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Seasonal Variations in Physico-Chemical Parameters and Zooplankton Diversity of Kot Dam, Rajasthan

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Abstract

The present investigation was carried out to evaluate the seasonal and annual fluctuations in the physico-chemical characteristics and zooplankton diversity of Kot Dam, Rajasthan, during the period July 2021 to June 2023. Water samples were collected from four sampling sites (S1, S2, S3, and S4) during summer, monsoon, and winter seasons. A total of 21 physico-chemical parameters and the composition of zooplankton communities were analyzed to understand the ecological status of the reservoir. The study revealed marked seasonal variation in water temperature, pH, transparency, dissolved oxygen, free carbon dioxide, nutrient concentration, dissolved solids, conductivity, and alkalinity. Statistical analysis indicated significant seasonal, spatial, and year-wise variations in several parameters. Zooplankton analysis revealed the occurrence of 43 species belonging to Protozoa, Rotifera, Cladocera, Copepoda, Ostracoda, and aquatic insects/arachnids. Rotifera emerged as the dominant group, followed by Cladocera and Copepoda. Zooplankton abundance was generally higher during summer and lower during monsoon, reflecting the influence of water quality and hydrological conditions. The results indicate that Kot Dam is a moderately productive freshwater ecosystem with appreciable biological activity and seasonal nutrient enrichment. The study emphasizes the importance of continuous limnological monitoring for ecological assessment and sustainable management of reservoir ecosystems.

Keywords: *Kot Dam, water quality, zooplankton, seasonal variation, limnology, freshwater ecology.*

Introduction

Freshwater reservoirs are ecologically and economically important aquatic ecosystems that provide water for domestic use, irrigation, fisheries, recreation, and biodiversity conservation. The ecological health of such water bodies is largely governed by their physico-chemical characteristics, which in turn influence the composition, distribution, and productivity of aquatic organisms.

The quality of water in freshwater ecosystems is determined by a number of interrelated parameters such as temperature, pH, dissolved oxygen, transparency, nutrients, dissolved solids, hardness, conductivity, alkalinity, and organic load. Seasonal changes in these parameters directly affect the biological productivity and ecological balance of reservoirs. In tropical and semi-arid regions, these variations are often intensified due to fluctuations in rainfall, evaporation, runoff, and catchment characteristics.

Among aquatic organisms, zooplankton serve as highly sensitive biological indicators of water quality and trophic status. They form an important link between primary producers and higher trophic levels, especially fish, and respond quickly to changes in nutrient concentration, pollution load, temperature, and hydrological conditions. Therefore, the combined analysis of physico-chemical parameters and zooplankton communities provides a reliable framework for evaluating the ecological condition of freshwater systems.

Rajasthan, being largely semi-arid, contains several reservoirs that experience pronounced seasonal changes in water quantity and quality. Kot Dam represents one such freshwater body of ecological significance. However, systematic limnological data on this reservoir remain limited. Therefore, the present study was undertaken to assess the seasonal and annual dynamics of physico-chemical parameters and zooplankton diversity of Kot Dam over a two-year period.

Materials and Methods

Study Area

The present investigation was conducted at Kot Dam, located in Kot village of Jhunjhunu district,

Rajasthan (27°39′ N, 75°25′ E), on the western margin of the Aravalli hill system in the Shekhawati region of northeastern Rajasthan. The study area falls within the semi-arid to arid climatic zone, characterized by extreme seasonal temperature fluctuations, low and erratic rainfall, high evaporation, sandy plains, scattered hillocks, and limited freshwater availability. The region receives most of its annual rainfall during the south-west monsoon (July–September), while summers are intensely hot and winters are comparatively cold. Such climatic and physiographic conditions make natural and artificial water bodies ecologically significant in this landscape (Singodia et al, 2024).

Kot Dam was constructed during 1923–1924 primarily for irrigation and water storage purposes and presently serves as an important freshwater resource for the surrounding region. The reservoir also holds ecological significance as it contributes to the hydrological support of the Shakambhari Conservation Reserve. Owing to its rocky basin, fluctuating water level, and seasonal inflow pattern, the reservoir provides a suitable environment for studying limnological characteristics and planktonic diversity.

