# Assessing Seasonal Changes in Physicochemical Traits and Biochemical Profiles of Key Carp Species in Masani Barrage Lake and JLN Canal

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**INTRODUCTION**

Seasonal fluctuations wield considerable influence on the delicate equilibrium of lake and canal ecosystems, impacting physicochemical parameters, phytozooplankton biodiversity, and the biochemical composition of fish. These ecosystems function as intricate systems where environmental variables, climatic variations, and biological responses intricately interconnect to sculpt a nuanced ecological framework. Temperature governs metabolic rhythms in aquatic realms, surging during summer and instigating pivotal shifts in dissolved oxygen and nutrient cycling. Winter introduces stratification, shaping nutrient distribution, while pH delicately oscillates, rising in spring and subtly shifting in autumn. Dissolved oxygen follows a seasonal rhythm, depleting in summer and rebounding in winter, while nutrient levels fluctuate with precipitation and runoff. Spring's vitality fuels algal blooms, and the growing season orchestrates a delicate balance in nutrient uptake by vegetation. These complexities mold the physicochemical stage for the unfolding drama in lakes and canals. A research investigation conducted between 2006 and 2008 at Surha Lake in the eastern region of Uttar Pradesh, India, unveiled a persistent escalation in pollution levels within the lake, leading to alterations in the physicochemical parameters (S. Mishra, Sharma, & Kumar, 2015). Approximately a thousand scientific publications annually delve into the changes in environmental conditions resulting from anthropogenic activities, elucidating the shifts in physicochemical parameters within lake, canal, and river ecosystems (Carpenter, Stanley, & Vander Zanden, 2011; Vasistha & Ganguly, 2020). Furthermore, anthropogenic activities, such as sewage discharge, industrial waste, chemical pollutants, and agricultural runoff, significantly transform the natural state of these resources to the extent that their physicochemical parameters undergo comprehensive alterations (Barange & Perry, 2009; Jeppesen et al., 2015).

Several freshwater ecosystems throughout India, including Wulur Lake in the Kashmir Himalayas (Sultan, Singh, Kumar, Malik, & Singh, 2023), Ganga Canal (Matta, Srivastava, Pandey, & Saini, 2017), Sambhar Lake in Rajasthan (Bhat & Sharma, 2015), Kolleru Lake in Andhra Pradesh (Krishna, Mastan, & Srilakshmi, 2012), Nainital Lake (Goswami, Das, Kumar, & Mishra, 2018), Bhimtal Lake in Uttarakhand (Panwar & Malik, 2014), and Sukhna Lake in Chandigarh , (JyotiDadwal & Kumar, 2014), have experienced fluctuations in water quality throughout different seasons, owing to increased anthropogenic activities. Investigations conducted by various researchers consistently reveal a discernible trend of degradation attributed to factors such as macrophyte proliferation, alterations in physicochemical parameters, and heightened pollution. Correlation analyses consistently unearth significant positive and negative associations among variables such as temperature, pH, conductivity, dissolved oxygen, total dissolved solids, hardness, chloride, nitrate, and phosphate content. The intricate relationships among these variables underscore the intricate interplay between human activities and the ecological well-being of these crucial water bodies, emphasizing the need for immediate attention and robust conservation measures.

In the realm of aquatic ecosystems, phytozooplankton exhibit seasonal responsiveness, flourishing in nutrient-rich waters during spring and summer. Synchronized with the abundance of phytoplankton, the movements of zooplankton are influenced by elevated temperatures and increased food availability during specific seasons. Despite their diminutive size, these microorganisms assume a pivotal role in preserving ecological equilibrium in lakes and canals. A study indicated that seasonal variations in temperature, light, and nutrients significantly influenced the diversity of phytoplankton and zooplankton in a eutrophic lake (Wang et al., 2018). Another study demonstrated that anthropogenic activities, such as sewage discharge and agricultural runoff, exerted a considerable impact on the diversity of phytoplankton and zooplankton in a freshwater canal (Ge et al., 2022). Additionally, a study highlighted that the diversity of phytoplankton and zooplankton in a polluted lake was markedly diminished due to the presence of heavy metals and other pollutants (Kondowe et al., 2022).

Below the water's surface, fish skillfully adjust their biochemical compositions in response to seasonal shifts. Feeding behaviors synchronize with temperature fluctuations and prey availability, manifesting in nutrient level variations during the abundance of summer. Autumn triggers a decrease in metabolic rates and a recalibration of profiles to conserve energy. Winter presents challenges with limited metabolic activities, emphasizing survival over growth. Spring initiates a biochemical rejuvenation, shaping composition through increased food resources in preparation for the spawning season. This cyclic pattern highlights the adaptability of fish life to the dynamic environmental conditions inherent in aquatic ecosystems, showcasing a remarkable interplay of biological resilience and environmental responsiveness. Seasonal fluctuations impact fish physiology in lakes and canals. A study on Schizothorax esocinus from Dal Lake observed elevated summer values for hemoglobin, white blood cell count, red blood cell count, and packed cell volume, alongside variations in erythrocyte indices (Reshi & Ahmed, 2022). Serum analytes peaked in summer and reached lows in spring, while glucose, urea, and cholesterol were higher in summer and lower in winter. An investigation on fish from the pesticide-contaminated River Ganga revealed oxidative, biochemical, and histopathological alterations, indicating long-term impacts on non-target organisms (Shah & Parveen, 2022). Himalayan snow trout, Schizothorax plagiostomus, exhibited sex-dependent variations in Hb concentration, total RBC count, and PCV values during summer (Sheikh & Ahmed, 2019). Physiochemical parameters such as temperature, pH, dissolved oxygen, and total dissolved solids significantly influenced fish species diversity in the Beas River, India (Kumar & Khanna, 2014). Similar influences were observed in the Ganga River (Lakra et al., 2010).

In this study, we conduct a comprehensive examination of a range of physicochemical parameters in Masani Barrage Lake (Figure 1) and JLN canal (Figure 2), located in the Rewari region of Haryana, India. The research is specifically designed to investigate the seasonal influence of various physicochemical and biological factors on the nutritional composition, including moisture, ash, protein, lipid, and fatty acid content, within the muscle and liver tissues of Indian Major carps, namely *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*.

## MATERIALS AND METHODOLOGY

### Materials

In the investigation conducted at Masani Barrage Lake (about 15-20 acres area) (Figure 1) and JLN Canal (about 10 acres area near JLN canal bridge) (Figure 2) in Rewari, Haryana, India, we explored the seasonal fluctuations in physiochemical parameters, phytoplankton biodiversity, and biochemical characteristics of major Indian carp species (*Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*) during winter (January-March), spring (April-June), summer (July-September), and autumn (October-December). Spanning from January 2021 to December 2023, the study meticulously examined ten samples per session (n=10) for water, phytozooplankton, and fish. This approach provided detailed snapshots of the dynamic ecosystems with a commitment to precision and scientific rigor. The comprehensive analysis of Masani Barrage Lake and JLN Canal, crucial habitats for diverse fish species, unveiled subtle variations in environmental conditions and ecological dynamics across the seasons.

### Investigation of physio-chemical parameters

During the comprehensive investigation into the physiochemical characteristics of both study sites, an exacting sampling methodology was employed to gain thorough insights. This involved the precise collection of water samples utilizing sterile, wide-mouth, screw-capped glass containers, ensuring accuracy at depths ranging from 1 to 2 meters. The selection of sampling sites was meticulously executed, positioning them in close proximity to both the water surface and the surrounding environment, with intentional spacing of several meters and between each collection point (Kilometers for JLN canal). The Van Dorn Sampler was deployed during the tranquil early morning hours, specifically between 5 to 6 AM, enhancing the precision of sample collection (Bhatnagar & Singh, 2010; N Manickam, Sarvana, Santhanam, Huvaneshwari, & Chitrarasu, 2017). Following extraction, an immediate and refrigerated transfer of water samples was conducted to preserve their intrinsic characteristics. Upon arrival at the laboratory, an instantaneous analysis of the physiochemical parameters of the water samples took place on the same day as collection. On-site measurements encompassed recording atmospheric and surface water temperatures using a thermometer. The quantification of pH, salinity, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO) was meticulously performed using the "µP Based Water and Soil Analysis Kit Model-1160." This systematic and meticulous approach played a pivotal role in upholding the integrity of the samples and ensuring accurate assessments of the physiochemical composition.

### Analysis of phytoplankton and zooplankton sample

Planktonic specimens were methodically gathered from five sites within the canal utilizing a 50 µm mesh plankton net. Following preservation in 5% buffered formalin, the samples underwent a quantitative analysis employing the Sedgwick Rafter cell method (Bhatnagar & Singh, 2010; N Manickam et al., 2017). This methodology yielded valuable insights into plankton dynamics, thereby advancing our comprehension of aquatic ecosystems. Within the laboratory setting, phytoplankton underwent taxonomic classification utilizing stereo zoom and compound microscopes. Zooplankton, encompassing Crustaceans and Insects, were identified using stereo zoom microscopes, with subsequent taxonomic refinement accomplished through compound microscopes. This holistic approach contributes significantly to our knowledge of the lake's planktonic composition, thereby enriching the broader ecological narrative.

**Biochemical analysis of carps**

Ten specimens each of *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala* at an advanced stage of development were captured from the lake. Promptly subjected to ice storage, their structural integrity remained intact during transit to the laboratory. Subsequently, dorsal muscle and liver tissues were meticulously extracted, sealed, and conserved at a temperature of -80 °C. The determination of ash content, protein, total lipid, and fatty acid levels followed established methodologies, as outlined in studies by (Baker & Chesnin, 1976; Ch, 1951; Egan, Cox, & Pearson, 1981; Kandemir & Polat, 2007). The obtained results, expressed as percentages on a wet weight basis, offer valuable insights into the biochemical composition of these fish. The moisture content analysis adhered to the standards set by the Association of Official Analytical Chemists (AOAC). This succinct analytical approach significantly contributes to our comprehension of the lake's aquatic ecosystem.

**Statistical analysis**

The data presented in this investigation underwent rigorous statistical analysis utilizing GraphPad Prism 5.0 to ascertain its statistical significance. Subsequent to this, a one-way analysis of variance (ANOVA) was executed, followed by the Tukey test, with the goal of discerning noteworthy variations among the means. The confidence level was established at 5% ($p < 0.05$) to enhance the robustness of the findings.

## RESULTS

**Physiochemical attributes characterizing of Masani Barrage lake**

In the Masani Barrage lake located in Rewari, the atmospheric temperature undergoes seasonal variations, with values in Winter at 14.86 ± 0.81, Spring at 18.43 ± 0.68, Summer at 29.32 ± 0.76, and Autumn at 29.79 ± 0.87 degrees Celsius (Figure 3). Similarly, surface temperature exhibits fluctuations across the seasons, recording values in Winter at 22.39 ± 1.62, Spring at 24.43 ± 0.88, Summer at 32.13 ± 1.13, and Autumn at 32.87 ± 1.12 degrees Celsius. The lake's pH levels show subtle variations throughout the seasons, with values in Winter at 7.53 ± 0.27, Spring at 7.43 ± 0.10, Summer at 7.68 ± 0.27, and Autumn at 7.67 ± 0.43. Salinity of the lake water follows a similar pattern, with values in Winter at 1.58 ± 0.32, Spring at 2.22 ± 0.34, Summer at 2.00 ± 0.40, and Autumn at 2.55 ± 0.18. Electrical conductivity (EC) of the water displays seasonal variations, with values in Winter at 1714.67 ± 88.15, Spring at 1307.67 ± 78.04, Summer at 1830.00 ± 116.29, and Autumn at 1986.67 ± 67.98. Total Dissolved Solids (TDS) in the lake water also demonstrate seasonal changes, with Winter at 214.33 ± 23.03, Spring at 296.67 ± 17.36, Summer at 380.33 ± 30.38, and Autumn at 475.67 ± 47.85. These parameters offer valuable insights into the dynamic environmental conditions of Masani Barrage lake, crucial for comprehending the ecosystem's health and potential impacts on aquatic life (Figure 3).

