Seasonal variations in the abundance of zooplankton groups in relation with physico-chemical parameters in three lotic ecosystems of Mysore

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ABSTRACT

Zooplanktons are microscopic organisms, which are integral components of aquatic food web, as they contribute significantly to productivity of freshwater ecosystems. They are also very sensitive to environmental changes; therefore they make ideal indicator organisms. Total zooplankton (Rotifer, Cladocera, Copepod and Ostracod) abundance was significantly more in Cauvery river with the mean abundance of 18 Org/L compared to Kapila river (15 Org/L) and at their confluence site (14 Org/L). Rotifers were the dominant groups in all the three sampling sites followed by Cladocera, Copepod and Ostracod throughout the study period of two years. The highest fortnightly variation in the abundance was shown by Rotifers in Cauvery and Kapila rivers with CV 52% and 61% respectively. Whereas, at the confluence site, the Copepod showed more (CV=51%) fortnightly variation. The season (rainy, winter and summer) wise grouped data revealed that the abundance of zooplankton was highest in rainy season followed by winter and summer seasons. The mean abundance of zooplankton showed significant differences in all the three seasons in Cauvery and Kapila rivers. Whereas, at the confluence site, winter and summer seasons were significantly similar but rainy season showed significant difference. Overall, the results indicated that the abundance of zooplankton showed decreasing tendency in Cauvery river after it joined with Kapila river. It is interesting and noteworthy to note that Copepod-calanoid group was completely absent in all the three sampling sites throughout the study period. Copepod- herpacticoids are present only in Cauvery river and were completely absent from the remaining ecosystems. The regression analysis revealed that in Cauvery River 49% of total zooplankton abundance was controlled by conductivity, in Kapila river, 52% of total zooplankton abundance was controlled by hardness and 43% of DO negatively controlled the total zooplankton abundance at the confluence site. Hence, this study suggests that the zooplankton may be good indicators of the variations in the water quality of these three lotic ecosystems.

Keywords: Cauvery river, Kapila river, confluence site, zooplankton, physico-chemical parameters

INTRODUCTION

Freshwater is the most essential requirement for life and yet comprises only <1% of the Earth's surface water [1]. Sustainable and optimal use of natural resources is imperative in any country due to its concomitant economic implications such as industrial and population growth infrastructure and development demand. Plankton is a part of aquatic life, which is composed of tiny organisms, living and drifting in the direction of water current. It acts as the main source of food for most fauna, both in lotic and lentic water ecosystems. Studies on the structure and functioning of planktonic communities in lotic ecosystems provide opportunities to investigate patterns of

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responses to cyclical variations and episodic disturbances [2]. The understanding of plankton dynamics can also be useful to evaluate the resilience of ecosystem.

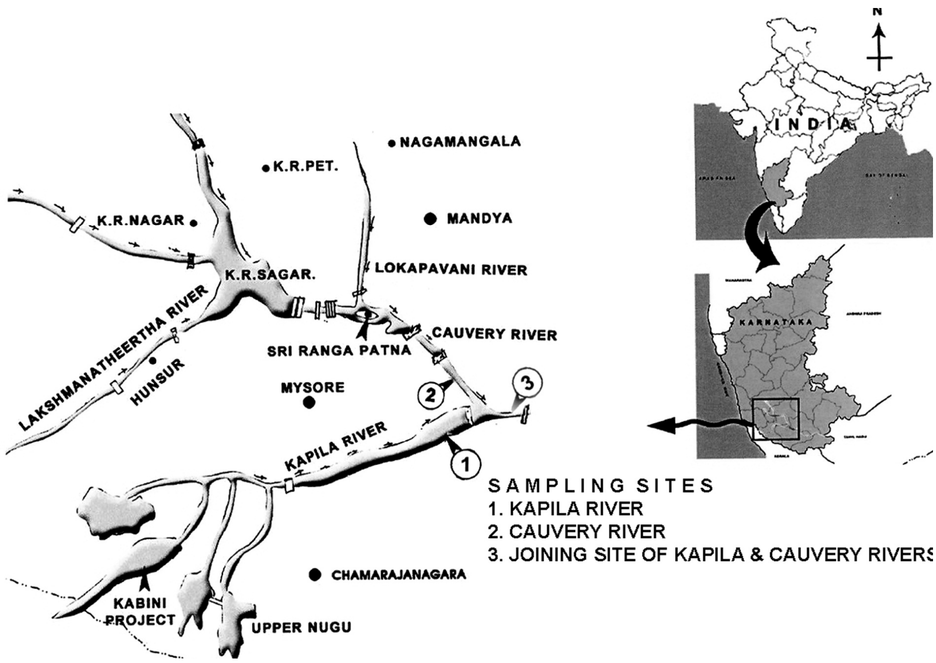
Fresh water zooplankton is an important biological component in aquatic ecosystems, whose main function is to act as a primary and secondary links in the food chain. Zooplanktons are the important aquatic organisms occurring abundantly in all types of aquatic habitats, and they play a vital role in energy transfer of aquatic ecosystems [3]. Zooplankton constitutes important food item of many omnivorous and carnivorous fish [4]. Light and predation are the important ecological factors regulating zooplankton abundance and distribution [5]. Zooplankton is the most valuable as indicator of tropic status than generally been realized, since they are larger and easier to identify than phytoplankton [6]. Zooplankton provides the necessary amount of protein required for rapid growth and development of different organs of fish [7]. The zooplankton community, which is closely related to all other components of the biota (phytoplankton, bacterioplankton, fish and benthos), is sensitive indicators of the state of the aquatic environment which allows ecologists to include it in the system of monitoring of water status.

