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Taxonomy of Rotifers of Genus *Keratella* with Concise Notes on Percentage Composition, Seasonal Variations and Water Quality Factors

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Abstract Research observation recorded five Keratella species viz., *Keratella valga*, *Keratella quadrata*, *Keratella tropica*, *Keratella cochlearis* and *Keratella serrulata* from a freshwater pond, Tripura. Important morphological features of five *Keratella* species were observed. Percentage composition of five *Keratella* species in different seasons of the year was also noted. Seasonal dynamics of the *Keratella* species showed that amongst five *Keratella* species, four *Keratella* species (*K. valga*, *K. tropica*, *K. cochlearis* and *K. serrulata*) exhibited their highest density in summer and least density during winter. However, *Keratella quadrata* exhibited maximum density during winter and minimum during summer. Variations of densities of different species of *Keratella* might be impact of water quality factors in the observed freshwater lentic ecosystem. Water quality parameters of the observed pond were also noted. To ascertain correlation between rotifer density and water quality factors, the observed variables were measured through Pearson's correlation coefficient. The density of *Keratella* showed significant positive interrelationship with water temperature ($r = 0.853$, $P<0.01$), pH($r = 0.627$, $P< 0.05$) and dissolved oxygen ($r = 0.571$, $P< 0.05$). It is noteworthy to mention that due to the possession of different trophic niches in the pond, the recorded *Keratella* species harmoniously abode in the same pond. The study infers that the existence of two pollutant tolerant *Keratella* species (*K. cochlearis* and *K. quadrata*) in the observed pond is an indication that the pond is approaching towards eutrophic status.

Keywords Rotifer, *Keratella*, Taxonomy, Percentage Composition, Seasonal Variations, Water Quality Factors

1. Introduction

Rotifera, minor phylum pseudocoelomate metazoans, most of which are found in the freshwater lentic ecosystem [1]. Phylum Rotifera is dominated by two major groups viz., Monogononta and Bdelloidea [2]. In the freshwater lentic ecosystem, the two most dominating rotifer genera under the monogononta are *Brachionus* and *Keratella* [3]. The different species under the genus *Keratella* are cosmopolitan in distribution [4]. A number of noteworthy researchers worked on taxonomy of genus *Keratella* [5-12]. Due to the possession of hard lorica and polygonal facets on the surface of lorica, the species under the genus *Keratella* is resistant to distortion in preserved condition and this taxonomical feature helps for ease identification of different species [13]. Rotifera is regarded as the most studied phylum for its role in trophic dynamics in freshwater lentic ecosystems [14-16]. Amongst different species under the genus *Keratella, Keratella serrulata* is found in oligotrophic water bodies *while Keratella cochlearis* and *Keratella quadrata* are found in eutrophic water bodies [17-18]. Researcher [19] while observing population dynamics reported that *Keratella cochlearis*

follow k-strategist showing a lower population growth rate. Water quality factors exerted an influential impact on seasonal dynamics of rotifers [20-24]. Different species of the genus *Keratella* probably belong separate trophic niches within the same water body and due to the possession of such characteristic feature, co-existence of different species would be possible as long as the water quality parameters of the water body remains suitable [15]. Pond as a small lentic aquatic ecosystem is quite rich in zooplankton especially, rotifer fauna which plays crucial roles in maintaining regional diversity [25].

In Tripura, Northeast India, the pioneer researchers, Banik and Debbarman [26] first reported the *Brachionus* species from pond ecosystem of Tripura. Chakrabarti [27] reported zooplankton density and seasonal variations with reference to water quality factors from perennial lentic ecosystem of Tripura. But, no studies from Tripura were carried out on rotifers of the genus *Keratella* with reference to taxonomy and seasonal succession in lentic ecosystem. So, a report on taxonomy, and seasonal dynamics of rotifers under genus *Keratella* was performed in a lentic water body (pond) of Tripura.

2. Materials and Methods

2.1. Site of Study

The observation has been performed in a freshwater pond located in Srirampur area, Kailashahar, Unakoti Tripura, India during two years study period. Geographically, the pond locates at 24°19'36.52"N Latitude and 92°0'45.46" E Longitude. Studied pond is rectangular and permanent. The size of the pond is about 2.4 ha. The pond retains 1.2 m of water in summer but during monsoon water column increases to about 2.5m. Aquatic macrovegetation, *Eicchornia crassipes* are sparsely distributed on the littoral surface of the pond.

