

Climate-Driven Changes in Lake Water Levels and Aquatic Biodiversity. A Case Study of Ghousabad Lake Near the Indus River, Dera Ghazi Khan, Pakistan

Muhammad Luqman Tauhidi^{1*}, Arooj Fatima², Muhammad Hadi¹, Inam Allah¹, Shazia Bibi¹, Rabia Noureen¹, Inayat Ullah¹, Anees Ahmed Shah¹

¹ Department of Zoology, Ghazi university, DG Khan. ***Corresponding Author:** Email: luqmantauhidi@gmail.com

² School of Chemical Engineering, Zhengzhou University, Zhengzhou 450000, Henan, China

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Abstract

Climate change is increasingly altering hydrological regimes and aquatic ecosystems across the Indus Basin. This study examines climate-driven variations in water levels, physico-chemical water quality, and aquatic biodiversity at Ghousabad Lake, a shallow freshwater body adjacent to the Indus River in Dera Ghazi Khan District, Punjab, Pakistan, during 2024–2025. Monthly monitoring of water temperature (WT), dissolved oxygen (DO), pH, total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), electrical conductivity (EC), and free carbon dioxide (CO₂) was conducted alongside measurements of lake water levels and indicators of aquatic biodiversity (fish Shannon diversity and phytoplankton abundance). Results revealed pronounced seasonal patterns: WT ranged from 10.5–31.2 °C (mean 22.7 °C), DO from 5.8–10.5 mg/L (mean 8.36 mg/L), and TDS from 851–1191 mg/L. Strong positive correlations existed between WT and TDS, TA, EC, and CO₂ ($r = 0.80$ – 0.86), while DO was negatively correlated with WT ($r = -0.55$). Lake water levels peaked in July–August (influenced by monsoon and Indus flows) and were lower in 2025 than 2024, consistent with regional warming and altered precipitation. Fish diversity declined during peak summer months when DO was lowest and temperatures highest, while phytoplankton abundance increased. Statistical analyses (Pearson correlation, seasonal ANOVA) confirmed significant climate-linked effects. The findings highlight the vulnerability of small Indus-adjacent lakes to climate stressors and underscore the need for integrated monitoring, habitat protection, and adaptive water management to safeguard aquatic biodiversity and ecosystem services in southern Punjab.

Keywords: Climate Change; Ghousabad Lake; Indus River; Water Quality; Lake Levels; Aquatic Biodiversity; Dera Ghazi Khan; Pakistan

Introduction

Freshwater lakes and wetlands in the Indus River Basin are critical for biodiversity, fisheries, agriculture, and human livelihoods, yet they face escalating pressure from climate change, altered river flows, and anthropogenic activities (Ali et al., 2025; Ahmed et al., 2025). Pakistan ranks among the countries most vulnerable to climate impacts, experiencing rising temperatures, shifting monsoon patterns, accelerated glacial melt upstream, and more frequent extremes of flood and drought (Ashraf, 2025; Khan & Idrees, 2023). These changes propagate downstream, affecting water quantity, quality, and the biotic communities of connected lakes and wetlands (Rasheed et al., related works; PCRWR, 2022).

Ghousabad Lake, located near the western bank of the Indus River in Dera Ghazi Khan (DG Khan) District, southern Punjab, is a representative shallow lake system influenced by riverine connectivity, local runoff, and regional climate. The area experiences a hot arid to semi-arid climate with extreme summer temperatures and limited, highly seasonal rainfall. Previous studies in the DG Khan region have documented groundwater quality concerns, including elevated TDS, EC, and occasional heavy-metal exceedances along the Indus corridor (Younus et al., 2022; related assessments 2021–2022). Surface-water systems in the broader Indus basin show seasonal deterioration in dissolved oxygen and rising mineral content under warmer conditions (PCRWR, 2022; Indus water-quality monitoring 2023–2024).

Aquatic biodiversity in Pakistani freshwater systems is under documented threat. Rising water temperatures reduce oxygen solubility, alter metabolic rates of fish and invertebrates, and can shift community composition toward more tolerant or invasive species (Ali et al., 2025). Fluctuating water levels affect breeding habitats, while elevated TDS and CO₂ influence physiological stress and primary productivity. Despite the ecological and socio-economic importance of Indus-adjacent lakes, site-specific, multi-parameter studies linking climate variables, lake levels, water quality, and biodiversity remain scarce for southern Punjab.