Diverse studies have been carried out on the abundance of zooplankton in various rivers in India [8-11]. Few studies on zooplankton community of Cauvery river water have also been carried out. Shahul Hameed [12] made observations about the abundance of zooplanktons in Cauvery river at Madikeri district, Karnataka and reported that the Radium concentration was high in Cauvery river water and this adversely affected the plankton population. Mathivanan et al. [13] studied the assessment of plankton population of Cauvery river with reference to pollution at Salem district, Tamilnadu. They have reported that Cauvery river water showed high zooplankton population and Rotifers were dominant group.

There are few studies have been carried out on zooplankton from our laboratory, unpublished results on zooplankton studies on river Cauvery and its tributaries like Shimsa, Arkavathy, Suvarnavathy, Kapila rivers, Lekshmanatheertha, Harangi, Hemavathy, Lokpavany, and Cauvery river ecosystems. Koorosh et al. [14] made investigative studies about the abundance of Copepods on three contrasting lentic ecosystems in Mysore and reported that the Copepod abundance was less than that of Rotifers. He also studied about the Biodiversity of four groups of zooplanktons. Beenamma Joseph and Yamakanamardi [15] have reported the abundance of zooplankton from Kukkarahalli lake for one year and noted that abundance was very low during rainy season probably due to high concentration of phosphate and nitrate and also Calanoids and Harpacticoids were completely absent throughout their study period. Savitha and Yamakanamardi [16] studied the abundance of zooplankton in three lakes of Mysore and reported that zooplanktons are the indicators of water pollution and also found out that the total abundance of zooplankton was high in polluted lake (Dalvoy) when compared to the other two lakes (Kalale and Alanahalli) studied. Other available reports about Cauvery and Kapila rivers are only on physico-chemical parameters. To the best of our knowledge, the zooplankton abundance of Cauvery and Kapila rivers and at their confluence has not been studied so far. Hence, the aim of this investigation was to find out season (winter, rainy and summer) wise changes in the abundance of zooplankton groups of river Cauvery and Kapila and at their confluence site.

MATERIALS AND METHODS

The location of sampling sites is shown in figure 1. The first sampling site was on river Cauvery which is one of the 14 major rivers of India and eighth largest river in India. River Cauvery originates in the Bramhagiri hills of 'Saiya Mountains' in the Western Ghats of Madikeri District. The second sampling site was on Kapila river, which is one of the important tributaries of river Cauvery and originates in Western Ghats at an altitude of 7000 ft and about 6km north of Panamaram in Wayanad district of Kerala State. The third sampling site was at the confluence of these two rivers at Tirumakudalu Narasipura, Mysore, which is considered as a sacred place, also known as Dakshina Kashi. Surface water samples were collected fortnightly for two years from June 2009 to May 2011 from all the three sampling sites. To study the abundance for different groups of zooplankton, one hundred liters of water sample was collected from each sampling site and filtered through 60µm mesh size net. Soon after collection, concentrated zooplankton was fixed and preserved using 4% formalin. After returning to the laboratory, to estimate the zooplankton abundance, the modified Sedgwick Rafter method as given in Kamaladasa [17] was followed. One ml from the concentrated sample from each sampling site was transferred in to Sedgwick Rafter counting chamber and observed under Olympus binocular microscope. The abundance of four groups (Rotifer, Cladocera, Copepod, and Ostracod) of zooplankton was carried out using the following formula as given in APHA [20]: number of organisms/m^3 $= C \times V_1 / V_2 \times V_3$, where, C= number of organisms counted, V_1= volume of concentrated sample (50 ml), V_2= volume of sample counted (1 ml), V_3= volume of grab sample ($0.1m^3$). Finally, to obtain organisms/L, the number of organisms per m^3 was divided by 1000. The physico-chemical parameters were done by using standard methods given in APHA [18] and Trivedi and Goel [19]. The statistical analysis was done by using SPSS 11.5 version.



RESULTS AND DISCUSSION

The mean abundance of zooplankton groups (Rotifer, Cladocera, Copepod and Ostracod) is given in table 1. It shows, the zooplankton population of the Cauvery river, Kapila river and at their confluence site comprised with Rotifers, Cladocerans, Copepods and Ostracod. All major groups of zooplanktons were present throughout the two years of investigation. Highest fortnightly variation in their abundance was shown by Rotifers in Cauvery river (CV=52%) and Kapila river (CV=61%) whereas, at the confluence site, Copepod showed more (CV=51%) fortnightly variation. The least fortnightly variation in their abundance was shown by Copepod in Cauvery river (CV=26) and at the Confluence site (CV=31). In Kapila river the least fortnightly variation was shown by Ostracod group (CV=31). The mean abundance of Rotifer and total zooplankton in Cauvery river showed significant differences from the other two sites. Whereas, Cladocera, Copepod and Ostracod groups did not show any significant differences. From the result it is clear that the total zooplankton abundance was significantly high in Cauvery river followed by Kapila river and at their confluence site (Table 1).

Table 1. Summary of the Abundance of Zooplankton variables (Org/L) in Kapila, Cauvery and at the confluence of both the rivers, June 2009-May 2011.

