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MALACOFAUNAL TAXONOMIC DIVERSITY IN RELATION TO PHYSICOCHEMICAL PARAMETERS OF RAIWADA RESERVOIR, ANAKAPALLI DISTRICT, ANDHRA PRADESH, INDIA

Zoology

P. John Kiran Department Of Zoology, Govt. Degree College, Nakkapalli, Anakapalli Dt. A. P, India

Purra Anuradha Department Of Zoology, Govt. Degree College (A), Khairatabad, Hyderabad, Telangana State, India.

K. Rama Rao Department Of Zoology, Dr. V. S. Krishna Govt. Degree College (A), Visakhapatnam, A.P, India

ABSTRACT

A total of 18 molluscan species, representing two classes, three orders, and eight families, were recorded from Raiwada Reservoir during 2023–2025. Gastropoda dominated the assemblage, contributing 66.67% at the class level, 87.50% at the family level, and 72.22% at the species level, while Bivalvia accounted for 33.33%, 12.50%, and 27.78%, respectively. Among the orders, Mesogastropoda was the most diverse, comprising four families, six genera, and nine species, whereas Basommatophora and Unionida exhibited lower diversity. Seasonal assessment of physico-chemical parameters indicated higher values during pre-monsoon, followed by post-monsoon and monsoon. The Water Quality Index (WQI) reflected similar trends, with values of 49.92 (pre-monsoon), 45.55 (post-monsoon), and 35.69 (monsoon), indicating generally good water quality. One-way ANOVA revealed no significant seasonal variation in WQI ($F = 0.00245$; $p = 0.997$), suggesting stable water quality throughout the year.

KEYWORDS

Molluscan, Raiwada Reservoir, Gastropoda, Bivalvia, Water Quality Index, ANOVA

INTRODUCTION

The Raiwada Reservoir, officially known as the Sri Varada Narayana Murty Raiwada Reservoir Project, is situated across the Sarada River near Raiwada village in Devarapalli Mandal, Anakapalli district, Andhra Pradesh, India. Constructed during 1981–82, the reservoir has a total storage capacity of 2,360 thousand cubic meters (tcm) and is located approximately 58 km from Visakhapatnam. It supplies water to the city through a 68 km canal and is managed by the Irrigation & CAD Department, playing a crucial role in meeting the region's water demands (Fig:1).

Freshwater molluscs constitute an important component of reservoir ecosystems due to their ecological, economic, and environmental significance. As filter feeders, they improve water quality by removing algae, bacteria, and suspended particles, thereby reducing turbidity and acting as bioindicators of aquatic health (Reuben et al., 2006; Wildlife Watch, 2024). Often referred to as the "liver of the river," mussels and other molluscs contribute to nutrient cycling, support the freshwater food web, and provide essential food for fish, birds, and other aquatic organisms (Shaikh et al., 2011; Tripathy & Amit, 2015). Moreover, they may offer economic benefits through fisheries and, in some cases, have medicinal value. Despite their importance, freshwater molluscs are vulnerable to habitat degradation, pollution, and invasive species, making their conservation in anthropogenically modified habitats, such as reservoirs, critical. Maintaining suitable environmental conditions, including near-neutral pH and adequate substrate availability, can help conserve local molluscan diversity. The present study aims to document and assess the distribution of molluscan communities in the Raiwada Reservoir, where no prior records exist, thereby providing baseline data for ecological assessment and conservation planning.

Fig: 1. Raiwada Reservoir

METHODS AND MATERIALS

I. Study Area

Water samples were drawn from the Raiwada Reservoir at three monitoring locations once every fifteen days from December 2023 to November 2024. Raiwada Dam side 18.008145, 82.965750 (S1), Velagalapadu, 18.023196, 82.951529 (S2), and Lovamukundapuram: 18.022511, 82.996830 (S2) were chosen as sample locations Fig 1.

