** Situated in the deep open basin; serves as the control monitoring point for stable limnological conditions.

2.3. Sample Collection & Handling:

To evaluate the physicochemical characteristics concentrations of Govind Sagar Dam (Lalitpur), five representative monitoring stations were established across the reservoir. Field sampling was conducted at bi-weekly intervals over a seven-month period from September 2023 to March 2024. Surface water samples were collected at a depth of 15–30 cm using pre-cleaned high-density polyethylene (HDPE) bottles. Samples designated for trace heavy metal analysis were acidified on-site with ultrapure nitric acid (HNO_3) to pH < 2 to prevent metal precipitation and wall adsorption. Water samples intended for general physicochemical analysis were stored in insulated cold boxes at 4°C in the dark during transport to the laboratory to minimize biological degradation and chemical alteration.

2.4. Physico-Chemical Analysis

Water temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO) were measured *in situ* at each sampling station using calibrated multi-parameter digital probes. Laboratory analyses were conducted to quantify chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD), total alkalinity, total hardness, nitrates (NO_3^-), and orthophosphates (PO_4^{3-}) in accordance with standard protocols outlined by the American Public Health Association (APHA).

2.5. Data Analysis & Quality Assurance

- All laboratory determinations were performed in triplicate, with results expressed as mean ± standard deviation.
- Spatial and temporal variations were evaluated using One-Way Analysis of Variance (ANOVA), Principal Component Analysis (PCA), and Water Quality Index (WQI) modeling.

3. Result and Discussion

The evaluation of physicochemical parameters provides a framework for assessing the pollution levels of aquatic ecosystems, the impact of human activities, and overall ecological health, which can be explained as follows:

3.1. Water Temperature

Controls chemical reaction kinetics, aquatic metabolic rates, and gas solubility, with higher temperatures reducing dissolved oxygen capacity. Water temperature is a fundamental physical parameter that directly influences chemical reaction kinetics, gas solubility, and biological processes within aquatic ecosystems. In the present study, water temperature ranged from a minimum of 23.28°C at station S3 to a maximum of 23.45°C at station S1. The recorded thermal values remained within normal ambient baseline limits for surface water bodies during the study period. Across the sampling locations, the parameter exhibited a standard deviation of approximately 3.0°C, primarily reflecting temporal variations associated with sampling across different months of the summer season.

3.2. pH

Indicates the acidity or alkalinity of water on a 0–14 scale; essential for maintaining chemical equilibrium and biological organism survival. The pH of an aquatic system is intimately linked with electrical conductivity and total alkalinity, reflecting shifts in the carbon dioxide–carbonate–bicarbonate equilibrium under changing physicochemical conditions. In the present study, pH values ranged from a minimum of 4.75 at station S3 to a maximum of 6.48 at station S2, indicating moderately acidic to slightly acidic conditions. Across all sampling locations, the parameter exhibited a standard deviation of approximately 1.0, highlighting moderate spatial variability. This acidity is largely attributable to localized pollution sources, including domestic sewage discharge and agricultural runoff carrying decaying organic matter from croplands and orchards.

Table 1: Month-wise Water Quality Parameter Variations (Dam Mean Values)

Parameter	Unit	Sept- 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Mar 2024
Water Temp	°C	27.5	25.1	21.4	17.2	16.5	20.8	25.3
pH	-	7.4	7.6	7.8	7.9	8.0	7.7	7.5
Total Dissolved Solids (TDS)	mg/L	218	205	195	185	179	198	214
Dissolved Oxygen (DO)	mg/L	5.8	6.2	7.0	7.8	8.1	7.2	6.1
Total Alkalinity	mg/L	142	135	128	120	115	125	138
Total Hardness	mg/L	155	148	140	132	126	135	149
BOD	mg/L	2.8	2.4	2.1	1.8	1.6	2.2	2.7
COD	mg/L	18.5	16.2	14.8	12.5	11.2	15.0	17.8
Nitrates (NO_3^-)	mg/L	3.2	2.6	2.1	1.6	1.4	2.0	2.8

