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SEASONAL FLUCTUATION IN ZOOPLANKTON DIVERSITY IN PUSHKAR LAKE

Dr. Shailendra Patni

Principal and Head Department of Zoology,

Shree Tagore College,

Kuchaman city, District Nagour (Rajasthan)

Abstract

The rapid response of zooplankton to changes in the surrounding environment makes it an ecological indicator of the prevailing conditions in the aquatic environment. In the present study, the influences of seasonal shifts on the zooplankton biodiversity in Pushkar Lake, which is situated in Town Pushkar of district Ajmer, Rajasthan, India (at a latitude of 26 degrees 49 minutes north and a longitude of 74 degrees 55 minutes east), were investigated. Between the months of December 2011 and November2012, an investigation of the seasonal variety of zooplankton species went into progress. During this time period, a total of 28 different species of zooplankton were seen. Among these, there were 19 different species of Rotifera, 5 different species of Copepoda, and 5 different species of Ostracoda. Rotifera was found to be the most numerous groups overall in this observation, accounting for 35% of the total. Cladocera also accounted for 29%, followed by Copepoda (29%), while Ostracoda accounted for 7%. Following an examination of the population density of several different zooplankton groups, it was found that the order of the zooplankton groups was as follows: Rotifera > Copepoda > Cladocera > Ostracoda. When compared to other times of the year, the population density was greatest during the summer and lowest during the early half of the monsoon season. It is possible that the spike in zooplankton population density that occurs during the summer months is due to the acceleration of the temperature in Pushkar Lake. The findings of this study demonstrated that the number of zooplankton that was produced in Pushkar Lake increased during the summer when the temperature was enhanced. This leads one to believe that temperature has a role in determining the variety of zooplankton. Because of this, the quantity of zooplankton that is generated may be impacted by the increasing temperatures that are caused by climate change. It is anticipated that the evaluation of zooplankton biodiversity will be of assistance in the near future in the process of monitoring the health (water quality) and richness of this lake or lake system.

Keywords: *Biodiversity, Zooplankton, Pushkar Lake*

INTRODUCTION

Indicators of the aquatic environment that are considered to be of significant ecological significance include the zooplankton biodiversity. It is vital to have a diverse population of zooplankton in order to sustain the health of our environment. This is due to the fact that every species in the ecosystem has a certain purpose (such as recycling nutrients, providing food for other species, and ensuring that the soil remains fertile), and some species may be responsible for the natural ecosystem's ability to operate in a healthy way. Because they are at the core of the aquatic food chain and because they are a significant source of nutrition for nearly all species of freshwater fish at some point in their lives, zooplankton are essential components of the ecosystems that are found in freshwater lakes. Furthermore, zooplankton populations are sensitive to the influences of human activity, and the study of these communities may be valuable in the prediction of long-term changes in lake ecosystems. Due to the fact that these communities are very sensitive to changes in the environment, their research may be quite beneficial. It has been reported by a number of studies that zooplankton can serve as an indicator of changes in trophic dynamics and the ecological state of lakes related to changes in nutrient loading and climate. Changes in zooplankton abundance, species diversity, and community composition can be indicators of changes or disturbances in the environment for several reasons. When it comes to the eutrophic status of a lake, the filtering ability of zooplankton has important significance. Both "natural" lake water chemistry and lake topography, as well as changes brought about by human activity in lakes and watersheds, can influence the organization of zooplankton communities, which includes the species density and species composition of the community. In aquatic systems, a change in the physicochemical conditions brings about a corresponding change in the relative composition and abundance of organisms that thrive in the water. As a result, these organisms can be utilized as a tool for monitoring aquatic ecosystems; consequently, zooplankton have been considered to be ecologically significant organisms. It is common practice to discharge an undesired material into the water of the lake by surface runoff, which has the effect of lowering the quality of the water. Based on the chemical, physical, and biological components that are present in water, the quality of the water may be determined. In order to successfully execute any management techniques, it is vital to have knowledge on the many aspects of water quality and the statuses of living species that are influenced by water bodies. The diversity of plankton was the ecological metric that was most relevant in both freshwater and saltwater marine environments. Each community has a variety of species that are distinct from one another in terms of both their taxonomic classification and their physical characteristics. In the context of a community, the term "species diversity" refers to the percentage of distinct species that are present, including both prolific and uncommon species. The variety of species is quite great in natural communities such as tropical and subtropical regions, but it is extremely low in communities that are managed by humans or that are physically manipulated. The richness of species and the evenness of species are the two primary components of species diversity. In layman's terms, the term "species richness" refers to the many kinds of species and the statistical significance of their numbers. The ratio between the total number of species (N) and the distinct species (S) is what is meant by this term in a technical sense. The phrase "species evenness" refers to a measurement that determines the degree to which species are distributed evenly in terms of their number. It is possible to assess the species diversity by using a variety of diversity indices, which are mathematical expressions that are derived from data on the abundance of species. The variety of species may be measured in a number of different ways, including species richness, evenness, or diversity as a component of the total. Pushkar Lake is a natural habitat lake that is located in the Pushkar Town of Ajmer District. An essential reason why the availability and value of freshwater in this lake is significant is that it offers Business opportunities to local resident and serves as the primary source of income for a number of the most communities in this region. Considering this, the present research was carried out with the purpose of examining the influence that seasonal shifts have on the zooplankton biodiversity in the perennial lake located in Pushkar, Ajmer, Rajasthan, India.