Dissolved oxygen levels display seasonal variations, with the highest concentration observed during Autumn (5.20 ± 0.07) and the lowest during Winter (3.79 ± 0.33) (Figure 3). Spring and Summer show moderate increases, with levels of 4.21 ± 0.18 and 4.35 ± 0.28, respectively. Free $CO_2$ concentrations also exhibit seasonal fluctuations, with Spring and Summer recording higher levels, values of 33.46 ± 1.95 and 33.24 ± 4.21, respectively. Winter and Autumn, on the contrary, show comparatively lower concentrations, with values of 24.86 ± 2.49 and 22.89 ± 3.10, respectively. Biochemical Oxygen Demand (BOD) values, serving as indicators of organic pollution, follow a similar seasonal pattern. The highest BOD is observed in Autumn (7.23 ± 0.36), while Winter exhibits the lowest values (5.78 ± 0.33). Spring and Summer display intermediate values of 6.27 ± 0.18 and 6.37 ± 0.32, respectively. These findings suggest a seasonal dynamic in water quality at Masani Barrage Lake, with potential implications for the ecosystem and aquatic life.

The levels of magnesium vary across seasons, with the highest concentration observed in Spring (64.67 ± 9.24), followed by Winter (60.33 ± 5.57) (Figure 4). Summer exhibits a notable decrease (46.33 ± 26.86), while Autumn shows the lowest concentration (31.00 ± 17.32). Bicarbonate levels fluctuate seasonally, with Winter having the highest concentration (344.00 ± 11.00) and Summer exhibiting a peak (417.00 ± 15.13). Spring and Autumn show intermediate values, with Spring (275.67 ± 15.89) having lower bicarbonate levels than Autumn (329.33 ± 41.65). Carbonate concentrations follow a similar trend, with Winter having the highest levels (36.60 ± 3.28), followed by Spring, Summer, and Autumn, which exhibit a gradual decline in carbonate levels. Calcium levels demonstrate a distinct seasonal pattern, with the highest concentration observed in Summer (60.33 ± 15.69) and the lowest in Spring (30.00 ± 13.00). Winter and Autumn exhibit intermediate calcium concentrations. Chloride concentrations are highest in Summer (8.28 ± 0.17) and lowest in Spring (4.47 ± 0.43), showing clear seasonal variation. The concentration of o-phosphate varies across seasons, with Spring exhibiting the highest level (0.059 ± 0.032) and Summer showing the lowest (0.041 ± 0.023). Winter and Autumn have intermediate o-phosphate levels. Total phosphate levels remain relatively consistent across seasons, with only minor variations observed. Total ammonia concentrations show slight variations, with the highest levels observed in Summer (1.58 ± 0.15) and the lowest in Autumn (1.20 ± 0.56). Winter and Spring display intermediate concentrations. Total alkalinity shows a steady increase from Winter (64.75 ± 3.15) to Autumn (84.29 ± 2.20), indicating a seasonal rise in alkaline substances. Total hardness levels exhibit a consistent upward trend across seasons, with Winter having the lowest concentration (142.00 ± 11.22) and Autumn showing the highest (221.33 ± 7.51). Spring and Summer display intermediate levels of total hardness (Figure 4).

**Phytoplankton and Zooplankton diversity**

The mean ± standard deviation values for diatoms within the lake exhibited seasonal variations: Winter (3085.67 ± 385.40), Spring (2742.00 ± 503.56), Summer (4442.00 ± 964.52), and Autumn (2597.67 ± 564.77) (Figure 5). Concurrently, the values for green algae were observed as follows: Winter (1506.67 ± 171.88), Spring (1451.00 ± 581.01), Summer (2079.00 ± 420.54), and Autumn (1752.00 ± 491.42). Cyanobacteria demonstrated distinct seasonal patterns with values in Winter (551.33 ± 160.38), Spring (434.33 ± 263.32), Summer (740.67 ± 299.78), and Autumn (723.67 ± 91.07). Crustaceans displayed mean ± standard deviation values of Winter (1982.67 ± 246.45), Spring (1554.33 ± 292.78), Summer (2599.33 ± 1374.07), and Autumn (1667.00 ± 266.25). Lastly, for insects, the corresponding values were documented as Winter (806.67 ± 76.61), Spring (698.00 ± 132.21), Summer (986.67 ± 144.40), and Autumn (845.67 ± 118.93). The observed fluctuations in these parameters throughout the seasons offer valuable insights into the ecological dynamics of the lake, reflective of variations in environmental conditions and the intricate interactions among diverse organisms within the ecosystem.

**Biochemical parameters of *Catla catla***

Seasonal fluctuations in moisture content were evident in the analysis of *Catla catla*'s muscle and liver tissues from female specimens (Figure 6 & 7). Notably, the muscle displayed distinct seasonal variations, reaching its peak moisture content during summer (75.76 ± 0.283) and its lowest levels in spring (74.87 ± 0.143). Conversely, the liver exhibited a contrasting pattern, with maximal moisture content observed in summer (70.42 ± 0.14) and minimal levels in spring (66.41 ± 0.41). Analysis of ash content revealed differing seasonal trends between the two tissues: in the muscle, the highest ash content was recorded during spring (1.25 ± 0.015), whereas in the liver, winter displayed the highest values (0.735 ± 0.005). Protein content also exhibited seasonal variations, with the muscle registering its peak in spring (18.95 ± 0.071) and the liver in summer (12.71 ± 0.343), while both tissues showed diminished levels during autumn. Lipid content displayed fluctuations across seasons, with the muscle demonstrating maximal levels in spring (3.81 ± 0.21) and the liver in winter (5.935 ± 0.24), with autumn recording the lowest values for both tissues. Fatty acid composition mirrored these seasonal dynamics, with the muscle exhibiting its highest content during winter (61.145 ± 0.035) and the liver in spring (60.965 ± 0.362), while both tissues displayed reduced levels during autumn. These findings underscore the substantial seasonal variability in the biochemical composition of *Catla catla*'s muscle and liver tissues, suggesting a nuanced interplay between environmental factors and tissue composition.

**Biochemical parameters of *Labeo rohita***

In this investigation of *Labeo rohita*, distinct disparities emerged in the biochemical profiles of muscle and liver tissues (Figure 8 & 9). Examining female muscle moisture content revealed a progressive rise from winter (76.315%) to autumn (79.495%), contrasting with the female liver, which experienced a decrease from summer (77.655%) to autumn (70.79%). These findings highlight a discernible seasonal fluctuation in water content, with muscle exhibiting an ascending trend and liver displaying a descending trend. Divergent patterns were observed in ash content between muscle and liver tissues. Muscle ash content peaked in spring (2.95%), whereas the liver exhibited its highest ash content in winter (3.005%). This discrepancy suggests a differential mineral composition between the two tissues throughout the seasons. Protein levels in both muscle and liver tissues displayed fluctuations. Muscle protein content decreased from winter (18.895%) to autumn (14.74%), whereas the liver experienced an increase from winter (0.905%) to summer (1.5%), followed by a decline in autumn (0.925%). Lipid content exhibited contrasting trends in muscle and liver tissues. In the muscle, lipid levels decreased from winter (3.21%) to autumn (1.79%), while in the liver, a significant increase occurred from winter (8.195%) to summer (12.215%), indicating a dynamic lipid metabolism in the two tissues. Fatty acid composition also varied between muscle and liver tissues. The muscle displayed a gradual decrease in fatty acids from winter (61.845%) to autumn (58.805%), whereas the liver showed a fluctuating pattern, with the highest fatty acid content observed in summer (53.96%). Overall, these results underscore the nuanced and intricate responses of muscle and liver tissues in *Labeo rohita* to seasonal influences on their biochemical composition.

**Biochemical parameters of *Cirrhinus mrigala***

Seasonal variability in moisture, ash, protein, lipid, and fatty acid content was investigated in the muscle and liver tissues of *Cirrhinus mrigala*. The moisture content in the muscle fluctuated seasonally, reaching its peak during winter (72.215 ± 1.06) and its nadir in summer (68.745 ± 0.715), whereas in the liver, the highest moisture content occurred during summer (72.7 ± 0.194) and the lowest in spring (67.565 ± 1.496) (Figure 10 & 11). Ash content in both muscle and liver tissues showed seasonal fluctuations. Muscle ash content peaked in spring (4.65 ± 0.442) and dipped in autumn (4.33 ± 0.636), whereas liver ash content was highest in winter (7.61 ± 0.214) and lowest in summer (7.075 ± 0.415). Protein content in muscle increased from winter (13.04 ± 0.07) to autumn (17.20 ± 1.06), while in the liver, the highest protein content was observed in summer (2.275 ± 0.165) and the lowest in winter (1.545 ± 0.477). Lipid content in muscle decreased from winter (5.99 ± 0.61) to summer (4.23 ± 0.42), whereas the liver exhibited the highest lipid content in summer (0.73 ± 0.04) and the lowest in winter (0.31 ± 0.183). Fatty acid levels in both tissues varied seasonally, with the highest content observed in winter for muscle (60.09 ± 0.707) and in spring for the liver (62.765 ± 0.845). Noteworthy distinctions in biochemical parameters were also evident between the genders, highlighting the complex interplay of seasonal and physiological factors in *Cirrhinus mrigala*.

**Physiochemical attributes characterizing of JLN canal**

Seasonal variations in atmospheric and surface temperatures, pH levels, salinity, and water quality indicators were investigated at JLN Canal in Rewari. The mean atmospheric temperature exhibited distinct fluctuations, reaching its highest point during Summer (29.320 ± 0.806) and the lowest in Winter (15.530 ± 0.613) (Figure 12). Intermediate values were recorded during Spring (18.100 ± 0.550) and Autumn (19.224 ± 1.887). Surface temperatures mirrored this pattern, with Summer (32.467 ± 1.894) and Autumn (32.537 ± 0.963) displaying the warmest conditions. Winter had the lowest mean surface temperature (23.723 ± 1.634), while Spring showed an intermediate value (24.753 ± 2.054).

The pH levels in the canal water exhibited slight seasonal variations, ranging from 7.433 ± 0.439 in Spring to 7.680 ± 0.270 in Summer. Winter and Autumn pH values were 7.530 ± 0.302 and 7.667 ± 0.409, respectively. Salinity levels in the canal water followed a pattern of increase from Winter (1.586 ± 0.337) to Spring (2.013 ± 0.334), Summer (2.377 ± 0.174), and finally Autumn (2.547 ± 0.166). The electrical conductivity (EC) of the water exhibited the highest mean in Autumn (1986.67 ± 94.20), followed by Summer (1763.00 ± 113.17), Winter (1736.33 ± 92.96), and Spring (1307.67 ± 68.03). Total Dissolved Solid (TDS) concentrations showed a steady increase from Winter (210.75 ± 24.34) to Spring (296.25 ± 15.29), Summer (380.25 ± 25.36), and Autumn (475.67 ± 47.61), indicating a potential accumulation of dissolved substances in the canal water over the seasons.