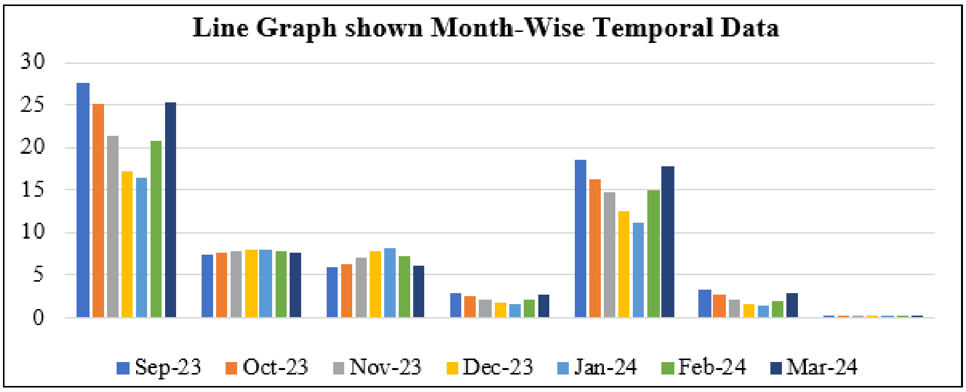

Figure 1: Comparison of physico-chemical parameters at five sampling stations of Gobind Sagar Dam against maximum permissible limits for variations.

Table 2: Station-Wise Physico-Chemical Parameter Data (September 2023 – March 2024)

Parameter	Unit	Standard Limit (BIS 10500)	Station 1 (S1)	Station 2 (S2)	Station 3 (S3)	Station 4 (S4)	Station 5 (S5)
Water Temperature	°C	Atmospheric	22.4 ± 4.1	22.1 ± 3.9	23.0 ± 4.2	22.6 ± 4.0	22.2 ± 3.8
pH	-	6.5 – 8.5	7.6 ± 0.2	7.8 ± 0.2	8.1 ± 0.3	7.5 ± 0.2	7.7 ± 0.2
Total Dissolved Solids	mg/L	500	198 ± 15	182 ± 12	233 ± 20	217 ± 18	188 ± 14
Dissolved Oxygen	mg/L	> 5.0	6.8 ± 0.9	7.2 ± 0.8	5.6 ± 1.1	6.1 ± 1.0	6.9 ± 0.8
Total Alkalinity	mg/L	200	124 ± 10	115 ± 9	148 ± 14	136 ± 12	118 ± 8
Total Hardness	mg/L	200	138 ± 12	126 ± 10	162 ± 15	150 ± 13	130 ± 11
BOD (20°C)	mg/L	< 3.0	2.1 ± 0.4	1.6 ± 0.3	3.2 ± 0.6	2.7 ± 0.5	1.8 ± 0.3
Chemical Oxygen Demand	mg/L	< 250	14.2 ± 2.8	11.5 ± 2.2	24.6 ± 4.1	19.8 ± 3.4	12.8 ± 2.5
Nitrates (NO_3^-)	mg/L	45	1.8 ± 0.6	1.3 ± 0.4	3.8 ± 0.9	2.9 ± 0.7	1.5 ± 0.5

3.3. Total Dissolved Solids (TDS)

Represents the total concentration of dissolved inorganic minerals and organic matter; serves as a primary marker for overall salinity. Total Dissolved Solids (TDS), representing the cumulative concentration of dissolved cations and anions in mg/L, ranged from a minimum of 182.00 mg/L at station S1 to a maximum of 276.25 mg/L at station S2. All recorded values remained well below the maximum permissible limits established for drinking water standards. Across all sampling stations, the parameter exhibited a standard deviation of approximately 19 mg/L, indicating spatial variation likely driven by localized pollution inputs at specific monitoring points.

3.4. Dissolved Oxygen (DO)

Dissolved oxygen (DO) is a critical indicator of aquatic ecosystem health, providing key insights into bacterial respiration, photosynthetic activity, nutrient dynamics, and thermal stratification. During summer, DO levels typically decline due to reduced gas solubility at elevated temperatures and heightened microbial respiration, despite temporary oxygen production from phytoplankton photosynthesis during periods of intense sunlight. In the present study, DO concentrations in Gobind Sagar Lake ranged from a minimum of 1.83 mg/L at station S1 to a maximum of 2.73 mg/L at station S2. Across all monitoring sites, the parameter exhibited a standard deviation of approximately 0.20 mg/L. The consistently depressed DO concentrations across all stations fall well below the minimum recommended standards for sustaining aquatic life, primarily driven by high summer temperatures and accelerated microbial oxygen consumption during organic decomposition.

3.5. Total Alkalinity

Measures the acid-neutralizing (buffering) capacity of water, preventing rapid pH fluctuations caused by acidic inputs. Total alkalinity measures the acid-neutralizing capacity of water, primarily governed by dissolved carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), and hydroxide (OH^-) ions. In the present study, the total alkalinity of the lake water samples ranged from a minimum of 24.33 mg/L at station S3 to a maximum of 138.75 mg/L at station S2. All recorded values remained well below the maximum permissible limit. Across all monitoring locations, the parameter exhibited a standard deviation of approximately 8 mg/L, indicating relatively low spatial variability across the sampling stations.