OBJECTIVES

1. To study Seasonal Fluctuation in Zooplankton Diversity in Pushkar Lake

2. To study Zooplankton Diversity in Pushkar Lake

RESEARCH METHODOLOGY

Study area

The study area is Pushkar Lake which is situated in Ajmer district of Rajasthan. This lake is a small natural lake located between a latitude of 26 degrees 49 minutes north and a longitude of 74 degrees 55 minutes east. The average depth of this lake is 8.0meters (26 feet), and its surface area of 22 square kilometers (8.5 square miles). Pushkar Lake is surrounded by 52 bathing ghats, where pilgrims throng in large number to take a scared bath especially around Kartik Pornima when the Pushkar Fair is held. Tourism in the surrounding have taken a heavy toll on the lake adversely affecting its water quality reducing the water levels and destroying the ecological health of the lake.

Collection and analyses of water samples

Over the course of a year, beginning in December 2011 and ending inNovember 2012, samples of water and plankton were collected from four different sites i.e. Gau Ghat, Jaipur Ghat, Indra Ghat and Varah Ghat. To collecting water samples, water bottles with screw closures and broad mouths that had been sterilized were utilized. Samples were obtained from the lake using a Van Dorn sampler. The samples were taken vertically between 1 and 2meters in depth, with a few meters separating each sample from the surface and bottom. After that, the samples were sent to the laboratory, where they were tested on the same day. Instantaneously, the temperature of the air and water on the surface of the surrounding object was measured. To determining pH, salinity, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO), the Microprocessor Based Water & Soil Analysis Kit (Model-1160) was used.

Qualitativeandquantitativeanalysesofzooplankton

(A) Sampling:

Four collecting zooplankton samples, small cups made up of Bolting Silk net number 25 with pore size of 200 pores per square inch were used. Known quantity of water was filtered through these cups to retain zooplankton. For the purpose of qualitative analysis, samples of thecupwere towed in a zigzag pattern horizontally at a depth ranging from 0.50 to 1.00 meters for about 5 to 10 minutes.

(B) Preservation and Storage:

In the next step, the plankton biomasses were transferred to certain bottles that had been pre-filled with 5% formalin and viewed using a stereo microscope. A number of different groups, including Copepoda, Cladocera, Ostracoda, and Rotifera, were selected from the zooplankton. In order to separate them, a fine needle and brush were used, and a binocular stereo zoom dissection microscope was utilized. Following the application of eosin stain, various species of plankton were positioned on microscopic slides and put on top of a drop of glycerin.

(C)Identifying the Zooplankton Sample:

The plankton were identified by checking standard manuals, textbooks and monographs Edmondson (1959), Needham and Needham (1978), Tonapi (1980) and APHA (1998). This was accomplished via the use of a research microscope and oculo-micrometer.

(C) Counting of Zooplanktons:

Before performing a count, one milliliter of the zooplankton sample was taken with the use of a pipette with a wide mouth. This sample was then transferred into the counting cell of the Sedgewick Rafter and allowed to settle for a period of time. Zooplanktons are counted under microscope by moving the cell horizontally and vertically. The procedure was repeated by taking another replica and counting till about 10 replicates were counted.

