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Studies on Seasonal Variation of Zooplankton Community in Beneshwar Dham, Rajasthan

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Abstract: Zooplankton communities serve as crucial bioindicators of aquatic ecosystem health and productivity. This study investigated the seasonal variation of zooplankton diversity and density in the aquatic ecosystem at Beneshwar Dham, Rajasthan, over a one-year period (January 2024 to December 2024). A total of 38 zooplankton species were identified, belonging to four major groups: Protozoa (12 species), Rotifera (6 species), Cladocera (13 species), and Copepoda (7 species). Seasonal analysis revealed maximum zooplankton density during the winter season (December-February: 845 ± 42 individuals/L), followed by summer (March-June: 412 ± 38 individuals/L), with minimum density recorded during the monsoon season (July-September: 178 ± 23 individuals/L). Rotifers dominated the community composition (38.2%), followed by Cladocera (31.6%), Copepoda (18.4%), and Protozoa (11.8%). Physicochemical parameters showed significant seasonal correlations with zooplankton abundance. The study provides baseline data for understanding zooplankton dynamics in semi-arid region aquatic ecosystems and emphasises the importance of Beneshwar Dham as an ecologically significant habitat.
Keywords: Seasonal variation, zooplankton community, Beneshwar Dham, Rotifera, Cladocera, Copepoda, Protozoa, biodiversity, semi-arid region, aquatic ecology.

I. INTRODUCTION

Zooplankton are microscopic, heterotrophic organisms that drift in aquatic environments and occupy a critical intermediate trophic level, linking primary producers (phytoplankton) to higher consumers such as fish and aquatic insects (Wetzel, 2001). They play an indispensable role in nutrient cycling, energy transfer, and maintaining water quality parameters in freshwater ecosystems. The composition, diversity, and density of zooplankton communities are highly sensitive to environmental changes, making them excellent bioindicators for ecological monitoring and water quality assessment (Sharma & Sharma, 2011).

Seasonal variations in zooplankton communities are governed by a complex interplay of physicochemical factors, including temperature, pH, dissolved oxygen, nutrient availability, and hydrological regimes (Lampert & Sommer, 2007). In tropical and subtropical regions like Rajasthan, seasonal fluctuations are pronounced, with distinct summer, monsoon, and winter periods exerting differential effects on aquatic biota. The extreme climatic conditions of Rajasthan—characterised by high summer temperatures (exceeding 40°C), erratic monsoon rainfall, and relatively mild winters—create unique selective pressures that shape zooplankton community structure (Jakher & Rawat, 2003).

Beneshwar Dham, located at the confluence of the Mahi, Som, and Jakham rivers in the Dungarpur district of Rajasthan, holds immense religious, cultural, and ecological significance. The perennial water bodies associated with this sacred site support diverse aquatic life forms and provide essential ecosystem services to local communities. Despite its ecological importance, limited scientific attention has been directed toward understanding the zooplankton diversity and its seasonal dynamics in this region.

The present study was undertaken with the following objectives: (1) to document the zooplankton species composition in the aquatic ecosystem of Beneshwar Dham; (2) to analyze seasonal variations in zooplankton density and diversity; (3) to correlate zooplankton abundance with key physicochemical parameters; and (4) to establish baseline ecological data for future conservation and management efforts. This research contributes to the growing body of limnological knowledge in semi-arid regions and supports the sustainable management of freshwater resources in Rajasthan.

II. STUDY AREA

Beneshwar Dham (23°32' N latitude, 74°15' E longitude) is situated in the Dungarpur district of southern Rajasthan, India, approximately 45 km from the district headquarters. The site is renowned as the "Prayag of Rajasthan" due to the sacred confluence (Triveni Sangam) of three rivers: the Mahi, Som, and Jakham. The aquatic ecosystem comprises perennial riverine stretches, pools, and man-made ghats used for religious bathing and rituals.

The climate of the region is tropical semi-arid, characterised by three distinct seasons: summer (March to June) with temperatures ranging from 28°C to 44°C; monsoon (July to September) with average annual rainfall of 600-800 mm; and winter (October to February) with temperatures between 10°C and 28°C. The water bodies at Beneshwar Dham are moderately alkaline, with fluctuating water levels depending on seasonal rainfall and upstream dam releases. The substrate is predominantly sandy loam with patches of clay, and aquatic vegetation includes emergent macrophytes like Typha and Eichhornia in littoral zones.