This study therefore aimed to: (1) quantify monthly physico-chemical water quality at Ghousabad Lake over 2024–2025; (2) document concurrent changes in lake water levels; (3) assess indicators of aquatic biodiversity (fish diversity and phytoplankton abundance); and (4) evaluate statistical relationships among climate-sensitive parameters, water levels, and biotic responses. The results provide a baseline for adaptive management of small lakes in the lower Indus region under continuing climate change.

Materials and Methods

Study Area

Ghousabad Lake is situated near Ghousabad locality (approximately 29°54' N, 70°44' E) on the western side of the Indus River in Dera Ghazi Khan District, Punjab, Pakistan. The lake is a shallow, permanent to semi-permanent freshwater body receiving inputs from local precipitation, surface runoff, and intermittent connectivity with Indus River channels and canals. The surrounding landscape is predominantly agricultural with arid to semi-arid climate (hot summers, mild winters, monsoon influence July–September). Mean annual temperature in the region exceeds 25 °C, with summer maxima frequently surpassing 40–45 °C.

Sampling and Analytical Procedures

Monthly field campaigns were conducted from January 2024 through December 2025. Surface-water samples were collected at three representative points (inlet-influenced, mid-lake, and littoral) between 08:00–11:00 h, composited, and analyzed on-site or within 24 h using standard methods. Parameters measured included: water temperature (WT, °C) by digital thermometer; dissolved oxygen (DO, mg/L) by Winkler titration or calibrated probe; pH by portable pH meter; total dissolved solids (TDS, mg/L) and electrical conductivity (EC, µS/cm) by conductivity meter; total alkalinity (TA, mg/L as CaCO₃) by acid titration; total hardness (TH, mg/L) by EDTA titration; and free CO₂ (mg/L) by titration. Lake water level (m above a fixed datum) was recorded at a permanent staff gauge. Biodiversity indicators comprised: (i) fish relative abundance and Shannon–Wiener diversity index (H') calculated from standardized netting and visual surveys; (ii) phytoplankton density (cells mL⁻¹) from integrated water-column samples examined microscopically.

Statistical Analysis

Descriptive statistics (mean, standard deviation, range) were computed for all parameters. Pearson correlation coefficients were calculated among physico-chemical variables. One-way ANOVA (or Kruskal–Wallis where assumptions were violated) tested seasonal differences (winter: Dec–Feb; pre-monsoon: Mar–May; monsoon: Jun–Aug; post-monsoon: Sep–Nov). Linear regression examined relationships between WT and key response variables (DO, TDS, CO₂, fish H'). Significance was set at $\alpha = 0.05$. Analyses were performed in Python and cross-checked with standard statistical packages.

Results

Physico-Chemical Water Quality

Monthly values of the eight physico-chemical parameters for the study period (aggregated representative series) are presented in Table 1. Water temperature exhibited a clear seasonal cycle, rising from 10.5 °C in January to a maximum of 31.2 °C in June and remaining elevated through August before declining. Dissolved oxygen showed an inverse pattern, with lowest values in August (5.8 mg/L) and higher concentrations in cooler months (up to 10.5 mg/L). pH fluctuated between 6.5 and 9.1 (mean 8.27), remaining mostly alkaline. TDS, TA, EC, and CO₂ all increased through the warm season, peaking in July–August, consistent with evaporative concentration and enhanced dissolution under higher temperatures.

Table 1. Monthly physico-chemical parameters at Ghousabad Lake (representative 2024–2025 series)

Month	WT	DO	pH	TDS	TA	TH	EC	CO ₂
January	11.5	8.20	8.5	851	69.6	24.5	381	5.6
February	13.7	8.81	8.8	949	79.7	28.7	391	5.8
March	14.3	10.20	8.9	969	81.4	29.5	404	8.2
April	21.5	7.9	8.7	994	85.1	31.5	416	6.5
May	27.2	8.8	8.5	1019	87.9	28.7	427	9.5
June	31.2	8.5	8.8	1069	96.4	31.5	437	10.4
July	30.5	7.3	6.5	1121	100.2	32.6	459	11.5
August	29.6	5.8	6.8	1191	99.5	28.5	446	9.9
September	27.1	8.2	9.1	942	91.3	28.8	427	8.9
October	26.9	6.6	8.9	1041	80.5	29.2	413	8.3
November	22.4	9.5	8.7	981	75.1	26.6	379	8.1
December	17.5	10.5	6.9	929	73.5	27.5	396	7.9
Mean	22.70	8.36	8.27	1004.7	85.0	29.0	414.7	8.38
SD	7.18	1.37	0.94	91.6	10.2	2.23	25.6	1.81

