International Journal of Ecology and Environmental Sciences 50: 83-96, 2024
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2024.3071

Evaluation of Water Quality Parameters and Zooplankton Community during Pre- and Post-Covid Phases at Chandravalli Lake, Chitradurga District, Karnataka, India

BASAVARAJ, S.K. AND GIRISH G. KADADEVARU*
Department of Zoology, Karnatak University, Dharwad, Karnataka, India
E-mail: basavarajsk54@gmail.com, kadadevarug@gmail.com
***Author for correspondence**

ABSTRACT
The present work deals with variations in physico-chemical parameters and zooplankton community during pre- and post-covid phases at Chandravalli Lake, a pre-historic water body located in Chitradurga district, Karnataka, India. Eighteen water quality parameters were analysed and zooplankton community diversity were studied during the two phases. A total of forty three zooplanktons were recorded during the study. Cladocera was the dominating group during both pre- and post-covid periods. *Tropocyclops prasinus* belonging to Copepoda was the most abundant species in this water body. Ostracods were recorded only when the water was turbid and the TDS was also high at pre-covid phase. After the lockdown period the water was clear and the Ostracods almost vanished. The Principal Component Analysis, CCA and correlation studies indicate the variations of biotic and abiotic factors during pre- and post-covid phases. The presence of eutrophic indicators in the water body suggests for regular monitoring to conserve the water body from further degradation.

Key words: Chandravalli Lake, Correlation, CCA, PCA, Zooplankton density.

INTRODUCTION

The life on this planet is facing most challenging problem of water eutrophication, diagnosis for total phosphorus and nitrates is being forged to the analysis of total nutrient enrichment (Yang et al. 2007). Nutrient enrichment can either be by natural aging or by the influx and sedimentation of organic components. In a water body, the twain natural processes and anthropogenic inputs determine the surface water quality (Kazi et al. 2009). Monitoring and maintaining the integrity of aquatic ecosystems can be done using bio-indicator planktons (Abdulwahab and Rabee 2015). These planktons live for a short period but they react instantly for any of the change in environmental aspects. Planktons are cosmopolitan in occurrence and act as natural water purifiers (Singh et al. 2021), they help the water body in recycling nutrients and also acts as intermediate for energy transfer from producers to consumers. The density and diversity of planktons can be depicted by the level of pollution in a study area (Dorak 2013). In the present work a comparative study of variation in physico-chemical parameters, plankton diversity and density during pre and post Covid phases was analysed.

MATERIAL AND METHODS

Sampling site

Chandravalli Lake (14°12’32" N, 76°23’10"E) is located in Chitradurga district of central Karnataka in southern India (Fig. 1). The water body is situated 5 km away from the Chitradurga city. It is located in the premises of famous Chandravalli caves, a heritage site recognized by Archaeological Society of India. This Lake is having a total area of 0.007227 km^2 and depth up to 10 m (Banakar et al. 2005). It is a man-made perennial lake and it has descriptions since pre-historic times (Iron Age). The literature also suggests that, the water body was also modified by Mayura Varma (345 CE) of Kadamba dynasty and it has been reconstructed by Government of Karnataka in the year 1981 (Ghosh 1990). The water is used for drinking and irrigation.

Sample collection and analysis

Water samples were collected during the morning hours between 6:00 and 9:00 A.M. The sample collection was initiated in July, 2019 and continued till February, 2020. Later after Covid Lockdown it was re started from July, 2020 and continued till February, 2021. EuTech PCS Testr 35 probe was used

Figure 1. Chandravalli Lake, Chitradurga district, Karnataka state, India

to measure the water parameters like air temperature, water temperature, pH, electric conductivity, total dissolved solids (TDS) and salinity. Secchi disc was used for transparency measurements and a hygrometer for recording humidity. Systronics spectrophotometer was used to measure the phosphates, sulphates and nitrates and other parameters were recorded using titration methods (Anonymous 1980). For Zooplankton studies sample was collected by sieving 100 litres of water through plankton collecting nylon bolting net (68 µm). The sieved plankton samples were fixed with 2 ml of glycerine and 4% formaldehyde. Qualitative and quantitative assessment of zooplankton was performed under Olympus CH 20i optical microscope using specialized literature (Edmondson 1959, Patil and Gouder 1989). Quantitative analysis of zooplankton was done using Sedgwick rafter counting cell. SPSS was used for statistical calculations and PCA was performed using the software PAST (version 3.16) (Hammer et al. 2001)

RESULTS

Abiotic factors

The study period is divided into two phases; Phase-1 is pre-covid period that spanned between July-2019 and February-2020. Phase-2 is post-covid that extended between July-2020 to February-2021. A total of eighteen physico-chemical parameters were documented during these two phases (Table 1). The average air temperature during pre-covid phase was 22.05±0.6. In post-covid phase, it was 23.75±0.5. Water temperature had an average value of 24.56±0.4 during the pre-covid phase and 21.4 to 26.5º C was its range during post-covid phase. Humidity had an

Table 1. Monthly variations in physico-chemical parameters at Chandravalli Lake Pre- and Post-Covid

	Pre-Covid										Post-Covid									
Parameters	**Jul-19**	**Aug-19**	**Sep-19**	**Oct-19**	**Nov-19**	**Dec-19**	**Jan-20**	**Feb-20**	**Average**	**Range**	**Jul-20**	**Aug-20**	**Sep-20**	**Oct-20**	**Nov-20**	**Dec-20**	**Jan-21**	**Feb-21**	**Average**	**Range**
AT, ° C	22	22	21.9	22.6	23.5	22.5	24	17.9	22.05±0.6	17-26	23.4	24.4	23.2	25.1	24	23.1	20.8	26	23.75±0.5	20-26
WT, ° C	24	23.8	23.9	26.5	25.5	23	26	23.8	24.56±0.4	23-26	26.5	26.2	26	21.4	24.8	22.6	23	26.4	24.61±0.6	21.4-26.5
Hum, %	61	62	70	64	44	54	64	54	59.12±2.6	54-70	48	42	52	58	46	52	58	52	51±1.8	42-58
Trans, cm	50	50	55	75	70	80	75	85	67.5±4.5	50-85	80	80	85	85	85	85	80	80	82.5±0.8	80-85
pH	8.5	8.5	8.59	8.5	7.9	8.2	8.3	8.5	8.37±0.07	7.9-8.5	8.2	8.3	7.8	7.6	7.6	7.9	8.2	8.4	8±0.1	7.6-8.4
EC, µmhos/cm	308	305	310	173.3	143.5	154.5	167.3	179.5	217.63±24.9	143-310	177.9	170.5	153.6	168.1	184.6	203	208	224	186.21±7.8	168.1-224
TDS, ppm	219	216	221	123	102	110	116	128	154.37±17.80	102-221	126	121	109	119	131	145	148	159	132.25±5.6	109-159
Salinity, ppt	148	144	150	85.3	71.1	75.9	84.6	93.5	106.55±11.3	71-148	93.3	89.4	81.1	88.1	96.3	105	107	116	97.02±3.8	81-116
DO, mg/l	10.4	9.7	6.9	10.5	12.8	14.4	12.4	10.9	11±0.7	6.9-14.4	9.7	13.2	11.8	10.4	7.8	11.7	18.8	18.8	12.77±1.3	7.8-18.8
Chlorides, mg/l	22	20.3	20	16	14	17	19.3	18	18.325±0.8	14-22	20	27.6	22	20	25	28	26	26	24.32±1.06	20-28
Free CO2, mg/l	0.66	0.66	0.66	0.66	0.66	0.66	1.32	0.66	0.74±0.07	0.66-1.32	0.66	1.32	0.66	0.66	0.66	1.32	1.32	0.66	0.9±0.1	0.66-1.32
Alkalinity, mg/l	23	20	20	20	20	20	13	20	19.5±0.9	13-23	20	23	30	20	23	23	20	26	23.12±1.1	20-30
Calcium, mg/l	24.8	25.6	34.4	21.6	18	16.8	16.2	26.8	23.02±2.03	16.2-34.4	29	22	17.8	30.4	35.2	37	40	44.8	32.02±3.0	17.8-44.8
Mg, mg/l	0.97	0.97	1.74	0.97	0.48	0.97	0.97	1.26	1.04±0.11	0.48-1.74	0.97	0.97	1.11	0.77	0.63	0.97	0.97	0.97	0.92±0.04	0.63-1.11
Hardness, mg/l	66	68	93.2	58	47.2	46	44.6	72.6	61.95±5.4	44.6-93.2	76.6	59.2	49.2	79.2	90.6	96.6	104	116	83.92±7.4	49.2-116
Phosphate, mg/l	0.003	0.002	0.003	0.002	0.002	0.004	0.003	0.004	0.002±0.0002	0.002-0.004	0.005	0.002	0.004	0.002	0.003	0.003	0.003	0.004	0.003±0.0003	0.002-0.005
Sulphate, mg/l	0.08	0.09	0.09	0.09	0.09	0.08	0.08	0.09	0.086±0.001	0.08-0.09	0.09	0.09	0.08	0.09	0.09	0.08	0.09	0.09	0.08±0.001	0.08-0.009
Nitrate, mg/l	0.45	0.61	0.33	0.23	0.55	0.67	0.62	0.52	0.49±0.05	0.23-0.67	0.47	0.61	0.48	0.75	0.59	0.28	1.23	0.45	0.6±0.09	0.28-1.23