Parameters related to water quality, such as Dissolved Oxygen and Free $CO_2$ levels, exhibited distinct seasonal patterns. The highest levels of Dissolved Oxygen were observed in Autumn (5.2 ± 0.065), while the lowest were in Winter (3.82 ± 0.336). Spring and Summer exhibited intermediate values of 4.21 ± 0.168 and 4.02 ± 0.218, respectively. Free $CO_2$ levels showed the highest values during Spring (33.79 ± 1.595) and Summer (33.573 ± 4.642), with Autumn displaying a comparatively lower concentration (22.893 ± 2.036) and Winter having an intermediate level of 24.827 ± 2.272.

Biochemical Oxygen Demand (BOD), a crucial indicator of water quality, increased from Winter (5.45 ± 0.36) to Spring (5.93 ± 0.41), Summer (6.37 ± 0.64), and reached the highest in Autumn (7.56 ± 0.43). This suggests a potential deterioration in water quality as BOD levels rise, particularly during the warmer seasons. Further investigation of water parameters, including magnesium levels, bicarbonate concentrations, carbonate levels, calcium concentrations, chloride levels, O-phosphate concentrations, and other factors, revealed dynamic interactions within the JLN Canal ecosystem (Figure 13). These variations throughout the seasons underscore the complexity of the ecosystem and emphasize the need for continued monitoring and research.

**Phytoplankton and Zooplankton diversity**

At the JLN Canal in Rewari, seasonal variations in diatom populations were observed, with mean values and standard deviations recorded as follows: Winter (1691.67 ± 113.86), Spring (1375.33 ± 121.53), Summer (1442.00 ± 108.47), and Autumn (931.00 ± 91.12) (see Figure 14). Concurrently, concentrations of green algae exhibited seasonal fluctuations: Winter (323.33 ± 33.17), Spring (349 ± 26.57), Summer (445.67 ± 26.95), and Autumn (152 ± 40.49). Distinct patterns in cyanobacteria populations were also evident across seasons, with mean values and standard deviations for Winter (84.67 ± 10.22), Spring (34.33 ± 10.41), Summer (107.67 ± 14.18), and Autumn (23.67 ± 9.11). The abundance of crustaceans displayed significant variation throughout the year: Winter (1236.00 ± 111.21), Spring (854.33 ± 78.95), Summer (1766.00 ± 121.56), and Autumn (567.00 ± 111.57). Insect populations similarly demonstrated seasonal changes, with mean values and standard deviations for Winter (225.33 ± 23.81), Spring (364.67 ± 21.80), Summer (453.33 ± 29.06), and Autumn (345.67 ± 27.29). These findings underscore dynamic ecological dynamics in the JLN Canal, suggesting fluctuations in the abundance of various aquatic organisms throughout the seasons.

**Biochemical parameters of *Catla catla***

The seasonal variation in moisture content is evident in both muscle and liver tissues of female *Catla catla*, as illustrated in Figure 15 and 16. During winter, the muscle exhibits a higher moisture level (76.815 ± 0.598) compared to the liver (69.36 ± 0.38), a trend that persists through spring, summer, and autumn. The ash content in both tissues follows distinct seasonal patterns. In winter, spring, and summer, the ash content increases in the liver (0.625 ± 0.045, 0.72 ± 0.03, 0.74 ± 0.03, respectively) while fluctuating in the muscle (2.725 ± 0.232, 3.450 ± 0.311, 4.070 ± 0.235). However, in autumn, the ash content slightly decreases in the liver (0.645 ± 0.055) and more significantly in the muscle (3.065 ± 0.355).

Protein levels in the muscle and liver exhibit notable variations across seasons. The muscle consistently maintains higher protein content than the liver throughout all seasons, with the greatest difference observed in summer (17.415 ± 0.155 in muscle vs. 12.62 ± 0.25 in liver). The lipid content in both tissues undergoes seasonal fluctuations. In winter, spring, and summer, the liver consistently exhibits higher lipid levels, while in autumn, the muscle (3.08 ± 0.10) slightly surpasses the liver (3.755 ± 0.184) in lipid content. Fatty acid levels in the muscle and liver also display seasonal variations, with the liver consistently showing higher levels in all seasons compared to the muscle. The most significant difference is observed in spring (65.78 ± 1.44 in liver vs. 64.24 ± 0.98 in muscle). In summary, the comparison of biochemical parameters between the muscle and liver of *Catla catla* underscores distinct seasonal variations and tissue-specific responses.

**Biochemical parameters of *Labeo rohita***

The seasonal dynamics of moisture content in *Labeo rohita* muscle exhibit notable fluctuations, reaching its peak in Spring (82.68 ± 0.535) and hitting the lowest point in Summer (79.715 ± 0.645) (Figure 17). In contrast, the liver displays a divergent trend, showcasing the highest moisture content during Summer (86.660 ± 0.692) and the lowest in Autumn (83.750 ± 1.130) (Figure 18). Both muscle and liver ash content experience seasonal variations, with Summer registering the highest ash content in muscle (1.41 ± 0.37) and Winter in the liver (5.445 ± 0.334). The lowest ash content is consistently recorded in Spring for both tissues. Protein levels in muscle and liver demonstrate seasonal fluctuations, with Autumn recording the highest muscle protein content (18.695 ± 0.575) and Spring reaching the peak for liver protein content (15.72 ± 0.70). Conversely, the lowest protein content for muscle and liver is observed in Spring and Summer, respectively. In terms of lipid content, muscle exhibits stability across seasons, with Autumn recording the highest (3.42 ± 0.25). In contrast, liver lipid content shows more variability, peaking in Spring (6.12 ± 0.16) and hitting the lowest in Summer (4.28 ± 0.56). Fatty acid composition in both muscle and liver undergoes seasonal variations, with the highest levels in Summer for muscle (63.23 ± 1.11) and in Summer for the liver (66.15 ± 1.79), while the lowest levels are in Spring for both tissues.

In *Labeo rohita*, the biochemical parameters underscore substantial differences between muscle and liver tissues, reflecting seasonal shifts (Figure 17 & 18). Moisture content in muscle decreases from Winter to Summer (81.355% to 78.23%), whereas the liver experiences an increase during the same period (83.53% to 85.98%). This contrasting water retention pattern suggests distinct regulatory mechanisms in the two tissues. Ash content in both muscle and liver follows a fluctuating pattern across seasons, with muscle peaking in Autumn (1.36%) and the liver reaching its highest point in Summer (5.40%). These variations may hint at diverse metabolic processes or dietary influences on the tissues. Protein levels in muscle show minimal fluctuations, with slightly higher values in Autumn (17.880%), while the liver exhibits more significant changes, reaching the highest protein content in Spring (16.805%). These differences may be linked to varying physiological demands on the two tissues. Lipid content reveals marked distinctions between muscle and liver tissues. Muscle lipid content peaks in Spring (2.38%) and hits its lowest in Summer (1.78%), while the liver experiences a more pronounced decrease from Winter to Summer (5.70% to 3.72%). These variations may reflect the dynamics of energy storage and utilization in the respective tissues. Fatty acid composition in muscle follows a consistent pattern, with the highest values in Summer (63.11%) and the lowest in Spring (59.74%). In the liver, fatty acid levels increase steadily from Winter to Autumn (58.695% to 66.695%), suggesting distinct metabolic processes and lipid metabolism regulation in muscle and liver tissues.

**Biochemical parameters of *Cirrhinus mrigala***

The seasonal dynamics of moisture content in the muscle tissue of female *Cirrhinus mrigala* reveal distinct fluctuations, reaching its zenith in winter (76.085 ± 0.493) and hitting the nadir in autumn (72.150 ± 1.111) (Figure 19). In parallel, the liver exhibits a comparable trend, experiencing its peak moisture content during winter (75.725 ± 0.581) and the trough in summer (70.89 ± 0.455) (Figure 20). The ash content in muscle displays a cyclic pattern across seasons, attaining its apex in spring (3.08 ± 0.10) and reaching the lowest point in summer (2.10 ± 1.34). Conversely, the liver's ash content remains relatively stable, peaking in autumn (2.91 ± 0.20) and hitting the lowest in winter (2.43 ± 0.21). Seasonal variations in protein levels demonstrate distinctive peaks in summer for both muscle (18.065 ± 0.228) and liver (17.97 ± 0.31), while the lowest values are observed in spring (16.91 ± 0.628) and winter (14.47 ± 0.69), respectively. The lipid content in muscle attains its zenith during summer (4.440 ± 0.185) and its nadir in autumn (2.475 ± 0.200). In the liver, the highest lipid content occurs in winter (7.395 ± 0.226), contrasting with the lowest in summer (4.590 ± 0.893). Fatty acid levels in both muscle and liver exhibit a seasonal cadence, peaking in winter and diminishing in summer. Notably, the muscle displays a more consistent pattern compared to the liver, suggesting nuanced metabolic responses to seasonal changes in nutritional demands.

## DISCUSSION

Seasonal fluctuations exert a profound impact on the physicochemical attributes of both lakes and canals. The heightened temperatures during spring and summer months play a pivotal role in shaping the water conditions, affecting parameters such as dissolved oxygen, pH, and nutrient levels, thereby influencing the metabolism and overall well-being of aquatic life. The outcomes of the biochemical analysis conducted on Masani Barrage lake (depicted in Figure 3) and JLN Canal (illustrated in Figure 12) in Rewari unveil discernible seasonal variations in physiochemical characteristics. In the case of Masani Barrage lake, atmospheric and surface temperatures, pH levels, salinity, electrical conductivity (EC), and Total Dissolved Solids (TDS) exhibit dynamic patterns across different seasons. Dissolved oxygen levels reach their zenith in autumn and nadir in winter, while free $CO_2$ concentrations and Biochemical Oxygen Demand (BOD) mirror analogous seasonal trends.

Magnesium levels peak in spring, whereas bicarbonate concentrations achieve their highest levels in summer (refer to Figures 4 & 13). Carbonate levels, calcium concentrations, chloride levels, o-phosphate concentrations, total phosphate, total ammonia, total alkalinity, and total hardness also demonstrate season-specific variations. These findings indicate a dynamic environmental milieu in Masani Barrage lake, carrying potential ramifications for the lake's ecosystem and aquatic inhabitants.

Similarly, JLN Canal manifests seasonal oscillations in atmospheric and surface temperatures, pH levels, salinity, EC, and TDS. Dissolved oxygen levels in the canal attain their zenith in autumn and their nadir in winter, closely mirroring the patterns observed in Masani Barrage lake. Free CO2 concentrations, BOD values, as well as the levels of magnesium, bicarbonate, carbonate, calcium, chloride, o-phosphate, total phosphate, total ammonia, total alkalinity, and total hardness also exhibit distinctive seasonal trends. Notably, the BOD values in JLN Canal signal a potential deterioration in water quality during the warmer seasons. These variations point to intricate interactions within the JLN Canal ecosystem, underscoring the impact of seasonal dynamics on water quality parameters. The dissimilarities between Masani Barrage lake and JLN Canal can be attributed to the inherent differences in their ecosystems. Lakes, characterized by their larger and more open nature, may undergo more pronounced temperature fluctuations and nutrient cycling, contributing to the observed variations in physiochemical parameters. In contrast, canals, being more regulated environments, still display seasonal variations, albeit to a lesser extent than natural lakes. Human activities, water flow regulation, and nutrient inputs emerge as key contributors to the distinctions in water quality dynamics between these two ecosystems.