The study was conducted over a period of two years, from July 2021 to June 2023, covering three major seasons: Summer, Monsoon and Winter. To represent the ecological variability of the reservoir, four sampling stations (S1–S4) were selected: S1 (tourist-disturbed site), S2 (agriculturally influenced site), S3 (least disturbed site), and S4 (water inlet zone). Water samples were collected monthly during the morning hours (7:00 a.m. to 10:00 a.m.) using standard sampling procedures. Physico-chemical parameters including temperature, transparency, pH, dissolved oxygen, free carbon dioxide, alkalinity, BOD, COD, TDS, TSS, hardness, nutrients, and major ions were analysed following standard methods. Biological assessment included qualitative and quantitative analyses of zooplankton and phytoplankton, while macroinvertebrates were examined from associated soil samples to evaluate the ecological status of the reservoir.

Zooplankton Collection and Identification

Zooplankton samples were collected from the selected stations using a standard plankton net and preserved for laboratory examination. The collected organisms were identified with the help of standard taxonomic keys and recorded as organisms per litre (org/L).

Statistical Analysis

The data obtained were subjected to Analysis of Variance (ANOVA) to determine the significance of variation among: Sampling stations, Seasons and Study years.

Results

Physico-Chemical Characteristics of Kot Dam

Table 1. Seasonal Mean Values of Physico-Chemical Parameters of Kot Dam (2021–2023)

Parameter	2021–22 Summer	2021–22 Monsoon	2021–22 Winter	2022–23 Summer	2022–23 Monsoon	2022–23 Winter
Water Temperature (°C)	29.53±0.25	24.99±0.22	12.98±0.27	22.21±0.11	26.49±0.24	14.41±0.26
pH	7.37±0.07	7.11±0.05	7.69±0.12	7.52±0.09	7.03±0.02	7.70±0.08
Transparency (m)	1.20±0.45	0.84±0.45	1.39±0.38	0.99±0.47	0.59±0.46	0.98±0.57
Dissolved Oxygen (mg/L)	5.91±0.62	6.04±0.84	8.07±0.99	7.51±1.00	6.97±0.41	8.95±0.77
Free CO_2 (mg/L)	33.56±11.23	30.00±10.31	49.18±9.22	39.93±15.06	33.31±14.49	43.62±14.26
BOD (mg/L)	4.39±0.32	4.90±0.96	3.71±1.13	3.83±0.86	4.08±0.63	2.85±0.89
COD (mg/L)	13.93±1.94	14.92±2.15	11.97±2.75	11.36±4.08	11.75±2.82	9.18±2.39
TSS (mg/L)	21.75±6.10	33.00±16.07	14.00±3.50	31.18±22.49	43.12±21.66	25.25±10.62
Total Hardness (mg/L)	156.31±27.33	144.62±50.25	142.00±33.55	170.25±7.96	172.06±41.98	148.75±22.44
Calcium Hardness (mg/L)	86.50±26.62	77.44±29.87	68.38±40.58	98.62±13.35	85.81±33.40	85.18±27.43
Magnesium Hardness (mg/L)	66.87±5.83	67.18±21.21	73.62±7.21	71.62±7.21	86.25±14.88	63.56±8.04
Calcium (mg/L)	34.31±10.66	30.62±12.07	27.06±16.29	39.12±5.34	34.37±13.39	33.93±11.20
Magnesium (mg/L)	20.93±6.51	18.62±7.31	16.56±9.79	24.18±3.24	20.93±8.10	20.62±6.64
Chloride (mg/L)	64.25±4.58	36.16±5.78	44.00±2.18	51.43±5.34	59.43±3.48	41.50±2.30
Phosphate (mg/L)	0.896±0.078	0.439±0.040	0.424±0.034	0.877±0.058	0.577±0.036	0.452±0.047
Fluoride (mg/L)	0.405±0.010	0.306±0.040	0.278±0.061	0.412±0.008	0.349±0.017	0.275±0.040
Sulphate (mg/L)	30.75±2.53	24.56±4.26	16.31±1.39	30.25±2.59	25.43±3.80	19.56±2.94
TDS (mg/L)	203.68±16.37	307.25±84.16	158.81±22.63	211.06±17.25	303.06±77.70	178.37±37.39
Conductivity (µmho/cm)	339.4±30.81	518.1±143.4	267.8±44.15	352.4±29.45	508.4±131.8	300.3±62.78

