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The nature and causes of cyclomorphosis in some species of Brachionus - *Brachionus falcatus* and *Brachionus forficula*

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Abstract
In the present study zooplankton samples were collected from Tighra Reservoir Gwalior. They were classified and measured under microscope with the magnification power of 10X. 15X. Form variation of two *Brachionus* species viz. *Brachionus falcatus* and *Brachionus forficula* was studied for a period of six months. In both the species the body size and the size of spines were decreased from May 2012 to October 2012. In *Brachionus forficula* the total length in the month of May was 0.255 mm which was decreased to 0.121 mm in the October, the length of postero-lateral spine decreased from 0.105 mm to 0.053 mm and the antero-lateral spine length also decreased from 0.030 mm to 0.053 mm in respective months. In *Brachionus falcatus* total length decreased from 0.435 mm in May to 0.277 mm in October and among the spines, the length of antero-intermediate spine decreased from 0.105 mm in May to 0.060 mm in October, the length of antero-lateral spine decreased from 0.030 mm to 0.015 mm and the length of postero-lateral spine also decreased in respective months from 0.180 mm to 0.112 mm. It is concluded that the temperature is the most important factor responsible for the cyclomorphosis. With increasing temperature the density of water decreases hence the size of body and spines of both spines increases which let them float in the less dense water.

Keywords: cyclomorphosis, zooplankton, rotifers, tighra reservoir, ocular disc, stage micrometer, *Brachionus*

1. Introduction
Tighra Reservoir is constructed on Sank River and situated near Tighra Village Gwalior district, Madhya Pradesh. Geographically the Tighra Reservoir lies on 78^0 01' 30" to 77^0 57' 54" E longitude and 26^o 11' 42" N to 26^0 14' 08" N latitude. It is situated approximately 23km west of Gwalior city from research center at an altitude of 218.58m from mean sea level. The Reservoir is surrounded by hills from three sides and has the catchment area of 412.25 sq.km with maximum length and width of 5.8km and 3.8km respectively

The temporal and cyclic change in morphology is known as cyclomorphosis. It is the phenomenon, particularly found in the rotifers Brachionus, Keratella and Asplanchna, and is often characterized by changes in shape and length of lorica or spines among individuals in a population [1]. Several factors are known to induce cyclomorphosis in rotifers. For example, water temperature, depth and trophic state, food resources, predation, competition etc.

Cyclic recurrent polymorphisms in planktonic organisms have been known to scientists since late nineteenth century. Lund [2] held the view that cyclomorphosis is brought about by a change in the temperature of water. In most cases a very obvious correlation of temperature with form variation of rotifer was observed [3, 4]. Lindstrom and Pejler [5] have experimentally showed effect of temperature on form variation. Yali Ge *et al.* [6] showed that water temperature is responsible to influence the antero median and antero-lateral spine lengths and the posterior spine length of spined *Keratella cochlearis* and all the morphometric parameters of unspined *K. cochlearis*. Korosi *et al.* [7] in his studies on bosmina reported that during high mortality risk (e.g., predation by larger invertebrates such as Chaoborus), longer mucros and increased carapace size increase prey-handling time and decrease the success rate of attacks.

Brachionus falcatus is not highly variable except for slight growth in the anterior and posterior spines. It has occipital margin with six spines; intermediates much longer and curved ventrally; medians and laterals shorter and of almost equal length. Posterior spines long, incurved and with widely separated bases. The anterior and posterior spines vary considerably. A form with very spines was found in large numbers from a river. This form with shorter spines may be a modification for running water existence since longer spines tend to entangle easily. Lorica composed of a dorsal and ventral plate and compressed dorso-ventrally. Anterior dorsal margin with six spines. The intermediates are much longer than the laterals and curved laterally outwards. Median spines equal to the lateral spines.

The Brachionus forficula has Lorica with four occipital spines, anterolaterals always longer than anteromedian spines. Lorica terminates posteriorly into two stout, long and sub square spines, basally wide separated and tapering to blunt points, geniculate swellings present at bases of posterior spines. Usually one egg attached in between base of posterior spines. The present study was conducted to assess the influence of physico-chemical characteristics on form variation of rotifers.