The investigation into the impact of seasonal changes on the physiochemical characteristics of the environment holds considerable importance, affecting the quality of water, soil, and air. In their study, Haque et al. focused on surface water samples derived from the Padma River in Bangladesh across three distinct seasons-summer, monsoon, and winter. The research revealed significant variations in physicochemical parameters across seasons and sites, with the exception of water temperature (Haque, Jewel, & Sultana, 2019). Noteworthy observations included the peak of bacterial parameters during the summer and their minimum levels during the monsoon season. Another study by Rameshkumar et al. explored the physicochemical parameters and distribution of aquatic macrophytes in seasonal wetlands along the coast of Palk Bay in southeast India, highlighting adverse effects of electrical conductivity (EC), total dissolved solids (TDS), and turbidity on aquatic macrophytes (Rameshkumar, Radhakrishnan, Aanand, & Rajaram, 2019). Contributing to the discourse, Ma, J., et al., analyzed water samples from the Hindon River in India, revealing significant variations in water quality parameters throughout the study period, including pH, temperature, turbidity, conductivity, total dissolved solids, total suspended solids, total alkalinity, biological oxygen demand, chemical oxygen demand, dissolved oxygen, total organic carbon, sulphate, nitrate, and phosphate (Ma, Wu, Shekhar, Biswas, & Sahu, 2020). Delving into the seasonal dynamics of physicochemical parameters in groundwater within the coastal region of Odisha, India, Mishra, A. P., et al. uncovered higher concentrations of total dissolved solids (TDS), chloride, and nitrate during the pre-monsoon season, while the post-monsoon season exhibited elevated levels of calcium, magnesium, and bicarbonate (A. P. Mishra et al., 2023).

The ecological dynamics of aquatic ecosystems are significantly shaped by seasonal variations, particularly in the abundance and diversity of phytoplankton and zooplankton species. Temperature, light availability, and nutrient levels exhibit intricate fluctuations across seasons, influencing the growth, reproductive patterns, and overall survival of these organisms. In India, several research investigations contribute valuable insights into the complex ecological patterns of phytoplankton and zooplankton diversity. For instance, a study conducted in Ukkadam Lake, Coimbatore, Tamil Nadu, observed heightened zooplankton productivity during the summer season, aligning with increased temperatures (Narasimman Manickam et al., 2018). This research emphasized the crucial role of temperature in shaping zooplankton diversity. Another study in a shallow man-made lake in Kolkata revealed that physicochemical factors linked to eutrophication processes predominantly dictated the temporal succession patterns of zooplankton species (Arora & Mehra, 2009). In Nanmangalam Lake, Chennai, it was found that the pre-monsoon season exhibited greater plankton diversity compared to the post-monsoon and monsoon seasons (Sultana & Balamurugan, 2015). Meanwhile, Valankulam Lake in Coimbatore District, Tamil Nadu, underscored the pivotal role of plankton communities as a crucial food source for aquatic organisms, with any detrimental alterations in the plankton community triggering a cascade effect throughout the entire ecosystem (Mohan et al., 2023). These diverse studies collectively contribute to a deeper understanding of the intricate ecological dynamics influenced by seasonal variations in phytoplankton and zooplankton diversity.

Seasonal variations in biochemical parameters, including protein, lipid, and fatty acids, were observed in common carp. Elevated temperatures during warmer seasons were associated with increased metabolic activity and lipid metabolism. The fluctuations in food availability and composition, in addition to changes in water temperature and oxygen levels, played a significant role in influencing the stress levels and biochemical responses of the fish.

The impact of temperature fluctuations on common carp differed between lakes and canals. Lakes, characterized by notable temperature changes, experienced thermal stratification, affecting oxygen distribution and nutrient cycling. These factors, in turn, influenced the distribution and behavior of carp in lakes. In contrast, canals, though more stable, still exhibited seasonal variations, albeit to a lesser extent than lakes. Human activities, water flow regulation, and nutrient inputs were identified as influential factors shaping physiochemical parameters, impacting the abundance and distribution of phytozooplankton. Collectively, these factors contributed to shaping the overall health and biochemical composition of common carp in canal ecosystems.

Detailed biochemical analysis conducted on *Catla catla* in Masani Barrage lake (Figure 6 & 7) and JLN canal (Figure 15 & 16) revealed distinct seasonal variations and tissue-specific responses. In Masani Barrage lake, the highest muscle moisture content was observed in summer, contrasting with the autumn peak observed in JLN canal (Figure 6 & 15). Similar trends were noted in liver moisture content, with the highest values in autumn (Masani Barrage) and summer (JLN canal) (Figure 7 & 16). The ash content in muscle and liver tissues varied across seasons in both locations, displaying some discrepancies in peak values and trends.

Protein levels in both tissues generally followed similar patterns, with higher values in spring for Masani Barrage and summer for JLN canal. Seasonal fluctuations in lipid content in muscle and liver tissues were evident in both ecosystems, with differences in peak values and trends. Fatty acid levels also exhibited seasonal variations, displaying variations in peak values and trends between the two locations.

Seasonal variations play a significant role in shaping the biochemical parameters of both muscle and liver tissues in *Catla catla* (Indian carp). A study conducted in the tropical climate of India delves into the dynamic changes in bio-indices influenced by season and gender (Pradhan, Patra, & Pal, 2015). Noteworthy alterations include considerable increases in the condition factor and gastro-somatic index during the pre-mating season, while the rainy season sees peak values in the gonadosomatic index (GSI) of the fish. Protein content, constituting the highest percentage among biochemical components, ranges from 15.2 to 19.0%. Spring witnesses heightened levels of protein, lipid, and fatty acids, whereas muscle and liver moisture content experiences increments during summer and the rainy season. Exposure of *Catla catla* to sub-lethal concentrations of cypermethrin induces changes in hematological and biochemical parameters, such as heightened activities of alanine aminotransferase and aspartate aminotransferase in the liver and inhibited lactate dehydrogenase activity in the muscle (Vani et al., 2012). Furthermore, acetylcholine esterase activity in the brain is suppressed in cypermethrin-exposed fish. Another study focusing on the biochemical composition of *Catla catla* muscles from Paithan, India, reveals seasonal variations in protein, lipid, and glycogen content (Chondekar & Deshmukh). Exploration into the seasonal fluctuations in biochemical constituents and calorific value in *Catla catla* demonstrates prominent variations (Ashraf, Zafar, & Naeem, 2011). Two separate regression lines elucidate the relationship between ambient water temperature and biochemical constituents, along with calorific value, with one encompassing temperatures between 18.0 and 29.0°C and another spanning temperatures between 29.0 and 33.0°C.

The examination of *Labeo rohita* in Masani Barrage Lake (depicted in Figure 8 & 9) and JLN Canal (illustrated in Figure 17 & 18) through biochemical analysis has unveiled intriguing distinctions and similarities, reflective of the unique ecosystems inherent in the two aquatic environments. Within Masani Barrage Lake, the liver (depicted in Figure 9) consistently displays broader fluctuations in biochemical parameters across seasons when compared to the muscle tissue (depicted in Figure 8), particularly in terms of moisture, ash, and lipid content. This observation implies a more dynamic response of the liver to seasonal changes. In contrast, muscle tissue exhibits more pronounced variations in protein levels. These discernible patterns suggest that diverse seasonal factors may exert distinct influences on the biochemical composition of muscle and liver tissues in Masani Barrage Lake. Conversely, in JLN Canal, the moisture content in both muscle (depicted in Figure 17) and liver (depicted in Figure 18) manifests contrasting trends between seasons, with muscle exhibiting a decreasing trend and the liver displaying an increasing trend. Both tissues in the canal exhibit notable variations in ash, protein, and lipid content, indicating dynamic metabolic processes and potential dietary shifts. Overall, the variances in biochemical parameters observed between the lake and canal ecosystems can be ascribed to disparities in water dynamics, nutrient availability, and environmental conditions. This underscores the necessity for a nuanced understanding of the distinct influences these aquatic habitats exert on the physiology of *Labeo rohita*.

A research investigation conducted in Faizabad, Uttar Pradesh, explored the variations in the muscle biochemical composition of *Labeo rohita* (Shekhar, Rao, & Abidi, 2004). The analysis revealed elevated levels of protein, carbohydrates, and total ash content during the summer season, coupled with decreased moisture content. Additionally, fat and cholesterol levels showed an increase in summer compared to winter. In a separate inquiry by the Department of Zoology at PAU, Ludhiana, Punjab, *Labeo rohita* specimens were collected from Farmer’s fish pond, the village pond of Muktsar, and Farmer’s fish pond of Ludhiana during the four seasons of 2019-20 (summer, monsoon, post-monsoon, winter) (Kaur & Kaur, 2023). Significant elevations in protein content were observed in the liver, gills, kidneys, and muscles of the fish in the Farmer’s fish pond of Ludhiana compared to the village pond and Farmer’s fish pond of Muktsar across various seasons. Moreover, a notable increase in lipid content in the liver and other organs (gills, kidneys, and muscles) was identified in the Farmer’s fish pond of Ludhiana compared to both Farmer’s Fish pond and the village pond of Muktsar during post-monsoon + winter and all seasons, respectively (Kaur & Kaur, 2023). A study conducted in Sultanpur, Uttar Pradesh, disclosed variations in the proximate composition, amino acid, and fatty acid profile of *Labeo rohita* in response to seasonal changes (S. P. Mishra, 2021). The fluctuations in environmental factors, such as water temperature, pH, salinity, and food availability, were found to influence the amino acid and fatty acid profile of the fish across different seasons.

The biochemical examination of *Cirrhinus mrigala* within Masani Barrage lake (depicted in Figures 10 & 11) and JLN canal (depicted in Figures 19 & 20) unveils discernible seasonal fluctuations in crucial parameters. Within Masani Barrage lake, the moisture content in the fish muscle (Figure 10) attains its zenith during winter, whereas the liver (Figure 11) showcases the highest moisture content in summer. Both tissues manifest oscillations in ash content, with the muscle peaking in spring and the liver reaching its pinnacle in winter. Protein levels in the muscle ascend from winter to autumn, while the liver demonstrates a diminishing trend. Lipid content in the muscle descends from winter to summer, whereas the liver attains its peak lipid content in summer. Fatty acid levels exhibit seasonal variability in both tissues, attaining their zenith during winter. In the JLN canal, the moisture content in the fish muscle (Figure 19) reaches its summit in summer, while the liver (Figure 20) attains the highest moisture content in winter. Both tissues display undulations in moisture content, with the muscle revealing a slightly broader range. The ash content in the muscle undergoes seasonal fluctuations, reaching its acme in autumn, while the liver peaks in summer. Protein levels in both tissues present seasonal variations, with the zenith values occurring in summer. Lipid content in the muscle ascends from winter to summer and subsequently descends in autumn, while the liver displays the highest lipid content in winter. Fatty acid composition in both tissues undergoes seasonal transformations, attaining its highest values in winter.