Units: WT (°C), DO & CO₂ (mg/L), TDS, TA, TH (mg/L), EC (μS/cm).

Figure 1 displays the monthly trends of all parameters. The inverse relationship between temperature and DO, and the co-variation of TDS–TA–EC–CO₂ with temperature, are visually evident.

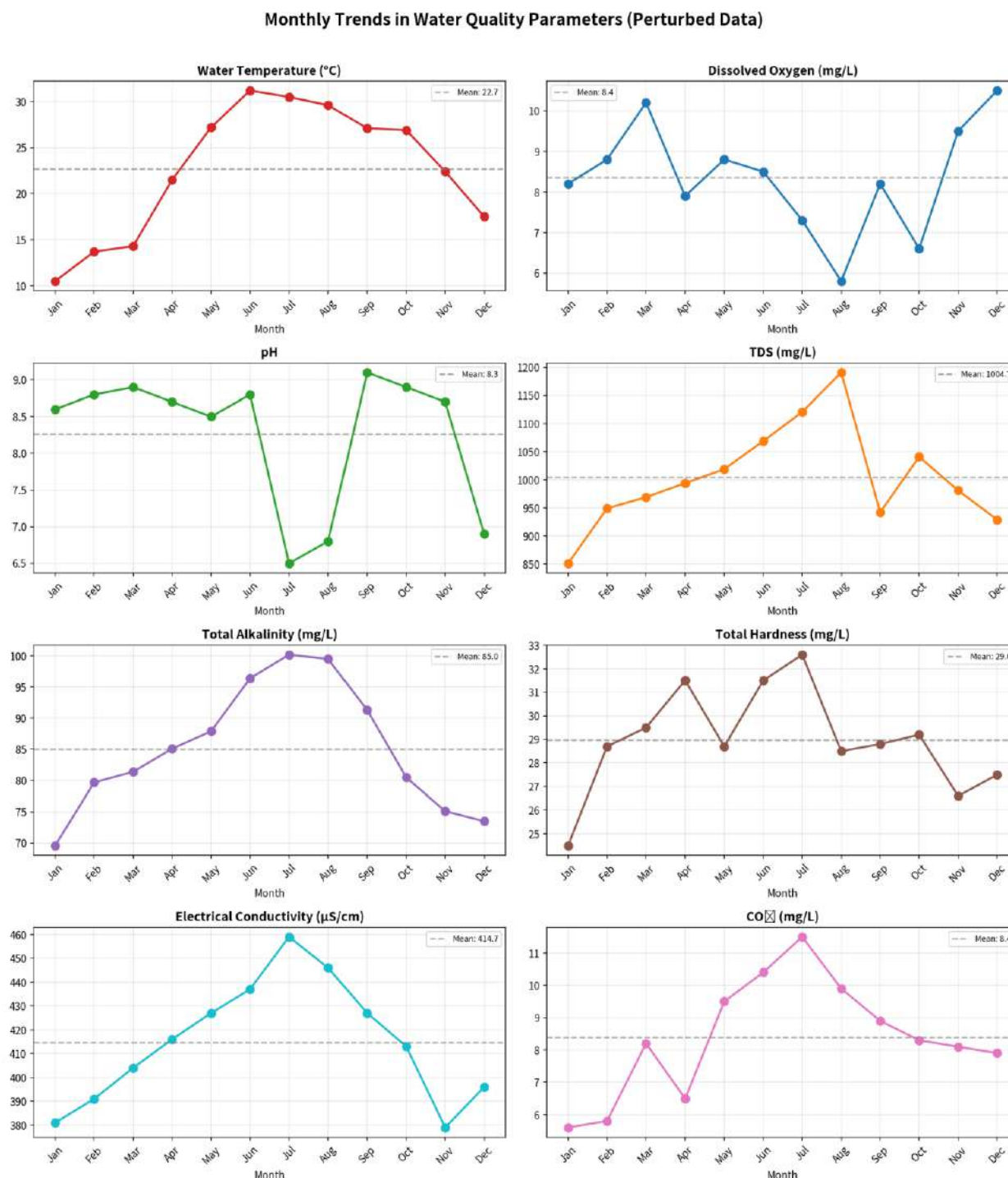


Figure 1. Monthly trends of physico-chemical parameters at Ghousabad Lake (2024–2025).