Zooplankton	Cauvery river			Kapila river			Confluence site			F	P Value
Variables	Mean	Range	CV (%)	Mean	Range	CV (%)	Mean	Range	CV (%)	value	
Rotifer	8^{b}	2-13	51	6^{a}	2-17	68	6^{a}	2-13	49	4.56	0.01*
Cladocera	4^{a}	1-8	44	3^{a}	1-8	50	4^{a}	2-9	42	0.37	0.964^{NS}
Copepoda	4^{a}	2-5	26	3^{a}	2-5	33	3^{a}	2-5	31	2.06	0.131^{NS}
Ostracod	2^{a}	1-5	44	3^{a}	1-6	31	2^{a}	1-5	33	0.18	0.889^{NS}
Total	18^{b}	7-29	36	15^{a}	7-31	42	14^{a}	8-28	35	5.21	0.001**

n=48; CV=Coefficient of variation; the superscripts are obtained from ANOVA post hoc non parametric test (Student- Newman Keuls Test); *=significant, p=<0.05. NS=non significant, p>0.05.

Abundance of Rotifer

The highest Rotifer abundance was observed during the period of June 2009 at Cauvery river, however, at Kapila river and at the confluence site, the highest abundance was found during July 2009. The result showed that, Rotifer abundance was more in Cauvery river Compared to Kapila river and at the confluence site. Similar results reported by Mathivanan et al. [13], they studied the assessment of plankton population of Cauvery river with reference to pollution at Salem district, Tamilnadu and reported that Cauvery river water shows high zooplankton population and Rotifers were the dominant group. The relationship between Rotifer and physico-chemical parameters was found out by using the correlation co-efficient test (Table 5). The result reveled that at the Cauvery river the abundance of Rotifer showed positive correlation with 17 physico-chemical parameters and negative correlation with DO and BOD. In the Kapila river, Rotifer abundance showed positive correlation with 10 physico-chemical parameters and negative correlation with 4 parameters. Whereas, at the confluence site, Rotifer abundance showed positive correlation with 9 physico-chemical parameters and negative correlation with BOD. The stepwise multiple regression analysis (Table 7) revealed that, 66% of Rotifer abundance was positively controlled by conductivity in Cauvery river. Whereas, 59% and 56% of Rotifer abundance at the Kapila river and at the confluence site were positively controlled by hardness respectively. From the regression analysis, it is clear that the physico-chemical parameters like conductivity and hardness were highly affecting the Rotifer abundance. Frutos et al. [20] reported almost similar result on their study on the zooplankton abundance on Paraguay river. The season wise grouped data (Table 2, 3 and 4) showed that in Cauvery river, Kapila river and at the confluence site the abundance of Rotifer was significantly different between the three seasons in both the years. The abundance was significantly more in rainy season followed by winter and summer seasons during first year of study. Whereas, during second year of study, the abundance was significantly more in rainy season and significantly similar during winter and summer seasons. The result reveled that Rotifer abundance showed significant differences between the seasons in both the years.

Abundance of Cladocera

It is noteworthy to note that the Cladocera abundance was more during September 2009 in all the three sampling sites. The relationship between Cladoceran abundance and physico-chemical parameters (Table 5) showed that the abundance of Cladocera positively correlated with 11 physico-chemical parameters and has negative correlation with BOD in Cauvery river. At Kapila river, Cladocera was shown 8 positive correlations and 3 negative correlations with physico-chemical parameters and at the confluence site the abundance of Cladocera showed 5 positive correlations and one negative correlation with physico-chemical parameters. The step wise regression analysis (Table 7) showed that, 43% of Cladoceran abundance was positively controlled by turbidity in Cauvery river. The 31% of Cladocera abundance in Kapila river was positively controlled by TSS and at the confluence site 17 % of Cladocera abundance was positively controlled by chlorophyll-a. The result described that the turbidity, TSS and chlorophyll are the major factors which are affecting the abundance of Cladocera. There are few studies which are supporting our findings. Jayabhaye [11] studied on zooplankton diversity of river Kayadhu and reported almost similar result. Anna Basińska [21] studied on the diurnal distribution of cladocerans and reported that Cladocerans are strongly correlated with chlorophyll-a. The season wise grouped data (Table 2, 3 and 4) showed that at Cauvery and Kapila rivers, the abundance of Cladocera was significantly similar in both rainy and winter seasons and summer season showed significant differences. Whereas, at the confluence site the Cladocera abundance showed significant difference in rainy season, winter and summer seasons were significantly similar. It is noteworthy to note that the abundance of Cladocera in rainy and winter season was significantly similar in both Cauvery and Kapila rivers.

Table 2. Season wise comparison of Zooplankton abundance in Cauvery river, June 2009 to May 2011.

Zooplankton variables	Sampling period	Rainy season	Winter season	Summer season	F-value	P-value
Rotifer	1st Year	11^c	5^b	3^a	47.62	0.000**
	2nd Year	12^b	5^a	3^a	24.68	0.000**
Cladocera	1st Year	4^b	4^b	2^a	8.99	0.020*
	2nd Year	6^b	5^b	2^a	9.21	0.001*
Copepod	1st Year	5^b	3^a	2^a	4.74	0.021*
	2nd Year	4^a	3^a	3^a	2.81	0.082
Ostracod	1st Year	3^b	4^a	2^a	4.27	0.021*
	2nd Year	3^a	4^a	2^a	2.53	0.099
	1st Year	22^c	16^b	9^a	34.62	0.000**
Total ZP	2nd Year	23^c	15^b	10^a	23.06	0.000**

n=48; the superscripts are obtained from ANOVA post hoc non parametric test (Student-Newman Keuls Test); *=significant, p=<0.05; NS=non significant, p>0.05; ZP=Zooplankton.

Table 3. Season wise comparison of Zooplankton abundance in Kapila river, June 2009 to May 2011.