The selection of Beneshwar Dham for this study was based on its perennial water availability, ecological significance, religious importance leading to anthropogenic influences, and the absence of prior systematic limnological investigations.

III. MATERIALS AND METHODS

A. Sampling Design and Frequency

The study was conducted over a period of twelve months, from January 2024 to December 2024. Three permanent sampling stations were established at Beneshwar Dham based on habitat heterogeneity: Station 1 (confluence point with moderate water current), Station 2 (ghat area with anthropogenic influence), and Station 3 (relatively undisturbed pool with aquatic vegetation). Sampling was performed monthly during the early morning hours (6:00 AM to 8:00 AM) to minimise diel variation effects.

B. Collection of Zooplankton Samples

Zooplankton samples were collected using a conical plankton net (No. 25 mesh size, 55 μm pore diameter, 50 cm mouth diameter) following standard protocols (APHA, 2017). For each sample, 100 litres of water were filtered through the net, and the concentrated sample (approximately 50 mL) was transferred into pre-cleaned polyethylene bottles. Samples were immediately preserved in 4% formalin solution (final concentration) containing 1% Rose Bengal stain to facilitate later identification.

C. Sample Processing and Identification

In the laboratory, preserved samples were allowed to settle for 48 hours, after which the supernatant was carefully decanted to obtain a concentrated volume of 10-20 mL. A 1 mL subsample was placed in a Sedgewick-Rafter counting chamber, and zooplankton were enumerated under a compound microscope (Magnus MS-24, 100-400× magnification). Identification was performed to the lowest possible taxonomic level using standard keys and monographs (Edmondson, 1959; Battish, 1992; Michael & Sharma, 1988).

D. Physicochemical Parameter Analysis

Water temperature was measured in situ using a mercury-filled Celsius thermometer. pH was determined using a portable digital pH meter (Hanna HI-98107). Dissolved oxygen (DO) was estimated by the Winkler iodometric method. Total alkalinity, total hardness, chloride, and nutrient parameters (nitrate and phosphate) were analysed following standard procedures (APHA, 2017).

E. Data Analysis

Seasonal means were calculated by grouping monthly data into three seasons: summer (March-June), monsoon (July-September), and winter (October-February). Diversity indices, including the Shannon-Weiner diversity index (H'), Pielou's evenness index (J'), and Simpson's dominance index (D) were computed using PAST software version 4.0. Pearson correlation coefficients were calculated to establish relationships between zooplankton density and physicochemical parameters.

IV. RESULTS

A. Physicochemical Parameters

The physicochemical parameters of the Beneshwar Dham aquatic ecosystem showed marked seasonal variation throughout the study period (Table 1). Water temperature ranged from 16.2°C in winter to 42.5°C in summer. pH remained alkaline throughout the year (7.8-8.6), with maximum values recorded during summer. Dissolved oxygen concentrations were highest during winter (8.4 ± 0.6 mg/L) and lowest during summer (4.8 ± 0.5 mg/L).

Electrical conductivity showed an inverse relationship with water level, peaking during summer (845 ± 56 μS/cm) and declining during monsoon (412 ± 38 μS/cm). Nutrient concentrations (nitrate and phosphate) increased substantially during the monsoon season due to agricultural runoff.

Table 1: Seasonal Variation of Physicochemical Parameters at Beneshwar Dham

Parameter	Summer (Mar-Jun)	Monsoon (Jul-Sep)	Winter (Oct-Feb)
Temperature (°C)	38.4 ± 3.2	29.6 ± 2.1	18.5 ± 2.4
pH	8.4 ± 0.2	7.9 ± 0.3	8.1 ± 0.2
Dissolved Oxygen (mg/L)	4.8 ± 0.5	5.6 ± 0.7	8.4 ± 0.6
Electrical Conductivity (µS/cm)	845 ± 56	412 ± 38	568 ± 42
Total Alkalinity (mg/L)	186 ± 22	124 ± 18	156 ± 20
Total Hardness (mg/L)	234 ± 28	168 ± 22	198 ± 24
Nitrate (mg/L)	0.28 ± 0.06	0.56 ± 0.12	0.32 ± 0.08
Phosphate (mg/L)	0.12 ± 0.03	0.28 ± 0.07	0.14 ± 0.04

Values represent mean ± standard deviation (n=12 per season)

