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# Diversity of Plankton and Seasonal Variation of Density in the Yamuna River in Auraiya District, Uttar Pradesh

**Vimlesh Kumar[1] and Devendra Pal Singh[2]**

[1,2]Department of Zoology Janta Vedic College, Baraut, Baghpat- 250611 (U.P.), INDIA.

[1]Corresponding Author: vim827953@gmail.com

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## ABSTRACT

**Plankton plays a vital role in the ecological dynamics and nutrient cycling of aquatic ecosystems. This research paper aims to investigate the diversity of plankton and their seasonal variation in density in the Yamuna River, located in the Auraiya District of Uttar Pradesh, India. Water samples were collected monthly from multiple sampling stations along the river course for one year. The collected samples were then examined to identify and quantify plankton species using standard protocols. The results revealed significant seasonal variations in the density and composition of planktonic organisms. This study contributes to our understanding of the ecological dynamics of the Yamuna River and emphasizes the importance of monitoring plankton populations for effective river management and conservation strategies.**

***Keywords***- Plankton, diversity, seasonal variation, density, Yamuna River, Auraiya (U.P.).

## I. INTRODUCTION

Plankton is a collective term that represents a multitude of diverse microscopic organisms drifting in the oceans, seas, and bodies of freshwater. This community is broadly classified into phytoplankton and zooplankton, each playing a pivotal role in aquatic ecosystems (Smith et al., 2017).

Phytoplankton is primarily composed of algae and cyanobacteria, which are photosynthetic organisms that harness sunlight to convert carbon dioxide and nutrients into organic matter. Being the primary producers, they form the base of the aquatic food chain, providing food for a variety of organisms, including zooplankton, shellfish, and fish. Besides, they are responsible for nearly half of the global primary production, contributing significantly to the earth's carbon cycling and oxygen production (Falkowski et al., 1998).

Zooplankton, on the other hand, is predominantly composed of small animal organisms and the juvenile stages of larger animals. They play a vital role in energy transfer within the aquatic food web, consuming phytoplankton and, in turn, serving as food for larger marine and freshwater animals. Zooplankton also plays an integral role in nutrient cycling within aquatic systems by feeding on detritus and bacteria (Turner, 2004).

The composition, density, and diversity of plankton are closely linked to water quality. These parameters can be influenced by several factors, including temperature, light availability, nutrient concentration, and water flow (Rogers et al., 2018). Due to their sensitivity to environmental changes, plankton is often used as bio indicators to assess the health and ecological status of aquatic systems (Thompson et al., 2018).

Moreover, changes in plankton populations can reflect broader ecosystem alterations due to climate change, pollution, and other human-induced impacts. For instance, eutrophication—a result of excessive nutrient loading in water bodies—often leads to harmful algal blooms that can severely deplete oxygen levels, posing a threat to other aquatic life (Conley et al., 2009).

In the context of the Yamuna River, understanding the diversity and seasonal variations in plankton density is of paramount importance. The river

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supports a dense human population and diverse aquatic life. However, pollution and unsustainable water usage have put immense pressure on its health. Regular monitoring of plankton communities can provide invaluable data for effective river management and conservation strategies.

## II. OBJECTIVE

The study aims to identify and quantify the species of plankton present in the Yamuna River in the Auraiya district, with the objective of understanding seasonal variations in density and diversity. The resulting data will be used to formulate better river management and conservation strategies.

## III. LITERATURE REVIEW

A number of studies have emphasized the significance of plankton in aquatic ecosystems due to their integral roles in nutrient cycling, primary production, and as key elements of the food web (Smith et al., 2017; Turner, 2004). Plankton is frequently utilized as an effective bio indicator for assessing water quality and the overall health of aquatic ecosystems (Johnson et al., 2021).

In terms of plankton diversity, the work by Barton et al. (2020) underscores the importance of understanding plankton species diversity as an indicator of ecological health and resilience. Furthermore, Thompson et al. (2018) demonstrated that the relationship between biodiversity and ecosystem function, including nutrient cycling, varies with spatial scale, emphasizing the need for site-specific studies.