3.6. Total Hardness

Reflects the combined concentration of divalent cations—mainly calcium (Ca^{2+}) and magnesium (Mg^{2+})- affecting water usability for domestic and agricultural purposes. Total hardness (TH) reflects the cumulative concentration of dissolved multivalent metallic cations—primarily calcium (Ca^{2+}) and magnesium (Mg^{2+})—associated with bicarbonates, sulfates, chlorides, and nitrates [24], serving as a critical determinant of water suitability for domestic, industrial, and potable uses. In the present study, total hardness ranged from a minimum of 29.57 mg/L at station S1 to a maximum of 38.47 mg/L at station S2. All recorded values remained well within the maximum permissible limits for drinking water. Across all sampling stations, the parameter exhibited a standard deviation of approximately 12 mg/L, reflecting spatial variation attributed to localized pollution inputs and varying anthropogenic influences across the monitoring sites.

3.7. Biochemical Oxygen Demand (BOD)

Quantifies the oxygen consumed by aerobic microorganisms to break down organic matter over 5 days, acting as a direct measure of organic pollution. Measures free oxygen gas dissolved in water, serving as the critical indicator of aquatic life survival and ecosystem health. Biochemical Oxygen Demand (BOD) measures the amount of dissolved oxygen consumed by microorganisms during the biological decomposition of organic matter in water. In the present study, the BOD of the lake water samples ranged from a minimum of 0.75 mg/L at station S1 to a maximum of 1.23 mg/L at station S2. All observed values remained well below the maximum permissible limits for surface water standards. Across all monitoring locations, the parameter exhibited a low standard deviation of approximately 0.04 mg/L, indicating minimal spatial variation in biodegradable organic contamination across the sampling stations.

3.8. Chemical Oxygen Demand (COD)

Measures the oxygen required to chemically oxidize all organic compounds (both biodegradable and non-biodegradable), representing total pollution load. Chemical Oxygen Demand (COD) measures the equivalent quantity of oxygen required for the chemical oxidation of organic matter present in water. In Gobind Sagar Lake, COD concentrations ranged from a minimum of 0.61 mg/L at station S3 to a maximum of 1.66 mg/L at station S1. All observed values remained well below the maximum permissible limits established for surface water standards. Across all monitoring sites, the parameter exhibited a standard deviation of approximately 0.40 mg/L, reflecting spatial fluctuations likely driven by localized organic inputs and varying anthropogenic influences.

4. Conclusion

The water in Uttar Pradesh's Govind Sagar reservoir is satisfactory in terms of standard mineral content and organic pollution levels, and it falls into the 'soft water' category; however, the local aquatic life and ecosystem face two major challenges: Acidity (Acidic Stress)- the reservoir's water is more acidic than normal. Runoff from agricultural and domestic waste has compromised the water's natural buffering capacity, leading to significantly increased acidity in certain areas. Severe Hypoxia (Critical Oxygen Depletion)- dissolved oxygen levels throughout the reservoir have dropped so drastically that the survival of fish and other aquatic organisms has become difficult. Rising temperatures and the decomposition of waste are rapidly depleting the water's oxygen supply.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements
The authors express their sincere gratitude to Meerut College, Meerut, and BBC Jhansi for their technical support and assistance in identifying fish specimens.

References

[1] An, D., Huang, J., & Wei, Y. (2021). A survey of fish behaviour quantification indexes and methods in aquaculture. *Reviews in Aquaculture*, 13(4), 2169–2189. https://doi.org/10.1111/raq.12564

[2] Arechavala-Lopez, P., Caballero-Froilán, J. C., Jiménez-García, M., et al. (2020). Enriched environments enhance cognition, exploratory behaviour and brain physiological functions of *Sparus aurata*. *Scientific Reports*, 10(1), 11252. https://doi.org/10.1038/s41598-020-68306-6

[3] Badiola, M., Mendiola, D., & Bostock, J. (2012). Recirculating Aquaculture Systems (RAS) analysis: Main issues on management and future challenges. *Aquacultural Engineering*, 51, 26–35. https://doi.org/10.1016/j.aquaeng.2012.07.004