AT-Air temperature, WT-Water temperature, Hum-Humidity, Trans-Transparency, EC-Electric conductivity, TDS-Total dissolved solids, DO-Dissolved oxygen, Mg-Magnesium, ppm – parts per million, ppt- parts per thousand.

Table 2. Systematic account of zooplankton species.

CLADOCERA
Family: Chydoridae
Alona monacantha
A. pulchella.
A. affinis
A. costata
Karualona karua
Chydorus reticulatus
Leydigia acanthocercoides
Chydorus sphaericus
Pleuroxus denticulatus
Coronatella rectangula
Alona sp.

Family: Bosminidae
Bosminopsis deitersi
Bosmina longirostris
B. longispina
B. cornuta
B. coregoni

Family: Daphniidae
Ceriodaphnia cornuta
Simocephalus vetulus
Daphnia pulex
Scapholeberis kingi

ROTIFERA
Family: Brachionidae
Brachionus caudatus
B. calyciflorus
B. diversicornis
B. falcatus
B. quadridentatus.
Keratella cochlearis
K. tropica
K. tecta

Family: Lecanidae
Monostyla quadridentata
Monostlya bulla

Family:Philodinidae
Rotatoria neptunia

Family: Notommatidae
Cephalodella gibba

Family: Testudinellidae
Testudinella patina

Family: Trichocercidae
Trihocerca cylindrica

COPEPODA
Family: Cyclopidae
Mesocyclops hyalinus
M. leuckarti
Paracyclops fimbriatus
Tropocyclops prasinus
Nauplius larva

OSTRACODA
Family: Cyprididae
Hemicypris fossulata.

Family: Ilyocypridae
Ilyocypris gibba

Family: Cyprididae
Chrissia sp

Family: Stenocyprinae
Stenocypris hislopi

average value of 59.15±2.6 % during pre-covid phase and an average value of 51±1.8 % was observed during post-covid phase. During pre-covid phase transparency had an average value of 67.5±4.5 cm and during post-covid phase it was 82.5±0.8 cm. During pre-covid phase the average value of pH was 8.3±0.07 and in post-covid phase it was 8±0.1. The electric conductivity had an average value of 217.63±24.9 µmhos/cm during pre-covid phase and 186.21±7.8 µmhos/cm during post-covid phase. Total Dissolved Solids (TDS) had an average value of 154.37±17.80 ppm during the pre-covid period and it was 132.25±5.6 ppm during post-covid phase. During pre-covid phase, salinity had an average value of 106.5±11.3 ppt and during post-covid phase its average value was 97.02±3.8 ppt. Dissolved oxygen (DO) levels at pre-covid phase had an average value of 11±0.7 mg/l, and during post-covid it had an average value of 12.7±1.3 mg/l. The average value of chlorides during pre-covid phase was 18.3±0.8 mg/l, while the average chloride value of post-covid phase was 24.3±1.06 mg/l. Free carbon dioxide during the pre-covid phase had an average value of 0.7±0.07 mg/l and during post-covid phase it was 0.9±0.1 mg/l. The alkalinity values in pre-covid phase had an average value of 19.5±0.9 mg/l. During post-covid phase, average alkalinity value was 23.12±1.1. During pre-covid phase, calcium values had an average value of 23.02±2.03 mg/l. Calcium values of post covid phase had an average value of 32.02±3.0 mg/l. Magnesium values during pre-covid phase had an average of 1.04±0.11 mg/l. During post-covid phase, magnesium values had an average value of 0.92±0.04 mg/l. Average value of hardness during pre-covid phase was 61.95±5.4 mg/l and during the post-covid phase it was of 83.9±7.4 mg/l. The phosphate values during pre-covid phase had an average of 0.002±0.0002 mg/l and during the post-covid phase the average value was 0.003±0.0003 mg/l. During pre-covid phase, sulphate values had an average value of 0.08±0.001 mg/l and its value during post-covid period was 0.08±0.001 mg/l. During pre-covid phase the average nitrate value recorded was 0.4±0.05 mg/l and at post-covid phase it was 0.6±0.09 mg/l (Fig. 2).

Biotic factors

Forty three species of Zooplanktons were recorded in Chandravalli Lake during the study period that belonged to four groups and 27 genera (Table 2). Group Cladocera represented with 12 genera and 20 species, Rotifer with seven genera and 14 species, group Copepoda having four genera with five species and Ostracoda having four genera with four species. During pre-covid phase, Cladocera was dominant group with 19 species exhibiting an abundance of 44% of the total population (Fig. 3). During this phase, maximum number of species (16) were recorded in December, 2019. During post-covid phase, a total of 20 species were recorded with an abundance of 67% and in December-2020 maximum number of species (15) were observed. In this group *Bosminopsis deitersi* was the most abundant species both in pre and post-covid phase.

During pre-covid phase, Rotifera represented with 12 species which was the least abundant group covering 15% of the total population (Fig. 3) with ten species of Rotifera occurring in December, 2019. In this phase *Keratella tropica* was the most abundant species. During post-covid phase, a total of 12 species with 13% of abundance was recorded. In February 2021 highest number of eight species of Rotifers were recorded. In this phase *K. cochlearis* was the most abundant species (Table 3).

Copepoda was the second abundant group with 25% population (Fig. 3) and four species during pre-covid phase. It is during November-2019, highest number of species were observed. In post-covid phase, five species of copepods recorded maintaining its second dominant position with 20% of the population. *Tropocyclops prasinus* was the most abundant species in this group both in pre and post-covid phase.

Ostracoda consisting four species with an abundance of 16% of the total population during pre-covid phase. *Hemicypris fossulata* was the most abundant species. All the four species were recorded in September-2019, with maximum number of individuals. Ostracoda was absent during post-covid phase (Fig. 3). *H. fossulata* was the only species observed during January-2021 (Table 3).