B. Zooplankton Species Composition

A total of 38 zooplankton species belonging to four major taxonomic groups were identified from the Beneshwar Dham aquatic ecosystem (Table 2). Rotifera represented the most diverse group (12 species, 31.6%), followed by Cladocera (11 species, 28.9%), Protozoa (8 species, 21.1%), and Copepoda (7 species, 18.4%). Among Rotifera, *Brachionus plicatilis*, *Philodina roseola*, and *Rotaria rotatoria* were the most abundant species. The cladoceran community was dominated by *Daphnia magna*, *Moina macrocopa*, and *Ceriodaphnia dubia*. Copepoda were represented predominantly by *Mesocyclops leuckartii* and *Cyclops scutifer*. Protozoan diversity included *Amoeba proteus*, *Paramecium caudatum*, and *Vorticella convallaria*.

Table 2: Seasonal Distribution of Zooplankton Species at Beneshwar Dham (ind./L)

Group/Species	Summer	Monsoon	Winter
PROTOZOA			
Amoeba proteus	12 ± 4	8 ± 3	18 ± 5
Paramecium caudatum	8 ± 3	15 ± 4	22 ± 6
Paramecium bursaria	6 ± 2	10 ± 3	14 ± 4
Paramecium aurelia	4 ± 1	12 ± 3	10 ± 3
Stentor coeruleus	2 ± 1	5 ± 2	8 ± 2
Centropyxis aculeata	10 ± 3	6 ± 2	15 ± 4

Group/Species	Summer	Monsoon	Winter
Actinophrys sol	5 ± 2	4 ± 1	12 ± 3
Epistylis plicatilis	15 ± 4	8 ± 2	20 ± 5
Vorticella convallaria	20 ± 5	12 ± 3	28 ± 6
Euglypha acanthophora	8 ± 2	6 ± 2	16 ± 4
Coleps sp.	6 ± 2	18 ± 4	12 ± 3
ROTIFERA			
Brachionus plicatilis	68 ± 12	22 ± 6	85 ± 14
Euchlanis dilatata	25 ± 6	15 ± 4	42 ± 8
Philodina roseola	32 ± 7	18 ± 5	58 ± 10
Conochilus unicornis	18 ± 4	28 ± 6	35 ± 7
Rotaria rotatoria	28 ± 6	14 ± 4	62 ± 11
Volvox sp.	45 ± 8	35 ± 7	28 ± 6
CLADOCERA			
Scapholeberis mucronata	15 ± 4	8 ± 2	25 ± 6
Daphnia magna	22 ± 5	12 ± 3	48 ± 9
Daphnia cephalata	12 ± 3	6 ± 2	28 ± 6
Daphnia tibetana	8 ± 2	4 ± 1	18 ± 4
Daphnia carinata	18 ± 4	10 ± 3	32 ± 7
Moina macrocopa	35 ± 7	18 ± 4	45 ± 8
Diaphanosoma brachyurum	10 ± 3	15 ± 4	20 ± 5
Simocephalus vetulus	14 ± 3	8 ± 2	22 ± 5

Group/Species	Summer	Monsoon	Winter
Simocephalus exspinosus	8 ± 2	5 ± 1	15 ± 4
Ceriodaphnia dubia	20 ± 5	12 ± 3	35 ± 7
Ceriodaphnia reticulata	12 ± 3	8 ± 2	18 ± 4
COPEPODA			
Microcyclops rubellus	15 ± 4	20 ± 5	25 ± 6
Cyclops scutifer	18 ± 4	25 ± 6	30 ± 7
Cyclops vicinus	12 ± 3	18 ± 4	22 ± 5
Cyclops parasite	8 ± 2	15 ± 4	14 ± 3
Mesocyclops leuckartii	25 ± 6	28 ± 6	38 ± 8
Macrocyclops albidus	10 ± 3	12 ± 3	18 ± 4
Mesocyclops edax	14 ± 3	16 ± 4	20 ± 5
OTHER CRUSTACEANS			
Leydigia spp.	6 ± 2	4 ± 1	12 ± 3
Oxyurella brevicaudis	8 ± 2	6 ± 2	14 ± 4
Pleuroxus procurvus	5 ± 1	8 ± 2	10 ± 3
Pleuroxus denticulatus	4 ± 1	10 ± 3	8 ± 2
Tinodes waeneri	2 ± 1	15 ± 4	6 ± 2

Values represent mean ± standard deviation (ind./L)

C. Seasonal Variation in Zooplankton Density

Total zooplankton density exhibited pronounced seasonal variation (Figure 1). Winter season recorded the highest mean density (845 ± 42 individuals/L), followed by summer (412 ± 38 individuals/L), while monsoon showed the lowest density (178 ± 23 individuals/L). One-way ANOVA revealed significant seasonal differences ($F = 36.47$, $p < 0.001$).