[4] Becker, L. J. S., Brooks, E. M., & Gabor, C. R. (2016). Effects of turbidity on foraging behavior in the endangered fountain darter (*Etheostoma fonticola*). *American Midland Naturalist*, 175(1), 55–63. https://doi.org/10.1674/amid-175-01-55-63.1

[5] Bosker, T., Santoro, G., & Melvin, S. D. (2017). Salinity and sensitivity to endocrine disrupting chemicals: A comparison of reproductive endpoints in small-bodied fish exposed under different salinities. *Chemosphere*, 183, 186–196. https://doi.org/10.1016/j.chemosphere.2017.05.063

[6] Browning, H. (2023). Improving welfare assessment in aquaculture. *Frontiers in Veterinary Science*, 10, 1060720. https://doi.org/10.3389/fvets.2023.1060720

[7] Camargo-dos-Santos, B., Gonçalves, B. B., Bellot, M. S., Guermandi, I. I., Barki, A., & Giaquinto, P. C. (2021). Water turbidity–induced alterations in coloration and courtship behavior of male guppies (*Poecilia reticulata*). *Acta Ethologica*, 24(2), 127–136. https://doi.org/10.1007/s10211-021-00369-8

[8] Claireaux, G., & Lefrançois, C. (2007). Linking environmental variability and fish performance: Integration through the concept of scope for activity.

Philosophical Transactions of the Royal Society B: Biological Sciences, 362(1487), 2031–2041. https://doi.org/10.1098/rstb.2007.2099

[9] da Silva, M. C., Canário, A. V. M., Hubbard, P. C., & Gonçalves, D. M. F. (2021). Physiology, endocrinology and chemical communication in aggressive behaviour of fishes. *Journal of Fish Biology*, 98(5), 1217–1233. https://doi.org/10.1111/jfb.14667

[10] FAO. (2023). *World Food and Agriculture – Statistical Yearbook 2023*. Rome, Italy: FAO. https://openknowledge.fao.org/handle/20.500.14283/cc8166en

[11] García-Jaramillo, M., Beaver, L. M., Truong, L., et al. (2020). Nitrate and nitrite exposure leads to mild anxiogenic-like behavior and alters brain metabolomic profile in zebrafish. *PLoS ONE*, 15(12), e0240070. https://doi.org/10.1371/journal.pone.0240070

[12] Henares, M. N. P., Medeiros, M. V., & Camargo, A. F. M. (2020). Overview of strategies that contribute to the environmental sustainability of pond aquaculture: Rearing systems, residue treatment, and environmental assessment tools. *Reviews in Aquaculture*, 12(1), 453–470. https://doi.org/10.1111/raq.12327

[13] Huntingford, F. A., Adams, C., Braithwaite, V. A., et al. (2006). Current issues in fish welfare. *Journal of Fish Biology*, 68(2), 332–372. https://doi.org/10.1111/j.0022-1112.2006.001046.x

[14] Johansen, J. L., & Jones, G. P. (2011). Increasing water temperatures reduce swimming performance and survival in a tropical coral reef fish. *Global Change Biology*, 17(9), 2971–2979. https://doi.org/10.1111/j.1365-2486.2011.02478.x

[15] Kleinhappel, T. K., Burman, O. H. P., John, E. A., Wilkinson, A., & Pike, T. W. (2019). The impact of water pH on association preferences in fish. *Ethology*, 125(4), 195–202. https://doi.org/10.1111/eth.12843

[16] Kültz, D., Podrabsky, J. E., Stillman, J. H., et al. (2015). Physiological mechanisms used by fish to cope with salinity stress. *Journal of Experimental Biology*, 218(12), 1907–1914. https://doi.org/10.1242/jeb.118695

[17] Leduc, A. O. H. C., Roh, E., Macnaughton, C. J., Benz, F., Rosenfeld, J., & Brown, G. E. (2010). Ambient pH and the response to chemical alarm cues in juvenile Atlantic salmon: Mechanisms of reduced behavioral responses. *Transactions of the American Fisheries Society*, 139(1), 117–128. https://doi.org/10.1577/T09-024.1

[18] Lu, Y., Zhang, Y., Deng, Y., et al. (2016). Uptake and accumulation of polystyrene microplastics in zebrafish (*Danio rerio*) and toxic effects in liver. *Environmental Science & Technology*, 50(7), 4054–4060. https://doi.org/10.1021/acs.est.6b00183

[19] MacIntyre, C. M., Ellis, T., North, B. P., et al. (2008). The influences of water quality on the welfare of farmed rainbow trout: A review. In *Fish Welfare* (pp. 150–184). John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470697610.ch10