2.2. Methodology

2.2.1. Sampling of *Keratella* Rotifers

Quantitative sampling of *Keratella* rotifer samples was done by sieving 100 litres of water with the help of plankton net (mesh size 68 µm) from the littoral areas of the studied water body at weekly interims. The collected samples were transferred to a polyethylene bottle of 500ml capacity and then fixed in 5% formaldehyde (treated with sodium borate buffer) for further analysis.

2.2.2. Enumeration and Identification of *Keratella* Rotifers

Enumeration of rotifer samples was performed by screening three aliquots, each aliquot containing 1ml samples poured into Sedgwick Rafter Plankton Counting Cell(Wildco, USA). Taxonomic identifications of different species of *Keratella*were carried out following keys as emphasized by Pennak [28], Battish [4], and Edmondson [29]. The photomicrographs of *Keratella* species (Fig.1a, 1b, 1c, 1d, and 1e**)** have taken using a compound microscope (Model: Olympus CX41) having a magnification range of 10x-100x. Camera Lucida drawings (Fig.2a, 2b, 2c, 2d, and 2e also has been done in order to get a clear concept regarding the body shape of the *Keratella* species.

2.2.3. Analysis of Water Quality Factors

Amongst water quality factors, water temperature was measured by mercury bulb thermometer and transparency was measured by Secchi disc on the field site. In the laboratory, the dissolved oxygen was measured through digital oxygen meter (Model: OMPCD 100D) and pH measurement was done through digital pH meter (Systronics, Model: SYS-335). The laboratory analysis of water quality parameters (such as free carbon dioxide, alkalinity, total dissolved solids, phosphate phosphorus, and nitrate nitrogen) following the standard methods of APHA [30].

2.2.4. Statistical Analysis

In order to ascertain the interrelationship between rotifer density and physico-chemical factors in the studied pond, Pearson's correlation matrix was performed and the degree of correlation among rotifer density and water quality factors was analysed with the help of SPSS software (version16).

3. Results and Discussions

The five observed rotifer species under genus *Keratella* in the studied pond of Tripura, Northeast India were *K. valga, K. quadrata, K. tropica, K. cochlearis* and *K. serrulata*. Their taxonomical features were studied and measurements also noted (Fig.1a, 1b, 1c, 1d and 1e).

3.1. Taxonomical Features of Rotifers of Genus *Keratella*

Keratella valga Ehrenberg, 1834

Anterior spines six; anterior width of the lorica is comparatively much wider than the posterior width; posterior spines two, is well developed, unequal in length, right posterior spine is nearly about one-third of the length of the lorica while the left one is nearly one-fourth of the length; medial series of undivided hexagonal reticulate sculpture on the dorsum (Fig.1a).

Measurements: length of the lorica 173 µm; width of the lorica 89 µm; length of median anterior spines 33 µm; length of intermediate anterior spines 28 µm; length of laterals anterior spines 30 µm; length of right posterior spine 61 µm; length of left posterior spine 39 µm.

Keratella quadrata Muller, 1786

Anterior spines six; anterior width of the lorica is comparatively slightly wider than the posterior width; posterior spines two, l posterior spines length is nearly half the length of lorica; well-developed punctuated sculpture on the dorsum (Fig.1b).

Measurements: Lorica(Length) 147 µm; width of lorica 83 µm; length of median anterior spines 28 µm; length of intermediate anterior spines20 µm; length of laterals anterior spines 24 µm; length of posterior spines 71 µm.

Keratella tropica Apstein, 1907

Dorsoventrally compressed lorica; two unequal posterior spines on the terminal portion of the lorica; right posterior spine longer than left one, anterior dorsal margin comprises of six spines; median spines longest, curved ventrally, lateral spines comparatively slightly longer than the intermediate spines (Fig.1c).

Measurements: Lorica (length):133 µm; lorica (width):89 µm; right posterior spine (length) 94 µm; left posterior spine (length) 28 µm; anterior median spine (length) 32 µm; anterior lateral spine (length) 18 µm; anterior intermediate spine (length) 17 µm.