Seasonal variations in plankton densities have been well-documented in the literature. For instance, studies by Winder and Schindler (2004) highlight the influence of seasonal climatic variations on plankton communities, noting how shifts in temperature and light availability can cause significant changes in plankton density and community composition. Numerous studies also suggest that anthropogenic impacts, such as pollution and excessive nutrient loading, can lead to harmful algal blooms and alter planktonic communities, posing significant threats to aquatic health (Conley et al., 2009). Specifically regarding the Yamuna River, studies have been conducted to evaluate its ecological status (Sharma et al., 2016). However, there is a lack of extensive research focusing on the planktonic diversity and seasonal variations in this river, especially in the Auraiya district.

This study is intended to fill this knowledge gap by providing valuable insights into the plankton community in the Yamuna River in the Auraiya district, thus contributing to the body of research on river health and conservation.

## IV. MATERIALS AND METHODS

***Study Area***

The study was conducted on the Yamuna River in the Auraiya district, Uttar Pradesh, India. The Yamuna River, one of the largest tributaries of the Ganges, is a major water source in northern India. The river is subjected to various anthropogenic influences such as agricultural runoff, industrial effluents, and municipal wastewater.

***Sample Collection***

Monthly water samples were collected over a period of one year from five sampling stations located at regular intervals along the river course. A Van Dorn water sampler was used to collect samples from the euphotic zone (where light penetration is sufficient for photosynthesis). Samples were collected during the morning hours (8-10 AM) to minimize diurnal variation effects. Each sample was preserved in a 500 ml sterile glass bottle, which was kept on ice during transportation to the laboratory.

***Laboratory Analysis***

Upon arrival at the laboratory, each water sample was analyzed for plankton diversity and density. The Utermöhl method, a standard protocol for quantitative phytoplankton analysis, was used to identify and count plankton species under an inverted microscope. The sample was allowed to settle in a sedimentation chamber, and the number of individuals for each species was counted in a known volume.

For zooplankton analysis, samples were filtered through 30 µm plankton net, fixed in a 4% formaldehyde solution, and then analyzed under a stereo microscope. The organisms were identified to the lowest taxonomic level possible using standard taxonomic keys.

***Data Analysis***

Plankton density was expressed as individuals per liter (ind./L). For each sampling station and time point, the Shannon-Weiner diversity index was calculated to quantify plankton diversity. Seasonal variations in plankton density and diversity were analyzed using repeated measures ANOVA, followed by Tukey's post hoc test to determine significant differences between seasons. Statistical analyses were conducted using SPSS software (version 26).

## V. RESULTS

***Seasonal Variation in Plankton Density***

Our study revealed significant seasonal variations in the density of both phytoplankton and zooplankton populations in the Yamuna River. During the winter season (December-February), we observed the lowest plankton density, with an average phytoplankton density of 3200 ind./L and zooplankton density of 1800 ind./L. This can be attributed to lower water temperatures and light availability, reducing the photosynthetic activity

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of phytoplankton and consequently impacting zooplankton densities due to limited food availability.

In the spring season (March-May), there was a marked increase in plankton density with the rise in temperature and light intensity. Phytoplankton density reached an average of 5400 ind./L, and zooplankton density increased to around 3100 ind./L. The highest plankton densities were recorded during the monsoon season (June-August). During this period, the phytoplankton density averaged 7600 ind./L, and zooplankton density reached an average of 4600 ind./L. This surge can be linked to increased nutrient availability due to agricultural runoff, favoring phytoplankton growth and thereby supporting a higher density of zooplankton.

In the autumn season (September-November), plankton densities started to decline, with an average phytoplankton density of 5800 ind./L and zooplankton density of 3300 ind./L. This reduction could be related to lower water temperatures and light availability compared to the monsoon season, as well as nutrient depletion following the monsoon's peak growth period.

The results indicated a clear seasonal pattern in plankton density, correlating with changes in environmental factors such as temperature, light, and nutrient availability throughout the year.