Pearson's correlation

Pre-covid analysis

Humidity had positive correlation with pH (r=0.814, P<0.05) and magnesium (r=0.713, P<0.05). Transparency had significant negative correlation with electric conductivity (EC) (r=-0.903, P<0.01),

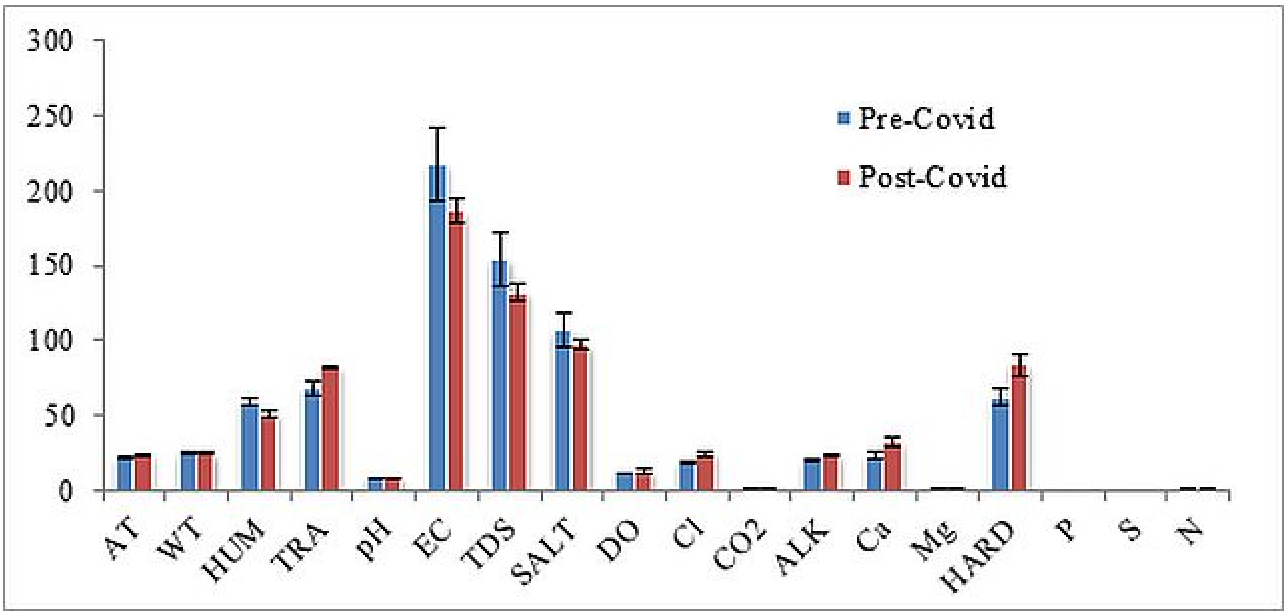

Figure 2. Variation in water characters between pre- and post-Covid phases

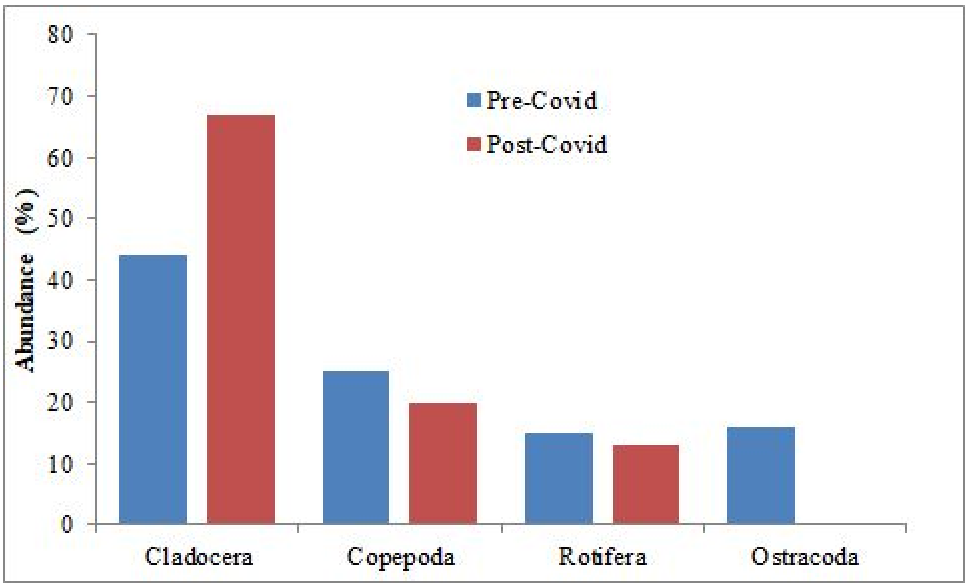

Figure 3. Zooplankton abundance (%) during study period

total dissolved solids (TDS) (r=-0.901, P<0.01) and salinity (r=-0.880, P<0.01). pH was negatively correlated with dissolved oxygen (DO) (r=-0.754, P<0.05) but positively correlated with calcium (r=0.732, P<0.05), magnesium (r=0.764, P<0.05) and hardness (r=0.744, P<0.05). EC had most significant positive correlation with TDS (r=1.00, P<0.01), salinity (r=0.998, P<0.01), chloride (r=0.825, P<0.05), calcium (r=0.758, P<0.05) hardness (r=0.744, P<0.05) and negatively correlated with DO (r=-0.786, P<0.05). TDS was positively correlated with salinity (r=0.998, P<0.01), chloride (r=0.819, P<0.05), calcium (r=0.765, P<0.05), hardness (r=0.752, P<0.05) and negatively correlated with DO (r=-0.789, P<0.05). Salinity was significantly correlated with chlorides (r=0.839, P<0.01), calcium (r=0.783, P<0.05), hardness (r=0.771, P<0.05) and negatively correlated with DO (r=-0.803, P<0.05). During the present study, DO exhibited negative correlation with calcium (r=-0.926, P<0.01), magnesium (r=-0.725, P<0.05), hardness (r=-0.921, P<0.01) and Ostracoda (r=-0.716, P<0.05) (Table 5). The highly significant negative correlation of Free carbon dioxide was observed with alkalinity (r=-

Table 3. Monthly variation of zooplankton abundance at Chandravalli Lake during pre-covid

Zooplankton group	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20
Cladocera								
Bosminopsis deitersi	9	13	2	14	7	6	16	12
Chydorus sphericus	1	0	0	2	2	0	5	1
Chydorus reticulatus	1	2	0	2	0	0	1	0
Alona monacantha	2	3	0	1	3	2	3	4
Alona affinis	2	4	0	0	0	0	0	2
Alona costata	0	0	0	0	2	1	3	0
Alona pulchella	0	0	0	0	3	1	0	0
Alona sp.	0	0	0	2	0	2	2	2
Bosmina longirostris	4	4	0	5	4	3	10	8
Bosmina longispina	5	4	0	7	6	4	13	10
Bosmina cornuta	0	0	0	2	1	2	0	1
Karua lonakarua	2	1	1	0	15	8	8	6
Pleuroxus denticulatus	2	1	2	1	3	4	3	5
Leydigia acanthocercoides	6	7	0	5	0	1	0	0
Simocephalus vetulus	0	0	0	0	0	1	0	1
Daphnia pulex	0	0	0	0	0	2	2	0
Ceriodaphnia reticulata	0	0	0	0	0	2	0	0
Coronatella rectangula	2	0	0	1	2	3	3	4
Scapholeberis kingi	0	0	0	0	0	0	0	0
Bosmina coregoni	4	5	0	6	3	1	7	6
Total	**40**	**44**	**5**	**48**	**51**	**43**	**76**	**62**
Copepoda								
Paracyclops fimbriatus	8	6	0	7	6	4	6	4
Mesocyclops leuckarti	2	3	0	3	2	2	1	1
Mesocyclops hyalinus	0	1	0	0	2	0	0	0
Tropocyclops prasinus	30	33	0	29	26	18	6	9
Nauplius larva	0	0	0	0	0	0	0	0
Total	**40**	**43**	**0**	**39**	**36**	**24**	**13**	**14**
Rotifera								
Keratella tropica	9	8	3	6	7	6	2	7
Keratella cochlearis	2	0	0	1	0	1	0	5
Brachionus calyciflorus	2	3	0	0	2	4	2	0
Brachionus falcatus	2	2	0	0	0	6	0	3
Rotatoria neptunia	2	0	1	1	0	0	1	0
Brachionus quadridentatus	0	0	0	0	0	3	1	2
Brachionus diversicornis	0	0	0	0	0	2	0	1
Brachionus caudatus	0	0	0	0	0	1	0	1
Monostyla quadridentata	0	0	0	0	0	1	0	0
Cephalodella gibba	0	2	0	0	0	4	3	2
Keratella tecta	0	0	0	0	0	3	1	5
Monostyla bulla	0	0	1	0	1	0	0	0
Testudinella patina	0	0	0	0	0	0	0	0
Trichocerca cylindrica	0	0	0	0	0	0	0	0
Total	**17**	**15**	**5**	**8**	**10**	**31**	**10**	**26**
Ostracoda								
Ilyocypris gibba	4	6	19	4	2	2	1	0
Hemicypris fossulata	0	0	40	3	2	3	2	3
Stenocypris hislopi	0	0	5	0	0	2	0	1
Chrissia sp.	0	0	31	0	1	2	0	0
Total	**4**	**6**	**95**	**7**	**5**	**9**	**3**	**4**