Keratella cochlearis Gosse, 1851

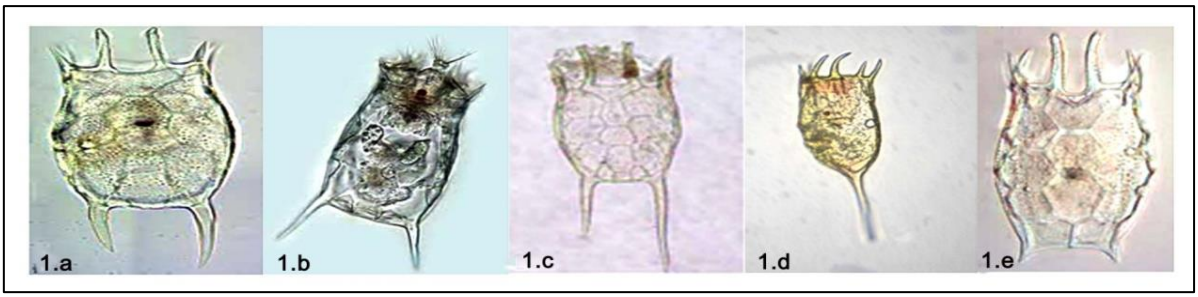
Lorica ovoid, a stout median posterior spine on terminal portion of lorica, anterior dorsal margin comprises six spines;median spines longest, intermediates comparatively shorter than the lateral spines and slightly diverge, laterals converge at their tips (Fig.1d).

Measurements: Lorica (length) 118 µm; lorica(width) 64 µm; median posterior spine(length) 41 µm; median occipital spine(length) 23 µm; intermediate occipital spine(length) 13 µm; lateral occipital spine(length) 17 µm.

Keratella serrulata Ehrenberg, 1838

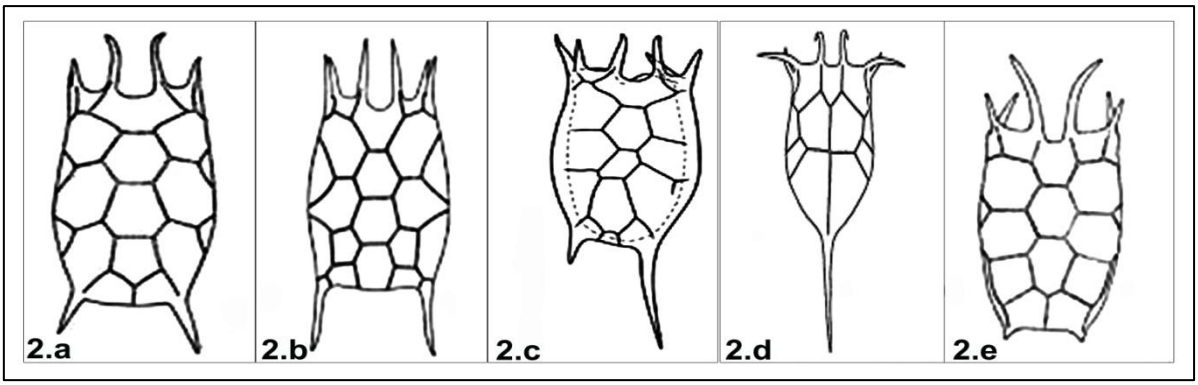
Lorica spotted (except spines), striated longitudinally; anterior spines six; longer two anterior spines on the dorsomedian positions; shorter equal sized four anterior spines on the dorsolateral positions; two short posterior spines, widely separated on lateral positions (Fig.1e).

Measurements: Lorica(length) 141 µm; lorica(width) 69 µm; median occipital spines(length) 38 µm; lateral occipital spines(length) 27 µm.



1.a *Keratella valga* 1.b *Keratella quadrata* 1.c *Keratella tropica* 1.d *Keratella cochlearis* 1.e *Keratella serrulata*

Figure 1. Photomicrographs of rotifer species under the genus *Keratella*



2.a *Keratella valga* 2.b *Keratella quadrata* 2.c *Keratella tropica* 2.d *Keratella cochlearis* 2.e *Keratella serrulata*

Figure 2. Camera Lucida drawings of rotifer species under the genus *Keratella*

3.2. Percentage Compositions of *Keratella* Species

In the studied pond, the species compositions (in terms of percentage) of different species of *Keratella* in different seasons of the year were recorded. During summer season, the percentage compositions were *K. valga* (13%), *K. tropica* (49%), *K. cochlearis* (27%), *K. quadrata* (7%) and *K. serrulata* (4%) (Fig.3). In the monsoon season, percentage compositions were *K. valga* (17%), *K. tropica* (41%), *K. cochlearis* (33%), *K. quadrata* (6%) and *K. serrulata* (3%) (Fig.4). During autumn, the percentage compositions were K. *valga* (21%), *K. tropica* (37%), *K. cochlearis* (26%), *K. quadrata* (11%) and *K. serrulata* (5%) (Fig.5), while in the winter season, the percentage compositions were*K. valga* (5%), *K. tropica* (43%), *K. Cochlearis*(29%), *K. quadrata* (16%) and *K. serrulata* (7%) (Fig.6).

