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RESEARCH ARTICLE

Physicochemical characterization and aquaculture suitability of Taudaha Lake, Kathmandu, Nepal

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ABSTRACT

Taudaha Lake, the only natural lake in Kathmandu, Nepal, was studied to evaluate its potential for aquaculture following the Nepal Water Quality Guidelines for Aquaculture (NWQGA, 2015). The study aimed to characterize physicochemical parameters, determine hydrochemical processes, and assess suitability for fish farming. Ten water samples were collected during January 2024 from strategically selected sites around Taudaha Lake, including inflow and outflow points as well as accessible locations along the lake boundary. In-situ measurements included temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), and total dissolved solids (TDS). Laboratory analyses measured total hardness, alkalinity, major cations (Ca^{2+}, Mg^{2+}, Na^+, K^+), anions (Cl^-, SO_4^{2-}, HCO_3^-), and nutrients (ammonia, phosphate) following APHA-AWWA-WEF (2017) standard methods. Results indicated that most parameters, including temperature (15.9–17.2 °C), pH (7.45–7.92), TDS (211–223 mg/L), phosphate (0.018–0.188 mg/L), and ammonia (0.030–0.097 mg/L), were within NWQGA limits, supporting cold and intermediate water fish species. However, DO levels (2.76–5.54 mg/L) were below recommended thresholds, and total hardness (98–150 mg/L) exceeded optimal limits potentially limiting fish growth and reproduction. Geochemical analyses using Piper, Gibbs, and mixing diagrams revealed a mixed Ca^{2+}–Mg^{2+}–Cl^-–SO_4^{2-} hydrochemical facies dominated by silicate and carbonate weathering with minimal anthropogenic influence. Overall, Taudaha Lake shows moderate aquaculture suitability. Long-term water quality monitoring, management of nutrient inputs, and maintenance of adequate oxygen levels are recommended to improve fish productivity while preserving the lake's ecological and cultural values.

Keywords: ***Taudaha lake, Water quality, Aquaculture, Physicochemical, Hydrochemistry***

INTRODUCTION

Wetlands and lakes are vital freshwater ecosystems that support biodiversity, provide essential ecosystem services such as water purification, flood regulation, and carbon sequestration, and sustain human livelihoods (Keddy, 2010; Zedler and Kercher, 2005). These ecosystems are also directly important for human activities such as aquaculture, where the physical, chemical, and biological characteristics of water critically influence ecological health and support the optimal growth, survival, and productivity of aquatic species (Boyd, 2017; Shaltami and Bustany, 2021).

Water quality in lakes and wetlands is influenced by natural processes including rainfall, rock weathering, and evaporation, as well as anthropogenic activities such as agricultural runoff and wastewater discharge (Pant et al., 2019; Paudyal et al., 2016). Monitoring these parameters provides critical insights into ecosystem functioning, trophic status, and the suitability of water for aquaculture, domestic use, and irrigation.

Taudaha Lake, the only natural lake in central Nepal, is situated at 1350 m above sea level (27°38.88' N, 85°17.05' E), approximately 10 km from Kathmandu city. Covering 4 hectares with a mean depth of 3 m, the lake has cultural, spiritual, and ecological significance, including providing habitat for birds, fish, and aquatic plants. It receives inflow from surrounding agricultural fields and discharges via a permanent outlet, with its water managed by the Karkotak Nagraja Nagrani Resident Restoration Society (KNNRRS) (Pradhananga et al., 2013). Despite its ecological and cultural importance, there is limited information on its water quality and suitability for aquaculture particularly under the pressures of urbanization and seasonal changes.

This study was conducted during January 2024 (winter season) to evaluate the physicochemical characteristics of Taudaha Lake and its suitability for aquaculture according to the Nepal Water Quality Guidelines for Aquaculture (NWQGA, 2015). Sampling in winter provides insight into water quality during a season of lower rainfall and reduced inflow, which may concentrate minerals and influence dissolved oxygen levels. Ten water samples were collected during January 2024 from strategically selected sites around Taudaha Lake, including key inflow and outflow points, as well as other accessible boundary locations, with replicate samples taken to ensure reliability. Hydrochemical analysis, including Gibbs, Piper, and mixing diagrams, were used to understand the natural and anthropogenic factors controlling water chemistry.

The primary objectives of this study were to characterize the lake's water quality, assess its potential for aquaculture especially for cold and intermediate water fish species and identify geochemical processes influencing water chemistry. By linking water quality to aquaculture potential, this research aims to inform strategies for pollution control, nutrient management, and the sustainable use of Taudaha Lake while maintaining its ecological and cultural significance

MATERIALS AND METHODS

Study area

Taudaha Lake is located in Kirtipur Municipality-6 within the Kathmandu district of Nepal at an elevation of 1,291 meters above sea level (27º 38' 55.5" N, 85º 16' 54.8" E). The lake lies approximately 6 km southwest of central Kathmandu along the route to the Dakshinkali shrine. Although relatively small, covering an area of about 4 hectares, Taudaha Lake has an irregular shape with eight distinct corners and reaches a maximum depth of 6 meters. The lake has a single outflow and receives water mainly from two inlets, which are particularly active during the monsoon season. The surrounding catchment is a mix of agricultural fields, forest patches, and built-up areas reflecting a mosaic of land use and land cover typical of the suburban Kathmandu region. The geology of the area is predominantly composed of fluvio-lacustrine deposits, alluvium, and weathered bedrock, which influence the lake's hydrochemistry and sediment composition. The region experiences a subtropical climate with warm, wet summers and cool, dry winters, and receives most of its precipitation during the monsoon season (June to September).

Taudaha Lake provides essential habitat for a variety of flora and fauna, including numerous fish species, benthic macroinvertebrates, and approximately 118 bird species, many of which are migratory. Despite its ecological and cultural importance, the lake is under environmental stress from multiple sources. These include nutrient enrichment and eutrophication from agricultural runoff, sedimentation, encroachment from urban development, and limited management of wastewater and solid waste. Such pressures can alter the water quality affecting both biodiversity and the lake's potential for aquaculture. This study focuses on characterizing the physicochemical properties of Taudaha Lake and evaluating its suitability for aquaculture, taking into account the lake's hydrology, surrounding land use, and environmental stressors.