Parameter	2021–22 Summer	2021–22 Monsoon	2021–22 Winter	2022–23 Summer	2022–23 Monsoon	2022–23 Winter
Total Alkalinity (mg/L)	178.68± 45.27	159.12± 37.44	214.50± 50.53	167.81± 24.71	143.75± 27.27	188.56± 43.97
Nitrate (mg/L)	0.991±0. 097	0.510±0. 054	0.486±0. 041	0.930±0. 058	0.640±0. 045	0.515±0. 040

Interpretation of Physico-Chemical Parameters

Water Temperature

Water temperature showed marked seasonal variation throughout the study period. During 2021–22, the highest temperature (29.8°C) was recorded at site S4 during summer, while the lowest temperature (12.6°C) was observed at the same site during winter. In 2022–23, the highest value (26.7°C) was recorded during monsoon, whereas the lowest value (14.2°C) occurred in winter. The mean seasonal values clearly indicate that water temperature was highest during summer/monsoon and lowest during winter, reflecting the direct influence of atmospheric conditions. Statistical analysis showed no significant variation among stations, but significant variation between seasons and years, suggesting that seasonal climatic factors played a dominant role in determining thermal conditions in Kot Dam.

pH:

The pH values remained within a neutral to slightly alkaline range throughout the study, varying from 7.00 to 7.89. The highest pH values were observed during winter, while lower values occurred during monsoon. This pattern may be attributed to dilution of alkaline substances during rainfall and enhanced decomposition during the rainy season. The pH values recorded in Kot Dam suggest that the reservoir water remains ecologically suitable for most freshwater organisms. Statistical analysis revealed significant seasonal and year-wise variation, though the differences among sites were not significant.

Transparency

Transparency varied noticeably during the study, with higher values in winter and lower values in monsoon. The maximum transparency was recorded at S2 during winter (1.87 m in 2021–22 and 1.7 m in 2022–23), while the minimum was observed at S1 during monsoon (0.55 m and 0.3 m, respectively). The lower transparency during monsoon can be attributed to surface runoff, suspended solids, and increased turbidity, whereas higher winter transparency indicates calmer and clearer water conditions. The analysis showed significant variation among sampling sites, suggesting that local environmental conditions influenced water clarity.

Dissolved Oxygen (DO):

Dissolved oxygen values were generally higher in winter and lower in summer and monsoon. The highest DO values were observed at S4 during winter in both years, while the lowest values were recorded during warmer seasons. The increase in winter DO may be attributed to lower temperature and greater oxygen solubility, whereas reduced summer values may result from higher respiration and decomposition rates. The observed DO levels indicate that Kot Dam maintains a reasonably healthy oxygen regime for aquatic life. Statistical analysis revealed significant seasonal and year-wise variation, though differences among sites were not significant.

Free Carbon Dioxide:

Free carbon dioxide exhibited moderate seasonal variation, with higher values during winter and relatively lower values during monsoon. The highest value was recorded at S4 during winter in both study years. Elevated winter CO_2 may be linked with decomposition of organic matter and reduced photosynthetic uptake, while lower monsoon values may result from dilution and mixing effects. Significant variation among sites indicates uneven distribution of organic matter and decomposition processes across the reservoir.

Biological Oxygen Demand (BOD):

BOD values in Kot Dam ranged from moderate to slightly elevated, indicating the presence of organic matter and microbial activity. Higher BOD values were generally observed during monsoon and summer, while lower values occurred during winter. This seasonal trend suggests greater influx of organic matter during rainfall and increased biological activity during warmer months. Significant site-wise variation in BOD indicates that some sampling locations may receive higher organic inputs than others.

Chemical Oxygen Demand (COD):

COD values followed a pattern similar to BOD, with higher values during monsoon and summer and lower values in winter. The highest COD values were associated with S1, indicating a relatively greater load of oxidizable organic and inorganic matter at this station. Although COD values were moderate, they reflect seasonal organic enrichment and runoff influence. Significant differences among sites further suggest localized variation in pollutant or organic matter inputs.