The freshwater piscine species *Cirrhinus mrigala*, commonly identified as Mrigal carp, assumes considerable significance in aquaculture due to its heightened economic value and nutritional abundance. The biochemical profile of *Cirrhinus mrigala* undergoes fluctuations influenced by various factors such as seasonal changes, environmental conditions, and exposure to diverse substances. Numerous investigations conducted in India have probed into these variations. One study scrutinized the biochemical responses of *Cirrhinus mrigala* subsequent to exposure to tris(2-chloroethyl) phosphate (TCEP) (Sutha et al., 2020). The results unveiled a noteworthy inhibition of thyroid-stimulating hormone (TSH), triiodothyronine (T3), and thyroxine (T4) levels in response to TCEP exposure. Another exploration examined the impact of heavy metals on the glycogen, protein, and lipid contents in the gill, liver, and muscle tissues of *Cirrhinus mrigala* (Bhilave, Muley, & Deshpande, 2008). This research established that both cadmium and lead induced a reduction in these biochemical constituents across all examined tissues (RAHMAN, 2023). Seasonal variations in blood parameters of freshwater fishes, including *Cirrhinus mrigala*, were investigated in another study. Particularly, protein and cholesterol levels in the serum exhibited an increase from the rainy season to winter. A separate study scrutinized the effects of Fenvalerate, a technical grade pyrethroid, on *Labeo rohita* and *Cirrhinus mrigala* (Susan, Sobha, Veeraiah, & Tilak, 2010). Variations in the distribution of biochemical constituents were observed in major tissues such as the liver, muscle, kidney, brain, and gill. An evaluation of the impact of Carbendazim on *Cirrhinus mrigala* revealed alterations in several biochemical parameters, including protein, amino acids, glycogen, nucleic acids, and various enzymes induced by exposure to this substance (Ray et al., 2023).

In comparison, the Masani Barrage lake and JLN canal exhibit disparities in the seasonal dynamics of biochemical parameters. The distinct responses in moisture, ash, protein, lipid, and fatty acid levels imply unique metabolic activities and potential adaptations in fish tissues in these two aquatic ecosystems. The variations may arise from differences in environmental conditions, nutrient availability, and anthropogenic influences between the natural lake and regulated canal environments. Further research is imperative to delve deeper into the ecological implications of these findings and their impact on the health and sustainability of *Cirrhinus mrigala* populations in these water bodies in accordance with the style of Nature journal.

## CONCLUSION

In summary, our thorough seasonal analysis of Masani Barrage Lake and JLN Canal in Rewari reveals the profound impact of seasonal changes on aquatic ecosystems. Both water bodies display distinct patterns in temperature, pH, salinity, and other parameters. The unique characteristics of lakes, with greater temperature fluctuations and nutrient cycling, contribute to differences in phytozooplankton and ecological dynamics compared to more regulated canals. Additionally, our study on common carp tissues shows clear seasonal variations in moisture, ash, protein, lipid, and fatty acid levels, indicating specific metabolic responses to environmental conditions. Understanding these nuances is crucial for grasping the diverse influences of these habitats on fish physiology, with lakes experiencing more significant variations than canals due to their larger and more open systems.

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**Figure 1.** Displays the google map view of the Masani Barrage lake.

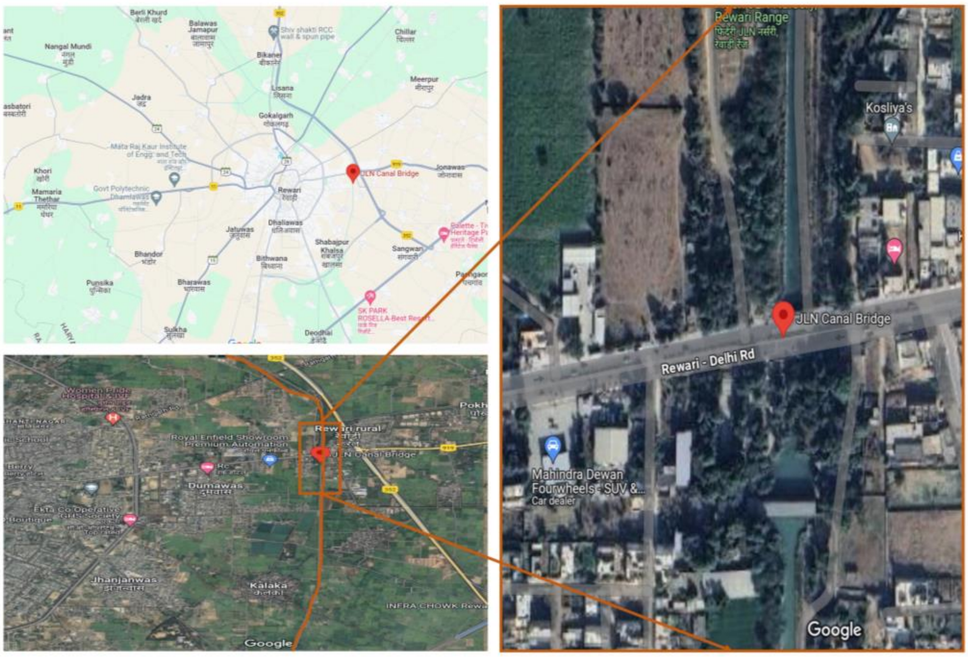


**Figure 2.** Displays the google map view of the site 1 JLN canal.

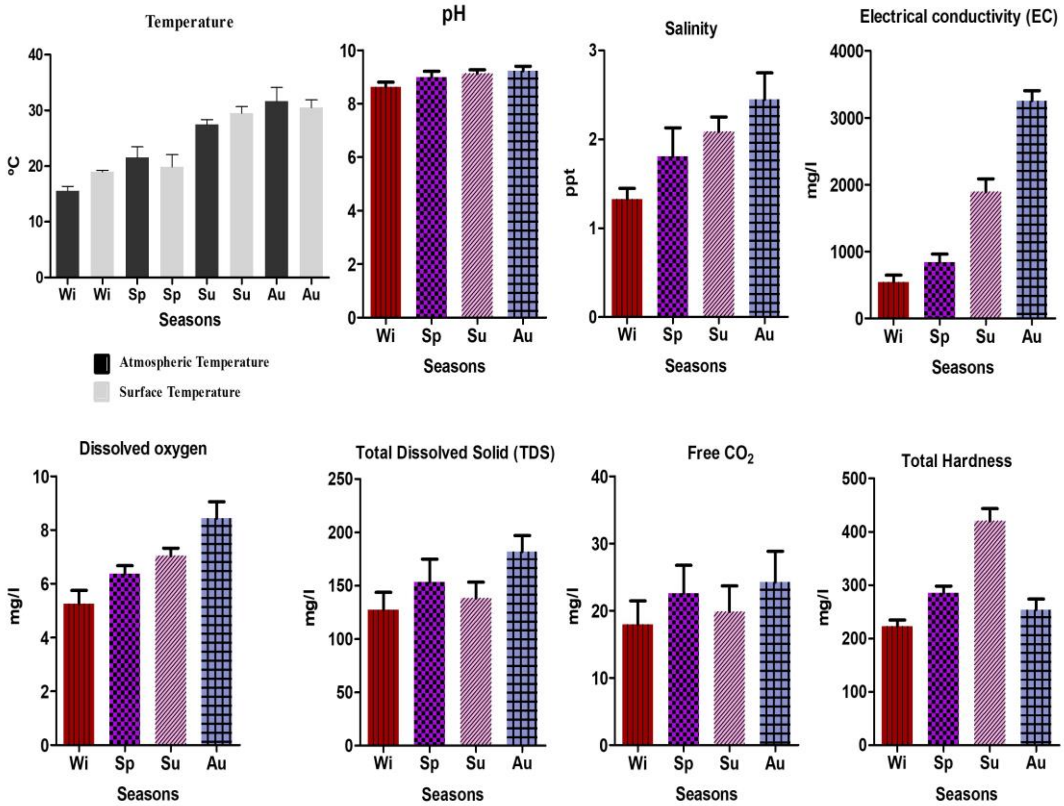


**Figure 3**. illustrates the variation in the physicochemical components of the Masani barrage lake, offering insights into its biochemical composition.

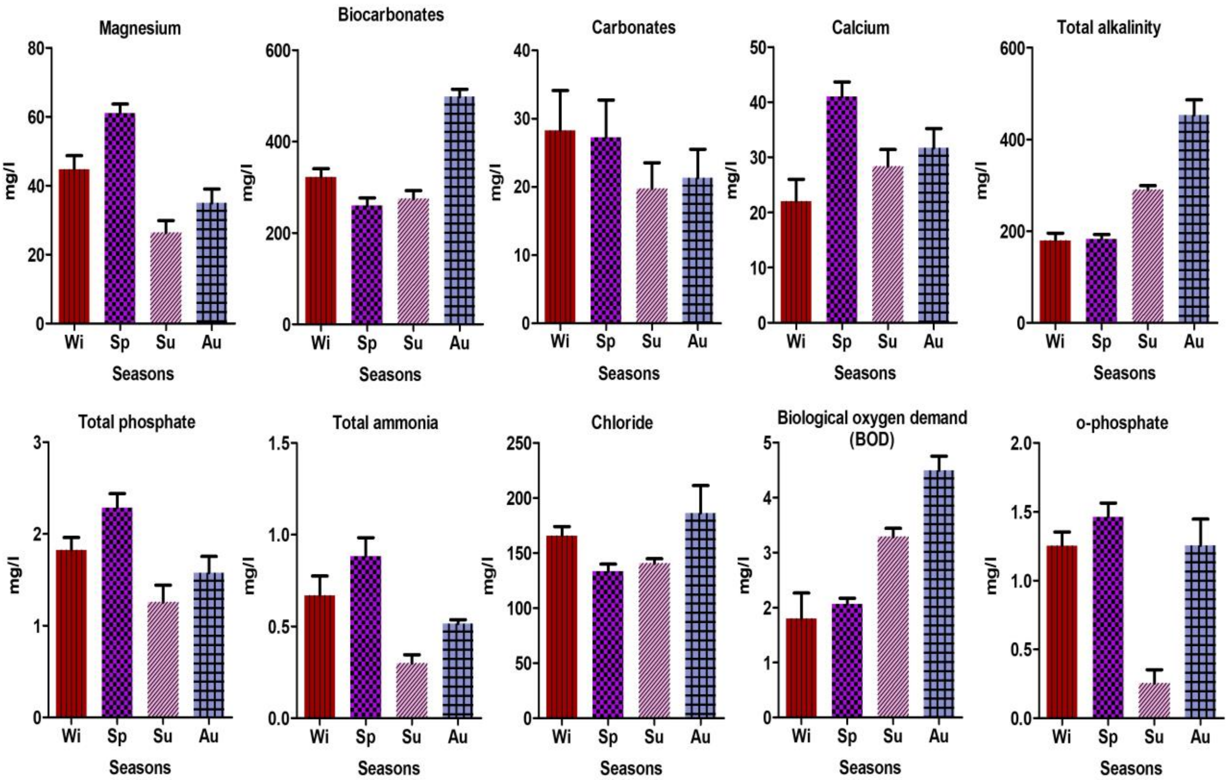


**Figure 4**. illustrates the variation in the mineral's components of the Masani barrage lake.

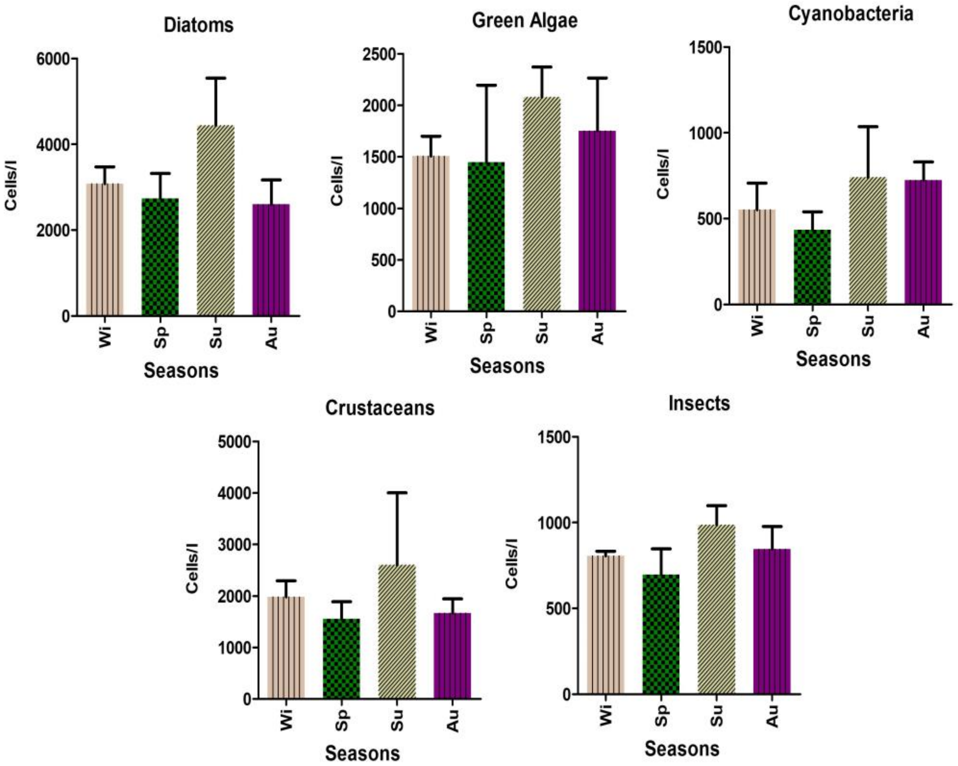


**Figure 5.** showcases the diversity and variation of phytoplankton and zooplankton in the Masani barrage lake, contributing to a nuanced understanding of the aquatic ecosystem.