Table 4. Monthly variation of zooplankton abundance at Chandravalli Lake during post-covid

Zooplankton group	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21
Cladocera								
Bosminopsis deitersi	14	16	10	14	12	11	16	14
Chydorus sphericus	3	2	0	1	3	2	4	2
Chydorus reticulatus	0	0	0	1	0	0	0	0
Alona monacantha	3	4	3	2	4	2	3	2
Alona affinis	0	0	3	0	0	2	1	0
Alona costata	2	0	1	0	1	2	0	1
Alona pulchella	0	2	0	0	1	0	0	0
Alona sp.	4	2	3	4	0	2	3	3
Bosmina longirostris	7	9	8	7	6	7	9	8
Bosmina longispina	11	12	12	11	9	10	12	10
Bosmina cornuta	3	2	0	1	2	2	0	1
Karua lonakarua	6	9	14	10	11	9	9	8
Pleuroxus denticulatus	4	4	3	4	2	4	2	3
Leydigia acanthocercoides	1	0	0	0	0	0	1	0
Simocephalus vetulus	0	2	0	0	0	0	0	0
Daphnia pulex	0	0	0	0	0	0	1	0
Ceriodaphnia reticulata	2	1	2	0	0	1	0	1
Coronatella rectangula	3	0	1	3	1	2	0	3
Scapholeberis kingi	5	11	8	8	6	7	5	8
Bosmina coregoni	6	5	4	3	4	3	0	5
Total	**74**	**81**	**72**	**69**	**62**	**66**	**66**	**69**
Copepoda								
Paracyclops fimbriatus	8	7	6	8	9	7	6	5
Mesocyclops leuckarti	0	3	2	1	0	2	1	0
Mesocyclops hyalinus	1	0	0	0	1	0	0	0
Tropocyclops prasinus	7	5	8	14	18	16	11	10
Nauplius larva	3	4	3	0	2	0	0	0
Total	**19**	**19**	**19**	**23**	**30**	**25**	**18**	**15**
Rotifera								
Keratella tropica	0	0	1	3	2	4	4	6
Keratella cochlearis	2	3	6	5	4	2	0	3
Brachionus calyciflorus	0	0	2	0	1	2	3	0
Brachionus falcatus	0	0	0	0	0	0	0	2
Rotatoria neptunia	0	0	0	0	0	0	0	0
Brachionus quadridentatus	0	0	0	0	0	2	3	1
Brachionus diversicornis	0	0	0	2	0	0	1	0
Brachionus caudatus	0	0	2	3	0	1	0	1
Monostyla quadridentata	0	0	0	0	0	2	1	2
Cephalodella gibba	2	0	0	0	0	0	2	2
Keratella tecta	0	0	0	0	0	0	0	0
Monostyla bulla	1	3	1	2	3	2	1	0
Testudinella patina	3	2	0	0	2	0	0	0
Trichocerca cylindrica	0	0	1	0	0	0	0	1
Total	**8**	**8**	**13**	**15**	**12**	**15**	**15**	**18**
Ostracoda								
Ilyocypris gibba	0	0	0	0	0	0	0	0
Hemicypris fossulata	0	0	0	0	0	0	1	0
Stenocypris hislopi	0	0	0	0	0	0	0	0
Chrissia sp.	0	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**

Table 5. Correlation between water parameters and zooplanktons during Pre-Covid

	AT	WT	Hum	Tra	pH	EC	TDS	Salt	DO	Cl	CO	Alk	Ca	Mg	Hard	P	S	N	Cla	Cop	Rot	Ost
AT	1	.486	.071	-.229	-.476	-.127	-.137	-.171	.265	-.163	.429	-.379	-.526	-.446	-.533	-.526	-.353	.089	.022	.234	-.494	-.025
WT		1	.052	.215	-.218	-.420	-.429	-.425	.077	-.417	.462	-.472	-.386	-.382	-.391	-.604	.151	-.394	.425	.177	-.666	-.230
Hum			1	-.429	.814*	.610	.602	.618	-.695	.667	.243	-.178	.523	.713*	.543	-.061	-.055	-.473	-.388	-.321	-.439	.536
Tra				1	-.352	-.903**	-.901**	-.880**	.620	-.646	.218	-.382	-.508	-.168	-.481	.462	-.050	.172	.578	-.278	.430	-.354
pH					1	.674	.674	.699	-.754*	.705	-.130	.196	.732*	.764*	.744*	.129	.145	-.500	-.355	-.197	-.099	.373
EC						1	1.000**	.998**	-.786*	.825*	-.270	.418	.758*	.516	.744*	-.159	.085	-.247	-.640	.032	-.258	.484
TDS							1	.998**	-.789*	.819*	-.288	.434	.765*	.520	.752*	-.155	.093	-.254	-.651	.032	-.252	.490
Salt								1	-.803*	.839**	-.257	.408	.783*	.551	.771*	-.121	.089	-.258	-.630	-.011	-.251	.496
DO									1	-.520	.250	-.259	-.926**	-.725*	-.921**	.250	-.512	.643	.657	.255	.559	-.716*
Cl										1	.152	.082	.501	.516	.507	.200	-.354	.016	-.251	-.133	-.007	.239
CO											1	-.929**	-.447	-.081	-.422	.061	-.488	.325	.592	-.336	-.233	-.174
Alk												1	.435	.041	.406	-.030	.244	-.331	-.563	.427	.233	.092
Ca													1	.807*	.999**	.040	.505	-.518	-.722*	-.352	-.252	.735*
Mg														1	.836**	.412	.167	-.393	-.583	-.728*	-.098	.794*
Hard															1	.076	.486	-.514	-.717*	-.393	-.240	.750*
P																1	-.455	.334	.068	-.584	.738*	.063
S																	1	-.448	-.279	.024	-.372	.295
N																		1	.467	.026	.575	-.444
Cla																			1	.198	.259	-.834**
Cop																				1	.047	-.653
Rot																					1	-.434
Ost																						1

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

Table 6. Correlation between water parameters and zooplanktons during Post-Covid

	AT	WT	Hum	Tra	pH	EC	TDS	Salt	DO	Cl	CO	Alk	Ca	Mg	Hard	P	S	N	Cla	Cop	Rot	Ost
AT	1	.247	-.268	.069	-.009	-.017	-.028	.008	-.138	-.123	-.524	.231	.030	-.267	.023	-.089	.238	-.535	.212	-.035	.130	-.767*
WT		1	-.685	-.486	.536	-.089	-.096	-.067	.060	.016	-.280	.488	-.279	.369	-.271	.590	.096	-.377	.514	-.425	-.448	-.325
Hum			1	.192	-.211	.242	.243	.227	.380	-.282	-.050	-.170	.372	.076	.376	-.050	-.111	.468	-.480	-.173	.725*	.509
Tra				1	-.930**	-.403	-.394	-.408	-.621	-.190	-.258	.269	-.227	-.359	-.239	-.258	-.577	-.308	-.480	.731*	.226	-.378
pH					1	.495	.491	.502	.711*	.375	.349	-.026	.240	.570	.259	.306	.293	.068	.503	-.799*	-.089	.256
EC						1	1.000**	1.000**	.662	.560	.268	-.176	.942**	-.016	.949**	.131	.207	.102	-.448	-.207	.601	.373
TDS							1	.999**	.660	.571	.281	-.173	.939**	-.010	.947**	.126	.191	.098	-.451	-.201	.602	.376
Salt								1	.657	.553	.247	-.166	.940**	-.016	.948**	.146	.213	.081	-.439	-.213	.596	.350
DO									1	.438	.366	.097	.493	.481	.510	.029	.156	.425	.041	-.749*	.532	.601
Cl										1	.737*	.123	.368	.092	.375	-.352	-.129	-.024	-.076	.035	.187	.209
CO											1	-.268	.089	.278	.099	-.467	-.149	.286	.159	-.058	-.078	.488
Alk												1	-.322	.449	-.312	.268	-.598	-.465	.099	-.199	.208	-.363
Ca													1	-.290	1.000**	.063	.315	.178	-.645	-.003	.660	.355
Mg														1	-.264	.408	-.497	-.135	.517	-.755*	-.016	.136
Hard															1	.075	.303	.175	-.634	-.024	.664	.361
P																1	-.149	-.339	-.018	-.349	-.078	-.098
S																	1	.490	.092	-.130	-.174	.218
N																		1	-.154	-.166	.110	.877**
Cla																			1	-.546	-.621	-.268
Cop																				1	-.110	-.255
Rot																					1	.228
Ost																						1