Zooplankton variables	Sampling period	Rainy season	Winter season	Summer season	P-value	F-value
Rotifer	1st Year	10^c	6^b	3^a	23.65	0.000**
	2nd Year	10^b	6^b	4^a	20.04	0.000**
Cladocera	1st Year	5^b	4^b	3^a	14.12	0.000**
	2nd Year	5^b	4^a	3^a	11.12	0.001*
Copepod	1st Year	5^b	4^a	3^a	4.11	0.031*
	2nd Year	4^a	3^a	3^a	3.35	0.053
Ostracod	1st Year	3^a	3^a	2^a	1.72	0.196
	2nd Year	3^a	2^a	2^a	1.08	0.356
	1st Year	22^c	16^b	8^a	32.25	0.000**
Total ZP	2nd Year	20^c	14^b	11^a	23.52	0.000**

n=48; the superscripts are obtained from ANOVA post hoc non parametric test (Student-Newman Keuls Test); *=significant, p=<0.05; NS=non-significant, p>0.05; ZP=Zooplankton.

Table 4. Season wise comparison of Zooplankton abundance in the confluence site, June 2009 to May 2011.

Zooplankton variables	Sampling period	Rainy season	Winter season	Summer season	P value	f-value
Rotifer	1st Year	9^b	4^a	3^a	22.54	0.000**
	2nd Year	9^b	5^a	4^a	21.36	0.000**
Cladocera	1st Year	5^b	4^a	3^a	6.19	0.008*
	2nd Year	5^b	3^a	3^a	8.05	0.002*
Copepod	1st Year	4^a	3^a	2^a	2.87	0.078
	2nd Year	3^a	3^a	3^a	1.26	0.308
Ostracod	1st Year	3^a	2^a	2^a	0.37	0.695
	2nd Year	3^a	2^a	2^a	0.54	0.586
Total ZP	1st Year	21^b	13^a	11^a	17.93	0.001*
	2nd Year	19^b	11^a	10^a	15.64	0.002*

N=48; the superscripts are obtained from ANOVA post hoc non parametric test (Student-Newman Keuls Test); *=significant, p=<0.05; NS=non-significant, p>0.05; ZP=Zooplankton.

Abundance of Copepod

During August 2009 more Copepod abundance observed in both Cauvery and Kapila rivers. Whereas, at the confluence site, the more Copepod abundance is observed in September 2009. Correlation analysis (Table 6) showed, in Cauvery river the Copepod abundance shows positive correlation with 9 physico-chemical parameters and at the Kapila river the Copepod abundance was positively correlated with 7 physico-chemical and negatively correlated with 2 physico-chemical parameters. At the confluence site, Copepod abundance was positively correlated with 7 physico-chemical parameters whereas, the Copepod abundance did not show any negative correlation with physico-chemical parameters in both Cauvery and at the confluence site. It is important to note that, though the copepod abundance was not showing any negative correlations with the physico-chemical parameters, the abundance of Copepod was less in all the three sampling sites as compared with rotifer and Cladocera. According to Wojciech et al. [22] Copepods serve as food for fishes, so predation might be the main reason for less abundance of Copepods. The regression analysis (Table 8) showed, 18% of Copepod abundance was positively controlled by POM in Cauvery river. However, at Kapila river 29% of Copepod abundance was positively controlled by Hardness and at the confluence site, Turbidity was positively controlled by 14% of Copepod abundance. The season wise grouped data (Table 2, 3 and 4) showed that at the Cauvery and Kapila rivers, the abundance of Copepod showed significant difference during first year of the study and during second year the Copepod abundance did not showed significant difference between the seasons. Interestingly, at the confluence site, the abundance of Copepod was significantly similar in all the three seasons of both the years. It is interesting and noteworthy to note that Copepod-calanoid group was completely absent in all the three sampling sites throughout the study period. Copepod- herpacticoids are present only in Cauvery river and were completely absent from Kapila river and at the confluence site of Cauvery and Kapila rivers. This result clearly indicated that Copepod-calanoid and Copepod-herpacticoids groups are good indicators of water pollution. These groups are highly sensitive to environmental pollution. Beenamma joseph and Yamakanamardi [15] also reported the similar results on their study about Kukkarahally Lake, Mysore.

Abundance of Ostracod

Fortnightly variations of Ostracod abundance revealed that, the abundance was more in September 2009 at Cauvery and at the confluence site. In the Kapila river, highest Ostracod abundance was observed in the month of September 2010. The relationship between Ostracod abundance and physico-chemical parameters (Table 6) showed that, the abundance of Ostracod positively correlated with 3 physico-chemical parameters and negatively correlated with Chloride and BOD in Cauvery river and at the confluence site. Ostracod abundance showed positive correlation with water temperature and negative correlation with turbidity and chlorophyll-a. It's noteworthy that Ostracod did not show any correlation at the Kapila river. The regression analysis (Table 8) revealed that, 20% of Ostracod abundance was positively affected by conductivity in Cauvery river and 11% Ostracod abundance at the confluence site was negatively controlled by turbidity. Whereas, physico-chemical parameters did not affect the growth and abundance of Ostracod group in Kapila river. The season wise grouped data (Table 2, 3 and 4) showed that Ostracod groups are significantly similar in all the three seasons in Kapila and at the confluence site in both the years. Cauvery river, the Ostracod abundance was significantly different during first year of study whereas, significantly similar during second year. Badsi et al. [23] on their study about the ecological factors affecting the distribution of zooplankton community in the Massa lagoon, suggested that, Ostracods are tolerant to extreme environmental conditions. Hence, this might be a reason for the Ostracod abundance showing significant similarity between the seasons.