Total Suspended Solids (TSS):

TSS values were markedly higher during monsoon, indicating increased inflow of suspended particles and soil runoff from the catchment area. The highest value (74.25 mg/L) was recorded at S4 during monsoon in 2022–23. The low winter TSS values indicate sediment settling and calmer hydrological conditions. Significant variation among sampling stations suggests that some locations are more prone to sediment loading than others.

Total Hardness, Calcium Hardness and Magnesium Hardness:

The water of Kot Dam may be classified as moderately hard, as reflected by the recorded values of total hardness, calcium hardness, and magnesium hardness. Total hardness values were relatively higher during summer and monsoon in the second study year, while winter values were slightly lower. Significant spatial variation suggests that mineral composition and geochemical characteristics of the surrounding catchment influenced hardness levels. These hardness values indicate that the reservoir has a suitable mineral content for freshwater productivity.

Calcium and Magnesium:

Calcium and magnesium concentrations exhibited moderate seasonal fluctuations, with generally higher values during summer and monsoon. These ions are important contributors to total hardness and play a vital role in the metabolism of aquatic organisms. Significant variation among stations indicates localized mineral enrichment or differential runoff input.

Chloride

Chloride concentrations showed seasonal variation, with relatively higher values during summer and monsoon. Elevated chloride during warmer months may be associated with evaporation, concentration effects, and catchment runoff. Although chloride values fluctuated significantly between seasons and years, they remained within ecologically acceptable limits.

Phosphate and Nitrate

Phosphate and nitrate are important nutrients controlling aquatic productivity. In the present study, both nutrients showed higher concentrations during summer, followed by monsoon, and comparatively lower values in winter. The higher nutrient concentration during summer may be attributed to reduced water volume, increased decomposition, and internal nutrient release from sediments. Significant seasonal and year-wise variation in both nutrients indicates their strong role in regulating biological productivity, particularly zooplankton abundance.

Fluoride and Sulphate

Fluoride and sulphate levels exhibited moderate seasonal variation, with relatively higher concentrations during summer and monsoon. The values remained within normal freshwater limits and did not indicate any toxic accumulation. Seasonal significance suggests that rainfall, evaporation, and runoff affected their concentration.

Total Dissolved Solids (TDS) and Conductivity:

Both TDS and conductivity were highest during monsoon, indicating the inflow of dissolved salts and mineral-rich runoff from the surrounding catchment. These parameters are closely related and reflect the ionic composition of water. Significant seasonal and year-wise variation confirms the hydrological influence on the dissolved mineral load of the reservoir.

Total Alkalinity

Total alkalinity values were generally higher during winter, indicating increased buffering capacity and carbonate-bicarbonate availability in the reservoir water. Higher alkalinity supports stable pH conditions and biological productivity. Significant spatial variation suggests localized influence of bottom sediments and geological characteristics.

Zooplankton Diversity and Abundance

A total of **43 zooplankton species** were recorded from **Kot Dam** during the study period, indicating a considerable diversity of microscopic and small aquatic organisms in the reservoir ecosystem. These zooplankton belonged to **three major taxonomic groups**, namely **Protozoa, Rotifera, and Arthropoda**. Among these, **Arthropoda** represented a diverse assemblage and was further categorized into **Cladocera, Copepoda, Ostracoda, and aquatic insects and arachnids**. The presence of these different groups reflects the ecological complexity of the dam and its suitability for supporting a wide range of planktonic life forms.

In terms of species composition, **Rotifera** emerged as the most dominant group with **13 species**, followed by **Protozoa** with **7 species**. Within the arthropod community, both **Cladocera** and **Copepoda** were represented by **6 species each**, while **Ostracoda** contributed **3 species**. In addition, **aquatic insects and arachnids** accounted for **4 species**. The diversity and abundance of zooplankton observed in Kot Dam suggest a productive aquatic environment, as these organisms play a crucial role in the food web by linking primary producers such as phytoplankton to higher trophic levels including fish and other aquatic fauna.