II. Sample Collection

Molluscan samples were randomly collected from the periphery of the Raiwada Reservoir banks as well as from the water body using scoop nets and hand-picking methods. The snails were taken to the laboratory, washed with clean water to remove debris, and detailed observations of fresh specimens were recorded. The specimens were preserved in 96% alcohol for 24 hours before removing the soft parts. The shells, which were often covered with mineral deposits and algae, were cleaned by immersing them in a dilute solution of oxalic acid for a few minutes, followed by gentle scrubbing with a soft brush and rinsing in water to reveal their sculpture (Mandahl Barth, 1962; Thompson, 2004). The cleaned shells were dried at room temperature and preserved for further studies. Identification and classification of the specimens were carried out using standard keys (Vaught, 1959; Subba Rao, 1959; Vaught, 1989; Subba Rao, 1993; Surya Rao, 2002; Mitra, 2005; Rama Krishna, 2007). To minimize changes in chemical composition, all water samples were collected in clean, sterile polypropylene wide-mouth reagent containers with a 1-litre capacity, transported to the laboratory, and stored at 4°C. The samples were analyzed using standard procedures. Parameters such as temperature, pH, transparency, dissolved oxygen (DO), biochemical oxygen demand (BOD mg/L), chemical oxygen demand (COD mg/L), total hardness, carbonates, bicarbonates, calcium (Ca^{2+} mg/L), magnesium (Mg mg/L), ammonia (mg/L), and nitrites (mg/L) were measured to compute the Water Quality Index (WQI).

III. Water Quality Index Calculation

The following methods were used to assess water quality: dissolved oxygen was analyzed using Winkler's method with azide modification; phosphates were estimated by the stannous chloride method; total alkalinity was determined by the standard titrimetric method using phenolphthalein and methyl orange; total hardness was measured using the EDTA titrimetric method; and nitrates were estimated following the Brucine method as described by ICMR (1975), Stojda and Dojlido (1983), Eaton and Clesceri (1998), CPHEEO (1991), Bureau of Indian Standards (BIS, 1991), the American Public Health Association (2005), the World Health Organization (2006), and Atef Faleh and Al Mashagbah (2015). The study results were compared with the permissible limits for drinking water quality specified by these standards.

WQI is calculated with the help of index method (Brown et al., 1972).

Calculation of WQI was performed by following the 'weighted arithmetic index method' using the equation:

WQI = $\sum QiWi / \sum Wi$ (Weighted Arithmetic Water Quality Index formula)

Qi = 100 [(Vi – V0 / Si – S0)] (Quality Rating for each parameter)
Wi = K/Si (Relative Weight for each parameter)
K = proportionality constant
K = 1/ ∑(1/Si)
Si = recommended standard value of ith parameter.
V0 = ideal value of parameter in pure water V0 = 0 (except pH = 7.0 & **D.O.** = 14.6 mg/lt.)
Vi = estimated concentration of ith parameter in the analyzed water.

According to Mishra and Patel, 2001, the appropriateness of WQI values is graded as follows (Dinius, 1987, Tiwari and Manzoor 1988). Water Quality Rating as per Weighted Arithmetic Water Quality Index Method (Brown et al., 1972)

Table: 1

Value of WQI	**Rating of water Quality**
0-25	Excellent
26-50	Good Water Quality
51-75	Poor Water Quality
76-100	Very Poor Water Quality
100 & above	Unsuitable for drinking purpose

Table: 2. *ICMR strands (1975), **CPHEEO Strands (1991), @ WHO

Physical Parameter	**Standard values**	**Chemical parameters**	**Standard values**
Ph	7-8.5	Magnesium (mg/l)	< 30
Transparency (cm)	5-25*	Ca^{2+} (mg/l)	< 75*
Turbidity	< 1	Chlorides	< 250
Total dissolved solids	< 500	Phosphates Po4	1
Chemical parameters	Standard values	DO (mg/l)	>5*
Total alkalinity as caco3	<200	BOD (mg/l)	5*
Total Hardness (mg/l) Caco3	<300	COD (mg/l)	20
Carbonates (mg/l)	120	Ammonia NH3 (mg/l)	<0.5
Bicarbonates (mg/l)	200	Nitrates (mg/l)	<50*