[20] Maia, C. M., Saraiva, J. L., & Gonçalves-de-Freitas, E. (2024). Preference, avoidance, motivation and their importance to fish welfare. *Fish and Fisheries*, 25(2), 362–379. https://doi.org/10.1111/faf.12812

[21] Martins, C. I. M., Galhardo, L., Noble, C., et al. (2012). Behavioural indicators of welfare in farmed fish. *Fish Physiology and Biochemistry*, 38(1), 17–41. https://doi.org/10.1007/s10695-011-9518-8

[22] Menon, S. V., Kumar, A., Middha, S. K., et al. (2023). Water physicochemical factors and oxidative stress physiology in fish, a review. *Frontiers in Environmental Science*, 11, 1240813. https://doi.org/10.3389/fenvs.2023.1240813

[23] Naylor, R. L., Hardy, R. W., Buschmann, A. H., et al. (2021). A 20-year retrospective review of global aquaculture. *Nature*, 591(7851), 551–563. https://doi.org/10.1038/s41586-021-03308-6

[24] Okomoda, V. T., Oladimeji, S. A., Solomon, S. G., Olufeagba, S. O., Ogah, S. I., & Ikhwanuddin, M. (2023). Aquaponics production system: A review of historical perspective, opportunities, and challenges of its adoption. *Food Science & Nutrition*, 11(3), 1157–1165. https://doi.org/10.1002/fsn3.3154

[25] Pekcan-Hekim, Z., & Lappalainen, J. (2006). Effects of clay turbidity and density of pikeperch (*Sander lucioperca*) larvae on predation by perch (*Perca fluviatilis*). *Naturwissenschaften*, 93(7), 356–359. https://doi.org/10.1007/s00114-006-0114-1

[26] Rodriguez-Dominguez, A., Connell, S. D., Leung, J. Y. S., & Nagelkerken, I. (2019). Adaptive responses of fishes to climate change: Feedback between physiology and behaviour. *Science of the Total Environment*, 692, 1242–1249. https://doi.org/10.1016/j.scitotenv.2019.07.226

[27] Scherer, E. (1992). Behavioural responses as indicators of environmental alterations: Approaches, results, developments. *Journal of Applied Ichthyology*, 8(1–4), 122–131. https://doi.org/10.1111/j.1439-0426.1992.tb00674.x

[28] Sharma, R. C., & Kumar, R. (2020). Water quality assessment and fish biodiversity of freshwater reservoirs in North India. *Environmental Monitoring and Assessment*, 192(5), 310. https://doi.org/10.1007/s10661-020-08264-9

[29] Suriyampola, P. S., Cacéres, J., & Martins, E. P. (2018). Effects of short-term turbidity on sensory preference and behaviour of adult fish. *Animal Behaviour*, 146, 105–111. https://doi.org/10.1016/j.anbehav.2018.10.014

[30] Tang, Z. H., Huang, Q., Wu, H., Kuang, L., & Fu, S. J. (2017). The behavioral response of prey fish to predators: The role of predator size. *PeerJ*, 5, e3222. https://doi.org/10.7717/peerj.3222

[31] Volkoff, H., & Peter, R. E. (2006). Feeding behavior of fish and its control. *Zebrafish*, 3(2), 131–140. https://doi.org/10.1089/zeb.2006.3.131

[32] Wing, J. D. B., Champneys, T. S., & Ioannou, C. C. (2021). The impact of turbidity on foraging and risk taking in the invasive Nile tilapia (*Oreochromis niloticus*) and a threatened native cichlid (*Oreochromis amphimelas*). *Behavioral Ecology and Sociobiology*, 75(3), 49. https://doi.org/10.1007/s00265-021-02984-8

[33] Wong, B. B. M., & Candolin, U. (2015). Behavioral responses to changing environments. *Behavioral Ecology*, 26(3), 665–673. https://doi.org/10.1093/beheco/aru183

[34] Yavuzcan Yildiz, H., Robaina, L., Pirhonen, J., Mente, E., Domínguez, D., & Parisi, G. (2017). Fish welfare in aquaponic systems: Its relation to water quality with an emphasis on feed and faeces—A review. *Water*, 9(1), 13. https://doi.org/10.3390/w9010013

[35] Zhang, Z., Fu, Y., Zhao, H., & Zhang, X. (2022). Social enrichment affects fish growth and aggression depending on fish species: Applications for aquaculture. *Frontiers in Marine Science*, 9, 1011780. https://doi.org/10.3389/fmars.2022.1011780