Table 2. Seasonal Mean Density of Zooplankton Groups (org/L)

Group	2021–22 Summer	2021–22 Monsoon	2021–22 Winter	2022–23 Summer	2022–23 Monsoon	2022–23 Winter
Protozoa	8.75±2.98	6.00±3.55	5.00±1.82	10.50±1.00	5.75±1.70	6.50±1.73
Rotifera	19.00±6.27	10.50±1.73	7.25±1.70	17.25±2.21	10.25±2.62	9.50±2.08
Cladocera	12.25±2.60	5.75±1.70	9.75±1.50	11.75±3.09	7.00±1.41	11.00±2.58
Copepoda	9.50±3.80	5.00±2.94	5.70±2.06	8.75±0.95	4.75±1.70	5.25±1.50
Ostracoda	2.75±0.95	2.25±0.50	1.75±0.50	2.75±0.95	2.50±0.57	1.75±0.50
Insects	4.25±0.9	6.25±1.5	3.25±0.	4.50±0.5	6.50±2.3	3.75±0.5

Group	2021–22 Summer	2021–22 Monsoon	2021–22 Winter	2022–23 Summer	2022–23 Monsoon	2022–23 Winter
& Arachnids	5	0	95	7	8	0

Interpretation of Zooplankton Results

Protozoa: A total of seven protozoan species were recorded during the study. Protozoan density was highest during summer in both years, with the peak population reaching 13 org/L in May 2022 and 12 org/L in April 2023. The lowest density was recorded during the monsoon season, which may be attributed to dilution effects, water turbulence, and reduced microbial prey concentration. The higher summer abundance suggests favorable warm-water conditions and greater organic availability.

Rotifera: Rotifera formed the dominant zooplankton group in Kot Dam, with 13 species recorded. Their abundance was highest during summer, reaching 27 org/L in May 2022 and 20 org/L in June 2023. The dominance of rotifers suggests that Kot Dam possesses moderate nutrient enrichment and a productive planktonic environment. Their reduced density during monsoon may be due to increased turbidity and dilution.

Cladocera: Cladocerans were represented by six species and showed higher abundance during summer and winter, while their density declined during monsoon. The highest cladoceran density (16 org/L) was recorded in April of both years. Their higher occurrence during clearer and relatively stable water conditions indicates the importance of transparency and food availability in supporting this group.

Copepoda: Copepoda were also represented by six species and exhibited greater abundance during summer. Their peak density was recorded in April/May, while lower values were observed during monsoon and winter. This pattern suggests that copepods responded positively to higher temperatures and food availability, while monsoon instability negatively influenced their abundance.

Ostracoda: Ostracods were represented by three species and remained a comparatively minor component of the zooplankton community. Their density remained low but stable across seasons, with slightly higher values during summer and monsoon. This indicates that ostracods are relatively tolerant but contribute less to the overall planktonic biomass.

Aquatic Insects and Arachnids: Unlike most planktonic groups, aquatic insects and arachnids showed relatively greater abundance during the monsoon season. Their higher density during rainy months may be linked to increased littoral vegetation, habitat heterogeneity, and inflow-associated ecological niches. This indicates that the marginal habitat of Kot Dam becomes more supportive of such organisms during the monsoon.

Discussion

The present study clearly demonstrates that the physico-chemical characteristics and zooplankton diversity of Kot Dam are strongly influenced by seasonal fluctuations, a pattern widely observed in tropical freshwater ecosystems.

The observed variation in water temperature is in close agreement with the findings of Wetzel (2001) and Mishra et al. (2016), who reported that thermal stratification and seasonal climatic conditions significantly regulate aquatic metabolism and ecological productivity in reservoirs. In Kot Dam, higher temperature during summer and monsoon likely accelerated microbial decomposition and nutrient cycling.

The neutral to slightly alkaline pH observed throughout the study is typical of productive freshwater bodies and agrees with the observations of Bhandarkar and Bhandarkar (2013) in Indian reservoirs. The slight reduction in pH during monsoon may be attributed to dilution effects and increased inflow of organic matter.

The trend of higher transparency in winter and lower transparency in monsoon has also been reported by Sharma et al. (2019) and is characteristic of reservoirs receiving runoff from catchment areas. Increased turbidity during monsoon not only reduces light penetration but also affects primary productivity and zooplankton distribution.