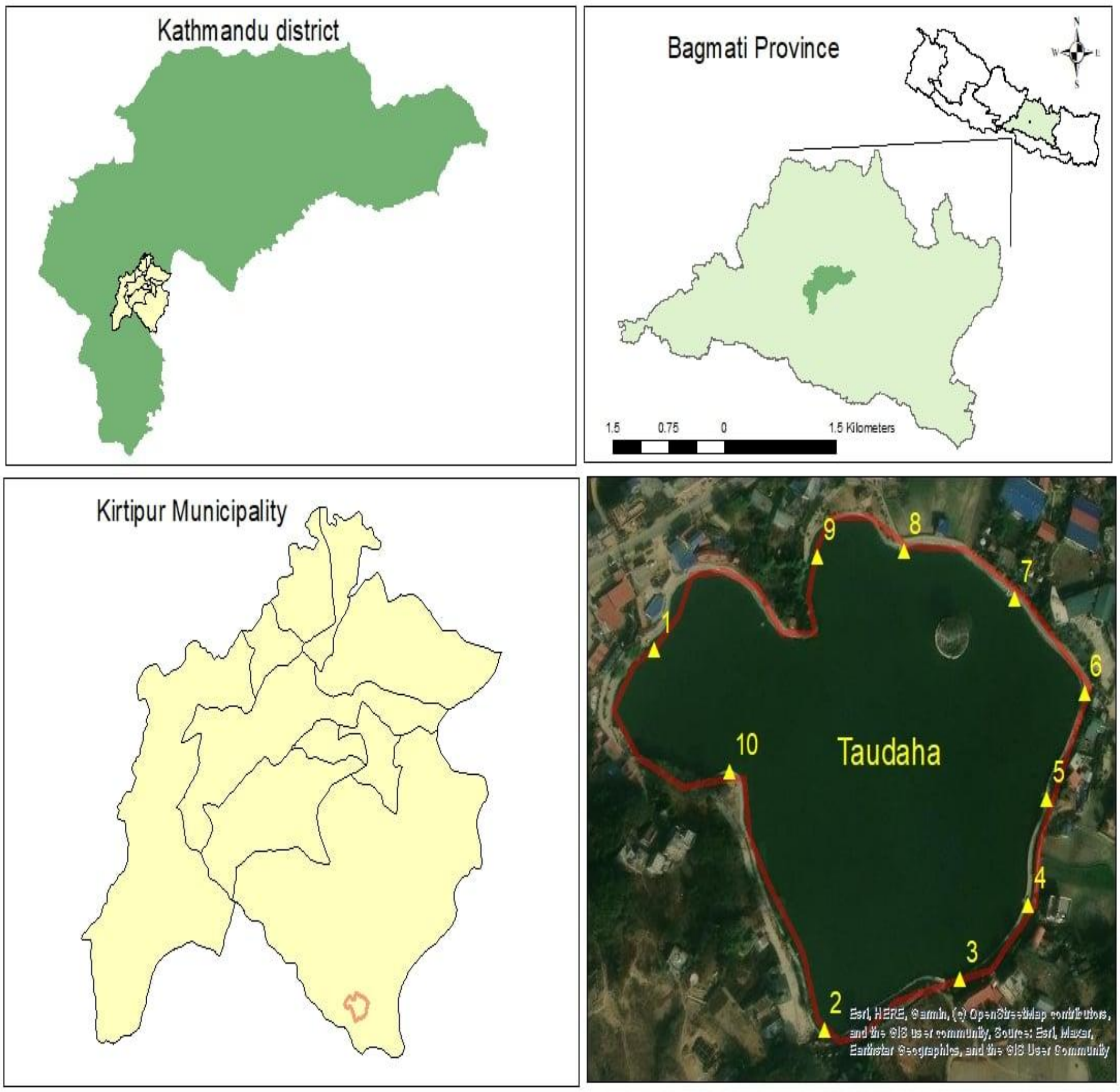

Fig. 1: Map representing the study area with sampling stations

Research Methodology

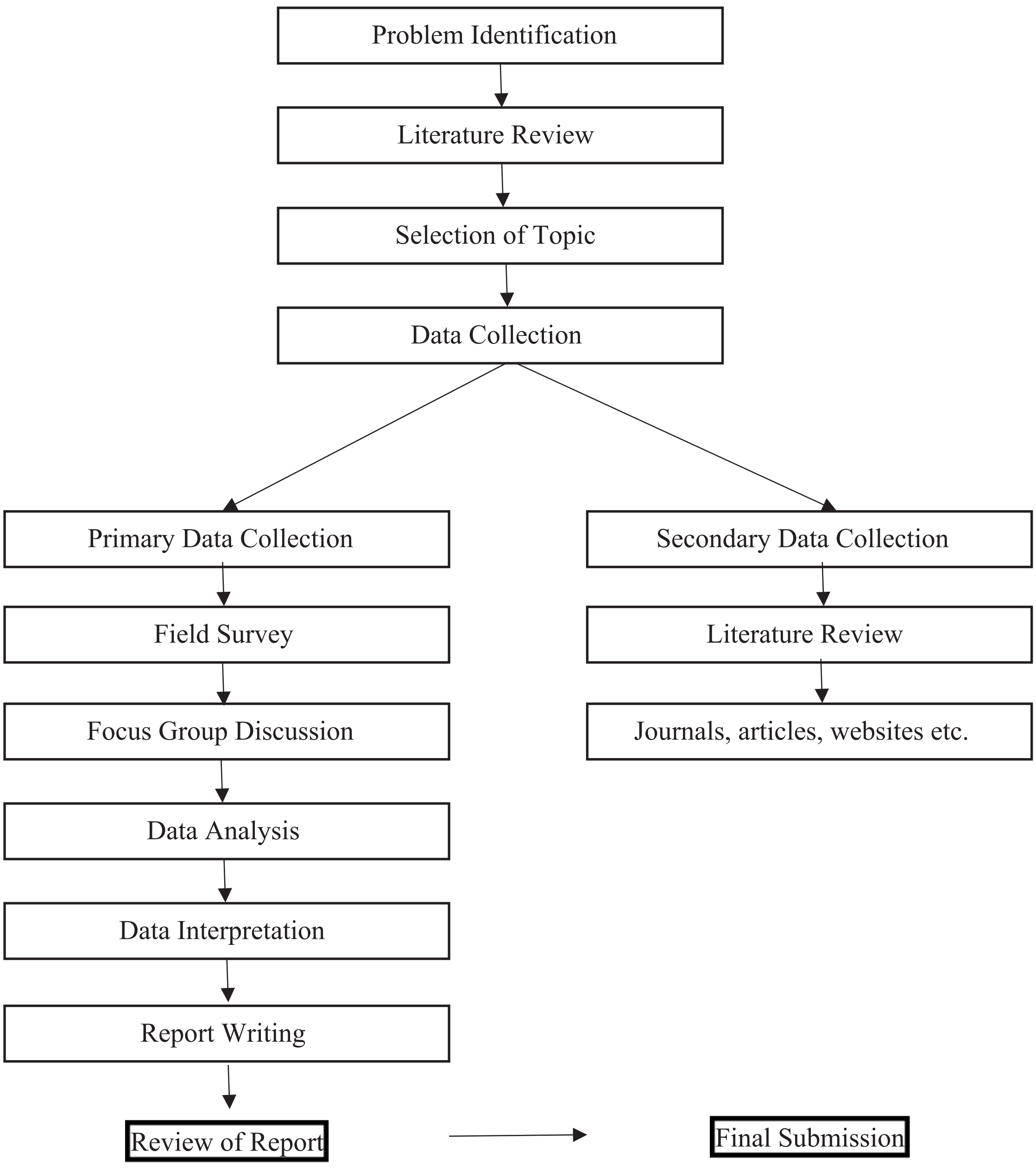

Fig. 2: Research methodology

Sampling and Physicochemical analysis

In January 2024, fieldwork and water sampling were conducted in Taudaha Lake which is located at an altitude of 1350 m. Following a purposive stratified sampling method, ten water samples were collected from strategically selected sites along the accessible paths and inflow/outflow points of the lake to capture spatial variability influenced by human activity and surrounding land use. Samples were collected from the surface layer (0.5 m depth) to ensure consistency and to target the zone most relevant to aquaculture species and water quality assessment. Each site was examined to ensure water samples were clear, uncontaminated, and free from debris, and sampling equipment was rinsed thoroughly with site water prior to collection to minimize contamination.

At each site, one-liter High-Density Polyethylene (HDPE) bottles were used for sample collection from the designated points along the lake's paths and shores. On-site measurements of water temperature (°C), pH, electrical conductivity (EC, µS/cm), and total dissolved solids (TDS, mg/L) were recorded immediately using a multiparameter probe. The instruments were calibrated according to manufacturer guidelines prior to field use with calibration checks performed every 24 hours and the relative error was maintained within ±2%.

Collected samples were transported in an ice bag to maintain a temperature close to 4°C and stored at 4°C in the laboratory until analysis. This precaution prevented changes in chemical characteristics prior to laboratory measurements. Laboratory analyses were carried out at the Central Department of Environmental Sciences, Tribhuvan University, Kirtipur, which was selected for its fully equipped facilities, trained personnel, and experience in freshwater quality analysis. In the laboratory, turbidity was measured using a turbidity meter. Major cations, sodium (Na^+) and potassium (K^+), were analyzed using a flame photometer (Wagtech Model 1382, UK). Dissolved oxygen (DO) was measured using a DO meter, and chemical oxygen demand (COD) was determined following standard APHA-AWWA-WEF (2017) methods. Other parameters, including chloride (Cl^-), total hardness (TH), alkalinity (HCO_3^-), and free CO_2, were evaluated using argentometric titration, EDTA titration, and acid-base titration with phenolphthalein indicator. Nutrients and trace elements, including ammonia (NH_4^+), nitrate (NO_3^-), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}), and iron (Fe^{3+}), were measured using a UV-Visible spectrophotometer (SSI-UV2101, UK) following standard procedures (APHA-AWWA-WEF, 2017).