2. Materials and Methods
The zooplankton samples were collected from Tighra Reservoir Gwalior by filtering 50 litres of reservoir water through plankton collecting net made of bolting nylon cloth. Sampling was done from May 2012 to October 2012 in the

last week of every month. A subsample of 20ml was take into the polyethylene bottle and preserved by adding 4-5 drops of 4% formalin and 2-3 drops of glycerine were also added for the softness of organisms. The zooplanktons were identified under the microscope by using various identification keys suggested by Edmondson [8] and Battish [9]. The figures were drawn with the help of camera lucida adjusted on the compound microscope with the magnification power of 10X.15X. The measurements were taken by ocular disc duly calibrated with the stage micrometer. Thirty individuals of each species were measured every month. Following measurements were taken during our study as shown in figure.

1. Total length: It is the length of lorica including the length of anterior and posterior spine lengths.
2. Length of lorica: The length without length of spines.
3. Width of lorica
4. Length of various spines

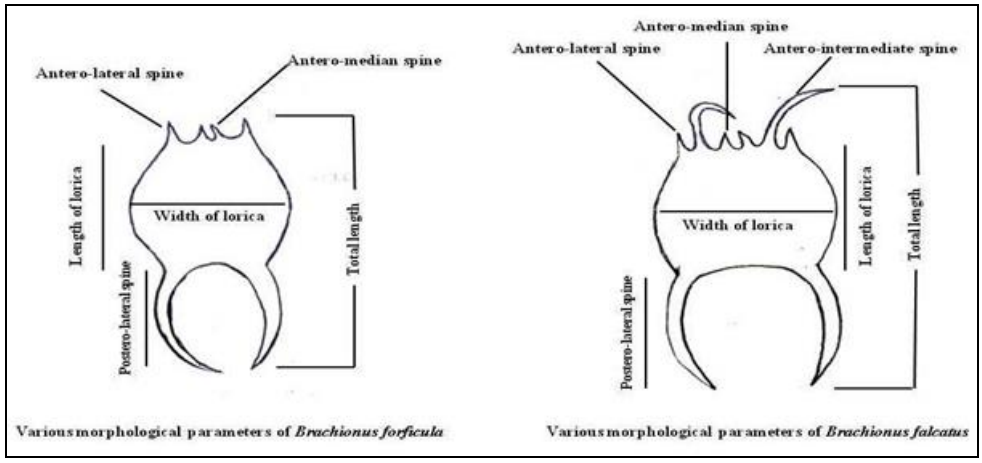

Fig 1: Showing various measurements taken during the course of study

These measurements were used to make various forms distinct from each other in a single species and different species.

3. Results

The present study was conducted on the two species of *Brachionus*,a very common rotifer organism of water bodies world over viz., *Brachionus falcatus* and *Brachionus forficula*. The camera lucida images of two species are presented in figures 2 and 3. In *B. falcatus* total length observed in the month of May was 0.435 mm which decreased to 0.277 mm in October (Table 1). The length and width of lorica has also shown a decreasing trend. The length of lorica in the month of May was 0.150 mm and it decreased to0.105 mm in the month of October. The width of lorica was 0.135 mm in May while in October it was recorded as 0.105 mm. Among the spines, the length of postero-lateral spine and antero-intermediate spine showed much change in the length. However, there was little change observed in antero-lateral spine length and no change in the antero-median spine length. The length of antero-intermediate spine decreased from 0.105 mm in May to 0.060 mm in October and the length of antero-lateral spine decreased from 0.030 mm in May to 0.015 mm in October. The length of postero-lateral spine also decreased in respective months from 0.180 mm to 0.112 mm (Table 1).