Table 5. Co-relationship between environmental parameters and Zooplankton groups of Cauvery river, Kapila river and at their confluence, June 2009 to May 2011.

Environmental	Rotifer			Cladocera		
variables	Cauvery	Kapila	Confluence	Cauvery	Kapila	Confluence
AT	0.297*	NS	0.431**	NS	NS	NS
WT	0.315*	0.285*	0.494**	NS	NS	NS
PH(F)	0.463**	0.352*	0.640**	NS	NS	0.300*
PH(L)	0.463**	0.404**	0.660**	NS	0.310*	0.288*
Cond	0.595**	0.401**	NS	0.477**	0.453**	NS
Turb	0.383**	0.563**	0.607**	0.652**	0.463**	0.313*
DO	-0.524*	-0.677**	NS	NS	-0.517**	-0.391**
BOD	-0.367*	NS	-0.699**	-0.335*	NS	NS
COD	0.511**	NS	0.426**	0.317*	NS	NS
CO2	NS	NS	NS	0.390**	NS	NS
Hard	0.676**	0.672**	0.751**	0.323*	0.487**	0.318*
Cal	0.334*	-0.358*	NS	NS	-0.345*	NS
Alk	0.535**	NS	0.368*	NS	NS	NS
Cl2	0.611**	-0.524**	0.556**	NS	-0.501**	0.329*
PO4	0.530**	0.323*	0.378**	0.494**	0.322*	NS
NO3	NS	NS	NS	NS	NS	NS
SO4	0.641**	NS	0.409**	0.626**	NS	NS
TSS	0.538**	0.600**	0.446**	0.391**	0.552**	NS
POM	0.397**	0.556**	0.524**	0.385**	0.475**	0.352*
Chl-a	0.589**	0.774**	0.615**	0.381**	0.550**	0.410**
TASA	0.717**	-0.309*	0.641**	0.445**	NS	0.363**

N=48, values are Pearson correlation coefficient, a 2-tailed test was applied and calculated after $\log_{10}$ transformation of all variables after scaling so that all values were >1, *$P < 0.05$, **$P < 0.005$*, and NS=Non-significant; AT=Air temperature, WT=Water temperature, pH (F)=pH measured in the field, pH (L)=pH measured in the laboratory, Cond=Conductivity, Turb=Turbidity, DO=Dissolved Oxygen measured in the field, BOD=Biological Oxygen Demand, COD=Chemical Oxygen Demand, CO_2=Free Carbon di-oxide, Hard=Hardness, Cal=Calcium, Alk=Alkalinity, Cl_2=Chloride, PO_4=Inorganic phosphate, NO_3=Nitrate, SO_4=Sulphate, TSS=Total Suspended Solids, POM=Particular Organic Matter, *Chl-a*=Chlorophyll-a, TASA =Total Anions in Strong Acid.

Table 6. Co-relationship between Environmental parameters and Zooplankton groups of Cauvery river, Kapila river and at their confluence, June 2009 to May 2011.

Environmental variables	Copepod			Ostracod			Total zooplankton		
	Cauvery	Kapila	Confluence	Cauvery	Kapila	Confluence	Cauvery	Kapila	Confluence
AT	NS	0.291*	NS	NS	NS	NS	NS	NS	0.395**
WT	0.293**	NS	NS	NS	NS	0.325*	0.285*	NS	0.505**
PH(F)	NS	NS	NS	NS	NS	NS	0.406**	0.313*	0.473**
PH(L)	NS	NS	NS	NS	NS	NS	0.406**	0.396**	0.500**
Cond	NS	NS	NS	0.447**	NS	NS	0.630**	0.420**	NS
Turb	NS	0.398**	0.373**	NS	NS	-0.330*	0.529**	0.544**	0.483**
DO	NS	-0.329*	NS	NS	NS	NS	-0.430*	-0.638**	NS
BOD	NS	NS	NS	-0.317*	NS	NS	-0.415**	NS	-0.653**
COD	0.302*	NS	NS	NS	NS	NS	0.453**	NS	0.309*
CO2	NS	NS	NS	0.343*	NS	NS	NS	NS	NS
Hard	0.370**	0.546**	0.302*	NS	NS	NS	0.596**	0.651**	0.644**
Cal	0.310*	NS	NS	NS	NS	NS	0.354*	-0.303*	NS
Alk	NS	NS	NS	NS	NS	NS	0.387**	NS	NS
Cl2	0.305*	-0.299*	NS	-0.327*	NS	NS	0.488**	-0.535**	0.493**
PO4	NS	0.297*	NS	NS	NS	NS	0.548**	0.359*	NS
NO3	NS	NS	NS	NS	NS	NS	NS	NS	NS
SO4	NS	NS	NS	0.370**	NS	NS	0.702**	NS	0.332*
TSS	0.409**	0.484**	0.312*	NS	NS	NS	0.513**	0.643**	0.452**
POM	0.430**	0.346*	NS	NS	NS	NS	0.446**	0.577**	0.399**
Chl-a	0.380**	0.442**	NS	NS	NS	-0.312*	0.585**	0.718**	0.524**
TASA	0.344*	NS	NS	NS	NS	NS	0.642**	-0.323*	0.553**

n=48, values are Pearson correlation coefficient, a 2-tailed test was applied and calculated after $\log_{10}$ transformation of all variables after scaling so that all values were >1, **P* <0.05*, ***P* <0.005*, and NS=Non-significant. AT=Air temperature, WT=Water temperature, pH (F)=pH measured in the field, pH (L)=pH measured in the laboratory, Cond=Conductivity, Turb=Turbidity, DO=Dissolved Oxygen measured in the field, BOD=Biological Oxygen Demand, COD=Chemical Oxygen Demand, CO_2=Free Carbon di-oxide, Hard=Hardness, Cal=Calcium, Alk=Alkalinity, Cl_2=Chloride, PO_4=Inorganic phosphate, NO_3=Nitrate, SO_4=Sulphate, TSS=Total Suspended Solids, POM=Particular Organic Matter, *Chl-a*=Chlorophyll-a, TASA=Total Anions in Strong Acid.