Calculation:

No. of zooplanktons / liter = No. of organisms counted / No. of replicates taken

(1 liter of lake water was filtered through plankton net)

(D) StatisticalAnalyses andDiversity Indices

For the purpose of conducting linear regression and correlation analysis on the data relating to physico-chemical and zooplankton parameters, IBM-SPSS version 20.0 was used. It was established that the species diversity index (H) was calculated by using the formula that Shannon and Weaver (1949) had created $H^1 = \text{pi}\ \Sigma\ \log_2\ \text{pi},\ I = 1$ s, (where, H^1 is species diversityin bitsperindividual(itis the individuals and populations in a community), pi ➔ ni/N(proportion of thesample belonging to the species), ni ➔ number of individualinall thesample;speciesrichness(SR)wascalculatedasdescribedbyGleason(1922); $D = 1 - C$, where $C = \Sigma\ \text{pi}^2$, pi − ni/N, ni − N/S, N ➔total numberof individuals, S ➔number of species in the collection; the evenness index (J1) was calculated using Pielous's (1966) formula, which is $J^1 = H^1/\log_2 s$, where S is the number of species and H^1 is the species diversity in bits of information per person. The method was used to determine all of the species in the collection. The species diversity index (H′), species richness index (SR), and evenness index (J) of Shannon and Weaver were investigated with the use of the Paleontological Statistics (PAST) application, which was updated to version 2.02.

DATA ANALYSIS

Physico-chemical parameters

The temperatures that were recorded for the surface water and the atmosphere throughout each of the four seasons that were investigated are shown in Figure 2a. According to the data, the temperature of the atmosphere and the surface water was determined to be between three and four degrees Celsius

23.78 ± 0.87 to 26.94 ± 1.01 °C and 24.61 ± 0.55 to 28.92 ± 0.39 °C respectively. The monsoon season had the lowest minimum temperature of the atmosphere and surface water throughout the study period, while the summer season had the greatest minimum temperature of the atmosphere and surface water. Both of these temperatures were measured during the spring and summer seasons. The estimates of the lake's salinity and pH were discovered to be different from 7.34 ± 0.35 to 8.57 ± 0.61 and 0.81 ± 0.09 to 1.02 ± 0.21 mg/l throughout the course of the inquiry (Figure 2b, c), throughout the whole process. The monsoon season and the summer season were found to have the lowest and highest pH values, respectively, during the course of those seasons. Within this particular framework, it was observed that the post-monsoon and winter seasons had the lowest salinity, while the summer season had the highest salinity.