RESULTS AND DISCUSSION

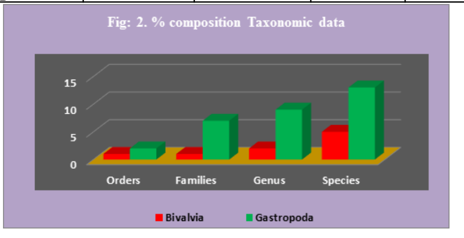
A total of 18 molluscan species were recorded from all sampling sites in Raiwada Reservoir during the study period (2023–2025). The molluscan community was represented by two classes, three orders, eight families, and 18 species (Table 3). Among the two major classes, Gastropoda contributed the highest proportion (66.67%), while Bivalvia accounted for 33.33% of the total orders. At the family level, Gastropoda was dominant with seven families (87.50%), whereas Bivalvia was represented by a single family (12.50%). Similarly, nine genera (81.85%) of Gastropoda and two genera (18.15%) of Bivalvia were identified. In terms of species composition, Gastropoda comprised 13 species (72.22%), whereas Bivalvia contributed five species (27.78%) of the total molluscan assemblage (Table 4; Fig. 2).

Table 3. Checklist Of Molluscans Taxonomic Position And IUCN Status

Phylum: Mollusca (Linnaeus, 1758)					
Class	**Order**	**Family**	**S. No**	**Scientific name**	**IUCN (2025-1)**
Bivalvia	**Unionida**	Unionidae	1	*Lamellidens consobrinus* (Lea, 1859)	LC
			2	*Lamellidens corrianus* (Lea, 1834)	LC
			3	*Lamellidens marginalis* (Lamarck, 1819)	LC
			4	*Parreysia corrugata* (Benson, 1862)	LC
			5	*Parreysia favidens* (Benson, 1862)	LC
Gastropoda	**Basommatophora**	Bullinidae	6	*Indoplanorbis exustus* (Desbayes, 1834).	LC
		Lymnaeidae	7	*Lymnaea* (*Pseudosuccinea*) *acuminata* (Lamarck, 1822)	LC
		Planorbidae	8	*Gyraulus labiatus* (Benson, 1850)	LC
			9	*Gyraulus convexiusculus* (Hutton, 1849)	LC
	Mesogastropoda	Ampullariidae	10	*Pila virens* (Lamarck, 1822)	LC
		Bithynidae	11	*Bithynia pulchella* (Bens'on, 1836)	LC
		Thiaridae	12	*Thiara lineata* (Gray, 1828).	LC
			13	*Melanoides tuberculatus* (Mueller, 1774)	LC
			14	*Tarebia granifera* (Lamarck, 1822	LC
			15	*Tarebia lineata* (Gray, 1828).	LC
		Viviparidae	16	*Bellamya bengalensis*	LC
			17	*Bellamya crassa* (Benson., 1836)	LC
			18	*Bellamya dissimilis* (Mueller, 1774)	LC

Table 4. Percentage Composition Of Taxonomic Data In Various Classes

Class	**% of Orders**	**% of Families**	**% of Genus**	**% of Species**
Bivalvia	33.33	12.50	18.18	27.78
Gastropoda	66.67	87.50	81.82	72.22



These findings are in agreement with earlier reports. Rama Rao and Amaravathi (2021) also observed Gastropoda as the dominant class (66.67%), with Bivalvia contributing 33.33% of the total orders. In their study, Gastropoda represented 68.18% of species, whereas Bivalvia accounted for 31.82%. Among the orders, Mesogastropoda contributed the maximum proportion (50.00%), followed by Unionida (31.19%) and Basommatophora (18.18%) in Kondkarla Lake. Similarly, Chutia and Kardong (2021) reported 16 species of molluscs from aquatic bodies of the PRF, distributed across five orders and seven families under the two major classes, Gastropoda and Bivalvia. Their findings also highlighted the dominance of Gastropoda (five families) compared to Bivalvia (two families, Unionidae and Cyrenidae). Interestingly, however, their abundance data showed Bivalvia (54.04%) contributing more than Gastropoda (45.95%), indicating variation across habitats and environmental conditions.