Table 3: Seasonal Variation in Zooplankton Density and Diversity Indices

Parameter	Summer	Monsoon	Winter
Total Density (ind./L)	412 ± 38	178 ± 23	845 ± 42
Protozoa Density	96 ± 14	104 ± 18	175 ± 22
Rotifera Density	216 ± 28	132 ± 20	310 ± 35
Cladocera Density	144 ± 20	106 ± 16	258 ± 28
Copepoda Density	102 ± 15	134 ± 19	167 ± 21
Shannon Index (H')	2.86	2.54	3.42
Evenness Index (J')	0.78	0.72	0.85
Simpson Index (D)	0.12	0.18	0.08

D. Group-wise Seasonal Distribution

Rotifera dominated the zooplankton community across all seasons, contributing 38.2% of total annual abundance. Maximum rotifer density (310 ± 35 ind./L) occurred during winter, with *Brachionus plicatilis* and *Philodina roseola* showing peak abundance. Minimum rotifer density (132 ± 20 ind./L) was recorded during monsoon.

Cladocera constituted 31.6% of total zooplankton, with winter dominance (258 ± 28 ind./L). *Daphnia magna* and *Moina macrocopa* were the most prevalent cladocerans, showing a positive correlation with increased dissolved oxygen and decreased temperature.

Copepoda represented 18.4% of the community, showing relatively stable distribution across seasons. Maximum copepod density (167 ± 21 ind./L) was observed in winter, while summer recorded the lowest (102 ± 15 ind./L). *Mesocyclops leuckartii* was the dominant copepod species.

Protozoa accounted for 11.8% of total zooplankton. Unlike other groups, protozoan density was highest during winter (175 ± 22 ind./L) and monsoon (104 ± 18 ind./L), with *Vorticella convallaria* and *Paramecium caudatum* being most abundant.

E. Diversity Indices

The Shannon-Weiner diversity index (H') ranged from 2.54 during the monsoon to 3.42 during winter, indicating moderate to high species diversity. Pielou's evenness index (J') was highest in winter (0.85), suggesting equitable species distribution during favourable conditions. Simpson's dominance index (D) was lowest in winter (0.08) and highest during monsoon (0.18), indicating reduced dominance pressure during winter.

V. DISCUSSION

The present study provides comprehensive baseline data on the seasonal dynamics of zooplankton communities in the Beneshwar Dham aquatic ecosystem of Rajasthan. The identification of 38 zooplankton species indicates moderate biodiversity compared to other freshwater bodies in semi-arid regions (Sharma & Sharma, 2011; Jakher & Rawat, 2003). The dominance of Rotifera in the community composition aligns with findings from other tropical and subtropical water bodies, where rotifers typically constitute 35-50% of zooplankton assemblages (Segers, 2007).

A. Seasonal Patterns and Driving Factors

The pronounced seasonal variation in zooplankton density, with winter maxima and monsoon minima, reflects the strong influence of physicochemical parameters on community structure. The winter peak (845 ind./L) can be attributed to optimal temperature conditions (16-20°C), high dissolved oxygen concentrations (8.4 mg/L), and increased water transparency, which collectively promote phytoplankton growth and, consequently, zooplankton proliferation (Lampert & Sommer, 2007). Similar winter maxima have been reported in other Indian freshwater ecosystems, including Lake Fatehsagar in Udaipur (Sharma & Sharma, 2011) and the Ganga River system (Verma & Prakash, 2015). The summer decline in zooplankton density (412 ind./L) despite favourable temperatures for rapid reproduction can be explained by multiple factors. High summer temperatures (exceeding 38°C) in Rajasthan approach the thermal tolerance limits of many zooplankton species, particularly cladocerans and rotifers (Goss & Bunting, 1983). Additionally, reduced dissolved oxygen (4.8 mg/L) during summer creates hypoxic stress, especially for larger-bodied cladocerans like *Daphnia* species (Porter, 2012). Elevated electrical conductivity (845 µS/cm) during summer indicates increased total dissolved solids, which may further stress sensitive species. The lowest zooplankton density during monsoon (178 ind./L) appears counterintuitive given the nutrient input from agricultural runoff. However, monsoon flooding leads to several adverse conditions: dilution of food resources, increased turbidity reducing photosynthetic activity, high water currents flushing out planktonic organisms, and rapid fluctuations in physicochemical parameters (Wetzel, 2001). The substantial decrease in electrical conductivity (412 µS/cm) during monsoon indicates dilution, which, while beneficial for some parameters, disrupts the ionic balance to which zooplankton are adapted (Michael & Sharma, 1988).