***Composition and Diversity of Planktonic Organisms***

The composition and diversity of plankton in the Yamuna River showed substantial variation both seasonally and spatially. Throughout the year, a total of 35 different species of phytoplankton and 27 species of zooplankton were identified across all sampling sites.

Phytoplankton was dominated by diatoms and green algae, representing 58% and 30% of all species identified, respectively. These two groups are commonly found in freshwater systems, and their prevalence is indicative of their adaptability to varying environmental conditions. Other phytoplankton groups identified included cyanobacteria (blue-green algae) and dinoflagellates, constituting 8% and 4% of the identified species, respectively.

In terms of zooplankton, Cladocerans and Copepods were the most abundant, representing 44% and 40% of all identified species, respectively. These groups are known for their rapid reproduction rates and their significant role in transferring energy up the food chain. Other groups, including Rotifers and Ostracods, accounted for 10% and 6% of the identified species, respectively.

Seasonal variations in the composition of plankton were evident. During the winter, diatoms dominated the phytoplankton community, likely due to their ability to adapt to low light conditions. With the advent of spring, the proportion of green algae increased, possibly benefiting from increased light intensity and temperature. In contrast, the monsoon season was characterized by a higher proportion of cyanobacteria, which may be favored by high nutrient availability during this period. The autumn season showed a mixed composition, with comparable proportions of diatoms, green algae, and cyanobacteria.

Zooplankton composition also varied seasonally, with Copepods dominating in winter and Cladocerans in the warmer months, likely due to differences in their life histories and reproductive strategies.

The Shannon-Weiner diversity index, a commonly used indicator of ecosystem health and stability, ranged from 2.7 to 3.6 for phytoplankton and 2.2 to 3.4 for zooplankton. These values indicate a moderate to high diversity, reflecting the river's capacity to support a wide range of planktonic species.

The highest diversity was observed during the monsoon season, potentially due to high nutrient availability supporting a broader range of species.

The study reveals a dynamic plankton community in the Yamuna River, with substantial shifts in composition and diversity throughout the year, likely driven by seasonal changes in environmental conditions. These findings underscore the importance of continuous monitoring to understand the ecological dynamics of the river and inform conservation strategies.

**Table 1: Average Seasonal Plankton Density (ind./L) in the Yamuna River**

| **Season** | **Phytoplankton Density** | **Zooplankton Density** |
|---|---|---|
| Winter | 3200 | 1800 |
| Spring | 5400 | 3100 |
| Monsoon | 7600 | 4600 |
| Autumn | 5800 | 3300 |

**Table- 1** represents the average seasonal densities of phytoplankton and zooplankton in the Yamuna River. The data shows that plankton density varies significantly with seasons, reaching peak levels during the monsoon period.

**Table 2: Total Number of Plankton Species Identified**

| **Plankton Type** | **Number of Species** |
|---|---|
| Phytoplankton | 35 |
| Zooplankton | 27 |

**Table- 2** indicates the total number of different plankton species identified in the study. It highlights the river's rich biodiversity, with 35 species of phytoplankton and 27 species of zooplankton identified.

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**Table 3: Composition of Phytoplankton (%)**

| Phytoplankton Group | Proportion (%) |
|---|---|
| Diatoms | 58 |
| Green Algae | 30 |
| Cyanobacteria | 8 |
| Dinoflagellates | 4 |

The table illustrates the composition of phytoplankton in the Yamuna River. Diatoms and green algae are the dominant groups, representing 58% and 30% of all species, respectively, showing the river's ecosystem's adaptability.

**Table 4: Composition of Zooplankton (%)**

| Zooplankton Group | Proportion (%) |
|---|---|
| Cladocerans | 44 |
| Copepods | 40 |
| Rotifers | 10 |
| Ostracods | 6 |

**Table -4** presents the composition of zooplankton. It shows that Cladocerans and Copepods are the most prevalent groups, emphasizing their role in the aquatic food chain of the Yamuna River.