Quality assurance and control practices included duplicate sampling at select sites, calibration of instruments before and during analysis, procedural blanks, and the use of reagent-grade chemicals and uncontaminated bottles to prevent cross-contamination. These measures ensured the accuracy and reliability of the data, allowing for a comprehensive characterization of the physicochemical properties of Taudaha Lake and providing a robust basis for assessing its suitability for aquaculture and ecological management.

Table 1: Different parameters along with the methodology

S.N.	Parameters	Methods	Instruments
1	Temperature	Electrometric	Milwaukee pH55, Uk
2	Ph	Electrometric	Milwaukee pH55, Uk
3	EC	Electrometric	Milwaukee EC59, Europe
4	TDS	Electrometric	Milwaukee EC59, Europe
5	DO	Electrometric	Oxy 70 Vio Dissolved Oxygen Meter
6	Turbidity	Nephelometric	Wagtech(2100 AN Turbidity Meter)
7	Free-CO^2	Titrimetric (Sodium hydroxide method),	Conical flask, Measuring cylinder, Pipette, Burette and Burette stand
8	Chloride	Argentometric method	Conical flask, Measuring cylinder, Pipette, Burette and Burette stand
9	Total Alk	Titrimetric	Conical flask, Measuring cylinder, Pipette, Burette and Burette stand
10	Total Hardness	Titrimetric	Conical flask, Measuring cylinder, Pipette, Burette and Burette stand
11	Calcium Hardness	Titrimetric	Conical flask, Measuring cylinder, Pipette, Burette and Burette stand
12	Sodium	Microprocessor flame photometer	Flame Photometer(Model 1382)
13	Potassium	Microprocessor flame photometer	Flame Photometer(Model 1382)
14	Sulphate	Turbidimetric method	Spectrophotometer (SS1 UV 2101)
15	Phosphate	Ammonium Molybdate method	Spectrophotometer (SS1 UV 2101)
16	Ammonia	Nessler's Reagent Method	Spectrophotometer (SS1 UV 2101)
17	Iron	Phenonthroline method	Spectrophotometer (SS1 UV 2101)
18	BOD	Titrimetric	Conical flask, Measuring cylinder, Pipette, Burette and Burette stand
19	COD	Titrimetric	Conical flask, Measuring cylinder, Pipette, Burette and Burette stand

The laboratory analysis of physicochemical parameters were carried out as per APHA-AWWA-WEF (2017).