In *Brachionus falcatus*, the total length and the length of lorica showed a significant positive correlation with water temperature, dissolved oxygen, free carbon dioxide and chloride while it exhibited a significant negative correlation with the water depth and transparency. There was small positive correlation with total alkalinity and moderate negative correlation with electrical conductivity, turbidity and pH and small negative correlation with total hardness and calcium. The width of lorica has shown a significant positive correlation with water temperature and dissolved oxygen and significant negative correlation with depth and transparency of water and has shown a moderate positive correlation with free carbon dioxide, total hardness and chloride and little negative correlation with electrical conductivity, pH, total alkalinity and calcium. The length of spines i.e., antero-lateral spine, antero-intermediate spine and the posterolateral spine exhibited a high positive correlation with water temperature, dissolved oxygen, free carbon dioxide and chloride and showed a significant negative correlation with depth, transparency and electrical conductivity whereas, the antero-intermediate spine showed a small positive correlation with total alkalinity and small negative correlation with electrical conductivity, turbidity, pH, total hardness and calcium but the length of antero-lateral spine and the length of postero-lateral spine showed a small positive correlation with total alkalinity and total hardness and small negative correlation with electrical conductivity, turbidity, pH, and calcium (table 4).

In case of *B. forficula* the total length decreased from May to October. The total length in the month of May was 0.255 mm which was decreased to 0.121 mm in the October (Table 2). The length of lorica and width of lorica has also shown a decreasing trend. In this study it was observed that the lorica length was always equal to lorica width, as the length of lorica decreases the width of lorica also decreases. The length of lorica and width of lorica was decreased from 0.150 mm in May to 0.105 mm in October. In case of spine length the postero-lateral spine length showed much variation. The length of postero-lateral spine decreased from 0.105 mm in May to 0.053 mm in October. The antero-lateral spine length also decreased from 0.030 mm to 0.053 mm. There was no

significant change in length of antero-median spine (Table 2). The total length of the *Brachionus forficula* exhibited a high positive correlation with the water temperature, dissolved oxygen and free carbon dioxide, but showed a moderate positive correlation with chloride. There was the significant negative correlation with the depth and transparency of water and moderate negative correlation with electrical conductivity, turbidity, pH, total alkalinity, total hardness and calcium. Similarly, the length and width of lorica and the length of spines i.e., antero-lateral spine and the postero-lateral spine also showed high positive correlation with water temperature, dissolved oxygen and free carbon dioxide, moderate positive correlation with chloride. Both length and width of lorica and the length of spines showed a significant negative correlation with depth and transparency of water and there was a little negative correlation with electrical conductivity, turbidity, pH, total alkalinity, total hardness and calcium (table

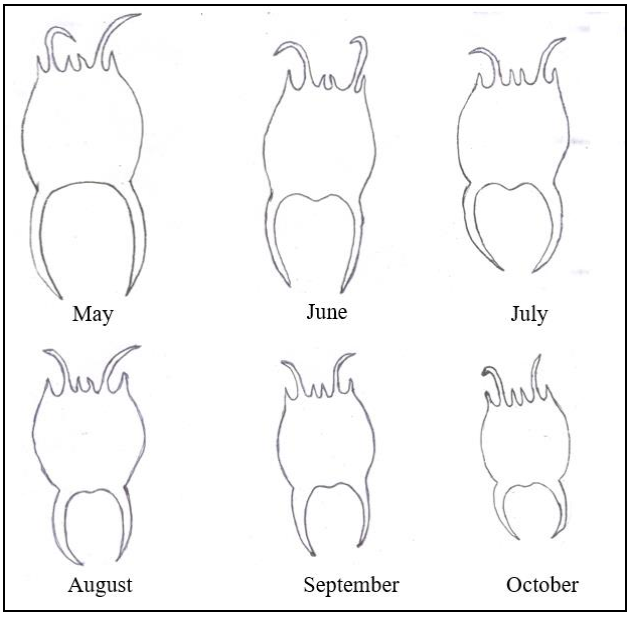

Fig 2: Camera Lucida images of *Brachionus falcatus* in different months

Table 1: Morphometric data of *Brachionus falcatus*

S. No.	Measurements (In mm)	May	June	July	Aug	Sep	Oct
1	Total length	0.435	0.397	0.375	0.337	0.307	0.277
2	Length of Lorica	0.150	0.135	0.135	0.127	0.120	0.105
3	Width of Lorica	0.135	0.127	0.135	0.120	0.120	0.105
4	Length of Antero-median Spine	0.015	0.015	0.015	0.015	0.015	0.015
5	Length of Antero-intermediate Spine	0.105	0.097	0.090	0.075	0.067	0.060
6	Length of Antero-Lateral spine	0.030	0.026	0.026	0.015	0.015	0.015
7	Length of Postero-Lateral Spine	0.180	0.165	0.165	0.135	0.120	0.112