Total zooplankton abundance

During the period of two year study, maximum total zooplankton abundance of Cauvery river was found during June 2009 and minimum was observed in the month of April 2010. Notably the highest total zooplankton abundance in Kapila river was found in June 2009 during first year of study and September 2010 during the second year. Minimum abundance is observed in the month of March 2010 in first year as well as second year. Similarly, at the confluence site the maximum abundance of total zooplankton is shown in June 2009 and minimum abundance found in February 2010. The relationship between total zooplankton abundance and physico-chemical parameters is shown in table 6. Among the 21 physico-chemical parameters, the abundance of total zooplankton at Cauvery river showed positive correlation with 16 physico-chemical parameters and negative correlation with DO and BOD. The total zooplankton abundance of Kapila river showed positive correlation with 9 physico-chemical parameters and negative correlation with 4 parameters and at the Confluence site the total abundance of zooplankton showed positive correlation with 13 physico-chemical parameters and negatively correlated with BOD. From the result it is clear that BOD is negatively affected, the total zooplankton abundance in Cauvery river. High BOD value may lead to decrease the amount of dissolved oxygen in an aquatic ecosystem and thus the high BOD value might be negatively affecting the growth of zooplankton community. The regression analysis (Table 8) showed that, 49% of the total zooplankton abundance was positively controlled by conductivity in the Cauvery river and other physico-chemical parameters like, sulphate and COD were also affecting the total zooplankton abundance. The Kapila river, 52% of total zooplankton abundance was positively controlled by hardness, moreover other parameters like chloride, POM, conductivity and calcium were also positively affected the total zooplankton abundance. At the confluence site, 42% of total zooplankton abundance were negatively controlled by DO, whereas, water temperature was positively affected the total zooplankton abundance. Almost similar result reported by Shayestehfar et al. [24] on their study about the Rotifers from Kor river, Fars, Iran. They suggested that water temperature and DO have an important role in the changes of zooplankton abundance. Zarfdijian et al. [25] on their study about zooplankton abundance in Aliakmon river, Greece, suggested that the abundance and distribution of zooplankton is guided by variety of ecological factors including physico-chemical parameters like, Temperature and pH, inorganic and organic conditions and the interrelationship with other organisms. All these factors played an important role in determining the nature, the pattern of fluctuation and population densities of zooplankton. Season wise grouped data revealed that, Total zooplankton groups showed significant variations in the abundance during different seasons (Table 2, 3 and 4). In Cauvery river the abundance of total zooplankton was high in rainy season both first year (22 org/L) and second year studies (23 org/L) followed by winter (16 Org/L and 15 Org/L) and summer seasons (9 and 10 Org/L). Kapila (22 and 20 Org/L) and at the confluence site (21 and 19 Org/L) also showed similar results with the abundance of zooplankton was high in rainy season than compared with winter and summer seasons. Nutrient levels in the river increasing in rainy season because of soil erosion, agricultural runoff carrying fertilizers and inflow of water from domestic areas, thereby increasing zooplankton abundance in this season.

Table 7. Results of stepwise multiple regression analysis between zooplankton variable and physico-chemical variables of Cauvery river, Kapila river and at their confluence site.

Zooplankton variables	Sampling sites	Physico-chemical parameters
Rotifer	Cauvery	Cond(+), TASA(+), BOD(-), AT(+), Cal(+), TSS(+), (R^2=0.66, F=43.44, P<0.005), WT(+), pH(F) (+), pH(L) (+), DO(-), Turb(+), Alk(+), Hard(+), Cl_2(+), COD(+), SO_4(+), POM(+)
	Kapila	Hard(+), Chl-a(+), Cl_2(-), (R^2=0.59, F=68.73, P<0.005), WT(+), pH(F) (+), pH(L) (+), DO(-), Turb(+), Cond(+), Cal(+), PO_4(+), TSS(+), POM(+), TASA(-)
	Confluence	Hard(+), POM(+), (R^2=0.56, F=59.39, P<0.005),AT(+),WT(+), pH(F) (+),pH(L) (+), DO(-), Turb(+), Alk(+), Cl_2(+), COD(+), SO_4(+), PO4(+), Chl-a(+), POM(+)TSS(+), TASA(+)
Cladoceran	Cauvery	Turb(+), Cond(+), (R^2=0.43, F=34.07, P<0.005), CO2(+), COD(+), BOD(-), Hard(+), PO4(+), Chl-a(+), POM(+), TASA(+)
	Kapila	TSS(+), Cond(+),Cl_2(-), (R^2=0.31, F=20.15, P<0.005), pH(L), DO(-), Turb(+), Hard(+), Cal(-), PO_4(+), Chl-a(+), POM(+)
	Confluence	Chl-a(+), (R^2=0.17, F=9.31, P<0.005), pH(F) (+), pH(L) (+), DO(-), Turb(+), Hard(+), Cl_2(+), POM(+), TASA(+)