The molluscan assemblage in Raiwada Reservoir thus reflects a higher taxonomic and species-level dominance of Gastropoda, consistent with several earlier studies (Chalapathi, 2018; Pathak, 2020). However, variations in abundance trends across different reservoirs suggest that physicochemical parameters, prey availability, and habitat heterogeneity may influence molluscan community composition and dominance patterns. Representative photographs of the molluscan taxa recorded from the study area are presented in Figure 2.

In the present investigation, the order Unionida was represented by a single family, contributing 12.50%, with two genera (18.18%) and five species (27.78%). The order Basommatophora comprised three families (37.50%), three genera (27.27%), and four species (22.22%), whereas Mesogastropoda exhibited the highest representation, consisting of four families (50.00%), six genera (54.54%), and nine species (50.50%) (Table 5; Fig. 3).

Seasonal analysis indicated that molluscan fauna was more abundant during the monsoon compared to the post-monsoon period. Certain genera exhibited clear seasonal predominance; for instance, Bellamya, Pila, and Lymnaea were dominant during the summer months. The early developmental stages of Thiara, Indoplanorbis, and Bellamya were frequently observed associated with aquatic macrophytes, while their adult forms were more common along the peripheral regions of the reservoir. Similarly, species such as Lamellidens and Parreysia were often encountered in shallow, muddy waters across various seasons, reflecting their preference for soft-bottomed habitats.

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These findings are comparable with those of Rama Rao et al., (2021), who documented that Mesogastropoda contributed the highest proportion of families (57.14%), followed by Basommatophora (42.86%) and Unionida (14.29%). Their study also revealed a higher species richness in Mesogastropoda (50.00%), followed by Unionida (31.19%) and Basommatophora (18.18%). Reports from other regions further support these observations. For instance, Rumeet Kour et al., (2018) and Sajan et al., (2019) highlighted the diversity of molluscan assemblages in the Narmada River and freshwater bodies of Andhra Pradesh and Telangana, respectively. Similarly, Amaravathi et al., (2019) reported notable molluscan diversity in Kondakarla Freshwater Lake, while Bijukumar et al. (2001) recorded 13 molluscan species from five orders, eight families, and ten genera in the Bharathapuzha River, Kerala. Surya Rao et al., (2013) identified 25 species under 13 genera and 10 families in Wyra Lake, and Roy and Gupta (2010) documented 16 taxa belonging to two classes, four orders, five families, and nine genera from the Barak River and its tributaries.

Overall, the present study reaffirms the dominance of Mesogastropoda in freshwater habitats, with Unionida and Basommatophora showing moderate representation. The seasonal variation in distribution and habitat preference of specific genera underscores the influence of hydrological regimes, substrate conditions, and macrophyte availability on molluscan assemblage patterns in Raiwada Reservoir.

In the present study, the order Unionida was represented by a single family contributing 12.50%, with two genera (18.18%) and five species (27.78%). The order Basommatophora comprised three families (37.50%), three genera (27.27%), and four species (22.22%), whereas Mesogastropoda emerged as the most diverse order, represented by four families (50.00%), six genera (54.54%), and nine species (50.50%) (Table 5; Fig. 3).