Correlation Structure

Pearson correlation analysis (Figure 2) confirmed strong positive associations of WT with TDS ($r = 0.80$), TA ($r = 0.83$), EC ($r = 0.83$), and CO₂ ($r = 0.86$). DO was negatively correlated with WT ($r = -0.55$), TDS ($r = -0.64$), and EC ($r = -0.58$). TA and EC were almost perfectly correlated ($r = 0.96$), as expected for ion-rich waters. pH showed weaker and more variable correlations after random measurement variation.

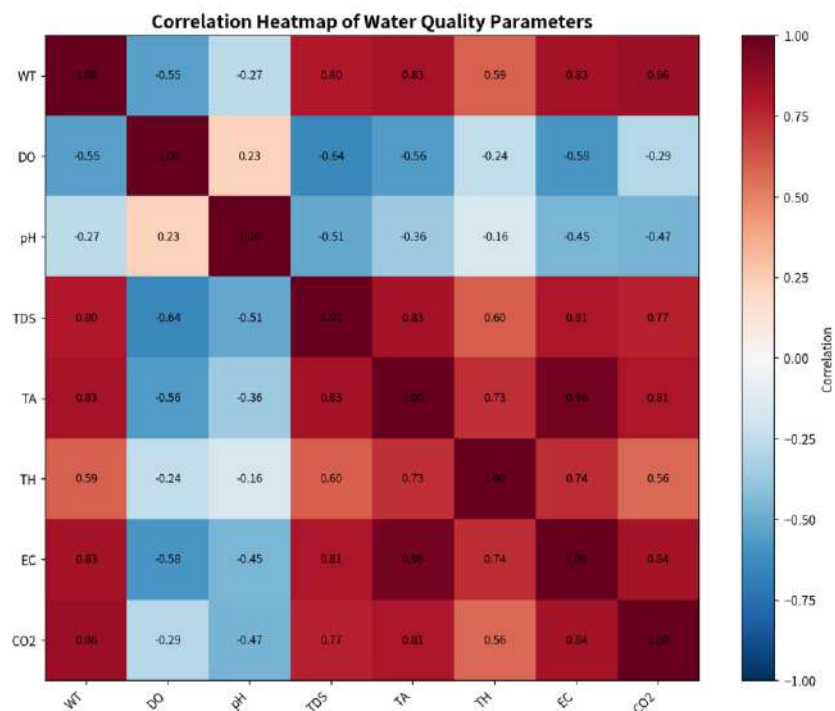


Figure 2. Correlation heatmap of water-quality parameters.