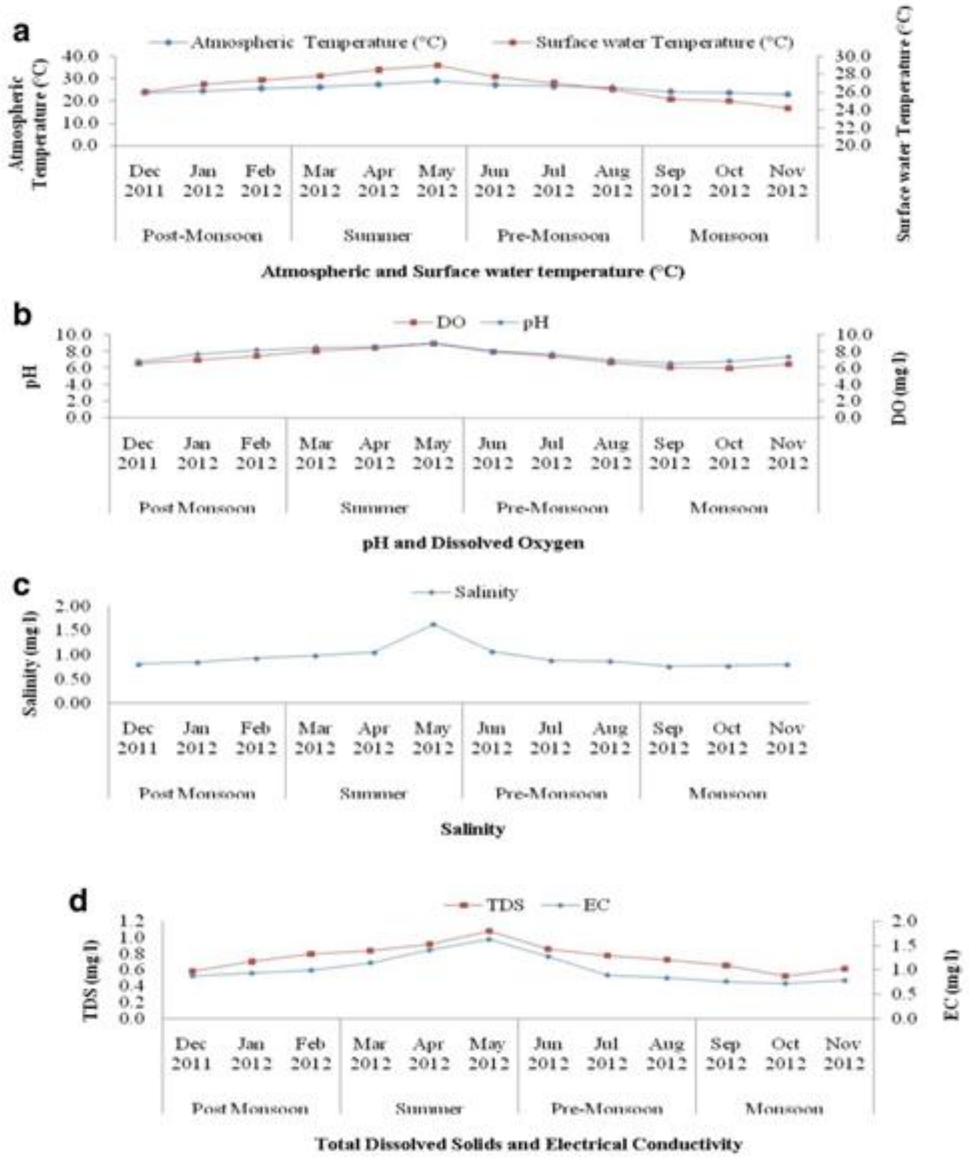

Fig. 2 Seasonal changes in Pushkar Lake's physico-chemical characteristics from December 2011 to November 2012 Temperatures of the atmosphere and surface water, pH, DO, salinity, TDS, and EC

The dissolved oxygen (DO), dissolved solids (EC), and total dissolved solids (TDS) levels that were measured inside Pushkar Lake varied from 6.18 ± 0.54 to 8.56 ± 0.59 mg/l, 0.79 ± 0.04 to 1.21 ± 0.07 mg/l, and 0.66 ± 0.06 to 0.85 ± 0.08 mg/l, respectively. During the summer, all three of these indicators were found to be higher, but during the monsoon, they were found to be lower.

The species makeup and diversity of zooplankton

There were a total of 28 species of zooplankton discovered in Pushkar Lake, which includes 9 species of Rotifera (two families and three genera), 9 species of Cladocera (four families and six genera), 5 species of Copepoda (two families and four genera), and 1 species of Ostracoda (one family and five genera) and is listed in Table 1. Based on the percentage composition of the present study, Rotifera is at the top of the list (35%), followed by Copepoda (29%), Cladocera (29%), and Ostracoda (7%), as shown in Figure 3. The density of the zoo-plankton population fluctuated from 73,085 to 110,900 Ind/m3 during the course of the study period (Fig. 4). Among all the seasons, the monsoon season had the lowest population density, while the summer season had the greatest population density with the highest population density. In comparison to the other zooplankton species, Rotifera had a significantly higher abundance ($p < 0.001$) throughout all seasons, as seen in Table 2. The findings of the study revealed that the post-monsoon and pre-monsoon seasons exhibited much higher populations of other species, including Copepoda and Cladocera, with statistical significance ($p < 0.001$). When seen from this angle, it is important to point out that the abundance of Ostracoda was much lower throughout the year.

Zooplankton, which includes Copepoda, Ostracoda, Cladocera, and Rotifera, had a group wise species diversity that ranged from 2.032 to 2.089, 2.067 to 2.133, 1.740 to 1.761, and 1.551 to 1.585, respectively, during the course of the study period. When compared to these, it was discovered that the monsoon season created the least amount of species diversity, but the post-monsoon season provided the greatest amount of diversity. Notwithstanding the fact that the productivity of the zooplankton species ranged from 1.157 to 1.257,