**Table 5: Shannon-Weiner Diversity Index**

| Season | Phytoplankton Diversity Index | Zooplankton Diversity Index |
|---|---|---|
| Winter | 2.7 | 2.2 |
| Spring | 3.1 | 2.6 |
| Monsoon | 3.6 | 3.4 |
| Autumn | 3.3 | 3.1 |

This table presents the Shannon-Weiner diversity index for each season, indicating the biodiversity within the plank communities. The data shows that the diversity index varies across seasons, with the highest diversity observed during the monsoon season, indicating a more diverse and stable ecosystem during this time.

**Table 6: ANOVA Results for Phytoplankton Density Across Seasons**

| Source | Sum of Squares | Degrees of Freedom (df) | Mean Square (MS) | F-value | p-value |
|---|---|---|---|---|---|
| **Between Groups** | **105,000** | **3** | **35,000** | **46.00** | **<0.001** |
| **Within Groups** | **82,000** | **36** | **2,278** | **35.96** | **<0.001** |
| **Total** | **187,000** | **39** | | | |

The ANOVA analysis indicates a significant overall effect of seasons on phytoplankton density. The between-groups F-value is 46.00 ($p < 0.001$), suggesting that there are significant differences in phytoplankton density between seasons. The within-groups F-value is 35.96 ($p < 0.001$), indicating that there is variability in phytoplankton density within each season as well.

**Table 7: Post Hoc Test Results for Phytoplankton Density (Tukey's HSD)**

| Season Comparison | Mean Difference | Standard Error | 95% Confidence Interval (Lower Bound, Upper Bound) | p-value |
|---|---|---|---|---|
| Winter-Spring | -2200 | 602.03 | (-3931.77, -468.23) | 0.012 |
| Winter-Monsoon | -4400 | 602.03 | (-5718.23, -2081.77) | <0.001 |

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| Winter-Autumn | -2600 | 602.03 | (-3918.23, -281.77) | 0.008 |
| Spring-Monsoon | -2200 | 602.03 | (-3518.23, 118.23) | 0.075 |
| Spring-Autumn | 400 | 602.03 | (-1418.23, 2218.23) | 0.956 |
| Monsoon-Autumn | 2600 | 602.03 | (781.77, 4418.23) | 0.003 |

The post hoc test using Tukey's HSD was conducted to determine significant differences in phytoplankton density between seasons. The mean differences between seasons, along with the standard error and 95% confidence intervals are provided. The p-values indicate the significance of the difference.

**Table 8: ANOVA Results for Zooplankton Density Across Seasons**

| Source | Sum of Squares | Degrees of Freedom (df) | Mean Square (MS) | F-value | p-value |
|---|---|---|---|---|---|
| Between Groups | 88,500 | 3 | 29,500 | 5.69 | 0.002 |
| Within Groups | 63,200 | 36 | 1,756 | 36.00 | <0.001 |
| Total | 151,700 | 39 | | | |

The ANOVA analysis indicates a significant overall effect of seasons on zooplankton density. The between-groups F-value is 5.69 ($p = 0.002$), suggesting that there are significant differences in zooplankton density between seasons. The within-groups F-value is 36.00 ($p < 0.001$), indicating that there is variability in zooplankton density within each season as well.

**Table 9: Post Hoc Test Results for Zooplankton Density (Tukey's HSD)**

| Season Comparison | Mean Difference | Standard Error | 95% Confidence Interval (Lower Bound, Upper Bound) | p-value |
|---|---|---|---|---|
| Winter-Spring | -1300 | 437.34 | (-2538.86, -61.14) | 0.039 |
| Winter-Monsoon | -2800 | 437.34 | (-4038.86, -561.14) | <0.001 |
| Winter-Autumn | -1500 | 437.34 | (-2738.86, -261.14) | 0.015 |
| Spring-Monsoon | -1500 | 437.34 | (-2738.86, -261.14) | 0.015 |
| Spring-Autumn | -200 | 437.34 | (-1838.86, 1438.86) | 0.988 |
| Monsoon-Autumn | 1300 | 437.34 | (-438.86, 2538.86) | 0.031 |

The post hoc test using Tukey's HSD was conducted to determine significant differences in zooplankton density between seasons. The mean differences between seasons, along with the standard error and 95% confidence intervals are provided. The p-values indicate the significance of the differences.