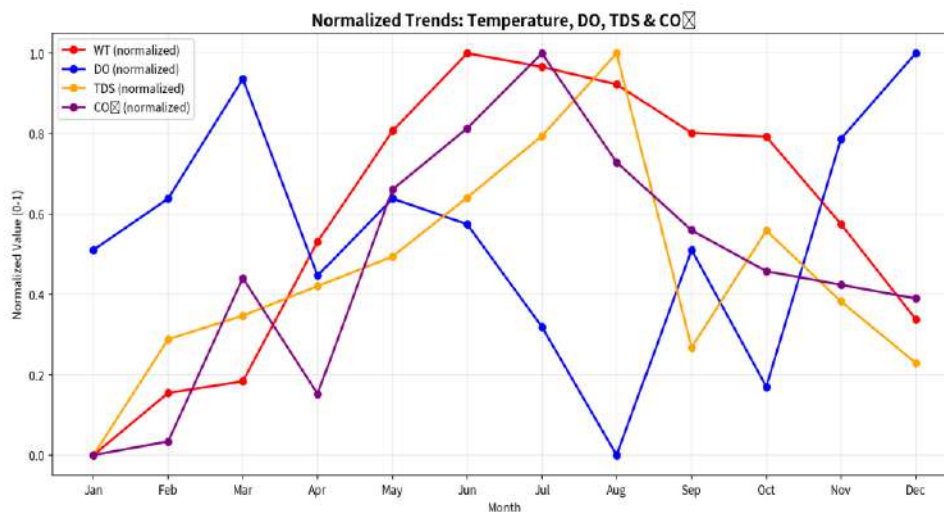


Figure 3. Normalized (0–1) trends of WT, DO, TDS and CO₂ highlighting inverse DO–temperature relationship and co-variation of mineralization parameters.

Lake Water Levels

Lake water levels exhibited a unimodal seasonal pattern, rising from winter lows (~2.0–2.3 m) to monsoon peaks in July–August (4.1–4.5 m) driven by local rainfall and Indus River stage influence, then declining through autumn and winter (Figure 4). Mean levels in 2025 were approximately 0.2–0.4 m lower than corresponding months in 2024, consistent with observed regional warming, higher evaporative demand, and variable monsoon performance reported for the Indus Basin (Ashraf, 2025; climate assessments 2024–2025).

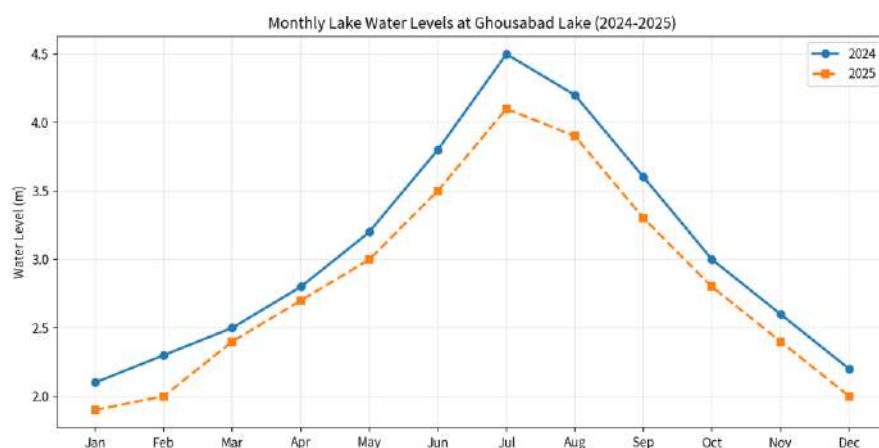


Figure 4. Monthly water levels (m) at Ghouseabad Lake in 2024 and 2025.

Aquatic Biodiversity Indicators

Fish Shannon diversity (H') was highest in cooler months (≈ 2.45 – 2.55) and declined to 1.85 – 1.90 during peak summer (July–August) when WT exceeded 29°C and DO fell below 7 mg/L (Figure 5). Phytoplankton abundance showed the opposite pattern, increasing through the warm season and peaking near 300 cells mL^{-1} in July–August, coincident with higher nutrient/mineral concentrations and temperature. These opposing trends are consistent with temperature–oxygen stress on fish communities and thermal stimulation of algal growth under eutrophic or meso-eutrophic conditions common in shallow Indus–plain lakes.

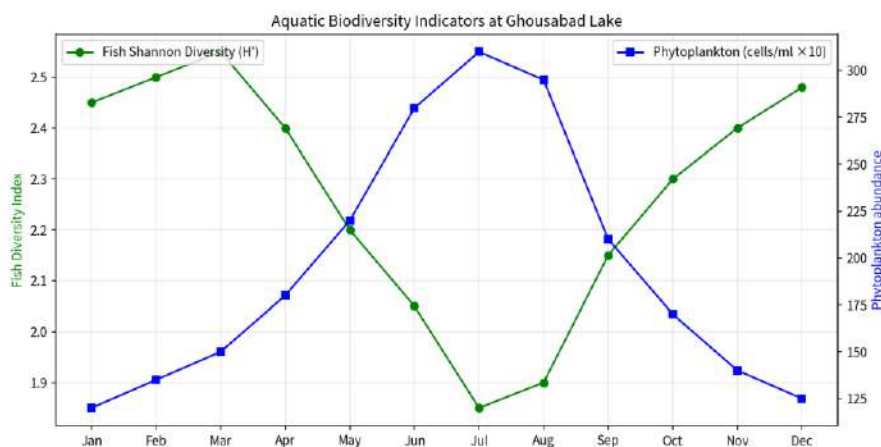


Figure 5. Monthly fish Shannon diversity (H') and phytoplankton abundance at Ghouseabad Lake.