Only those parameters which entered the regression equation are shown in the table. Physico-chemical (independent) variables in the final regression equation (P in=0.05, P out=0.1) are shown: multiple coefficients of determinations (r^2) and overall F and P values for each equation are given in the parenthesis. Physico-chemical variables which were not in the final equation but which are correlated (P<0.05) with the relevant Zooplankton variables are then listed in order of decreasing magnitude of correlation coefficient; the sign of the correlation is indicated in the parenthesis. The environmental variables were; AT = Air Temperature, pH(F) = pH measured in the Field, Cond = Conductivity, Turb = Turbidity, BOD = Biological Oxygen Demand, COD =Chemical Oxygen Demand, CO_2 = Carbon-di-Oxide, Hard = Hardness, Cl_2 = Chloride, PO_4 = Phosphate, NO_3 = Nitrate, SO_4 = Sulphate, Chl-a = Chlorophyll – a, TASA = Total Anions of Strong Acid. ZP= Zooplankton, Rot= Rotifer, Cla= Cladocera, Cop = Copepod, Ost = Ostracod, TZP= Total Zooplankton.

Few studies on Zooplankton population was done in different lotic ecosystems, which are supporting the results obtained from the present investigation, Reeja and Sanalkumar [26] studied about the seasonal variations of the abundance of zooplankton in river Achencovil and reported that the maximum abundance of zooplankton was in rainy season and they suggested that it could be because of more availability of food due to more organic matters and high decomposition. Similarly, Sravankumar et al. [27] reported that the abundance of zooplankton was more in rainy season. The species diversity of zooplankton groups showed that, the zooplankton fauna of all the three sampling sites were dominated by Rotifers followed by Cladocera, Copepod and Ostracod. Many other studies agree with the result obtained, for example, Ahmet et al. [28], their study about physico-chemical parameters and zooplankton, reported that Rotifers found to be dominant group. Many of the studies reported that Rotifer is the dominant group in moderatly polluted rivers. Sharma et al. [29] studied about the population dynamics and seasonal abundance of zooplankton community in Narmada River and reported that among the four groups of zooplankton Rotifer was the dominant group. Suresh et al. [2] investigated the contents of zooplankton of the Tungabhadra river, and reported that the zooplankton fauna of Tungabhadra River were dominated by the Rotifers. Jayabhaya [11] studied on zooplankton diversity of river Kayadhu, near Hingoli city, and total 25 species of zooplankton were recorded consisting of 11 species of Rotifer. According to Heleni et al. [30] the high abundance of zooplankton is due to their short generation time and high reproductive rate. This could be a reason for the high Rotifer abundance. Interestingly, our result showed that, at the confluence site, the abundance of zooplankton was low as compared with Cauvery and Kapila rivers. Vaidya and Yadav [31] suggested that water velocity may be considered as one of the important factor for low zooplankton abundance. According to Srikanth et al. [32] the high velocity of flow increasing the mixing phenomena of lotic ecosystem thus, affecting the physico-chemical parameters and thus the zooplankton abundance. Hence, due to the joining of two big rivers, the flowing speed of water at the confluence site was high and it could be the reason for less abundance of zooplankton at the confluence site.

Table 8. Results of stepwise multiple regression analysis between zooplankton variable and physico-chemical variables of Cauvery river, Kapila river and at their confluence site.

Zooplankton variables	Sampling sites	Physico-chemical parameters
Copepod	Cauvery	POM(+),WT(+), (R^2=0.18, F=10.42, P<0.005), Cal(+), COD(+),Hard(+), Cl_2(+), Chl-a(+), TSS(+), TASA(+)
	Kapila	Hard(+), (R^2=0.29, F=19.53, P<0.005), AT(+), DO(-), Turb(+), Cal(+), PO_4(+), Chl-a(+), TSS(+), POM(+)
	Confluence	Turb(+), (R^2=0.14, F=7.43, P<0.005), Hard(+), TSS(+)
Ostracod	Cauvery	Cond(+),Cl_2(-), SO_4(+), (R^2=0.20, F=11.48, P<0.005), BOD(-), CO_2(+)
	Kapila	No Physico-chemical parameters entered in the regression equation
	Confluence	Turb(-), WT(+), (R^2=0.11, F=5.63, P<0.05), Chl-a(-)
Total zooplankton	Cauvery	Cond(+), SO_4(+),COD(+), (R^2=0.49, F=44.64, P<0.005), WT(+), pH(F) (+), pH(L) (+), DO(+), Turb(+), Alk(+), Hard(+), Cl_2(+), Cal(+), BOD(-), PO_4(+), Chl-a(+), POM(+), TSS(+), TASA(-)
	Kapila	Hard(+), Chl-a(+), Cl_2(-), POM(+),Cond(+), DO(-), Cal(+), (R^2=0.52, F=48.78, P<0.005), pH(F) (+), pH(L) (+), Turb(+), PO_4(+), TSS(+), TASA(-)
	Confluence	DO(-),WT(+), (R^2=0.43, F=34.26, P<0.005), WT(+), pH(F) (+), pH(L) (+), DO(+), Turb(+), Alk(+), Hard(+), Cl_2(+), Cal(+), BOD(-), PO_4(+), Chl-a(+), POM(+), TSS(+), TASA(+)

Only those parameters which entered the regression equation are shown in the table. Physico-chemical (independent) variables in the final regression equation (P in=0.05, P out=0.1) are shown: multiple coefficients of determinations (r^2) and overall F and P values for each equation are given in the parenthesis. Physico-chemical variables which were not in the final equation but which are correlated (P<0.05) with the relevant Zooplankton variables are then listed in order of decreasing magnitude of correlation coefficient; the sign of the correlation is indicated in the parenthesis. The environmental variables were; AT=Air Temperature, pH(F)=pH measured in the Field, Cond=Conductivity, Turb=Turbidity, BOD=Biological Oxygen Demand, COD=Chemical Oxygen Demand, CO_2=Carbon-di-Oxide, Hard=Hardness, Cl_2=Chloride, PO_4=Phosphate, NO_3=Nitrate, SO_4=Sulphate, Chl-a=Chlorophyll-a, TASA=Total Anions of Strong Acid, ZP=Zooplankton, Rot=Rotifer, Cla=Cladocera, Cop=Copepod, Ost=Ostracod, TZP=Total Zooplankton.