B. Group-specific Responses

The dominance of Rotifera across all seasons is consistent with their ecological characteristics as r-strategists with rapid reproduction rates, short generation times, and tolerance to a wide range of environmental conditions (Segers, 2007). *Brachionus plicatilis*, the most abundant rotifer, is known for its euryhaline and eurythermal properties, enabling it to thrive under varying conditions (Lubzens et al., 2001). The high abundance of *Philodina roseola* and *Rotaria rotatoria* (bdelloid rotifers) during winter reflects their preference for cooler, well-oxygenated waters. Cladoceran abundance peaked sharply during winter, with *Daphnia magna* showing a four-fold increase compared to monsoon. This pattern aligns with the known temperature preferences of Daphniidae, which exhibit optimal growth and reproduction at temperatures between 15-22°C (Porter, 2012). The virtual absence of large cladocerans during summer suggests thermal stress and possibly increased fish predation pressure, as ectothermic predators become more active in warm water (Lampert & Sommer, 2007). Copepoda showed the least seasonal variation among all groups, reflecting their greater ecological plasticity. Cyclopoid copepods, particularly *Mesocyclops leuckartii* and *Cyclops scutifer*, maintained relatively stable populations across seasons. Their ability to undergo diapause during unfavourable conditions and their omnivorous feeding habits contribute to this resilience (Dodson & Frey, 2001). Protozoan density was surprisingly highest during winter and monsoon, contrary to typical expectations of warm-water preference. This may be explained by the specific microhabitat preferences of species like *Vorticella convallaria* (attached form) and *Centropyxis aculeata* (testate amoeba), which thrive in association with aquatic vegetation that is more abundant during these seasons (Patterson, 2014).

C. Ecological Implications

The diversity indices reveal that winter represents the most ecologically stable and diverse period in the Beneshwar Dham ecosystem. The high Shannon index (H'=3.42) and evenness (J'=0.85) during winter suggest equitable resource partitioning and reduced competitive exclusion (Magurran, 2004). The low Simpson dominance index (0.08) confirms that no single species overwhelmingly dominates the winter community.

Conversely, the monsoon community, despite receiving nutrient inputs, showed reduced diversity (H'=2.54) and increased dominance (D=0.18). This paradox suggests that physical disturbances (flooding, turbidity, and scouring) override the positive effects of nutrient enrichment, creating a "disturbance-dominated" regime that favours a few opportunistic species (Connell, 1978).

D. Comparison with Other Studies

The zooplankton diversity recorded at Beneshwar Dham (38 species) is comparable to other freshwater bodies in Rajasthan. Sharma and Sharma (2011) reported 42 zooplankton species from Lake Fatehsagar, Udaipur, while Jakher and Rawat (2003) documented 35 species from the Jaisamand Lake. The dominance of Rotifera in these semi-arid ecosystems appears to be a consistent pattern, likely due to their tolerance to high salinity and temperature fluctuations characteristic of the region.

However, the density values recorded in this study (178-845 ind./L) are lower than those reported from eutrophic systems like the Ganga River (500-1500 ind./L) but higher than oligotrophic systems of the Himalayan region (50-200 ind./L) (Verma & Prakash, 2015). This intermediate range suggests that the Beneshwar Dham ecosystem maintains moderate productivity, with seasonal fluctuations driven by natural rather than extreme anthropogenic perturbations.

E. Conservation and Management Implications

The ecological significance of Beneshwar Dham as an aquatic habitat is underscored by the presence of diverse zooplankton communities that support higher trophic levels, including fish populations of religious and economic importance. However, increasing anthropogenic pressures—including religious tourism, bathing rituals, sewage input, and potential agricultural runoff—pose threats to water quality and biotic communities (Kumar et al., 2018).