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

0.929, P<0.01). Calcium was positively correlated with hardness (r=0.999, P<0.01), magnesium (r=0.807, P<0.05), Ostracoda (r=0.735, P<0.05) and negatively correlated with Cladocera (r=-0.722, P<0.05). Magnesium had a significant positive correlation with hardness (r=0.836, P<0.01), Ostracoda (r=0.794, P<0.05) and negative correlation with Copepoda (r=-0.728, P<0.05). Hardness was positively correlated with Ostracoda (r=0.750, P<0.05) and negatively correlated with Cladocera (r=-0.717, P<0.05). Phosphate was significantly correlated with Rotifera (r=0.738, P<0.05). In this Lake, Cladocera showed negative correlation with Ostracoda (r=-0.834, P<0.01) (Table 5).

Post-covid analysis

Air temperature was negatively correlated with Ostracoda (r=-0.767, P<0.05). Humidity was positively correlated with Rotifera (r=0.725, P<0.05). Transparency had negative correlation with pH (r=-0.930, P<0.01).pH was positively correlated with dissolved oxygen (DO) (r=0.711, P<0.05) and negatively correlated with Copepoda (r=-0.799, P<0.05) (Table 6). Electric conductivity (EC) was most significantly positively correlated with TDS (r=1.00, P<0.01), salinity (r=1.00, P<0.01), calcium (r=0.942, P<0.01) and hardness (r=0.949, P<0.01). TDS was positively significantly correlated with salinity (r=0.999, P<0.01), calcium (r=0.939, P<0.01) and hardness (r=0.947, P<0.01) (Table 6). The correlation of salinity with calcium (r=0.940, P<0.01)and hardness (r=0.948, P<0.01) depicts the highly significant positive values. DO had negative correlation with Copepoda (r=-0.749, P<0.05) (Table 6). Chloride was positively correlated with free carbon dioxide (r=0.737, P<0.05). Calcium readings at the present study site were highly significant possessing positive correlation with hardness (r=1.00, P<0.01). Magnesium was negatively correlated with Copepoda (r=-0.755, P<0.05). Nitrates had highly significant positive correlation with Ostracoda (r=0.877, P<0.01) (Table 6).

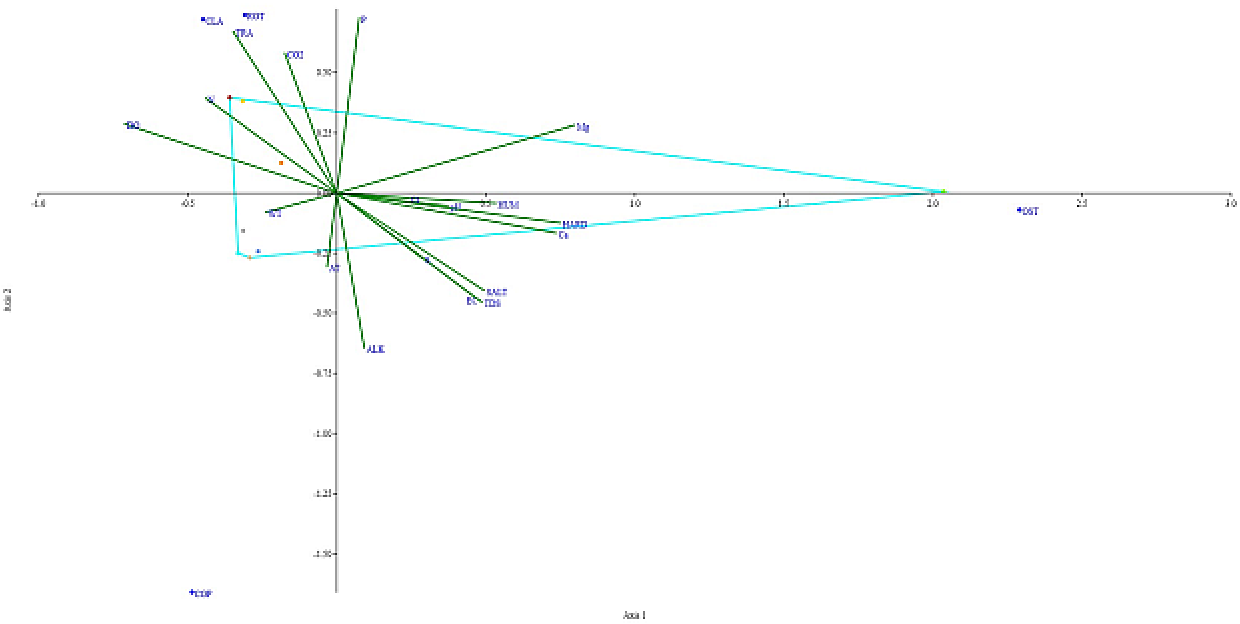

Figure 4. CCA during pre-Covid period

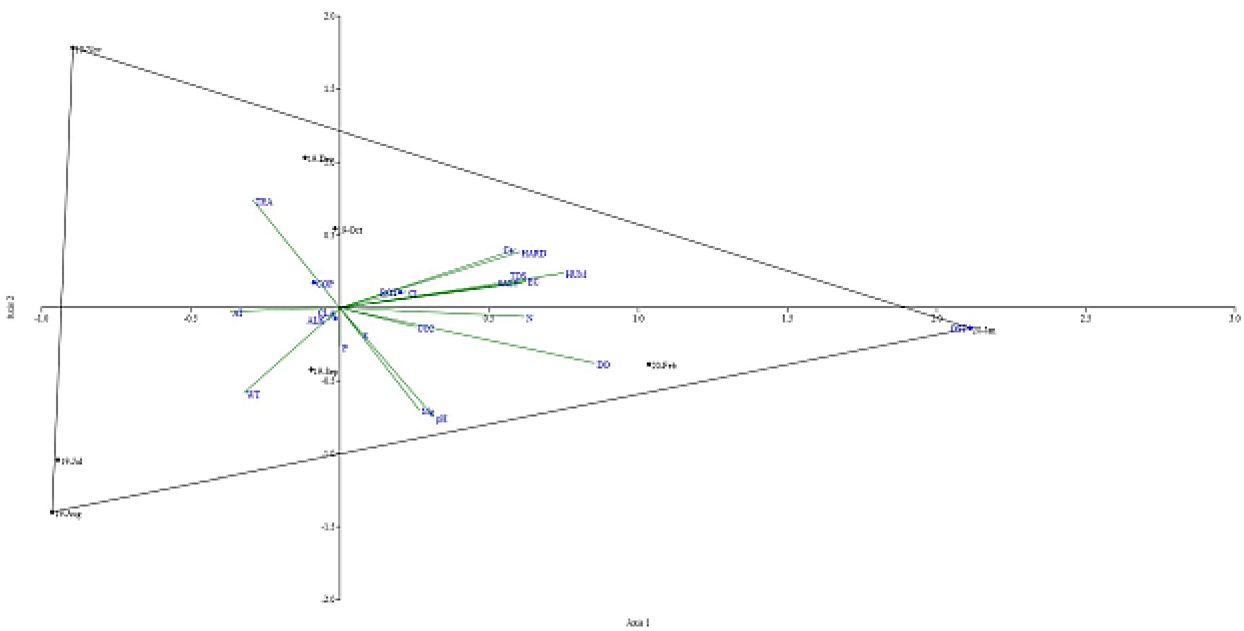

Figure 5. CCA during post-Covid period

Canonical Correspondence Analysis (CCA)