Data Analysis

Descriptive statistics including mean, standard deviation, minimum and maximum of all parameters using IBM SPSS 26. The results obtained from descriptive statistics analysis provides the overall hydrochemistry of the lake. Also, this analysis helps to compare spatial variation in water quality parameter as well as comparison with Nepal Water Quality Guidelines for Aquaculture (NWQGA).

Piper Diagram

A trilinear graphical tool for classifying the chemical properties of water is called a Piper diagram (Piper, 1944). Origin Pro22 software was used to construct this diagram, which has two distinct triangle plots, one for cations and the other for anions, and a diamond-shaped field in the middle that mixes the two. In water quality research, piper plots are frequently used to categorize water samples into six different hydrochemical groups according to their predominant ion composition. These types are as follows: 1) calcium-bicarbonate (Ca^{2+}-HCO_3^-), 2) sodium-chloride (Na^+-Cl^-), 3) mixed calcium-sodium-bicarbonate (Ca^{2+}-Na^+-HCO_3^-), 4) mixed calcium-magnesium-chloride (Ca^{2+}-Mg^{2+}-Cl^-), 5) calcium-chloride (Ca^{2+}-Cl^-), and 6) sodium-bicarbonate (Na^+-HCO_3^-) (Chalaune et al., 2020; Khadka and Ramanathan, 2021).

Gibbs Plot

Gibbs plots are used to evaluate the variables affecting the lake's water chemistry. The ratios of sodium to the sum of sodium and calcium $[Na^+/(Na^+ + Ca^{2+})]$ and chloride to the sum of chloride and bicarbonate $[Cl^-/(Cl^- + HCO_3^-)]$ are plotted against total dissolved solids (TDS) in this diagram. It helps in determining the main mechanisms governing the chemistry of water, including rock weathering, evaporation, and precipitation (Gibbs, 1970; Prasanna et al., 2011). Precipitation is the major controlling factor when samples show low TDS levels (about 300 mg/L) along with high ion ratios (0.5–1) (Pant et al., 2018).

Mixing Diagram

To better understand the hydrochemical changes, a mixing diagram was applied. This approach involved plotting molar ratios normalized to sodium (Na^+), such as calcium to bicarbonate (Ca^{2+}/HCO_3^-) and calcium to magnesium (Ca^{2+}/Mg^{2+}), to examine spatial variations in water chemistry. The study showed that the lake's water chemistry is mainly shaped by minerals coming from three sources: carbonates, silicates, and evaporites (Gaillardet et al., 1999)

RESULTS

Descriptive Statistics of Physiochemical parameters

Table 2 summarizes the minimum, maximum, mean, and standard deviation of water quality parameters in the winter season in Taudaha Lake. The total sample size is 10. It is also compared with the guideline's values for aquaculture.

Table 2: Descriptive statistics of hydrochemical variables

Parameters	Minimum	Maximum	Average	SD	Nepal Standard for Aquaculture (2015)
Temperature(°C)	15.9	17.2	16.68	0.4284	4-18 °C for cold water fish 16-32 °C for intermediate species. 4-30 °C for warm water fish.
pH	7.45	7.92	7.6	0.1331	6.5-9.0
DO(mg/l)	2.76	5.54	3.823	0.74121	6-9 mg/l for cold water species. 5-8 for intermediate water species 5-8 for warm water species
EC(µS)	344.5	374.6	360.64	9.23	
TDS(mg/l)	211.2	222.72	217.312	3.6357	<2000mg/l
Turbidity	85	236	153.3	47.36	<25NTU
Chloride(mg/l)	63.9	215.84	124.96	44.466	Value not recommended (fish can survive at <600 but the production is not optimum.
Alkalinity(mg/l)	170	225	199	16.093	
Ca-hardness(mg/l)	50	130	93	24.417	
Mg- hardness (mg/l)	20	74	36	16.97	<15mg/l
Total hardness(mg/l)	98	150	129	18.466	20-100mg/l
Free $C0_2$(mg/l)	17.6	33	26.62	3.990	
Sulphate (mg/l)	13.13	21.73	17.29	2.9117	
Phosphate(mg/l)	0.018	0.188	0.090	0.05037	
Ammonia(mg/l)	0.02981	0.0968	0.0612	0.01832	<30µg/l
Iron(mg/l)	0.243	0.26	0.2486	0.005589	<10µg/l
Sodium(meq/l)	19.7	24.9	22.06	1.3771	
Potassium(meq/l)	13.2	13.7	13.4	0.1612	
BOD(mg/l)	1.018	1.800	1.4628	0.247	
COD(mg/l)	60	256	141.6	65.292	<40mg/l

The physicochemical analysis of Taudaha Lake showed several important characteristics in relation to aquaculture suitability. Water temperature ranged from 15.9 to 17.2°C, with an average of 16.68°C which falls within the recommended range for cold-water fish species (4–18°C). The pH of the lake varied slightly between 7.45 and 7.92 (mean 7.6) indicating a neutral to slightly alkaline environment suitable for aquaculture (6.5–9.0). Dissolved oxygen (DO) levels ranged from 2.76 to 5.54 mg/L, averaging 3.82 mg/L, which is below the recommended 6–9 mg/L for cold-water fish and 5–8 mg/L for intermediate and warm-water species, suggesting potential oxygen limitation.

Electrical conductivity (EC) ranged from 344.5 to 374.6 µS/cm with a mean of 360.64 µS/cm, while total dissolved solids (TDS) averaged 217.31 mg/L (range 211.2–222.72 mg/L), both indicating low to moderate mineral content. Turbidity was high (85–236 NTU, mean 153.3 NTU), exceeding the recommended <25 NTU which may affect light penetration and aquatic productivity. Chloride concentrations varied from 63.9 to 215.84 mg/L (mean 124.96 mg/L), which is within tolerable limits for fish survival (<600 mg/L), though higher concentrations may reduce optimal production.

Alkalinity ranged from 170 to 225 mg/L (mean 199 mg/L), while calcium hardness (50–130 mg/L) and magnesium hardness (20–74 mg/L) were observed resulting in total hardness of 98–150 mg/L (mean 129 mg/L) exceeding the recommended range (20–100 mg/L) which could influence water buffering capacity and fish health. Free CO_2 levels averaged 26.62 mg/L (range 17.6–33 mg/L), and sulphate concentrations were low (13.13–21.73 mg/L, mean 17.29 mg/L). Nutrients such as phosphate (0.018–0.188 mg/L) and ammonia (0.0298–0.0968 mg/L) were generally within acceptable limits for aquaculture.