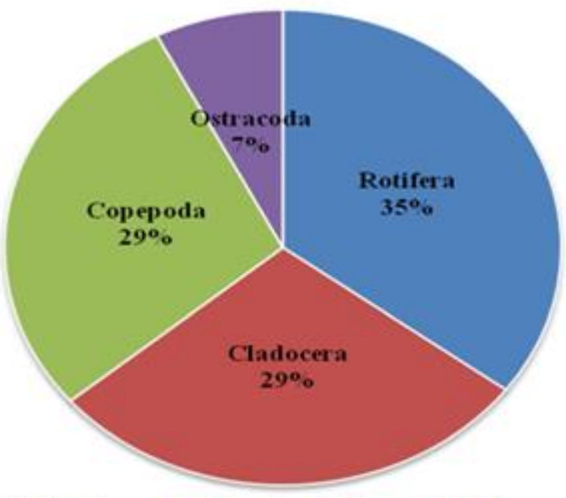

Fig. 3 Percentage composition of zooplankton recorded in the Pushkar Lake during December 2011-November 2012

As can be seen in Table 3, the ranges for Rotifera, Cladocera, Copepoda, and Ostracoda are as follows: 1.177 to 1.321, 0.749 to 0.800, and 0.718 to 0.891, respectively. When compared to the pre-monsoon to monsoon season, the post-monsoon to summer season had the greatest species richness. In general, the post-monsoon to summer season had the lowest species richness. According to Table 3, the observed species evenness of Ostracoda, Rotifera, Cladocera, and Copepoda varied from 0.943 to 0.976, 0.848 to 0.999, 0.878 to 0.938, and 0.950 to 0.970, respectively, throughout the course of the study period. However, the least amount of evenness was seen during the post-monsoon season, whereas the greatest evenness was observed during the pre-monsoon season. Moreover, a statistically significant correlation was found to exist between the physicochemical parameters and the zooplankton population density in Pushkar Lake (Table 4).

Discussion

To make effective use of any lake, it is necessary to have a solid understanding of its hydrology. The physical-chemical features of lake water as well as the nutrient content of the water have a significant impact on the dispersion patterns and species composition of plankton. Environmental factors in aquatic habitats, such as the solubility of gases and solids, light penetration, temperature, and density, as well as the chemical characteristics of the water, such as salinity, pH, hardness, phosphates, and nitrates, are essential for the growth and dispersal of phytoplankton, which is the food source for zooplankton. Phytoplankton is the primary source of nutrition for zooplankton. The physicochemical parameters of the Pushkar Lake, the species composition, the population density, the species diversity, the species evenness, and the species richness of a number of different zooplankton species all changed dramatically from one research study to the next. Significant variations in the evenness, diversity, density, and richness of zooplankton in the Pushkar Lake were induced by seasonal changes in the physicochemical parameters of the water, as shown by this statement. The temperature of the surface water is one of the most significant and changeable environmental factors. This is due to the fact that it influences the distribution and growth of the flora and fauna that are found in the lake ecosystem. On top of that, it is well knowledge that surface water has an impact on limnological phenomena such as stratification, gas solubility, pH, conductivity, and planktonic dispersion. Increases in temperature trigger rapid reactions in both the chemical and biological systems. The kinetics of the biochemical oxygen demand, which is also partially impacted by the temperature of the water, have also been characterized in connection to the development and death of microorganisms because of their relationship to the water temperature.

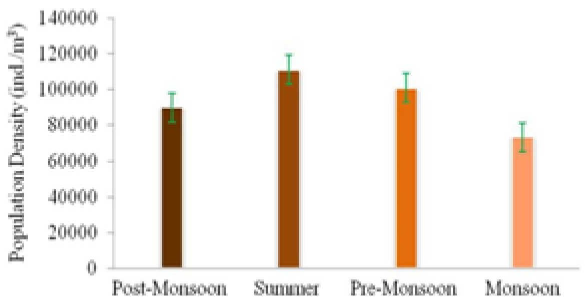

Fig. 4 Population density of zooplankton recorded in the Pushkar Lake during December 2011-November 2012

Each and every metabolic and physiological function, as well as the activities that make up life, are significantly influenced by the temperature of the water. These activities include feeding, reproduction, movement, and dispersion of aquatic organisms. In addition, the present study provides evidence that zooplankton species that are much smaller in size become prevalent when the temperatures in the fall increase. In response to an increase in temperature, biological activities accelerate, and the solubility of gases decreases. It has been seen again and again that the temperature of the atmosphere is constantly higher than the temperature of the ocean. It is possible that the shallowness of Pushkar Lake is the reason why the highest air and surface temperatures were seen during the summer months in the present investigation, while the lowest temperatures were observed during the monsoon season. In light of the fact that the temperature of the surface water has shown a tendency to closely follow the temperature of the air, this result is in agreement with the findings of prior research. It is possible that the gradual increase in water and air temperatures from April to August may be linked to the intensification of solar radiation and the concomitant increase in evaporation that is brought about by the longer days. Similar to the last example, a gradual drop in solar radiation might be the cause of a fall in