The pattern of higher dissolved oxygen during winter and comparatively lower values during summer and monsoon is consistent with the findings of Sreenivasan (1974) and Kumar et al. (2018). Lower winter temperatures increase oxygen solubility, while higher summer temperatures enhance respiration and organic decomposition, thereby reducing dissolved oxygen concentration.

The seasonal increase in BOD, COD, TSS, TDS, and conductivity during monsoon suggests external loading of organic matter, suspended solids, and dissolved minerals from the catchment. Similar trends have been reported by Rai and Kumar (2015) and Sharma et al. (2019) in Indian freshwater reservoirs. These parameters indicate that monsoon acts as a period of hydrological disturbance and nutrient influx.

The observed concentration of nitrate and phosphate during summer is ecologically important. Similar nutrient enrichment during warmer months has been reported by Venkatesharaju et al. (2010) and Madhuri et al. (2020), who attributed it to evaporation, sediment nutrient release, and decomposition of organic matter. The increased summer nutrient availability in Kot Dam likely contributed to the higher

abundance of zooplankton, especially rotifers and cladocerans.

The moderate values of hardness and alkalinity indicate that Kot Dam is a mineral-rich and biologically favorable freshwater system, which supports productive aquatic life. According to Boyd (1981), moderately hard and alkaline waters are generally favorable for plankton development and fish production.

The dominance of Rotifera in Kot Dam is of particular ecological significance. Rotifers are widely recognized as indicators of mesotrophic to eutrophic freshwater systems, and their numerical dominance in the present study suggests moderate nutrient enrichment and active biological productivity. Similar observations were reported by Battish (1992) and Sharma and Saksena (2007) in Indian freshwater ecosystems.

The higher abundance of Protozoa, Cladocera, and Copepoda during summer is in agreement with earlier studies by Michael (1968) and Edmondson (1992), who reported that warmer water, better food availability, and stable limnological conditions favor zooplankton multiplication. Their reduced abundance during monsoon may be due to turbulence, dilution, and reduced feeding efficiency caused by turbidity.

Interestingly, the relatively higher abundance of aquatic insects and arachnids during monsoon suggests that the littoral and marginal habitats of Kot Dam become more suitable during the rainy season, possibly due to increased vegetation cover and habitat complexity.

Overall, the present study indicates that Kot Dam is a moderately productive freshwater reservoir with appreciable ecological stability, although seasonal nutrient enrichment and monsoon runoff influence its limnological dynamics. The observed relationships between water quality and zooplankton diversity confirm that both abiotic and biotic parameters are valuable tools for ecological monitoring of reservoir ecosystems.

Conclusion

The present study provides a comprehensive understanding of the **physico-chemical characteristics** and **zooplankton diversity** of **Kot Dam** over a period of two years. The findings reveal that the reservoir exhibited **distinct seasonal variations** in most physico-chemical parameters, reflecting the dynamic nature of the freshwater ecosystem. The **summer and monsoon seasons** were characterized by comparatively **higher nutrient concentration, total solids, electrical conductivity, and organic load**, indicating increased runoff, evaporation, and biological activity during these periods. In contrast, the **winter season** showed **better water transparency, higher dissolved oxygen, and greater alkalinity**, suggesting comparatively stable and favorable water quality conditions.

The water of Kot Dam remained **neutral to slightly alkaline** in nature and **moderately hard**, which indicates a suitable freshwater environment capable of supporting diverse aquatic life. A total of **43 zooplankton species** were recorded during the study period, demonstrating a rich and varied planktonic community within the reservoir. Among these, **Rotifera** emerged as the **dominant group**, followed by **Cladocera** and **Copepoda**, highlighting their ecological significance in the aquatic food web. The abundance of zooplankton was generally found to be **higher during summer**, which may be attributed to **warmer temperature, increased nutrient availability, and enhanced biological productivity**.

Overall, the ecological condition of Kot Dam indicates that it is a **moderately productive and biologically active freshwater ecosystem**. The study confirms that the combined analysis of **physico-chemical parameters and zooplankton diversity** serves as an effective approach for assessing the **ecological health and productivity** of freshwater reservoirs. Therefore, **regular monitoring** of these parameters is essential for the **sustainable management, conservation, and ecological maintenance** of Kot Dam.

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