Table 5. Percentage Composition Of Systematic Position In Various Orders

Order	% of Families	% of Genus	% of Species
Unionida	12.50	18.18	27.78
Basommatophora	37.50	27.27	22.22
Mesogastropoda	50.00	54.55	50.00

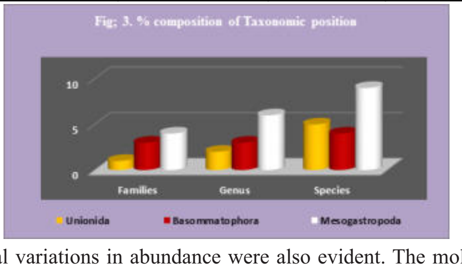

Fig: 3. % composition of Taxonomic position

Seasonal variations in abundance were also evident. The molluscan fauna was more abundant during the monsoon season compared to the post-monsoon period, suggesting a strong influence of hydrological and ecological conditions. Among the recorded taxa, Bellamya, Pila, and Lymnaea were predominant during the summer, while the early developmental stages of Thiara, Indoplanorbis, and Bellamya were commonly associated with hydrophytes. Adult forms of these genera were typically observed along the peripheral zones of the reservoir, indicating ontogenetic habitat shifts. Similarly, Lamellidens and Parreysia species were frequently encountered in shallow muddy waters across different seasons, reflecting their substrate preference.

These observations align with the findings of Rama Rao et al., (2021), who reported that Mesogastropoda contributed the highest proportion of families (57.14%), followed by Basommatophora (42.86%) and Unionida (14.29%). Their study also highlighted the dominance of Mesogastropoda at the species level (50.00%), followed by Unionida (31.19%) and Basommatophora (18.18%). Comparative studies from other regions further corroborate the present findings. For instance, Rumeet Kour et al., (2018) and Sajan et al., (2019) documented rich molluscan diversity in the Narmada River and various freshwater systems of Andhra Pradesh and Telangana, respectively. Similarly, Amaravathi et al., (2019) reported high diversity in Kondakarla Freshwater Lake, while Bijukumar et al., (2001) identified 13 molluscan species belonging to five orders, eight families, and ten genera in the Bharathapuzha River, Kerala. Surya Rao et al., (2013) recorded 25 species under 13 genera and 10 families from Wyra Lake, and Roy and Gupta (2010) reported 16 taxa (two classes, four orders, five families, and nine genera) from the Barak River and its tributaries.

Taken together, the present results confirm the dominance of Mesogastropoda in Raiwada Reservoir, consistent with patterns observed in other freshwater ecosystems across India. The seasonal abundance trends and habitat-specific distribution of certain genera highlight the ecological plasticity of molluscs, particularly their ability to adapt to fluctuating hydrological regimes and microhabitats. Such diversity not only reflects the ecological health of the reservoir but also underscores the role of molluscan communities as important bioindicators in freshwater ecosystems.

In the present study, the physico-chemical characteristics of Raiwada Reservoir were assessed seasonally, and most of the parameters recorded higher values during the pre-monsoon season, followed by post-monsoon and monsoon (Table 6). The Water Quality Index (WQI) also reflected this trend, with the highest value in the pre-monsoon (49.92), followed by post-monsoon (45.55) and monsoon (35.69), all of which indicate good water quality (Table 1; Fig. 5). The average WQI value of 43.72 further confirms that the water quality of Raiwada Reservoir falls within the good category, supporting its suitability for aquatic life and domestic usage.

Comparable results have been documented in other freshwater systems. Sarikar and Vijaykumar (2022) reported that the pH of Bhosga Reservoir ranged between 7.43 and 7.8 across five sampling sites, suggesting nearly neutral to slightly alkaline conditions. Similarly, Bora and Goswami (2017) observed total alkalinity (TA) variations ranging from 52 mg/L to 296 mg/L in the Kolong River, attributing these fluctuations largely to carbonate and hydroxide concentrations, with minor contributions from phosphates. Murthuzasab et al. (2010) and Bouslah et al. (2017) also highlighted the significance of physico-chemical parameters in determining water quality in reservoirs such as Koudiat Medouar.