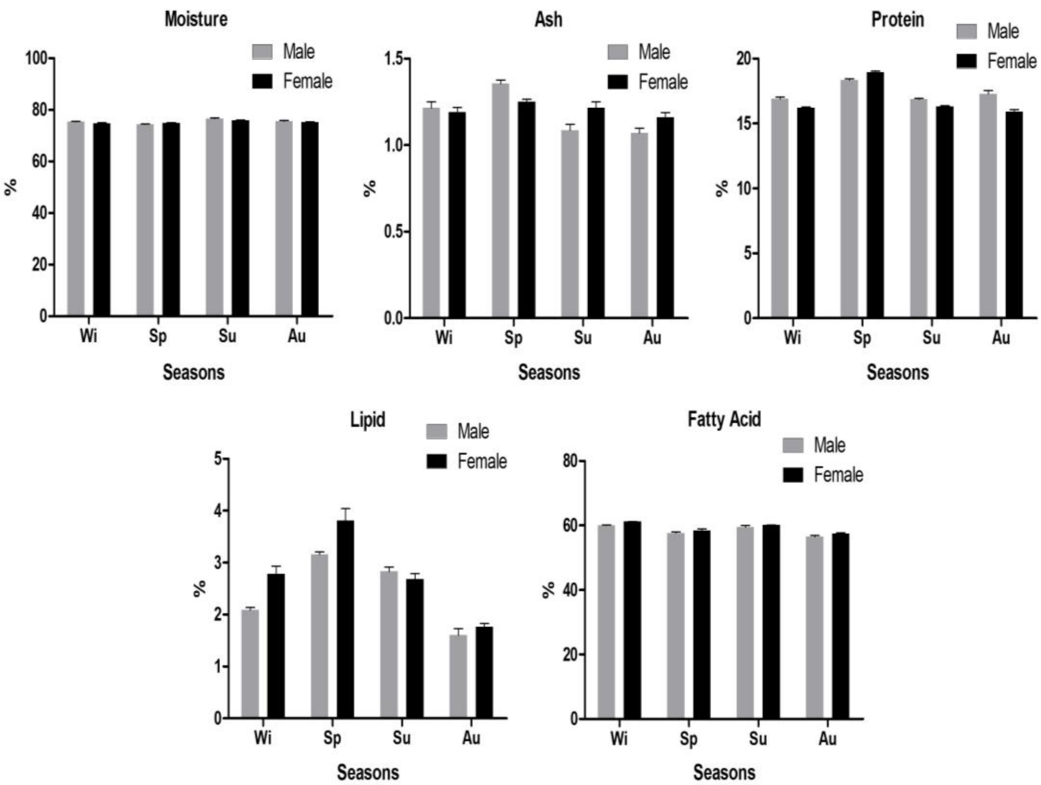


**Figure 6** delineates the variation in the muscle biochemical composition of *Catla catla* within the Masani barrage lake, shedding light on the intricate physiological aspects of this fish species.

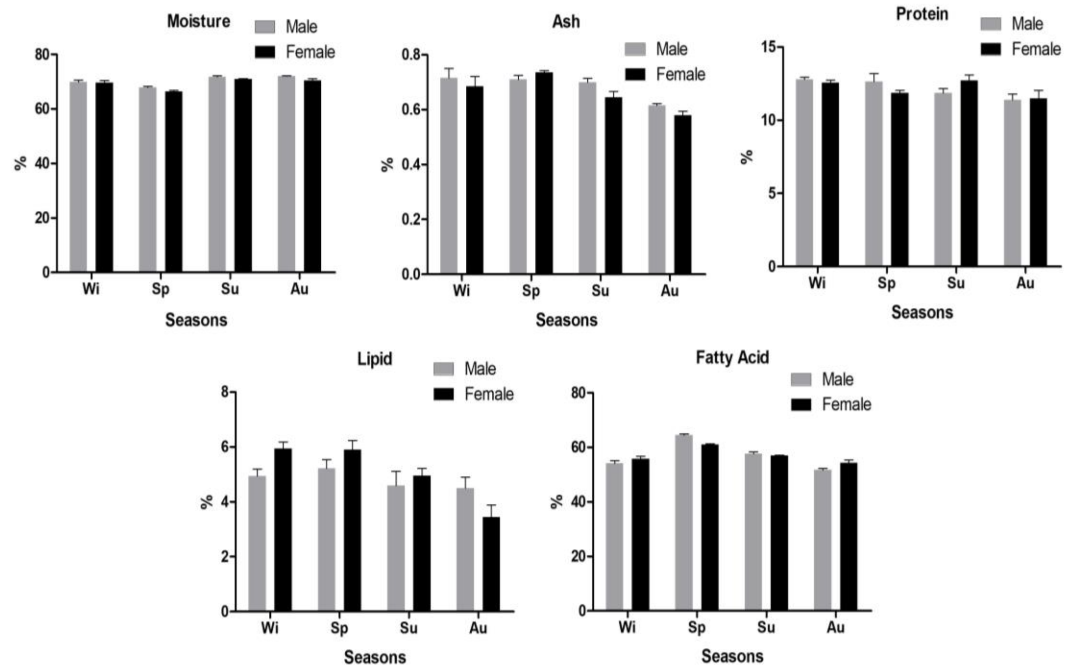


**Figure 7** delineates the variation in the liver biochemical composition of *Catla catla* within the Masani barrage lake, shedding light on the intricate physiological aspects of this fish species.

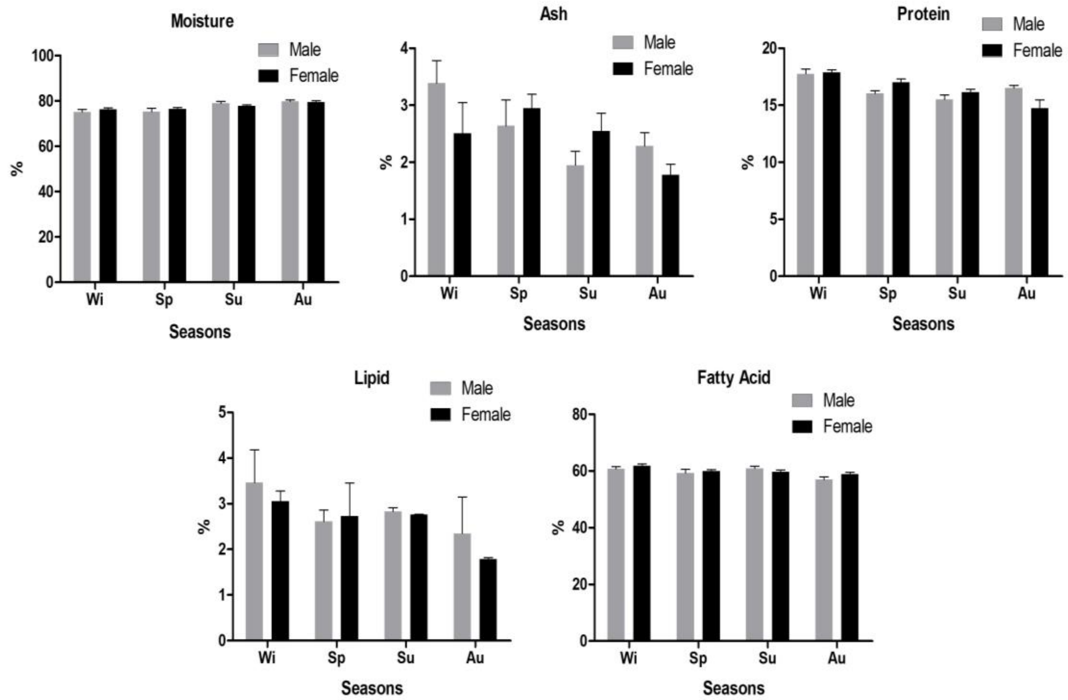


**Figure 8** depicts the variation in muscle biochemical composition of *Labeo rohita* in the Masani barrage lake, elucidating distinctive features of this fish's physiological makeup within the canal ecosystem.

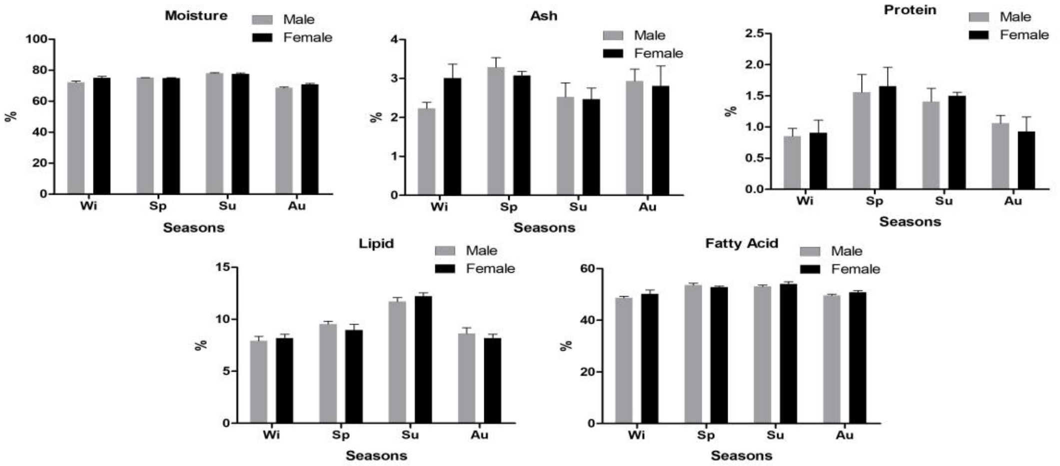


**Figure 9** depicts the variation in liver biochemical composition of *Labeo rohita* in the Masani barrage lake, elucidating distinctive features of this fish's physiological makeup within the canal ecosystem.