CCA was used to analyse and evaluate the relationships between the physical factors and the zooplankton groups in Chandravalli Lake, during pre-covid phase, the Eigen values for Axis-1 = 0.600, P = 0.90, Axis- 2 = 0.066, P = 0.335 and Axis-3 = 0.038, P = 0.625 were observed. Percentile calculations were, Axis-1 = 85.07%, Axis-2 = 9.44% and Axis-3 = 5.483% (Fig. 4). During post-covid the Eigen values for Axis-1 = 0.012, P = 0.63, Axis-2 = 0.011, P = 0.57 and Axis-3 = 0.006, P = 0.97. Percentile calculations were, Axis-1 = 41.75%, Axis-2 = 37.51% and Axis-3 = 20.91% (Fig. 5).

Diversity indices

Pre-Covid

Highest value for Shannon's and Simpson diversity index was noted for Cladocera where Copepoda expressed the lowest value. Species richness and diversity indices exhibited identical pattern (Table 7).

Post-Covid

Shannon's and Simpson diversity index was found to be highest for Cladocera and it was least for Ostracoda. Species richness and diversity indices exhibited identical pattern (Table 7).

Principal Component Analysis (PCA)

PCA was performed with a data set of eight month analysis (Fig. 6) for pre and post Covid analysis of water quality parameters and zooplanktons yielded seven principal components (Eigen values > 1) which all together explained 82.95% of the variance in the data. The first three components have explained 56.46% of the variance.

DISCUSSION

In the present study, water temperature remained higher than the atmospheric temperatureduring several months. Similar observations were done at Attiveri and Bachanaki reservoir by Kudari et al. (2006). Slightly alkaline condition was observed throughout the study period. Ahmad et al. (2011) and Ismail and Adnan (2016) also reported similar observations at Aligarh pond, Uttar Pradesh and Harapan and Aman Lakes, respectively. pH showed significant positive correlation with calcium and magnesium. Barbieri et al. (1999) also reported significant positive correlation of pH with calcium and magnesium. Electric conductivity is the capacity of liquid to conduct electric charge (Marandi 2013, Rusydi 2018) and it depends upon ionic

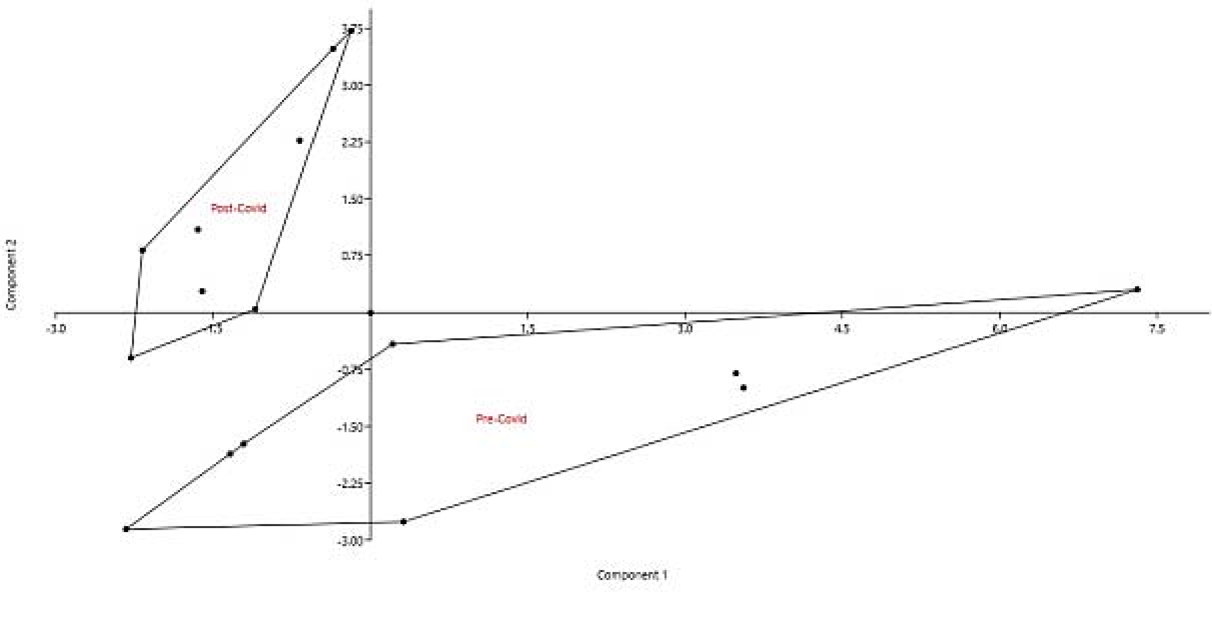

Figure 6. Principal Component Analysis for Chandravalli Lake using 18 physicochemical parameters during pre- and post-Covid

Table 7. Diversity indices of zooplanktons at Chandravalli Lake during Pre- and Post-Covid

	Pre-Covid				Post-Covid			
	Cladocera	Copepoda	Rotifera	Ostracoda	Cladocera	Copepoda	Rotifera	Ostracoda
Taxa_S	19	5	12	4	20	5	12	1
Individuals	369	219	122	133	559	168	104	1
Dominance (D)	0.1068	0.56	0.2018	0.3094	0.1125	0.3999	0.1359	1
Simpson (1-D)	0.8932	0.44	0.7982	0.6906	0.8875	0.6001	0.8641	0
Shannon (H)	2.508	0.8426	1.99	1.242	2.429	1.101	2.21	0
Evenness (E)	0.6465	0.4645	0.6097	0.8659	0.5672	0.6013	0.7593	1