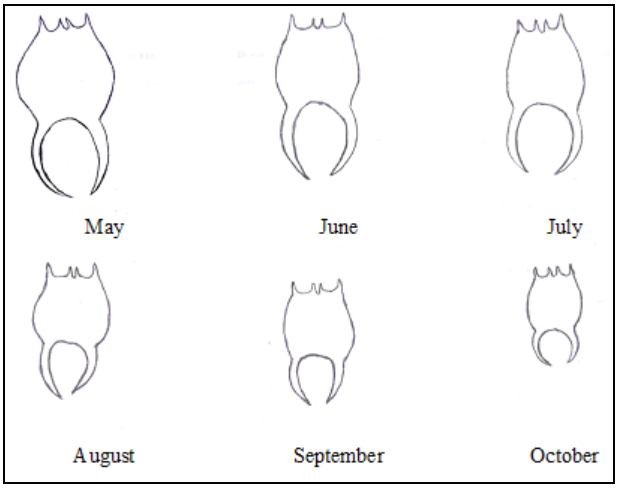

Fig 3: Camera Lucida images of *Brachionus forficula* during different months under 150 X magnification.

Table 2: Morphometric data of *Brachionus forficula*

S. No.	Measurements (In mm)	May	June	July	Aug	Sep	Oct
1	Total length	0.255	0.247	0.233	0.214	0.195	0.121
2	Length of Lorica	0.120	0.112	0.105	0.098	0.090	0.053
3	Width of Lorica	0.120	0.112	0.105	0.098	0.090	0.053
4	Length of Antero-median Spine	0.015	0.015	0.015	0.015	0.015	0.015
5	Length of Antero-Lateral spine	0.030	0.030	0.030	0.026	0.015	0.015
6	Length of Postero-Lateral Spine	0.105	0.105	0.098	0.090	0.090	0.053

Table 3: Mean values of physico-chemical characteristics of Tighra Reservoir during May 2012 to October 2012

S.No	Parameters	May	June	July	Aug	Sep	Oct
1	Amb. Temperature (ºC)	36.08	33.4	32.5	32.8	31.1	29.6
2	Water Temperature (ºC)	32.2	31.7	31.5	30.8	30.5	27.8
3	Colour	L.G	L.G	L.G	G	G	G
4	Depth (cm)	268.1	230.7	228.7	651.1	656.0	578.1
5	Transparency (cm)	103.7	114.4	112.7	110.0	166.2	185.0
6	Electrical conductivity (μScm^{-1})	156.8	126.0	162.4	184.8	170.8	162.4
7	Turbidity (NTU)	0.97	1.15	1.7	1.9	1.3	1.4
8	pH	9.27	8.45	9.8	10.22	9.4	9.4
9	Dissolved Oxygen (mgL^{-1})	7.09	7.6	6.8	5.68	4.7	3.7
10	Free Carbon Dioxide (mgL^{-1})	12.1	8.8	0.5	3.3	0.5	-
11	Total Alkalinity (mgL^{-1})	176.2	158.7	156.2	161.2	151.2	176.2
12	Total Hardness (mgL^{-1})	78.1	69.0	85.0	70.5	71.5	83.0
13	Chloride (mgL^{-1})	40.1	25.9	25.5	22.0	21.6	25.9
14	Calcium (mgL^{-1})	23.2	22.4	20.4	22.8	21.0	23.8

Table 4: Correlation coefficient of various lengths with different physico-chemical parameters in *Brachionus falcatus*