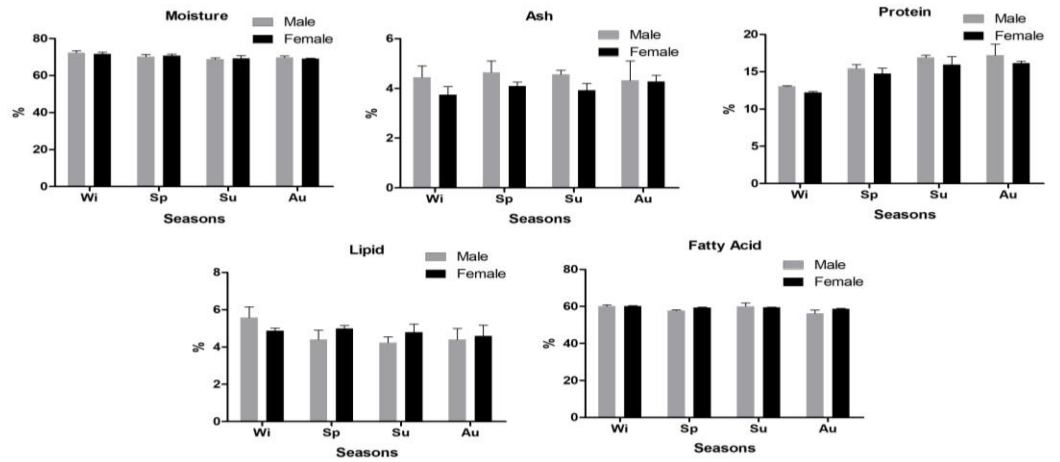


**Figure 10** highlights the variation in muscle biochemical composition of *Cirrhinus mrigala* at the Masani barrage lake, offering valuable insights into the unique biochemical profile of this fish species thriving in the lake environment.

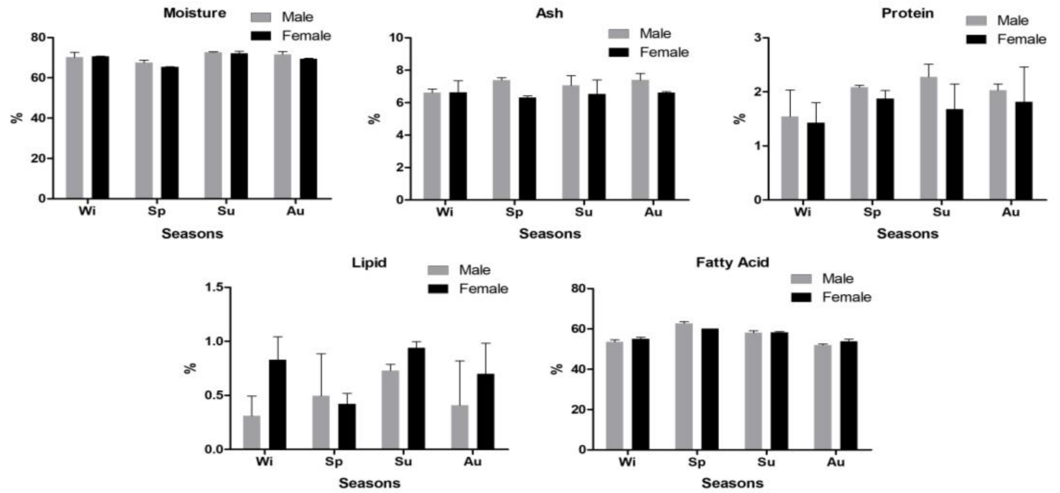


**Figure 11** highlights the variation in liver biochemical composition of *Cirrhinus mrigala* at the Masani barrage lake, offering valuable insights into the unique biochemical profile of this fish species thriving in the lake environment.

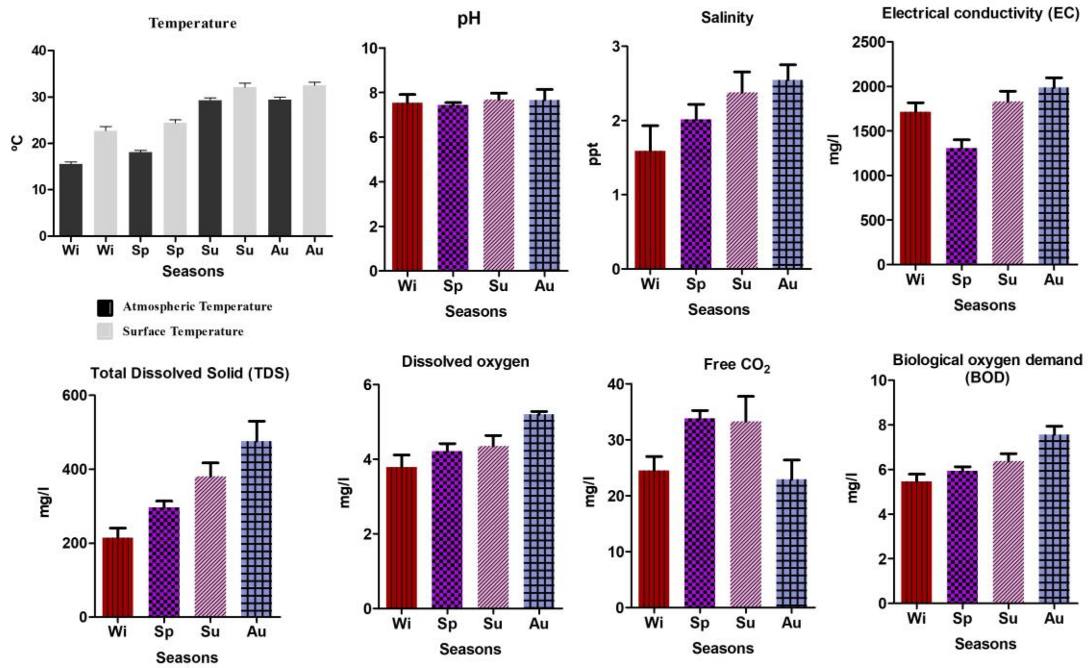


**Figure 12** illustrates the variation in the physicochemical components of the JLN canal, offering insights into its biochemical composition.

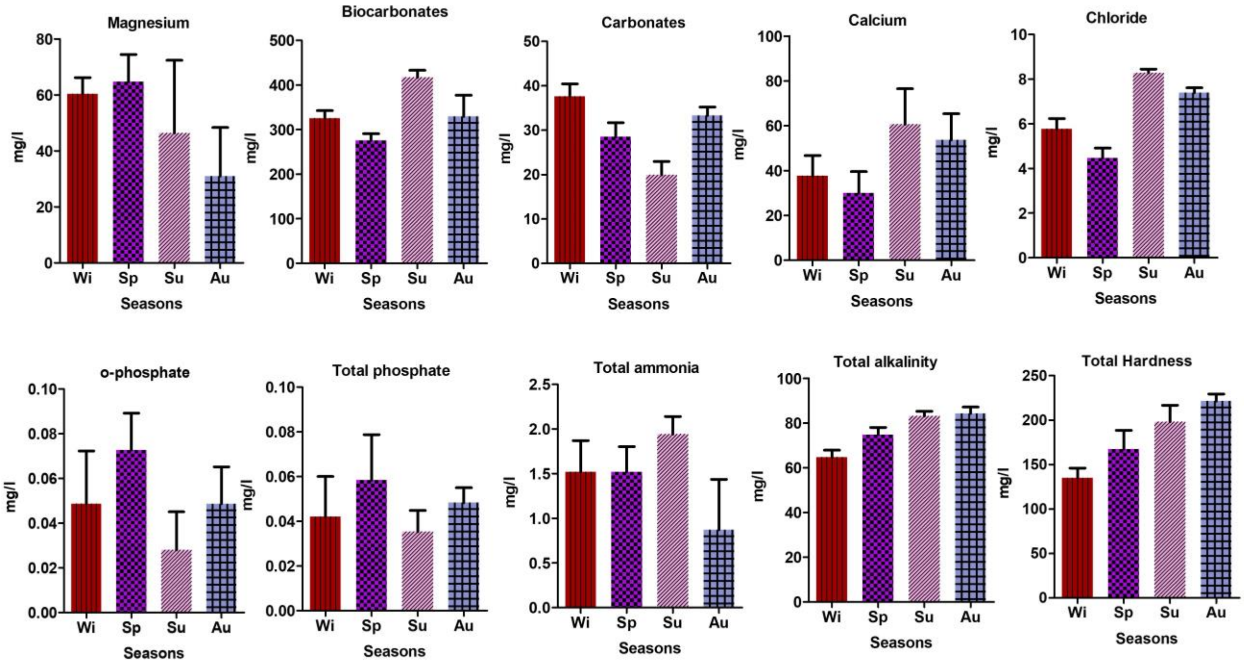


**Figure 13** illustrates the variation in the minerals components of the JLN canal.

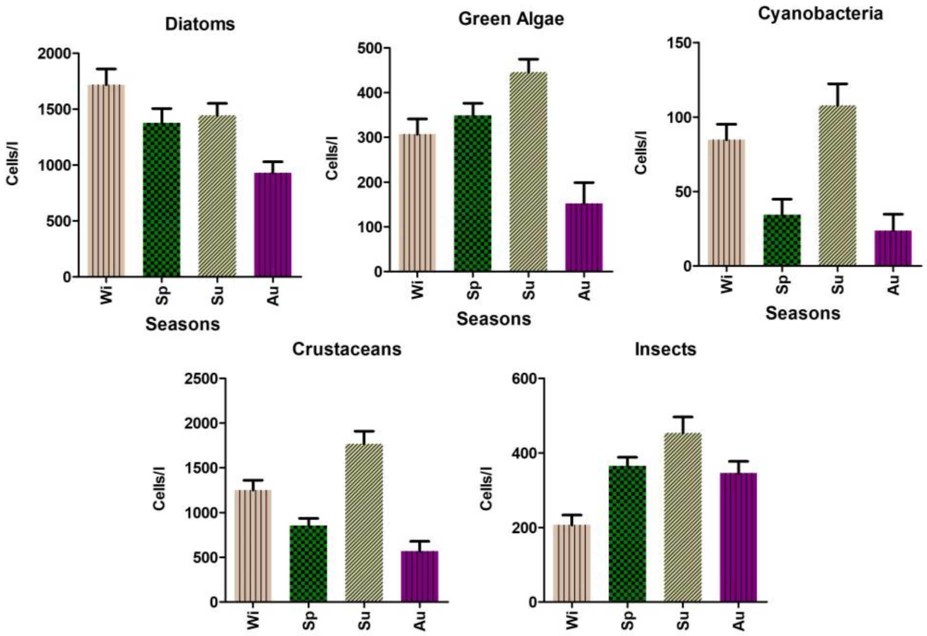


**Figure 14** showcases the diversity and variation of phytoplankton and zooplankton in the JLN canal, contributing to a nuanced understanding of the aquatic ecosystem.