concentration present in the water (Bose et al. 2019). The correlation and correspondence of electric conductivity was highly significant with TDS, chlorides, salinity, calcium and hardness. Kudari et al. (2006) and Pattan and Sunkad (2017) also observed similar pattern. Fluctuation in the inflow of water makes the TDS to vary (Manickam et al. 2018). Silt, clay and other materials of drainage and runoff water increases TDS value (Ahmad et al. 2011). During September, 2019 highest TDS was observed due to accumulation of silt, clay and other material brought by rain. TDS levels showed significant positive correlation with hardness and calcium. Correlation between TDS with hardness and calcium was also reported by Pattan and Sunkad (2017) at Kangrali water body of Belagavi. Salinity had negative correlation with DO; it may be due to reduced photosynthetic activity and increase in the decomposition process as suggested by Kotti et al. (2005) and Manickam et al. (2018). Depletion of DO may be due to the high concentration of organic matter in surface water (Kotti et al. 2005). In addition, the rate of pollution degradation reduces as the concentration of DO reduces (Haddout et al. 2022). The increase and decrease in dissolved oxygen value might be due to photosynthetic and respiratory activity in the water body (Kumar et al. 1991). Surana et al. (2010) observed decreasing DO values with increase in dissolved solids. Similarly, lowest value of DO was observed during summer season with high TDS and conductivity at Lake Pichhola, Udaipur, Rajasthan (Riddhi et al. 2011) and at Samrat Ashok Sagar of Maharashtra (Raina et al. 2013). In a water body the chloride levels are affected by the decomposition process (Birasal et al. 1987). Lesser the organic effluents lower the concentration of chloride (Kumar et al. 1992). Correlation of chlorides with free carbon dioxide at Chandravalli study site is a significant proof for the work of Birasal et al. (1987) at Supa reservoir and Kudari et al. (2006) at Bachanki reservoir. In the present study there were no much variationsin the free carbon dioxide levels, due to early sampling hours. The release of carbon dioxide during respiratory activity may increase in the bicarbonate alkalinity. As the values of alkalinity were under 30 mg/l, there was no such concern with respect to the acidification of the water body. In Chandravalli Lake, values of magnesium are of lowest, on the other hand, similar readings were recorded at AkwaIbom state, Nigeria for the analysis of pipe born water (Etim et al. 2013). The hardness concentration as $CaCO_3$ (44.6-116 mg/L) was moderately soft at Chandravalli Lake. The classification of water as soft (<50 mg/L) to very hard (>250mg/L) on the basis of hardness was done by Hegde and Kale (1995) and Kudari et al. (2006). Presence of excessive phosphate in a water system is due to the human activity (Korostynska et al. 2012). Presence of phosphate is a limiting factor for planktons as it is a factor of eutrophication that affects the productivity (Pennak 1946). In the present study Phosphate range from 0.002 to 0.005 mg/L which shows high productivity to low. The lower value of nitrate concentration indicates the water body as non-polluted as observed in River Wainganga by Chavan et al. (2012). Among zooplanktons Cladocerans prefer clean water, in the present study we have recorded highest species and abundance of Cladocerans as the water in the Lake is clear and supported more Cladocerans. Hosetti and Venkateshwarulu (2001) also made a similar observation. The number of Cladocerans was almost double in the post-covid period when compared to pre-covid. During the lockdown period there was no disturbance in the water body hence it was clear and responsible for more Cladocerans indicating low trophic level (Swar 1981). Cladocera showed an inverse relationship with Rotifera as they avoid competition between the groups; similar observations were made by Hulyal and Kaliwal (2008). In tropical freshwaters, Rotifers taxonomic richness is common, however in density their number is minimum (Kudari et al. 2006). In the present study though the group was represented with 14 species the abundance was low (226 individuals) and in this group *Keratella tropica* was the dominant individual. This was in accordance with the observations of Bhat et al. (2012) and Kudari et al. (2005). *K. cochlearis* was dominant than *K. tropica*. This was in accordance with the observations of Ferrara et al. (2002) and Pereira et al. (2002). Presence of Brachionus species indicates the water body having alkaline conditions (Shivashankar and Venkataramana 2013). They also act as indicators of eutrophication (Vladimir 1983). In the present study, Rotifers show significant positive correlation with phosphate ($r=0.738$, $P<0.05$). According to Vaidya and Mannikeri (2000), Ostracoda distribution depends on nature of sediment, salinity and depth. In the present study, Ostracoda had a negative correlation with atmospheric temperature, which depicts the favour towards low temperature, as observed by Hulyal and Kaliwal (2008). However, Ostracods showed negative correlation with Cladocera. Cladocera were dominant when the water was clear (Uttangi 2001) with high conductivity and Ostracods were dominant when the water was turbid with high values of TDS and hardness, which is a bottom dweller found abundant in sediments (Vaidya and Mannikeri 2000). During post-covid phase as the turbidity levels were low and no Ostracodes were observed. In Talsande and Attigre reservoirs similar pattern was observed (Hujare 2005).

CONCLUSION

In the physico-chemical parameters except for few, there were no prominent differences observed between the two phases. During post-covid phase the water was more transparent with less salinity which supported Cladocerans that increased to almost double the number observed in pre-covid phase. On the other hand Ostracodans almost vanished during post-covid phase. *Bosminopsis deitersi* was the most abundant individual in the group Cladocera and *Tropocyclops prasinus* was the most abundant Copepodan representative. *Keratella tropica* and *K. cochlearis* were the most abundant species of Rotifera. The present study indicates that the Chandravalli Lake responds quickly to the environmental changes by both biotic and abiotic factors. The presence of eutrophic indicators like *Brachionus, Keratella* and *Trichocerca* indicates that regular monitoring and analysisare needed to protect and conserve this historic water body from degradation.

ACKNOWLEDGEMENTS

The first author sincerely thanks Karnatak University for providing University Research Scholarship for the study and his brother Jayabasavaraj S.K. for helping in collecting the water samples. BSK acknowledge Dr. Harsha D. Neelgund for providing the MagCam-DC5 to capture the zooplankton pictures, Mr. Manjunath B. Hosamani for training in SPSS and Mr. Rahul M. Handi for support and encouragement.

Authors' contributions: Both the authors contributed equally

Conflict of interest: Authors declare no conflict of interest

REFERENCES

Abdulwahab, S. and Rabee, A.M. 2015.Ecological factors affecting the distribution of the zooplankton community in the Tigris River at Baghdad region, Iraq. The Egyptian Journal of Aquatic Research, 41(2), 187-196. https://doi.org/10.1016/j.ejar.2015.03.003.

Ahmed, U., Parveen, S., Khan, A.A., Kabir, H.A., Mola, H.R.A. and Ganai, A.H. 2011. Zooplankton population in relation to physic-chemical factors of a sewage fed pond of Aligarh (UP), India. Biology and Medicine, 3, 336-341. https://www.walshmedicalmedia.com/open-access/zooplankton-population-in-relation-to-physicochemical-factors-of-a-sewage-fed-pond-of-aligarh-up-india-0974-8369-3-123.pdf

Anonymous. 1980. Standard Methods for Examination of Water and Waste Water.15th edition, APHA AWWA WPCF, Washington. D.C.

Banakar, A.B., Kiran, B.R., Puttaiah, E.T., Purushotham, R. and Manjappa, S. 2005. Hydrochemical characteristics of surface water in Chandravalli Pond, Near Chitradurga. Indian Journal of Environmental Protection, 25(3), 249-253.

Barbieri, A., Veronesi, M., Simona, M., Malusardi, S. and Straskrabova, V. 1999. Limnological survey in eight high mountain Lakes located in Lago Maggiore watershed (Switzerland). Journal of Limnology, 58(2), 179-192. https://doi.org/10.4081/jlimnol.1999.179

Bhat, N.A., Wanganeo, A. and Wanganeo, R. 2012. Composition and dynamics of Rotifera fauna from Upper Basin (Bhoj wetland) as parameter of water quality. International Journal of Applied Biology and Pharmaceutical Technology, 3(3), 373-381.

Birasal, N.R., Nadkarni, V.B. and Gouder, B.Y.M. 1987. The first five months of the Supa reservoir, river Kali, India. Regulated Rivers: Research and Management, 1(3), 275-281. https://doi.org/10.1002/rrr.3450010308

Bose, R., Bose, A.K. and Das, A.K. 2019. Fish diversity and limnological parameters Influencing fish assemblage pattern in Chambal River Basin of Madhya Pradesh, India. Proceedings of the National Academy of Sciences, India,Section. B. Biological Sciences,89, 461-473. https://doi.org/10.1007/s40011-017-0958-5.

Chavan, A.W., Dhamani, A.A. and Murkute, V.B. 2006. Seasonal variation in the physicochemical parameter of river Wainanga near Bramhapuri, Dist: Chandrapur. Vidhyabharati: International Interdisciplinary Research Journal, 1, 28-35.

Dorak, Z. 2013. Zooplankton abundance in the lower Sakarya River Basin (Turkey): Impact of environmental variables. Journal of Black Sea/Mediterranean Environment, 19(1), 1-22. https://dergipark.org.tr/en/download/article-file/103620

Edmondson, C. H. 1959. Hawaiian Grapsidae. Occasional Papers of the Bernice P. Bishop Museum, 22, 153-202.

Etim, E.E., Odoh, R., Itodo, A.U., Umoh, S.D. and Lawal, U. 2013. Water quality index for the assessment of water quality from different sources in the Niger Delta Region of Nigeria. Frontiers in Science, 3(3), 89-95.

Ferrara, O., Vagaggini, D. and Margaritora, F.G. 2002.Zooplankton abundance and diversity in Lake Bracciano, Latium, Italy.Journal of Limnology, 61(2): 169-175. https://doi.org/10.4081/jlimnol.2002.169.