Trace elements, including iron (0.243–0.26 mg/L) and sodium (19.7–24.9 meq/L), as well as potassium (13.2–13.7 meq/L) were measured, with iron concentrations exceeding the recommended <10 µg/L for aquaculture indicating potential concern. Biological oxygen demand (BOD) ranged from 1.018 to 1.8 mg/L (mean 1.46 mg/L) suggesting low organic pollution while chemical oxygen demand (COD) was elevated (60–256 mg/L, mean 141.6 mg/L) exceeding the recommended <40 mg/L indicating the presence of oxidizable pollutants.

Overall, while Taudaha Lake's temperature, pH, and many nutrient levels are suitable for aquaculture, the low dissolved oxygen, high turbidity, elevated total hardness, and high COD highlight potential environmental limitations that would need to be managed to ensure sustainable fish farming.

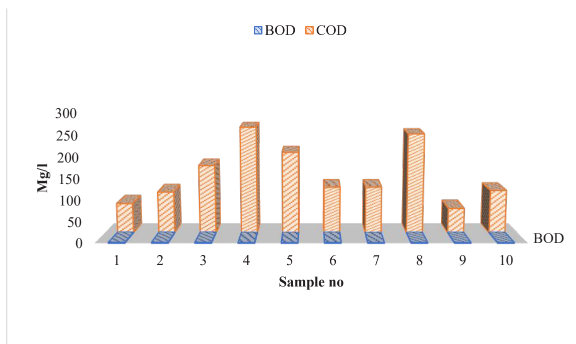

Fig. 3: Comparative representation of BOD and COD of water samples in Taudaha Lake

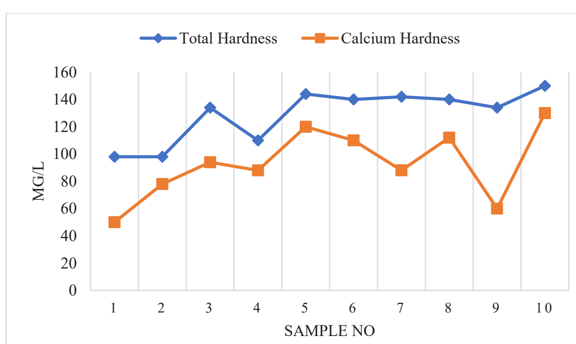

Fig. 4: Chart showing total hardness and calcium hardness of the water samples in Taudaha Lake

Hydrochemistry of Taudaha Lake

The Gibbs diagram is a valuable tool for unraveling the geochemical processes determining the chemistry of natural waters (Fig. 5). It can be used to identify whether it is precipitation, weathering of rocks, or evaporation controlling water chemistry. Two Gibbs plots are illustrated in the given figure: panel (a) is the plot of Total Dissolved Solids (TDS) against the ionic ratio $Na^+/(Na^+ + Ca^{2+})$, and panel (b) is the plot of TDS against $Cl^-/(Cl^- + HCO_3^-)$. These plots are utilized to classify the geochemical processes occurring in the water samples.

The blue dots in the two graphs represents the collected water samples. The majority of data points are within the rock dominance zone showing that the chemical characteristics of the water are mainly influenced by interactions with rocks. This indicates that minerals like carbonates and silicates especially are dissolving into the water from surrounding rocks, contributing to the ionic content. Because the samples do not group in the precipitation and evaporation areas, it is a sign that the two processes do not significantly affect water chemistry at this point. The moderate TDS values also support this as high evaporation would have resulted in elevated TDS concentrations. Therefore, the Gibbs diagram also confirms that mineral dissolution due to rock weathering is the governing factor controlling the composition of water