Table 2 Density of zooplankton population in Pushkar Lake between December 2011 and November 2012

Season	Rotifera	Cladocera	Copepoda	Ostracoda	F value	P - value
Post-monsoon	6508 ± 75a	5012 ± 39c	5257 ± 26b	1205 ± 29d	5975.37	0.000
Summer	9196 ± 64a	5514 ± 51b	5045 ± 42c	2425 ± 23d	8663.32	0.000
Pre-monsoon	7078 ± 38a	5980 ± 36b	5601 ± 18c	1497 ± 31d	19,149.31	0.000
Monsoon	5243 ± 29a	3863 ± 23c	4685 ± 26b	826 ± 18d	17,520.37	0.000

Beginning in October and continuing through February (monsoon to post-monsoon), the temperature tends to climb, and then it begins to rise once again in March. In addition, the temperature of the water is a factor that determines the solubility of oxygen and carbon dioxide, as well as the calculations for the equilibrium of bicarbonate and carbonate.

The pH scale is used to determine the degree of acidity or alkalinity of water by measuring the quantity of hydrogen ions (H+) in the water. This is shown by the higher pH level that was observed in May, which corresponds to the summer season, which indicates that the rate of photosynthesis in water bodies is rather high. In the most recent study, the researchers discovered that the months of summer had the greatest pH, while the months before to the monsoon had the lowest pH. Because of the high temperature and maximum pH, the aquatic environment absorbed a higher amount of carbon dioxide during the summer months. This was also due to the fact that the rate of photosynthesis increased at this time. Along the same lines, the findings of the present research suggest that the pH level is at its maximum during the summer months and at its lowest during the pre-monsoon season. A significant rise in salinity during the summer months is likely the result of higher temperatures, which in turn leads to an increase in the amount of water that evaporates. This is the conclusion that can be drawn from the current study. On the other hand, a drop in salinity during the monsoon months may be associated with reductions in temperature as well as an increase in the amount of freshwater from rainfall. It's possible that salt is having an indirect effect on zooplankton numbers by attracting organisms that are able to survive in environments with high amounts of salt. When viewed from the perspective of climate change, our data suggest that trophic structure changes in lakes located in temperate zones may be predicted as a result of increasing temperatures and perhaps concurrent increases in salinity.

As a result of the current investigation, it was discovered that the levels of DO are higher during the summertime. This could be due to the fact that phytoplankton is more frequently engaged in photosynthesis. On the other hand, the monsoon months had the lowest DO levels observed. This could be attributed to the utilization of DO, the breakdown of organic materials, and the respiration of both micro and microorganisms. According to the findings of the most recent study, the electrical conductivity was at its maximum during the summer hours and at its lowest during the rainy season. It was found that there is a seasonal pattern of fluctuations in the salinity and conductivity of water. In the environment of the freshwater lake, the pioneer researchers collected with an elevated EC during the summer month of May 2012, while the EC was small during the monsoon month of October 2012. The total dissolved solids (TDS) have been seen to increase and decrease over the summer, post-monsoon, and monsoon months. This phenomenon may be attributed to the differences in the input and outflow of water that occur during the distinct seasons.

Table 3 Seasonal fluctuations in the diversity of zooplankton species in Pushkar Lake from December 2011 to November 2012