Parameters	Total length	Length of Lorica	Width of Lorica	Length of Antero-intermediate Spine	Length of Antero-Lateral spine	Length of Postero-Lateral Spine
Water Temperature (ºC)	0.89	0.94	0.94	0.87	0.75	0.86
Depth (cm)	-0.82	-0.72	-0.76	-0.87	-0.95	-0.90
Transparency (cm)	-0.87	-0.89	-0.83	-0.85	-0.70	-0.86
Electrical conductivity ($\mu S\ cm^{-1}$)	-0.49	-0.31	-0.27	-0.55	-0.62	-0.50
Turbidity (NTU)	-0.42	-0.33	-0.19	-0.43	-0.50	-0.35
pH	-0.33	-0.17	-0.09	-0.38	-0.43	-0.29
Dissolved Oxygen (mgL^{-1})	0.94	0.90	0.88	0.95	0.87	0.95
Free Carbon Dioxide (mgL^{-1})	0.85	0.81	0.41	0.81	0.67	0.71
Total Alkalinity (mgL^{-1})	0.10	0.01	-0.23	0.09	0.18	0.08
Total Hardness (mgL^{-1})	-0.09	-0.11	0.02	-0.05	0.20	0.05
Chloride (mgL^{-1})	0.71	0.66	0.48	0.69	0.74	0.67
Calcium (mgL^{-1})	-0.07	-0.17	-0.48	-0.09	-0.11	-0.14

Table 5: Correlation coefficient of various lengths with different physico-chemical parameters in *Brachionus forficula*

Parameters	Total length	Length of Lorica	Width of Lorica	Length of Antero-Lateral spine	Length of Postero-Lateral Spine
Water Temperature (ºC)	0.99	0.99	0.99	0.82	0.99
Depth (cm)	-0.67	-0.64	-0.64	-0.80	-0.60
Transparency (cm)	-0.91	-0.90	-0.90	-0.96	-0.84
Electrical conductivity (μScm^{-1})	-0.34	-0.31	-0.31	-0.39	-0.33
Turbidity (NTU)	-0.21	-0.25	-0.25	-0.03	-0.23
pH	-0.20	-0.19	-0.19	-0.11	-0.23
Dissolved Oxygen (mgL^{-1})	0.94	0.92	0.92	0.95	0.90
Free Carbon Dioxide (mgL^{-1})	0.81	0.87	0.87	0.56	0.81
Total Alkalinity (mgL^{-1})	-0.28	-0.25	-0.25	-0.01	-0.40
Total Hardness (mgL^{-1})	-0.32	-0.33	-0.33	-0.04	-0.39
Chloride (mgL^{-1})	0.40	0.44	0.44	0.45	0.32
Calcium (mgL^{-1})	-0.35	-0.32	-0.32	-0.13	-0.44

4. Discussion

Zooplanktons are known to develop morphological defenses in response to environmental signals and predation pressure. During the study period from May 2012 to October 2012, the maximum temperature was found in the month of May and it showed a decreasing trend up to the October. The total length,

the length and width of lorica and the length of spines also decreased with decreasing temperature. Similar results were observed by the Wesenberg-Lund [2], Ahlstrom [10] and Gallagher [11]. Sairam Pattnaik [12] in his studies on different *Brachionus* species showed that the body length and spine length is dependent on various environmental factors and same effect was found in present studies. Ostwald [13] noted that the physico-chemical factors, which bring about changes in the viscosity of water, are responsible for the phenomenon of cyclomorphosis, Similar results were observed in the present study as due to the decreasing temperature the viscosity of the water decreases and the size of specimen also decreases. Several workers such as, Saksena and Sharma [14]; Sarma and Rao [15]; Sanoamuang [16] and Hansen *et al.* [17] found that certain environmental factors such as food concentration, food quality and temperature are responsible for morphological changes in rotifers. Hillbricht-Illkowska [18] correlated increasing size of lorica of *K. cochlearis* with water temperature. Dieguez *et al*. [19] has shown that the size of lorica in *K. cochlearis* is not related to water temperature but also to food resourses. Similar results were obtained in our studies on *B. falcatus* and *B. forficula* as the temperature of water decreases not only the size of lorica but also the length of spines decreased.

5. Conclusion

From the above work it is concluded that the temperature is the most important factor responsible for the cyclomorphosis. With increasing temperature the density of water decreases hence the size of body and spines of both spines increases which let them float in the less dense water.

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