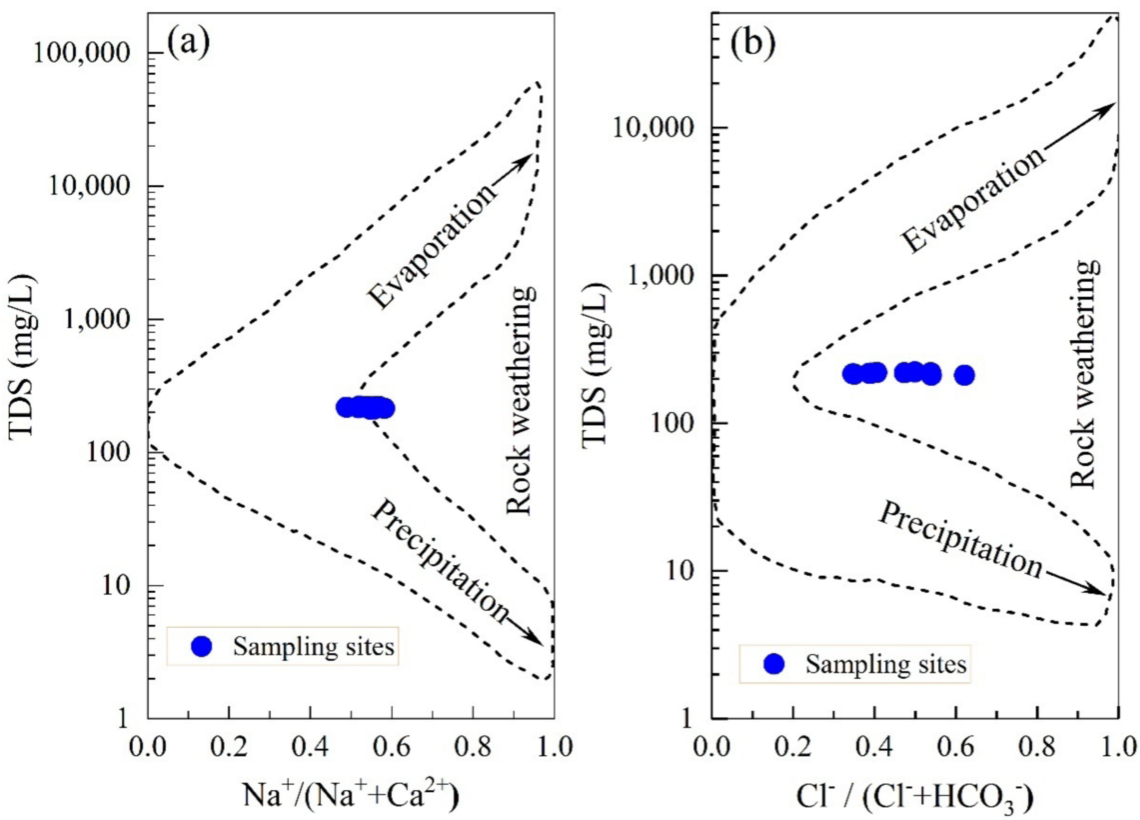

Fig. 5: Gibbs diagram showing (a) TDS vs. $Na^+/(Na^+ + Ca^{2+})$ and (b) TDS vs. $Cl^-/(Cl^- + HCO^{3-})$ for Taudaha Lake, Nepal

Mixing diagram

Figure 6 shows the lithological controls on the water chemistry. The image displays two geochemical mixing diagrams. Panel (a) plots the bicarbonate to sodium ratio (HCO_3^-/Na^+) against calcium to sodium (Ca^{2+}/Na^+), and panel (b) plots the magnesium to sodium ratio (Mg^{2+}/Na^+) against Ca^{2+}/Na^+. These visual aids are useful for determining whether silicate, carbonate, or evaporite weathering is responsible for the predominant geochemical fingerprints in the water.

In both graphs, the plotted water samples (blue dots) are mostly clustered in the region representing silicate weathering. The presence of silicate weathering in which calcium and bicarbonate are produced during the decomposition of silicate minerals is suggested by panel (a)'s moderate HCO_3^-/Na^+ ratios (approximately ranging from 3 to 10) and Ca^{2+}/Na^+ values near 1. This interpretation is supported by Panel (b), which shows that silicate rock dissolution is the predominant source of dissolved ions due to the relatively low Mg^{2+}/Na^+ ratios and the intermediate Ca^{2+}/Na^+ values.

Additionally, areas showing carbonate or evaporite influence show little to no grouping, indicating that such lithologies have contributed very little. In conclusion, silicate weathering is the dominant geochemical activity influencing the water chemistry in the region as indicated by the arrangement of the data points in these diagrams which reflects the basin's lithological composition.

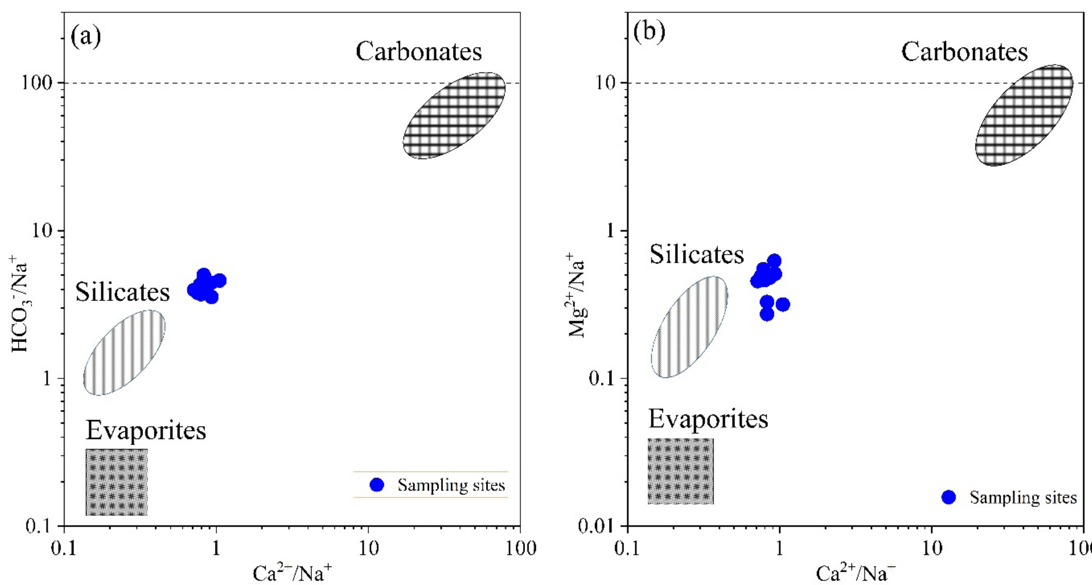

Fig. 6: Mixing diagram for Taudahaa Lake, showing Na+-normalized molar ratios of (a) Ca^{2+} vs. HCO^{3-} and (b) Ca^{2+} vs. Mg^{2+}.

Characterization of Geochemical Facies

Tracing the origin and geochemical evolution of both surface and groundwater requires the use of hydrochemical facies which are distinctive water types that reflect the geochemical processes affecting water composition. The Piper diagram integrates two triangular plots representing major cations and anions into a central diamond to indicate the overall water type making it a popular method for visualizing water facies (Fig.7).

The water samples are shown as blue dots in the Piper plot. The samples are primarily grouped toward the Ca^{2+} and Mg^{2+} corners according to the cation triangle indicating that they are the primary cations with calcium being somewhat more prevalent.

A larger concentration of Cl^- and SO_4^{2-} ions in comparison to bicarbonate is suggested by the anion triangle which also shows that the majority of samples trend toward these apexes. The distribution of points that results from projecting the cation and anion compositions onto the central diamond field is within the Ca^{2+}– Mg^{2+}– Cl^-– SO_4^{2-} hydrochemical facies. The results suggest that the water chemistry is mainly influenced by the dissolution of carbonate and sulfate minerals via natural rock weathering, while Cl^- and SO_4^{2-} levels may reflect anthropogenic inputs, including sewage and agricultural runoff.

When every factor is considered, the Piper diagram clearly shows that the predominant water type in the region at this time of year is a mixed Ca^{2+}– Mg^{2+}– Cl^-– SO_4^{2-} type influenced by both potential human activities and natural geological interactions.