Ghosh, A. (Ed). 1990. An Encyclopaedia of Indian Archaeology. India: Brill. ISBN: 90-04-09262-5.

Haddout, S., Priya, K.L., Hoguane, A.M., Cecilia, J. Casila, C. and Ljubenkov, I. 2022. Relationship of salinity, temperature, pH, and transparency to dissolved oxygen in the Bouregreg estuary (Morocco): First results. Water Practice & Technology, 17(12), 2654-2663. https://doi.org/10.2166/wpt.2022.144

Hammer, Ø., Harper, D.A. and Ryan, P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica, 4(1), 9. https://palaeo-electronica.org/2001_1/past/past.pdf

Hegde, G. and Kale, Y.S. 1995. Quality of lentic waters of Dharwad District in North Karnataka. Indian Journal of Environmental Health, 37(1), 52-56.

Hosetti, B.B. and Venkateshwarlu, M. 2001.Trends in Wildlife Biodiversity Conservation and Management (Vol. 1). Daya Books, New Delhi.

Hujare, M.S. 2005. Hydrobiology studies on some water reservoirs of Talsande and Attigre Maharashtra. Ph.D. Thesis submitted to Shivaji University, Kolhapur India.

Hulyal, S.B. and Kaliwal, B.B. 2008. Dynamics of phytoplankton in relation to physico-chemical factors of Almatti reservoir of Bijapur District, Karnataka State. Environmental Monitoring and Assessment, 153(1-4), 45–59. https://doi.org/10.1007/s10661-008-0335-1.

Ismail, A.H. and Adnan, A.A. 2016. Zooplankton composition and abundance as indicators of eutrophication in two small man-made lakes.Tropical Life Sciences Research, 27(supp1), 31–38. https://doi.org/10.21315/tlsr2016.27.3.5.

Korostynska, O., Mason, A. and Al-Shamma'a, A. 2012. Monitoring of nitrates and phosphates in wastewater: Current technologies and further challenges. International Journal on Smart Sensing and Intelligent systems, 5(1), 149-176. https://doi.org/10.21307/ijssis-2017-475

Kotti, M.E., Vlessidis, A.G., Thanasoulias, N.C. and Evmiridis, N.P. 2005. Assessment of river water quality in Northwestern Greece. Water Resources Management, 19, 77-94. http://dx.doi.org/10.1007/s11269-005-0294-z.

Kudari, V.A., Kadadevaru, G.G. and Kanamadi, R.D. 2005. Zooplankton composition in some ponds of Haveri district, Karnataka. Zoos' Print Journal, 20(12), 2094-2099.

Kudari, V.A., Kadadevaru, G.G. and Kanamadi, R.D. 2006. Characterisation of selected lentic habitats of Dharwad, Haveri and Uttar Kannada districts of Karnataka State, India. Environmental Monitoring and Assessment, 120, 387-405. https://doi.org/10.1007/s10661-005-9069-5.

Kudari, V.A., Kanamadi, R.D. and Kadadevaru, G.G. 2006. Limnological studies of Attiveri and Bachanki Reservoirs of Uttar Kannada District, Karnataka, India. Ecology, Environment and Conservation, 12(1), 87.

Manickam, N., Bhavan, P.S., Santhanam, P., Bhuvaneswari, R., Muralisankar, T., Srinivasan, V. and Karthik, M. 2018. Impact of seasonal changes in zooplankton biodiversity in Ukkadam Lake, Coimbatore, Tamil Nadu, India, and potential future implications of climate change. The Journal of Basic and Applied Zoology, 79, 1-10. https://doi.org/10.1186/s41936-018-0029-3.

Marandi, A., Polikarpus, M. and Jõeleht, A. 2013.A new approach for describing the relationship between electrical conductivity and major anion concentration in natural waters. Applied Geochemistry, 38, 103-109. https://10.1088/1755-1315/118/1/012019.

Patil, C.S. and Gouder, B.Y.M. 1989. Freshwater Invertebrates of Dharwad, Karnataka State, India. Prasaranga, Karnatak University, Dharwad, India. 144 pages.

Pattan, K.I. and Sunkad, B.N. 2017. Water quality assessment of Kangrali water body of Belagavi. International Journal of Innovative Research in Science, Engineering and Technology, 6(3).

Pereira, R., Soares, A.M., Ribeiro, R. and Gonçalves, F. 2002. Assessing the trophic state of Linhoslake: A first step towards ecological rehabilitation.Journal of Environmental Management, 64(3), 285–297. https://doi.org/10.1006/jema.2001.0521

Raina, R., Kumar, P., Sonaullah, F. and Wanganeo, A. 2013. Limnological study on a Samrat Ashok Sagar with special reference to zooplankton population. International Journal of Biodiversity and Conservation, 5(6), 317-332. https://10.5897/IJBC2013.0568.

Ridhhi, S., Sharma, V., Sharma, M.S., Verma, B.K., Rachana, M. and Gaur, K.S. 2011. Studies on limnological characteristics, planktonic diversity and fishes (species) in Lake Pichhola, Udaipur, Rajasthan (India). Universal Journal of Environmental Research and Technology, 1(3), 274-285.

Pennak, R.W. 1946. The dynamics of Fresh-water Plankton Populations. Ecological Monographs, 16(4), 339-355. https://doi.org/10.2307/1961640.

Rusydi, A.F. 2018. Correlation between conductivity and total dissolved solid in various type of water: A review. IOP Conference Series: Earth and Environmental Science, 118, 012019. https://doi.org/10.1088/1755-1315/118/1/012019.

Shivashankar, P and Venkataramana, G.V. 2013. Zoplankton diversity and their seasonal variations of Bhadra reservoir, Karnataka, India. International Research Journal of Environmental Sciences, 2(5), 87-91.

Singh, S., Kumari, V., Usmani, E., Dutta, R., Kumari, R., Kumari, J. and Arif, M. 2021. Study on zooplankton diversity in a fresh water pond (Raja Bandh) of Jamtara, Jharkhand, India. International Journal of Advancement in Life Sciences Research, 4(2), 5-13. https://doi.org/10.31632/ijalsr.2021.v04i02.002.

Surana, R., Subba, B. and Limbu, K. 2010. Physico-chemical studies on Chimdi Lake of Sunsari District during its restoration stage. Our Nature, 8(1), 258-269. https://doi.org/10.3126/on.v8i1.4337.

Swar, D.B. 1981. Seasonal abundance of limnetic crustacean zooplankton in Lake Phewa, Pokhara Valley, Nepal. Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen, 21(1), 535-538. https://doi.org/10.1080/03680770.1980. 11897037

Uttangi, J.C. 2001. Conservation and management strategy for the water fowls of minor irrigation tank habitats and their importance as stopover site in the Dharwad district. pp. 179-221. In: Hosetti, B.B. and Venkateshwaralu, M. (Eds.) Trends in Wildlife and Management.Daya Publication House, New Delhi, India.

Vaidya, A.S. and Mannikeri, M.S. 2000. Ostracode as ecological indices from the west coast of India. IGCP – 367.

Vijaykumar, K., Paul, R and Kadadevaru, G. 1991. Physico-chemical features of Attikolla pond during pre-monsoon period. Journal of Environmental Ecology, 9(2), 393-395.

Vijaykumar, K., Paul, R. and Kadadevaru, G. 1992. Diel cycle of physico-chemical features of freshwater tank. Journal of Environmental Ecology, 10(2), 421-423.

Sladecek, V. 1983. Rotifers as indicators of water quality. Hydrobiologia, 100, 169-201. https://doi.org/10.1007/BF00027429

Yang, X.E., Wu, X., Hao, H.L. and He, Z.L. 2008.Mechanisms and assessment of water eutrophication. Journal of Zhejiang University, Science B, 9(3), 197-209. https://doi.org/10.1631/jzus.B0710626.

Received: 13th June 2023
Accepted: 7th November 2023