Further, Ramita and Aarif (2018) demonstrated that WQI values often varied seasonally, with pre-monsoon samples ranging from 50.50 to 64.174 and post-monsoon samples between 51.50 and 70.604, indicating poor water quality status in their study area. Interestingly, their findings showed that monsoon season produced the best WQI values (mean 48.14), compared to pre-monsoon (46.08) and post-monsoon (43.68). This contrasts with the present study, where the pre-monsoon season exhibited the highest water quality index. Such variations may be attributed to differences in hydrological regimes, catchment characteristics, rainfall intensity, and anthropogenic influences across reservoirs.

Overall, the present findings emphasize that Raiwada Reservoir maintains good water quality throughout the study period, with seasonal variations that reflect the natural influence of monsoon-driven hydrological changes. These observations reinforce the importance of seasonal monitoring of physico-chemical parameters to ensure sustainable management of freshwater reservoirs and to safeguard their ecological integrity.

The one-way ANOVA conducted for the Water Quality Index (WQI) across different seasons indicated no statistically significant variation among seasonal means. The calculated F-value (0.00245) was well within the 95% acceptance region, confirming that any observed differences are most likely attributable to random variation rather than true seasonal effects. Furthermore, the p-value (0.997), being much higher than the conventional threshold ($p < 0.05$), strongly supports the null hypothesis (H_0) that there is no significant difference among seasonal means. This statistical evidence suggests that the WQI remains relatively stable throughout the year, with no meaningful seasonal fluctuations (Table 6; Fig. 5).

Biologically, most of the molluscan species recorded during the study period were common to all three sampling stations, though species counts exhibited unequal seasonal distribution, indicating ecological adjustments despite stable water quality conditions. This suggests that biotic responses may be more sensitive to microhabitat factors and ecological interactions than to seasonal changes in WQI.

Table 6. Seasonal Water Quality Parameters With Water Quality Index

S. No	parameters	Pre monsoon	Monsoon	Post monsoon	Average

I. Physical parameters					
1	Temperature (0^C)	29.25±2.01	27.45±1.15	25.45±1.85	27.38
2	Ph	7.84±0.78	7.02±0.5	7.22±1.24	7.36
3	Total dis. Solids	217±5.36	375±10.3	284±8.56	292
4	Transparency (cm)	42±2.12	49±4.5	45±3.25	45.33
II. Chemical parameters					
1	Alkalinity (mg/l)	185±7.45	155±8.23	169±8.85	169.67
2	Carbonates (mg/l)	74.32±3.25	52.33±1.7	63.45±3.65	63.37
3	Bicarbonates (mg/l)	122.25±6.78	75.65±2.48	103.47±7.56	100.47
4	Total Hardness (mg/l)	105.42±6.23	70.12±3.5	94.65±3.67	90.06
5	Chlorides	74.22±4.85	45.35±3.1	58.34±4.25	59.30
6	DO (mg/l)	4.49±0.65	5.12±0.26	4.82±1.05	4.81
7	BOD (mg/l)	4.21±0.75	2.35±1.86	3.13±0.65	3.23
8	COD (mg/l)	18.54±2.45	15.65±1.12	16.65±2.45	16.95
9	Ca2+ (mg/l)	56.27±4.25	44.12±2.37	49.34±4.68	49.91
10	Magnesium (mg/l)	26.45±0.08	16.45±1.81	21.72±2.47	21.54
11	Phosphates (mg/l)	0.42±0.05	0.28±0.12	0.37±0.08	0.36
12	Ammonia (mg/l)	0.19±0.05	0.11±0.003	0.17±0.01	0.16
13	Nitrites (mg/l)	24.75±3.42	21.5±0.05	22.75±2.85	23.00
	WQI	49.92	35.69	45.55	43.72

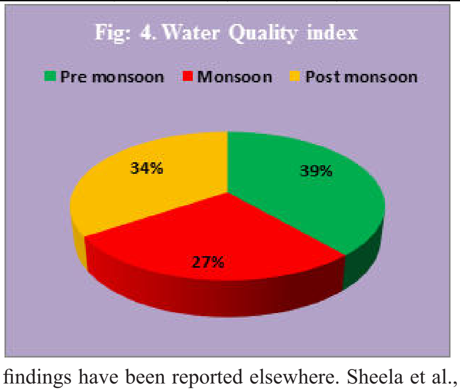

Fig: 4. Water Quality index

Similar findings have been reported elsewhere. Sheela et al., (2012) applied multivariate techniques to assess water quality in Akkulam Veli Lake, India, and demonstrated that contaminant sources were closely linked to seasonal rainfall events, highlighting the hydrological influence on water quality.