Zooplankton groups		Zooplankton species diversity indices (sites 1–3; average value)											
		Post-monsoon		Summer			Pre-monsoon			Monsoon			
		Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	May 2012	Jun 2012	Jul 2012	Aug 2012	Sep 2012	Oct 2012	Nov 2012
Shannon	Rotifera	2.032 ± 0.037		2.086 ± 0.016			2.089 ± 0.014			2.052 ± 0.022			
(H)	Cladocera	2.067 ± 0.027		2.102 ± 0.008			2.133 ± 0.010			2.106 ± 0.023			
	Copepoda	1.752 ± 0.008		1.759 ± 0.006			1.761 ± 0.005			1.740 ± 0.015			
	Ostracoda	1.551 ± 0.031		1.581 ± 0.007			1.585 ± 0.014			1.563 ± 0.022			
Evenness	Rotifera	0.848 ± 0.031		0.891 ± 0.017			0.899 ± 0.013			0.865 ± 0.019			
	Cladocera	0.878 ± 0.024		0.909 ± 0.007			0.938 ± 0.009			0.913 ± 0.020			
	Copepoda	0.961 ± 0.007		0.968 ± 0.006			0.969 ± 0.005			0.950 ± 0.014			
	Ostracoda	0.943 ± 0.029		0.972 ± 0.007			0.976 ± 0.013			0.955 ± 0.022			
Richness	Rotifera	1.217 ± 0.027		1.156 ± 0.024			1.204 ± 0.024			1.257 ± 0.016			
	Cladocera	1.271 ± 0.045		1.176 ± 0.030			1.234 ± 0.032			1.321 ± 0.025			
	Copepoda	0.789 ± 0.016		0.748 ± 0.019			0.755 ± 0.078			0.799 ± 0.011			
	Ostracoda	0.831 ± 0.066		0.717 ± 0.024			0.788 ± 0.038			0.891 ± 0.044			

Table 4 the connection between the Pushkar Lake's zooplankton population and abundance throughout

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the research period (December 2011–November 2012) and physico-chemical parameters

Physico-chemical parameters vs. zooplankton abundance	'y'—value (linear type)	R	R2	Correlation	'p' values
Atmospheric temperature	y = 579.78x − 10,135.73	0.997	0.994	Positive	0.003
Surface water temperature	y = 434.490x − 7024.97	0.952	0.907	Positive	0.048
pH	y = 1188.315x − 4520.06	0.820	0.673	Positive	0.180
Salinity	y = 7137.77x − 1740.56	0.837	0.701	Positive	0.163
Dissolved oxygen	y = 800.527x − 1192.43	0.964	0.929	Positive	0.036
Electrical conductivity	y = 3907.52x + 932.21	0.861	0.742	Positive	0.139
Total dissolved solids	y = 9900.094x − 2815.88	0.996	0.992	Positive	0.004

The highest average value of total dissolved solids that was recorded by the pioneers may have been the consequence of an accumulation of human activities that damaged the quality of the water. According to the findings of the most recent study, the high concentration of total dissolved solids (TDS) in the lake over the summer periods suggests that nutrient stagnation led to an increase in the production of zooplankton. There was a total of 28 different species of zooplankton that were discovered during this particular observation. Nine of these species belong to the Rotifera and Cladocera taxa, while five of them belong to the Copepoda and Ostracoda taxa respectively. Earlier studies provided evidence that supported the present decision. It was particularly concerned with the effects of high temperatures that the zooplankton diversity of the Pushkar Lake was concerned with. Alterations in the temperature of the surface water have a direct influence on the growth and reproduction of zooplanktonic organisms. This is because these variations affect the metabolic rate and activity level of these organisms. According to the findings of this research, there is no doubt that the higher temperatures that are caused by the discharge of industrial and residential waste may lead to an improvement in total dissolved solids (TDS). As a result, it is well knowledge that, under some circumstances, the increased water temperature and total dissolved solids (TDS) may contribute to the growth of the zooplankton population. According to the findings of the statistical analysis, there is a positive association between the zooplankton population in Pushkar Lake and the physicochemical characteristics of the water. In the Pushkar Lake, zooplankton population was at its highest during the summer months and at its lowest during the rainy season, according to the results that are now being presented, which are in agreement with the conclusions of the previous research.

CONCLUSION

The results of the research indicated that an increase in temperature led to an increase in the amount of water that evaporated, which in turn led to an increase in the quantity of zooplankton and rich nutrient levels in the lake during the summer months. Furthermore, during this time period, zooplankton levels decrease as a result of the monsoon-induced dilution of the lake that is caused by rainfall. The present study suggests that the temperature of the water may thus be able to positively support the diversity of the zooplankton population. This is due to the significant positive correlation that exists between temperature, total dissolved solids, and plankton density. However, further study is required to get a better understanding of the long-term consequences that climate change will have on the distribution of zooplankton. This knowledge may be used to differentiate between sentinel and sensitive species and to devise conservation strategies that are both efficient and effective. A constant monitoring of the lake's ecosystem is being carried out.

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