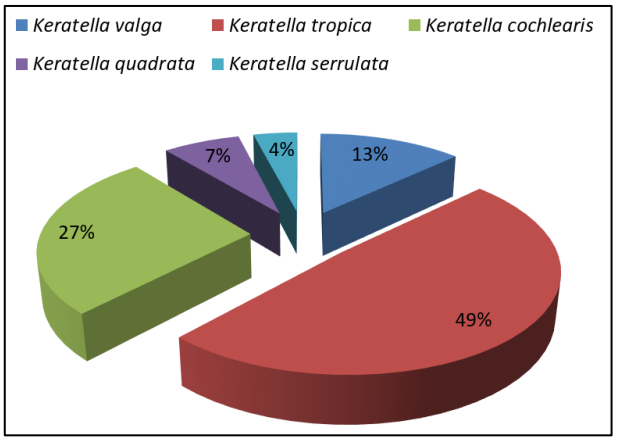


Figure 3. Percentage composition of rotifers of genus *Keratella* during summer season

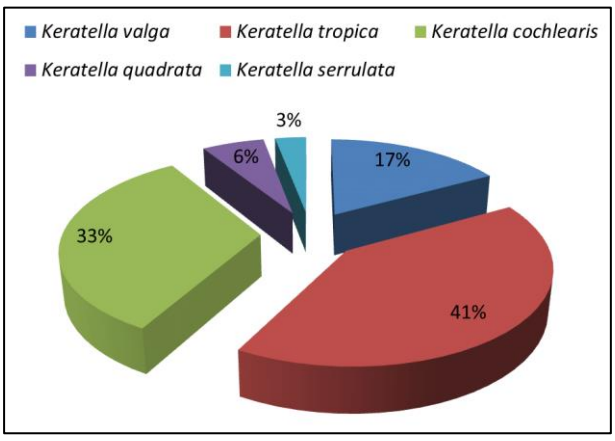


Figure 4. Percentage composition of rotifers of genus *Keratella* during monsoon season

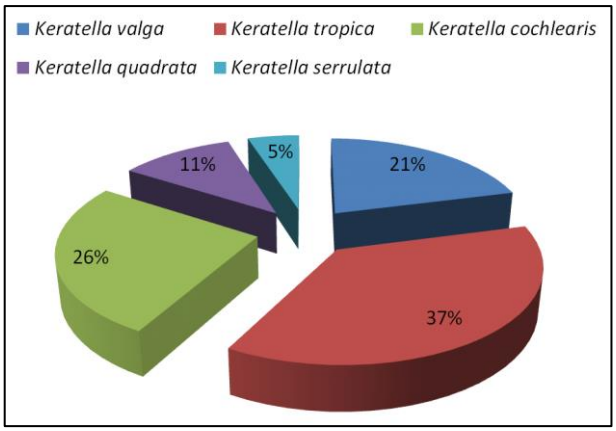


Figure 5. Percentage composition of rotifers of genus *Keratella* during autumn season