In contrast, Milana et al., (2012) found statistically significant variation in dissolved oxygen (DO) ($F = 76.961$, $p = 0.000$) across sampling points, indicating that oxygen dynamics can vary strongly with season and location. Their study in Serbia's Veliki Baki Canal revealed no notable differences in some parameters, but BOD, TDS, and EC were strongly associated with the first axis in multivariate analysis, suggesting they were the primary drivers of site separation.

Khalik et al. (2013) conducted a one-way ANOVA on water quality in the Bertam River, Cameron, and observed significant differences for most parameters except pH, DO, salinity, COD, and ammoniacal nitrogen, whereas turbidity levels varied significantly ($p < 0.05$) across sites influenced by different land use categories. Similarly, Jayawardana et al. (2016) highlighted that nutrients (NO_2^-, PO_4^{3-}), dissolved ions (F^-), and hardness were the main contributors to site separation in their statistical analysis.

Thus, the present findings suggest that, unlike in some other aquatic systems, the Raiwada Reservoir exhibits stable WQI values across seasons, possibly due to its regulated hydrological regime and controlled anthropogenic influences. However, the unequal distribution of species richness across seasons despite stable water quality underscores the importance of integrating biological indicators with physico-chemical parameters for a holistic understanding of freshwater ecosystem health.

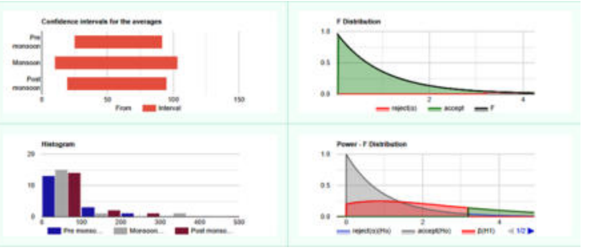

Fig: 5. One way ANOVA of Water Quality Index

CONCLUSION

The present investigation on the molluscan diversity of Raiwada Reservoir highlights the intricate interplay between hydrological conditions, habitat characteristics, and species distribution. Seasonal analysis revealed that molluscan abundance was highest during the monsoon, with distinct genera exhibiting seasonal predominance, such as Bellamya, Pila, and Lymnaea in summer, and Lamellidens and Parreysia in shallow, muddy substrates. The observed habitat specificity of several genera illustrates their ecological plasticity and ability to exploit a range of microhabitats under monsoon-driven hydrological regimes. Such patterns reaffirm the importance of molluscs as bioindicators capable of reflecting both ecological integrity and environmental stability. Interestingly, the study revealed that while water quality index (WQI) values remained relatively stable across seasons, species composition and abundance exhibited notable variability. This suggests that molluscan communities respond more sensitively to microhabitat conditions and ecological interactions than to broad physico-chemical parameters alone. Overall, the study confirms that Raiwada Reservoir maintains good ecological quality with minimal anthropogenic stress, while simultaneously supporting diverse molluscan communities. The seasonal and habitat-specific variations observed during the study provide valuable insights into ecosystem functioning and resilience. These results not only strengthen the role of molluscs as ecological sentinels but also highlight the importance of long term, multi seasonal monitoring for sustainable reservoir management. In conclusion, the present work contributes significantly to understanding freshwater biodiversity dynamics and reinforces the value of molluscan fauna as vital components of aquatic ecosystem assessment and conservation.

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Conflicts Of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

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