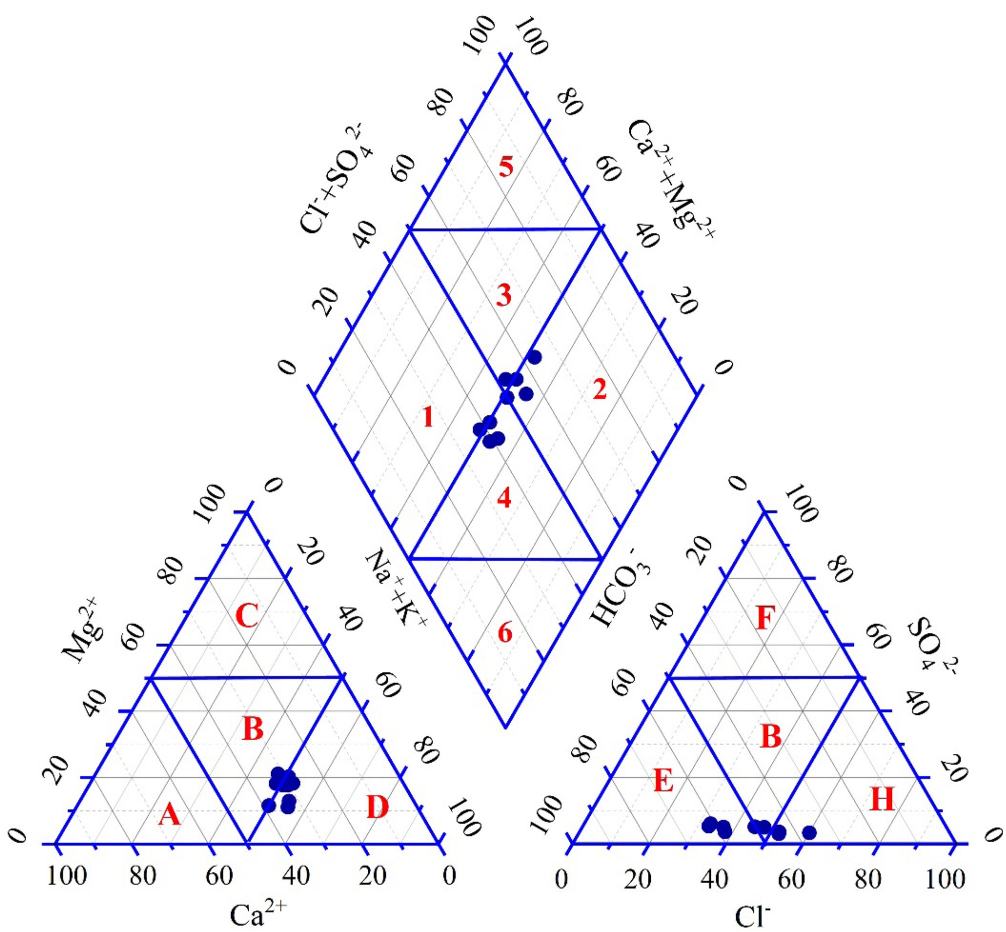

Fig.7: Piper diagram characterizing the hydrochemical facies for Taudaha Lake, Nepal

DISCUSSIONS

The physicochemical assessment of Taudaha Lake indicates that most water quality parameters generally comply with the Nepal Water Quality Guidelines for Aquaculture (NWQGA, 2015). The average water temperature of 16.68 °C falls within the range suitable for cold-water and intermediate aquaculture species, though it is below the optimal range for warm-water species. Dissolved oxygen (DO) concentrations averaged 3.82 mg/L which is below the recommended minimum of 5 mg/L suggesting that fish and other aquatic organisms may experience oxygen stress during the pre-monsoon season. This illustrates the potential need for interventions to improve oxygenation if aquaculture is to be promoted.

The water chemistry was stable with respect to pH which averaged 7.6 and remained within the acceptable range of 6.5–9.0. Total hardness (129 mg/L) classified the water as moderately hard, slightly above the ideal range (20–100 mg/L) likely due to reduced flow and evaporation during the dry season (Thakur et al., 2023). Chloride concentrations (average 125 mg/L) were well below levels considered harmful to fish (<600 mg/L) indicating minimal salinity stress. Alkalinity and total dissolved solids (TDS) were generally within acceptable limits with slight elevation in alkalinity potentially affecting buffering capacity. Nutrient concentrations including ammonia, phosphate, and BOD were within safe ranges indicating a low risk of nutrient-induced eutrophication and favorable conditions for aquatic life (Boyd and Tucker, 1998). Overall, while most parameters are suitable for aquaculture, low DO and slightly elevated hardness may limit optimal fish health and growth.

Hydrochemical facies analysis using the Piper diagram revealed that Ca^{2+} and Mg^{2+} were the dominant cations, with Ca^{2+} slightly exceeding Mg^{2+}, while Cl^- and SO_4^{2-} dominated the anions. The pre-monsoon water type is therefore classified as mixed Ca^{2+}– Mg^{2+}– Cl^-– SO_4^{2-} facies, reflecting contributions from both natural geological sources and anthropogenic inputs, such as agricultural and residential runoff (Pant et al., 2018). This composition indicates ongoing rock-weathering processes and human impacts shaping the water chemistry.

The Gibbs diagram further supports this interpretation with most data points falling in the rock-weathering dominance zone highlighting mineral dissolution and geologic interactions as the primary processes controlling the lake's hydrochemistry. TDS values ranged from 94 to 315 mg/L, while $Na^+/(Na^+ + Ca^{2+})$ and $Cl^-/(Cl^- + HCO_3^-)$ ratios confirmed the predominance of geochemical processes over precipitation or evaporation effects. These findings are similar with observations in other Nepalese river basins, such as the West Seti and Dudhkoshi, where rock-water interactions similarly dominate hydrochemistry (Shrestha et al., 2023; Ghimire et al., 2021).

Collectively, the results suggest that Taudaha Lake's water quality supports aquaculture for cold-water and intermediate species while also reflecting underlying geological and anthropogenic influences. The identified limitations particularly low DO point to the importance of regular monitoring and potential management interventions to maintain ecosystem health and ensure sustainable use of the lake for aquaculture and conservation purpose.