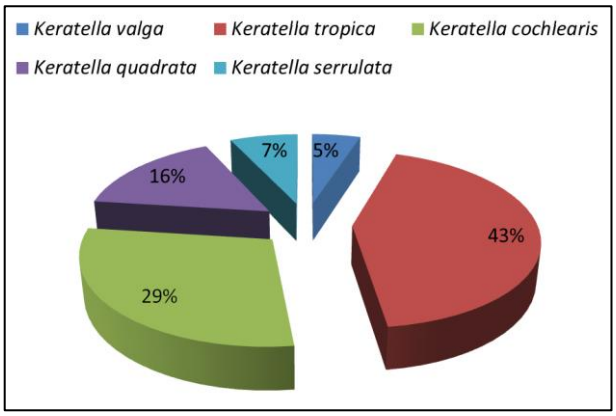


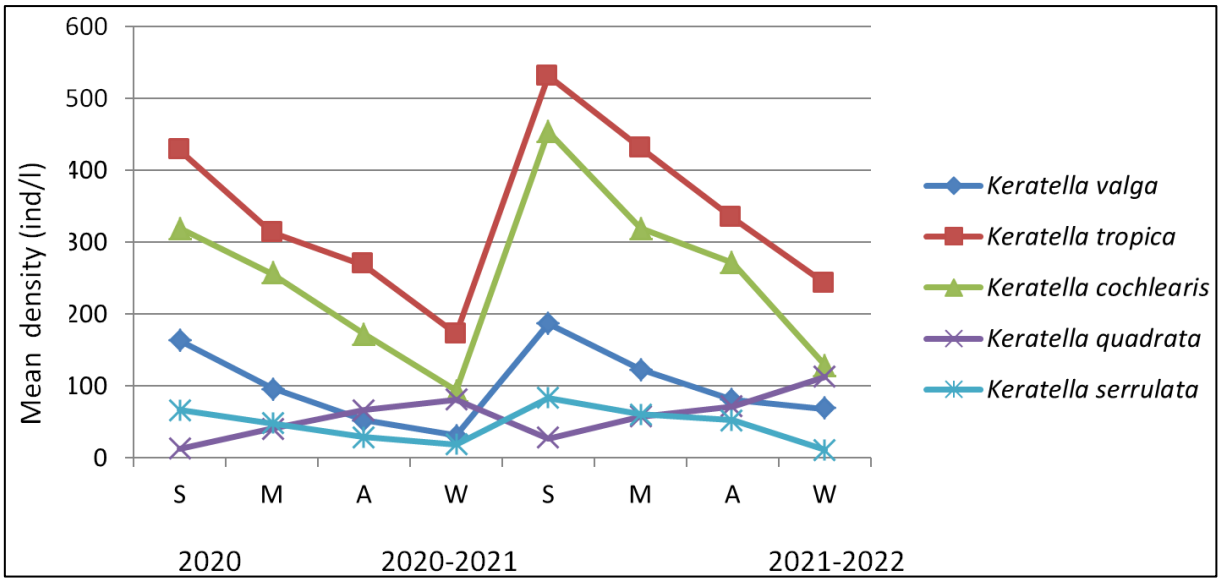
Figure 6. Percentage composition of rotifers of genus *Keratella* during winter season

3.3. Seasonal Variations of *Keratella* Species

Seasonal dynamics of the *Keratella* species showed that *K. valga* showed its highest density (187ind/lit) in the summer while least density during winter season (21ind/l). *K. tropica* showed its maximum density (531ind/l) during summer season and minimum density in winter (119ind/l). *K. cochlearis* exhibited highest density (473ind/l) in the summer season and lowest density in the winter (73 ind/l) while *K. serrulata* showed its maximum density (127 ind/l) in the winter season and minimum density during summer (13 ind/l). However, *K. quadrata* showed maximum density (121ind/lit) during winter and minimum during summer (11 ind/l) (Fig.7).

3.4. Water Quality Factors

Water quality parameters of the observed pond were also noted (Table1). To ascertain correlation between rotifer density and water quality factors, the observed variables were measured through Pearson's correlation coefficient (Table 2).



S denotes Summer (March to May); M denotes Monsoon (June to August); A denotes Autumn (September to October); W denotes Winter (November to February)

Figure 7. Seasonal variations of different rotifer species under the genus *Keratella*

Table 1. Water quality factors in the observed pond

Seasons Water quality factors	Summer Mean SD±	Monsoon MeanSD±	Autumn MeanSD±	Winter Mean SD±
Water Temperature(℃)	34.1 ±1.23	28.6 ±1.06	21.7 ±0.71	7.9±1.65
Transparency(cm)	5.37 ±0.85	8.13 ±0.87	5.13 ±1.29	4.17 ±0.16
pH	6.81 ±0.06	6.63 ±0.05	7.52 ±0.06	8.74 ±0.05
Alkalinity(ppm)	126.43 ±2.8	94.32 ±2.71	77.13 ±4.21	65.3 ±7.13
Dissolved oxygen(ppm)	6.23 ±0.25	5.85 ±0.37	7.47 ±0.13	8.5 ±0.23
Free carbon dioxide(ppm)	1.73 ±0.53	2.26 ±0.42	1.18 ±0.15	1.25 ±0.19
Total Dissolved Solids (ppm)	32.3 ±4.11	49.13 ±1.73	29.37 ±2.17	21.33 ±0.51
Phosphate phosphorus(ppm)	0.061 ±0.01	0.083 ±0.01	0.073±0.01	0.065 ±0.03
Nitrate nitrogen(ppm)	0.035 ±0.02	0.077 ±0.01	0.053 ±0.01	0.071 ±0.02