The seasonal patterns identified in this study provide critical baseline data for monitoring ecosystem health. The sensitivity of Cladocera to summer stress and Rotifera to monsoon disturbance suggests that deviations from expected seasonal patterns could serve as early warning indicators of environmental degradation. For instance, a decline in winter cladoceran abundance might indicate organic pollution, while abnormal rotifer dominance during monsoon could suggest eutrophication (Sládeček, 1983).

Management recommendations derived from this study include (1) regular monitoring of physicochemical parameters and zooplankton communities at quarterly intervals; (2) restriction of direct sewage entry into the confluence area; (3) maintenance of minimum water flow during summer to prevent complete stagnation; and (4) public awareness programmes highlighting the ecological value of the site beyond its religious significance.

F. Limitations and Future Research Directions

This study has certain limitations. The one-year sampling period, while capturing seasonal patterns, may not reflect interannual variability. Additionally, the study did not simultaneously quantify phytoplankton abundance, which would help establish trophic relationships more precisely. Future research should extend over multiple years, incorporate phytoplankton analysis, examine zooplankton-fish interactions, and investigate the impact of religious activities on water quality and biotic communities. Molecular taxonomic approaches (DNA barcoding) could resolve cryptic species and provide more accurate diversity estimates.

VI. CONCLUSION

This study conclusively demonstrates that the zooplankton community of Beneshwar Dham, Rajasthan, exhibits significant seasonal variation, with maximum diversity and density during winter (845 ind./L) and minimum during monsoon (178 ind./L). A total of 38 species representing Rotifera (12 species), Cladocera (11 species), Protozoa (8 species), and Copepoda (7 species) were documented. Rotifera dominated the community across all seasons (38.2%), followed by Cladocera (31.6%), Copepoda (18.4%), and Protozoa (11.8%). Physicochemical parameters including temperature, dissolved oxygen, and conductivity showed strong correlations with zooplankton abundance. The winter community exhibited the highest species diversity (Shannon H'=3.42) and evenness (J'=0.85), indicating optimal ecological conditions. The study establishes essential baseline data for long-term ecological monitoring and emphasises the need for conservation measures to protect this ecologically and culturally significant aquatic ecosystem. Given the sensitivity of zooplankton to environmental changes, regular monitoring of these communities can serve as an effective tool for assessing water quality trends and guiding sustainable management practices at Beneshwar Dham.

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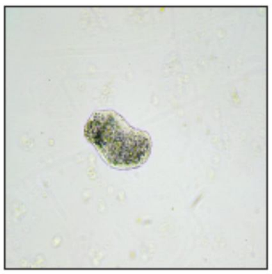
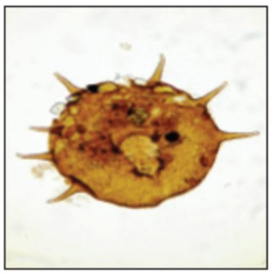
ZOOPLANKTON



A. ***Amoeba proteus***



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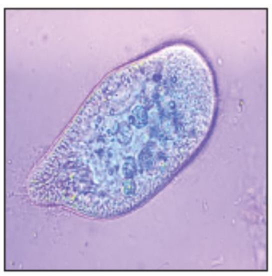
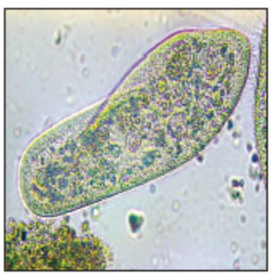


C. ***Paramecium aurelia***



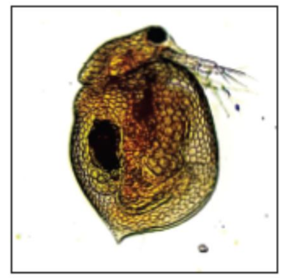
D. ***Paramecium caudatum***

E. ***Paramecium bursaria***

F. ***Stentor coeruleus***

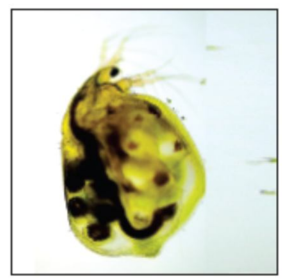
ZOOPLANKTON

A. ***Ceriodaphnia dubia***



B. ***Ceriodaphnia reticulata***

C. ***Simocephalus vetulus***



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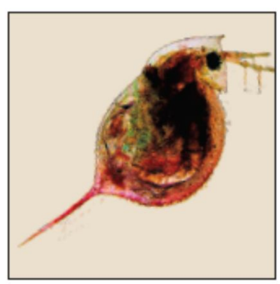
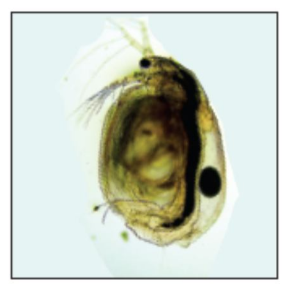