CONCLUSION

Based on the Nepal Water Quality Guidelines for Aquaculture (NWQGA), Taudaha Lake's physicochemical parameters indicate that the water quality is generally suitable for aquaculture, particularly for cold-water and temperate fish species. The average water temperature of 16.68°C and pH of 7.6 provide favorable conditions for fish metabolism and overall health. However, the average dissolved oxygen (DO) level of 3.82 mg/L falls below the recommended minimum of 5 mg/L which may induce physiological stress, reduce growth rates, and limit reproductive success in fish. This low DO represents a key limitation for aquaculture sustainability in the lake and indicates the potential need for aeration or periodic water exchange to maintain optimal oxygenation.

The lake's total hardness, averaging 129 mg/L classifies the water as moderately hard and slightly above NWQGA guidelines. Elevated hardness can influence osmoregulation in fish, affect nutrient availability, and potentially reduce feed efficiency. This condition is likely linked to seasonal factors including reduced water flow and evaporation which concentrate dissolved minerals. Other parameters including chloride, TDS, alkalinity, free CO_2, BOD, ammonia, and phosphate generally fall within permissible limits suggesting a balanced nutrient load and relatively low pollution levels that support aquaculture.

Hydrochemical analyses using Piper and Gibbs diagrams indicate that rock-water interactions particularly weathering of silicate and carbonate minerals dominate the lake's geochemistry. The water is characterized as mixed Ca^{2+}– Mg^{2+}– Cl^{-}– SO_4^{2-} facies reflecting both natural geological contributions and minor anthropogenic inputs such as agricultural runoff.

While most parameters are suitable for aquaculture, the identified limitations low DO and moderately high hardness underscore the need for adaptive management. Potential mitigation strategies include implementing aeration systems, promoting riparian vegetation to reduce organic load, regulating nutrient inflow from surrounding agriculture, and enhancing water circulation. Routine monitoring of DO, hardness, and nutrient levels should be prioritized, particularly before and during the dry season, to anticipate and prevent conditions that could impair fish health and productivity. Linking these interventions directly to the study's findings provides a practical framework for sustaining aquaculture protecting the lake's ecological integrity and maintaining its cultural and economic significance for the local community

REFERENCES

APHA—AWWA-WEF, 2017. WEF - Standard Methods for the Examination of Water and Wastewater (24th ed.). Washington, American Public Health Association, American Water Works Association and Water Environment Federation.

Boyd, C. E. and Tucker, C. S., 1998. Water quality and aquaculture: preliminary considerations. In *Pond aquaculture water quality management* (pp. 1-7). Boston, MA: Springer US.

Boyd, C. E., 2017. General relationship between water quality and aquaculture performance in ponds. In Fish diseases (pp. 147-166). Academic Press.

Chalaune, T. B., Dangol, A., Sharma, J. and Sharma, C. M., 2020. First results on physico-chemical status and bathymetry of lakes in Ramaroshan Wetland, Far West Nepal. Nepal Journal of Environmental Science, 8, 17–27. https://doi.org/10.3126/njes.v8i1.34464

Gaillardet, J. D. B. L., Dupré, B., Louvat, P. and Allegre, C. J., 1999. Global silicate weathering and CO2 consumption rates deduced from the chemistry of large rivers. Chemical geology, 159(1-4), 3-30.

Ghimire, N. P., Adhikari, N., Pant, R. R. and Thakuri, S., 2021. Characterizations of water quality in west-Seti and Tamor river basins, Nepal. Scientific world, 14(14), 106-114.

Gibbs, R. J., 1970. Mechanisms controlling world water chemistry. Science, 170 (3962), 1088-1090. https://dou.org/10.1007/s00244-007-9117-y.

Keddy, P. A., 2010. Wetland ecology: principles and conservation. Cambridge university press.

Khadka, U. R. and Ramanathan, A. L., 2021. Hydrogeochemical analysis of Phewa lake: A lesser Himalayan Lake in the pokhara valley, Nepal. Environment and Natural Resources Journal, 19(1), 68–83.

NWQGA, 2015. *Nepal Water Quality Guidelines for Aquaculture*. Department of Agriculture Development, Government of Nepal.

Pant R.R., Zhang F., Rehman F.U., Wang G., Ye M., Zeng C. and Tang H., 2018. Spatiotemporal variations of hydrogeochemistry and its controlling factors in the Gandaki River Basin, Central Himalaya, Nepal. Science of Total Environment, 622, 770-782.

Pant, R.R., Dhakal, T.M., Thapa, L.B., Baral, U., Dangol, A., Chalaune, T.B. and Pal, K.B., 2019. Water quality assessment of the Betkot Lake, Sudurpaschim Province, Nepal. North American Academic Research, 2 (12), 36–62.

Paudyal, R., Kang, S., Sharma, C. M., Tripathee, L. and Sillanpää, M., 2016. Variations of the physicochemical parameters and metal levels and their risk assessment in urbanized Bagmati River, Kathmandu, Nepal. Journal of Chemistry, 2016.

Piper, 1944. A Graphic Producer in the Geochemical Interpretation of Water Analysis. American Geophysical Union, 914-928.

Pradhananga, A. R., Shakya, R. K. and Shakya, P. R., 2013. Assessment of physico-chemical parameters of surface water quality of Taudaha lake of Kathmandu and their comparison with other global published values. Bibechana, 9, 141-150.

Prasanna, M. V., Chidambaram, S., Gireesh, T. V. and Jabir Ali, T. V., 2011. A study on hydrochemical characteristics of surface and sub-surface water in and around Perumal Lake, Cuddalore district, Tamil Nadu, South India. *Environmental Earth Sciences*, *63*(1), 31-47.

Shaltami, O. and Bustany, I., 2021. Water Quality- A review.

Shrestha, O. H., Thakuri, S., Bobori, D. and Bhusal, D. R., 2023. Fish Diversity and Water Quality Parameters of Dudhkoshi River, Nepal. Egyptian Journal of Aquatic Biology and Fisheries, 27(4).

Thakur, K., Sharma, D., Chauhan, D., Mahajan, D., Choudhary, K., Brar, B., Sharma, A.K., Sinha, R., Kumar, R., Kumar, S. and Kumar, R., 2023. A Systems Biology Approach in Fisheries Science. In Systems Biology, Bioinformatics and Livestock Science (Vol. 76). Bentham Science Publishers.

Zedler, J.B. and Kercher, S., 2005. WETLAND RESOURCES: Status, Trends, Ecosystem Services and Restorability. Annual Review of Environment and Resources, 30(1), 39-74.