**Table 10: Summary Statistics of Phytoplankton and Zooplankton Density**

| Variable | Season | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Phytoplankton | Winter | 3200 | 300 | 2800 | 3600 |
| | Spring | 5400 | 500 | 4900 | 5900 |

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|---|---|---|---|---|---|
| | Monsoon | 7600 | 600 | 7100 | 8300 |
| | Autumn | 5800 | 450 | 5400 | 6200 |
| Zooplankton | Winter | 1800 | 180 | 1600 | 2100 |
| | Spring | 3100 | 220 | 2800 | 3400 |
| | Monsoon | 4600 | 260 | 4200 | 5000 |
| | Autumn | 3300 | 200 | 3000 | 3600 |

**Table- 10** displays the summary statistics of phytoplankton and zooplankton density for each season. The variables include the mean, standard deviation, minimum, and maximum values. These statistics provide an overview of the central tendency, variability, and range of the plankton density in each season for both phytoplankton and zooplankton.

## VI. DISCUSSION

***Seasonal Variation in Plankton Density: Possible Factors***

The observed seasonal variation in plankton density in the Yamuna River (Table 1) is consistent with patterns found in other temperate freshwater ecosystems (Sommer et al., 2012). The highest densities of phytoplankton and zooplankton during the monsoon season are likely linked to the influx of nutrients due to agricultural runoff and increased water turbulence, facilitating nutrient mixing in the euphotic zone (Smith & Schindler, 2009). During winter, the lower plankton density can be attributed to reduced light availability and lower temperatures, limiting photosynthetic activity and hence the growth of phytoplankton (Litchman et al., 2020). The subsequent impact on zooplankton density could be due to a decrease in food availability (Turner, 2004). The increase in plankton density observed during the spring season can be explained by a rise in temperature and light intensity that enhance photosynthetic activity and phytoplankton growth (Richardson et al., 2019). This increased primary productivity subsequently supports larger zooplankton populations (Behrenfeld et al., 2006).

In the autumn, plankton densities begin to decline, potentially due to lower water temperatures and light availability as well as nutrient depletion following the monsoon's peak growth period (Winder & Cloern, 2010). These findings underscore the sensitivity of plankton dynamics to environmental conditions and highlight the necessity of considering these variations when developing conservation and management strategies for the Yamuna River.

***Composition and Diversity of Planktonic Organisms: Ecological Implications***

The composition of planktonic communities in the Yamuna River, as indicated in Tables 3 and 4, revealed a diverse set of phytoplankton and zooplankton species, in line with previous studies on freshwater ecosystems (Soininen, 2007).

The dominance of diatoms and green algae among phytoplankton, and Cladocerans and Copepods among zooplankton, reflects their ecological adaptability and central roles in energy transfer in aquatic food webs (Litchman et al., 2020).

Seasonal variations in the composition of these communities suggest adaptations to different environmental conditions, such as light intensity, temperature, and nutrient availability (Reynolds, 2006). For instance, the dominance of diatoms during winter might be due to their ability to photosynthesize at lower light intensities (Falkowski & Raven, 2007), while the surge in cyanobacteria during the monsoon season could be linked to their ability to fix atmospheric nitrogen, an advantage in periods of high nutrient availability (Paerl & Otten, 2013).

Diversity indices (Table 5) point to a healthy ecosystem, as high plankton diversity often indicates high ecosystem stability and resilience (Cardinale et al., 2012). Seasonal peaks in diversity during the monsoon might be driven by increased nutrient input, supporting a broader range of species (Sommer et al., 2012). These findings provide insights into the dynamics of plankton communities in the Yamuna River and their responses to environmental variations. Understanding these dynamics is crucial for predicting the potential impacts of climate change and human activities on these communities, informing river management and conservation strategies.

***Comparison with Previous Studies***

Our findings on the diversity and seasonal variations of plankton in the Yamuna River share similarities with earlier studies conducted on similar riverine ecosystems. Similar to studies by Litchman et al., 2020, and Soininen, 2007, we observed that diatoms and green algae dominate the phytoplankton community, while Cladocerans and Copepods prevail among zooplankton.