Table 2. Pearson's correlation coefficient between rotifer density and water quality factors

Water quality factors	Rotifer (ind/l)	WT	TRANS	pH	ALK	DO	FCO_2	TDS	PO_4-P	NO_3-N
Rotifer(ind/l)	1.									
WT(℃)	0.853**	1.								
TRANS(cm)	0.169	0.337	1							
pH	0.627*	0.476	0.153	1						
ALK(ppm)	0.731	0.649	0.273	-0.817	1					
DO (ppm)	0.571*	0.519*	0.131	0.273	0.437	1				
FCO_2(ppm)	0.187	0.526	0.297	-0.286	0.113	-0.229	1			
TDS (ppm)	0.523	*0.759	0.136	-0.671	*0.614	*0.513	-0.127	1		
PO_4-P (ppm)	0.539	-0.137	0.771*	-0.526	0.0391	-0.642*	0.0372	0.563	1	
NO_3-N (ppm)	-0.273	0.561	0.837**	-0.913**	0.671*	-0.721**	0.334	0.551*	0.791*	1

**Correlation significant at the 0.01 level (2-tailed)
*Correlation significant at the 0.05 level (2-tailed)

Where WT- denotes Water temperature; TRANS denotes Transparency; ALK denotes Alkalinity; DO denotes Dissolved oxygen; FCO_2 denotes Free carbon dioxide; TDS denotes Total dissolved solids; PO_4-P denotes Phosphate phosphorus; NO_3-N denotes Nitrate nitrogen

The lowering of water level in the summer resultant the rotifers being concentrated and as such maximum or peak density of rotifers under the genus *Keratella* were noticed in the observed pond. Several noteworthy researchers [31, 8, 32, 33] also reported maximum density of *Keratella* species during summer. Increased abundance of phytoplankton in summer provides acceptable food for rotifers that acts as the suitable abode for flourishing as well as survival of rotifers [34-36]. During winter months due to the sudden sharp reduction in water temperature, the rotifers undergo diapauses and as such lowest density of rotifers occurred as stated by researcher [37].

In the said research observation, rotifer density depicted significant positive interrelationship with water temperature ($r = 0.853$, $P<0.01$). This interrelationship supports observed result as highest rotifer density was observed during summer season when the highest water temperature occurred. Rotifer density also showed positive and significant relation with pH($r = 0.627$, $P< 0.05$) and dissolved oxygen($r = 0.571$, $P<0.05$).Water quality factors (transparency, alkalinity, free carbon dioxide, total dissolved solids, phosphate phosphorus and nitrate nitrogen did not depict any significant correlation with the density of rotifers. In the present observation, it is noteworthy to report that the *K. cochlearis* was numerically abundant at a water temperature range of 26-28.5 ℃ while *K. tropica* preferred water temperature in the range of numerically abundant at a water temperature range of 9.4-11.6 ℃. The numerical abundance of *Keratella* species was observed in the alkaline range of pH (pH 7.8-8.2) and dissolved oxygen value in the range of 6.2-6.5ppm. Researcher [38] stated that pH is not the single important influential water quality factor regulating the rotifer density. Researcher [39] reported the impact of oxygen concentration on the density and distribution of rotifer. Researchers [18, 40] reported that *K. cochlearis* and *K. quadrata* are numerically abundant in eutrophic water bodies and their existences are indication of high trophic status in the freshwater lentic ecosystem.

4. Conclusions

While observing taxonomy, the important taxonomical characteristics of different species of *Keratella* have been taken into account. The research observation infers that the seasons play a very crucial role in *Keratella* species composition. Densities of different species of *Keratella* also vary in different seasons due to optimal range of some abiotic (water quality) factors in the observed freshwater lentic ecosystem. It is noteworthy to mention that due to the possession of different trophic niches in the pond, the recorded *Keratella* species harmoniously abode in the same pond. The research observation also presumed that with the existence of two pollutant tolerant species of *Keratella* (such as *K. cochlearis* and *K. quadrata*), the observed pond is approaching eutrophic status.

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