Overall, the present study revealed that the total abundance of zooplankton was high in Cauvery river when compared with Kapila river and at their confluence site. Also found out that there is decreasing tendency in the abundance of zooplankton in Cauvery river after it joins Kapila river. The species diversity of zooplankton showed that Rotifer was the dominant group in all the three sampling sites. The season wise results showed that the abundance of zooplankton was more in rainy season. It is interesting and noteworthy to note that Copepod-calanoid group was completely absent in all the three sampling sites throughout the study period. Copepod- herpacticoids are present only in Cauvery river and were completely absent in Kapila river and at the confluence site of Cauvery and Kapila rivers. The changes of physico-chemical parameters were affected positively; sometimes negatively the abundance of zooplanktons. Hence, this study suggests that the zooplankton may be good indicators of the variations in the water quality of these three lotic ecosystems.

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REFERENCES

[1] Johnson N, Revenga C, Echeverria J. Science 2001, 292:1071-1072.
[2] Suresh S, Manjappa M, Puttaiah ET. Journal of Ecology and the Natural Environment 2009, 1(9):196-200.
[3] Altaff K. A Manual of Zooplankton. The New College, Chennai, India, 2004, 1-154.
[4] Sharifan N. Journal of Fisheries and Hydrobiology 2007, 2(2):789-792.
[5] Leech DM, Boeing W, Cooke SL, et al. Limnol. Oceanogr. 2009, 54:1152-1161.
[6] Kovalev AV. Journal of Zoology 1999, 23:45-48.
[7] Islam A, Bhuiyan AS. Journal of Fisheries and Hydrobiology 2007, 2(1):18.
[8] Pandey J, Verma A. J. Environ. Biol. 2004, 25(1):81-87.
[9] Sahib SS. Journal of Ecobiology 2004,16(2):159-160.
[10] Sheeba S, Ramanujan N. Pollution Research 2005, 24(1):119-122.
[11] Jayabhaya UM. International Research Journal of Shodh Samiksha aur Mulyankan 2009, 2:11-12.
[12] Hameed S, Shaheed K. Journal of Biosciences 1997, 22:235-231.
[13] Mathivanan V, Vijayan P. Journal of Environmental Biology 2007, 28(2): 523-526.
[14] Jalilzadeh K, Yamakanamardi SM, Altaff K. Journal of Aquatic Biology 24 (2):90-98.
[15] Joseph B, Yamakanamardi SM. Journal of Environmental Biology 2011, 32:551-557.
[16] Savitha N, Yamakanamardi SM. Journal of Environmental Biology 2012, 33(6):1079-1085.
[17] Kamaladasa AI, Jayatumka YA. Journal of Biosciences 2007, 36(1):1-7.
[18] APHA. In: Standard methods for examination of water and wastewater, 18th Ed., Greenberg AE, Clesceri LS, Eaton AD (eds), American Public Health Association, Washington, D.C., 1992.
[19] Trivedy RK, Goel PK. Chemical and biological methods of water pollution studies. Environmental Publication, Karad, 1986, 1-93.
[20] Frutos SM, Neiff PD, Neff J. Journal of Limnology 2006, 42(2):277-288.
[21] Basińska A, Cichocka M, Kuczyńska-Kippen N. International Journal of Oceanography and Hydrobiology 2008, 2:145-147.
[22] Piaseckil W, Andrew E, Goodwin C, et al. Zoological Studies 2004, 43(2):193-205.
[23] Badsi H, Ali HO, Loudiki M, et al. African Journal of Environmental Science and Technology 2010, 4(11):751-762.
[24] Shayestehfar A, Soleimani M, Mousavi1 SN, Shirazi F. Journal of Environmental Biology 2008, 29(5):715-720.
[25] Maria-Heleni Z, Michaloudi E, Bobori DC, Mourelatos S. Belg. J. Zool. 2000, 130:29-33.
[26] Jose R, Sanalkumar MG. Journal of Scientific and Research Publications 2012 2(11):1-5.
[27] Sravankumar A, Rajkumar M, Serebiah S, Thivakaran GA. Journal of Biological Sciences 2001, 10(2):1-5.
[28] Altindag A, Buyurgan O, Kaya M. Journal of Animal and Veterinary Advances 2009, 8(8):1484-1490.
[29] Sharma S, Siddique A, Singh K, et al. Researcher 2010, 2:45-48.
[30] Maria-Heleni Z, Michaloudi E, Bobori DC, Mourelatos S. Belgian Journal of Zoology 2000, 130:29-33.
[31] Vaidya T, Yadav KR. J. Nat. Hist. Mus. 2008, 23:8-15.
[32] Darapu SSK, Sudhakar B, Sivaramakrishna K, et al. International Journal of Engineering Research and Applications 2010, 1(2):174-182.