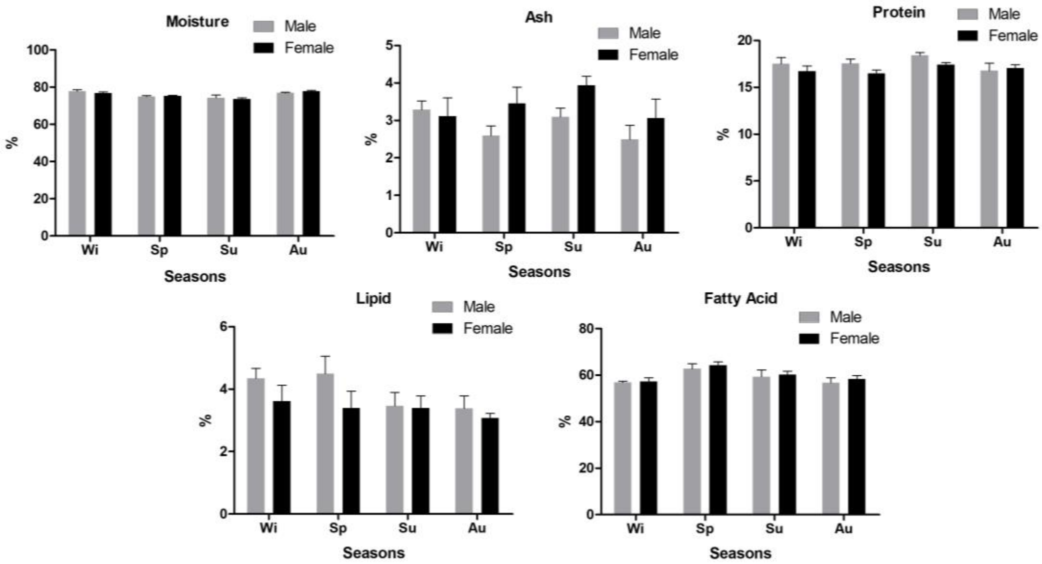


**Figure 15** delineates the variation in the muscle biochemical composition of *Catla catla* within the JLN canal, shedding light on the intricate physiological aspects of this fish species.

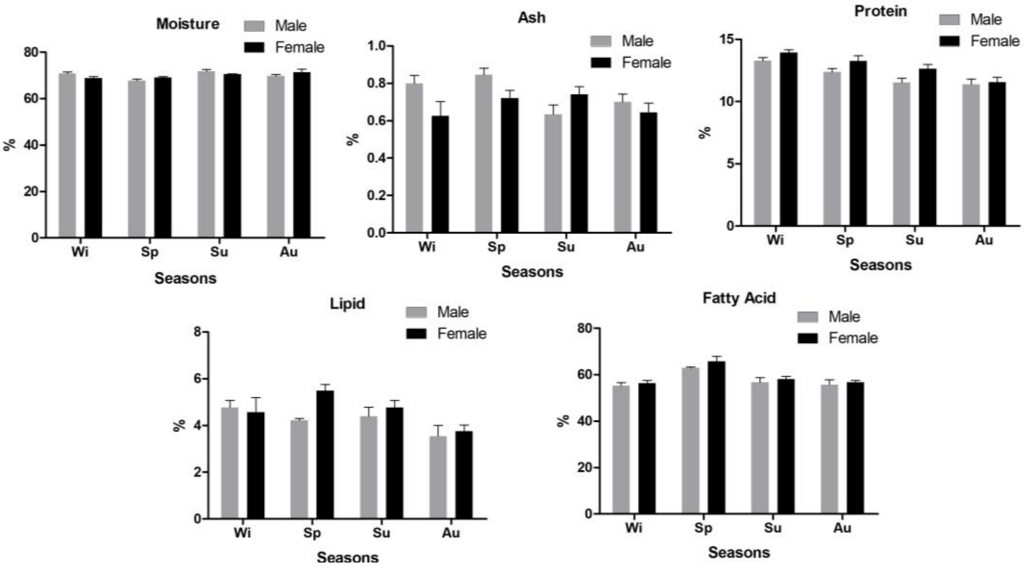


**Figure 16** delineates the variation in the liver biochemical composition of *Catla catla* within the JLN canal, shedding light on the intricate physiological aspects of this fish species.

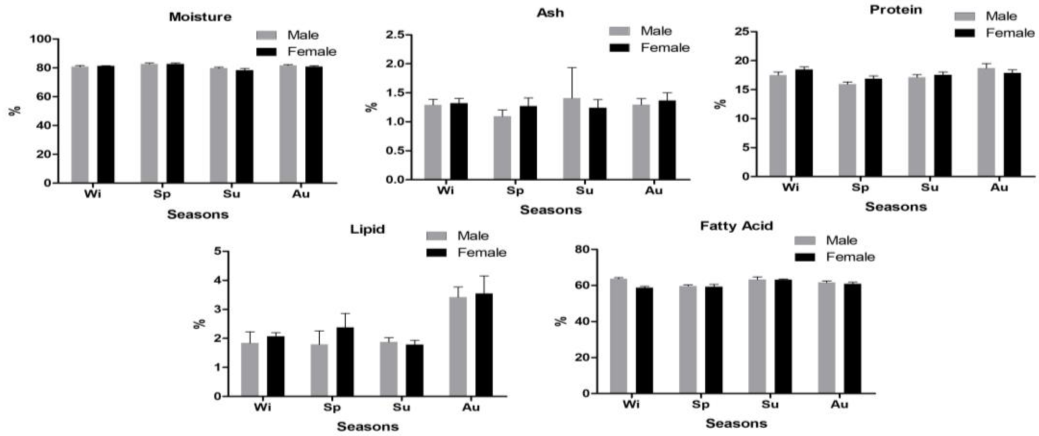


**Figure 17** depicts the variation in muscle biochemical composition of *Labeo rohita* in the JLN canal, elucidating distinctive features of this fish's physiological makeup within the canal ecosystem.

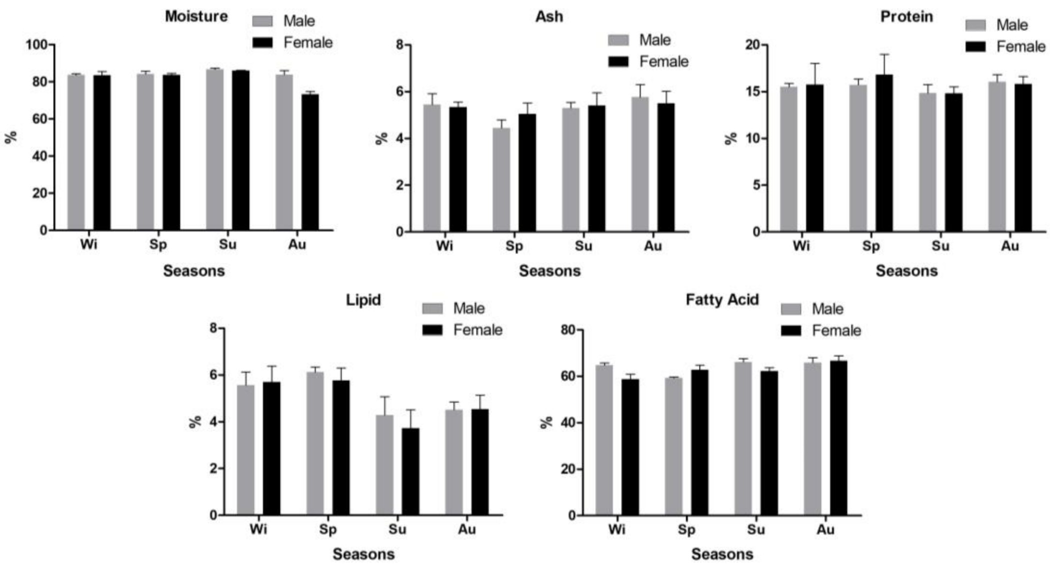


**Figure 18** depicts the variation in liver biochemical composition of *Labeo rohita* in the JLN canal, elucidating distinctive features of this fish's physiological makeup within the canal ecosystem.

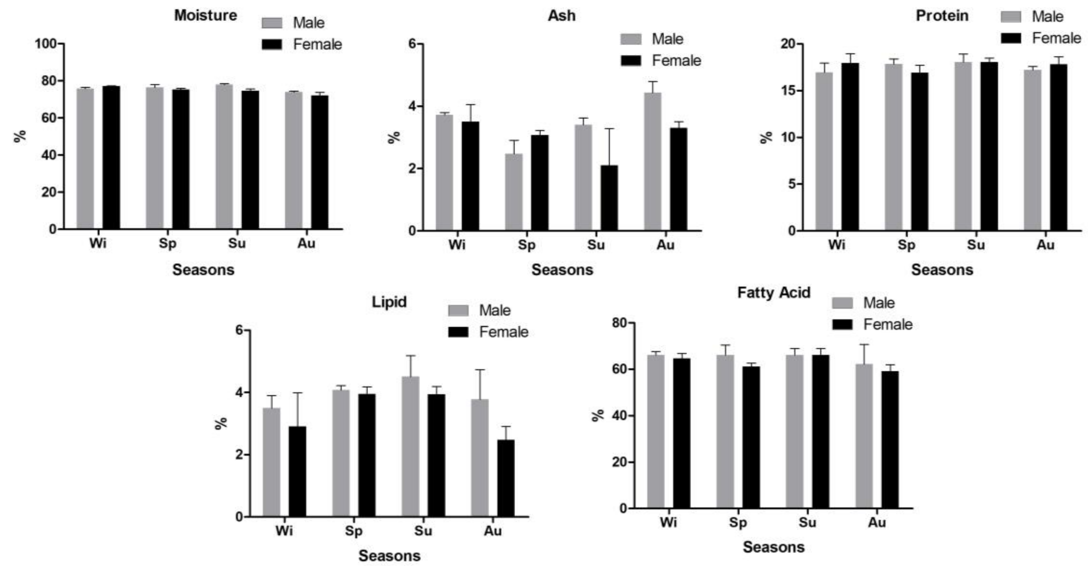


**Figure 19** highlights the variation in muscle biochemical composition of *Cirrhinus mrigala* at the JLN canal, offering valuable insights into the unique biochemical profile of this fish species thriving in the canal environment.

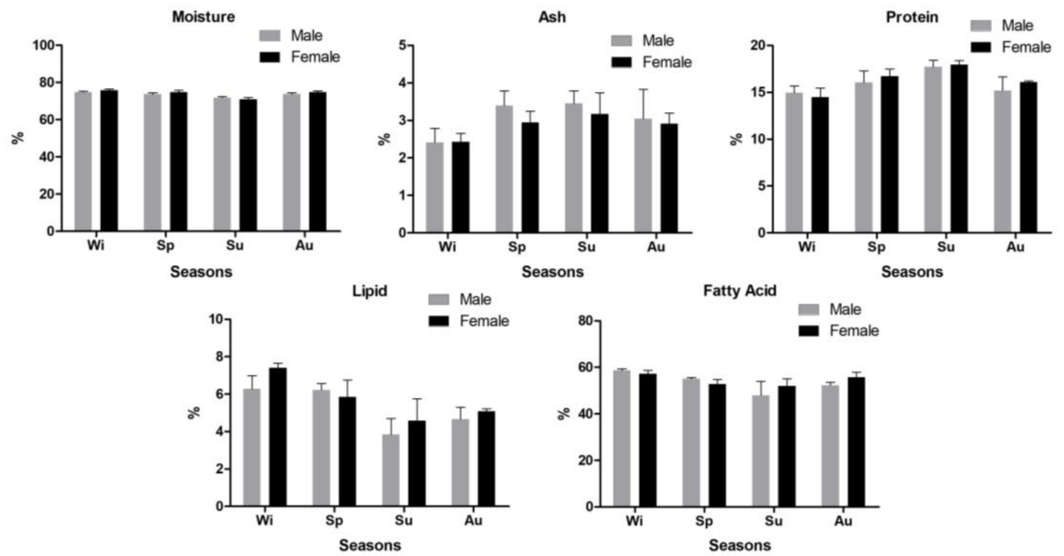


**Figure 20** highlights the variation in liver biochemical composition of *Cirrhinus mrigala* at the JLN canal, offering valuable insights into the unique biochemical profile of this fish species thriving in the canal environment.

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