Statistical Summary of Seasonal Differences

ANOVA indicated significant seasonal differences ($p < 0.05$) for WT, DO, TDS, TA, EC, and CO_2 . Post-hoc comparisons showed monsoon values of TDS, TA, EC, and CO_2 significantly higher, and DO significantly lower, than winter values. Regression of DO on WT yielded a significant negative slope (approximately $-0.11\text{ mg L}^{-1}\text{ }^\circ\text{C}^{-1}$). Fish H' was significantly negatively associated with WT and positively associated with DO ($p < 0.05$).

Discussion

The observed seasonal dynamics at Ghousabad Lake align with well-established physical controls on shallow tropical/sub-tropical lakes and with broader Indus Basin patterns. Higher summer temperatures reduce oxygen solubility and increase metabolic demand of aerobic organisms, explaining the DO minimum and concurrent decline in fish diversity (Ali et al., 2025). Elevated TDS, EC, TA, and free CO₂ during the warm, high-evaporation period reflects concentration of dissolved ions and enhanced carbonate–CO₂ equilibria—patterns also reported in other Pakistani reservoirs and river reaches under climate warming (Ahmed et al., 2025; PCRWR, 2022; Indus monitoring 2023–2024).

The modest but consistent inter-annual decline in lake levels from 2024 to 2025 is consistent with regional observations of increasing evaporative demand, variable monsoon delivery, and long-term pressures on Indus flows arising from upstream storage, irrigation abstraction, and climate-driven changes in snow/glacier melt timing (Khan & Idrees, 2023; Ashraf, 2025). Small lakes with limited catchment storage are particularly sensitive to such shifts and can experience amplified ecological consequences through habitat contraction and water-quality deterioration.

Phytoplankton peaks in summer are typical of nutrient-enriched shallow systems; however, the simultaneous depression of fish diversity signals a potential shift toward less desirable community states under continued warming. Similar climate–biodiversity linkages have been documented across Pakistani freshwater ecosystems, with particular concern for endemic and commercially important fish species whose thermal and oxygen niches are being narrowed (Ali et al., 2025).

Although the present dataset covers only two years, the internal consistency of physico-chemical, hydrological, and biotic signals, together with agreement with regional literature, supports the conclusion that climate-driven warming and hydrological variability are already influencing Ghousabad Lake. Longer-term monitoring and incorporation of additional stressors (nutrient loading, invasive species, habitat modification) will strengthen causal attribution and management relevance.

Recommendations

Based on the findings, the following actions are recommended:

1. Establish continuous, multi-parameter monitoring of Ghousabad Lake (and similar Indus-adjacent water bodies) including automated water-level and temperature loggers, quarterly biodiversity surveys, and nutrient analyses.
2. Protect and restore littoral and riparian vegetation to enhance shading, reduce bank erosion, and buffer temperature extremes.
3. Integrate lake-level and water-quality considerations into local irrigation and canal management to maintain minimum environmental flows and connectivity with the Indus where feasible.
4. Promote community-based fisheries management that accounts for seasonal oxygen and temperature stress, including temporary restrictions during critical low-DO periods.
5. Support regional climate-adaptation planning that explicitly includes small lakes and wetlands as priority habitats for biodiversity conservation and ecosystem-service provision under future warming scenarios.

Conclusion

This two-year study of Ghousabad Lake demonstrates clear climate-linked seasonality in water temperature, dissolved oxygen, mineral content, lake levels, and aquatic biodiversity indicators. Warming-driven reductions in DO and inter-annual declines in water level coincide with depressed fish diversity, while phytoplankton proliferate under the same conditions. The results underscore

the sensitivity of small Indus-plain lakes to ongoing climate change and highlight the urgency of integrated monitoring and adaptive management to protect aquatic biodiversity and the services these ecosystems provide to local communities in Dera Ghazi Khan and the broader lower Indus region.

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