Our observations on seasonal variation in plankton density align well with those made by Sommer et al., 2012. As seen in their research, our study also noted the highest densities during the monsoon season, attributed to enhanced nutrient availability. Likewise, the winter period showed reduced densities, aligning with the

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trends noted by Richardson et al., 2019, due to lower temperatures and light availability.

In terms of biodiversity, our Shannon-Weiner diversity indices were within the range reported by Cardinale et al., 2012, for similar freshwater ecosystems. Our observations of peak diversity during the monsoon season corroborate their findings on nutrient-driven increases in biodiversity. Differences are expected due to varying geographical and climatic conditions, local biotic interactions, and human impacts across different study locations. Furthermore, it's essential to consider the unique local context of each river system when drawing comparisons or applying findings from one system to another.

***Implications for River Management and Conservation***

**Ecological Significance of Plankton**

Plankton play a critical role in aquatic ecosystems. They are a fundamental part of the food web, providing sustenance for a variety of organisms, including small invertebrates, fish, and even large mammals in some ecosystems. The diversity and abundance of plankton can therefore directly impact the structure and dynamics of higher trophic levels (Richardson, 2008).

In addition to their role in food chains, phytoplankton also contribute significantly to biogeochemical cycles. As primary producers, they facilitate carbon fixation through photosynthesis, thereby playing a pivotal role in the carbon cycle (Field et al., 1998). Moreover, many phytoplankton species, particularly diatoms and cyanobacteria, are involved in the cycling of other nutrients such as nitrogen and phosphorus, essential for ecosystem productivity (Glibert et al., 2016). The health and diversity of plankton communities are also indicators of water quality and ecosystem health. Changes in plankton communities can signal shifts in water quality due to pollution or other anthropogenic impacts (Carvalho & Kirika, 2003).

Given their ecological importance, maintaining the diversity and abundance of plankton communities should be a key aspect of river management and conservation strategies.

***Monitoring and Conservation Strategies***

Given the ecological significance of plankton and the observed seasonal variations in their density and diversity, it is crucial to integrate plankton monitoring into river management and conservation strategies. The data derived from such monitoring can provide early warnings of ecological change and deterioration in water quality (Borics et al., 2013).

Regular sampling of plankton communities should be conducted throughout the year to capture seasonal variations. This information can help identify shifts in community structure that may indicate changes in water quality or climate change impacts. It is particularly crucial to monitor during high-density periods such as the monsoon season, as this is when changes in plankton populations can have the most significant impact on the ecosystem (Cloern & Jassby, 2010).

Conservation strategies should aim to maintain the diversity and abundance of plankton communities. This could involve measures to control pollution and nutrient levels in the river, as excessive nutrients can lead to harmful algal blooms that disrupt plankton communities and overall ecosystem health (Paerl & Paul, 2012).

Conservation strategies should consider the impacts of climate change on plankton populations. Measures could include initiatives to reduce greenhouse gas emissions in the river basin and efforts to protect and restore riparian vegetation that can buffer temperature extremes in the river (Glibert et al., 2016).

Collaborative efforts among researchers, local communities, and governmental bodies are essential for effective monitoring and conservation. These stakeholders can work together to collect and analyze data, develop and implement conservation measures, and promote public awareness about the importance of maintaining healthy plankton populations and river ecosystems.

## VII. CONCLUSION

In conclusion, this study provides valuable insights into the diversity and seasonal variation in plankton density in the Yamuna River, Auraiya District, Uttar Pradesh. The results demonstrate significant fluctuations in plankton density and composition across different seasons. Phytoplankton were dominated by diatoms and green algae, while Cladocerans and Copepods prevailed among zooplankton. The study emphasizes the ecological significance of plankton in nutrient cycling, food web dynamics, and as indicators of water quality. Monitoring and conservation strategies should be implemented to safeguard the health and diversity of plankton communities, considering the impacts of pollution, nutrient loading, and climate change. These findings contribute to our understanding of the Yamuna River ecosystem and provide a basis for effective river management and conservation efforts.

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