E. ***Daphnia galeata***



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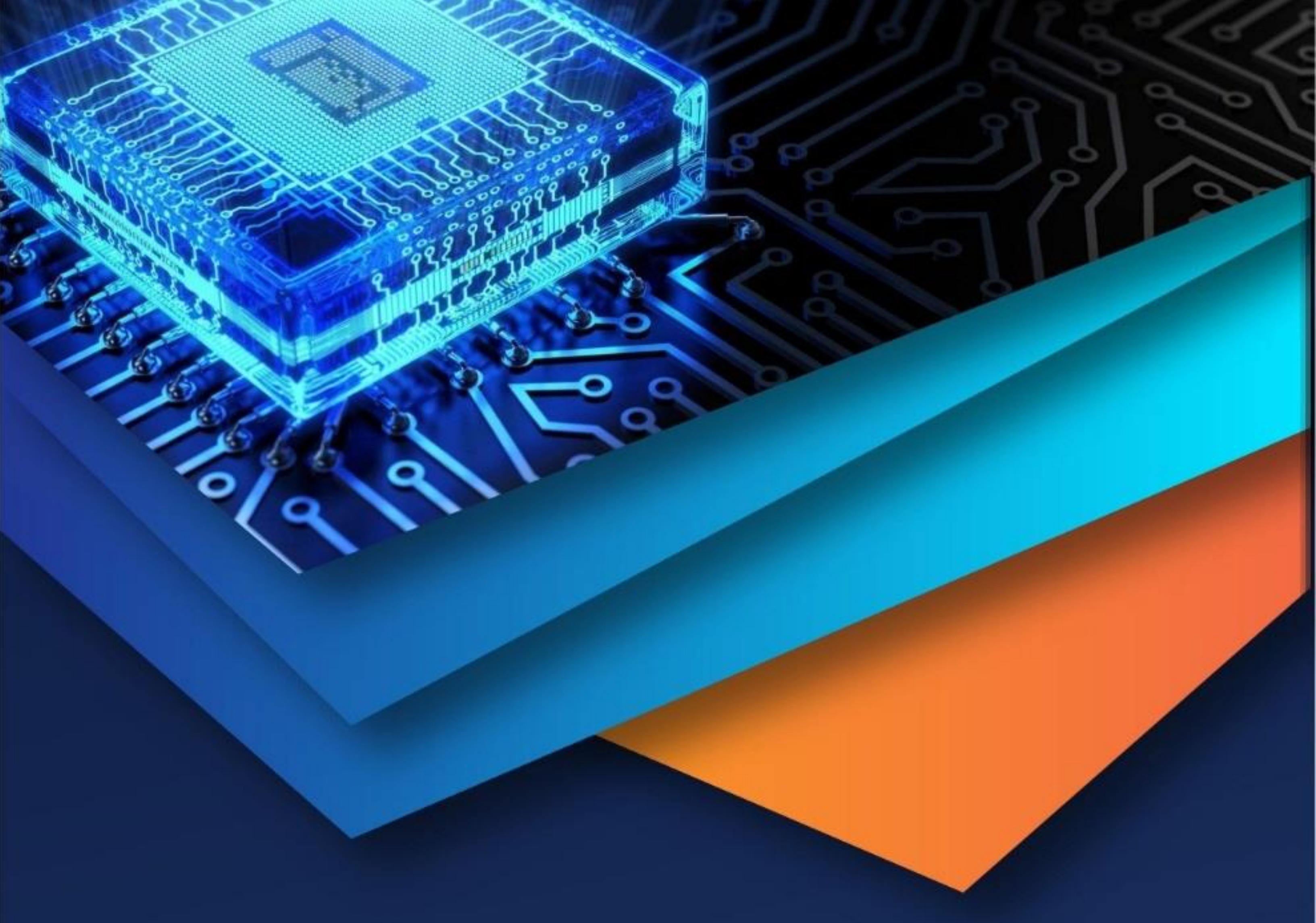

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