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Research Paper

INFLUENCE OF MICROBIAL AND PHYSICO-CHEMICAL VARIABLES ON THE ABUNDANCE OF MICRO ZOOPLANKTONS IN RIVER CAUVERY AND ITS UPSTREAM TRIBUTARIES IN SOUTHERN KARNATAKA

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Abstract

The interrelationship between the abundance of micro-zooplankton and other microbial and physico-chemical variables in the river Cauvery and its four upstream tributaries were investigated by calculation of Pearson's Correlation Coefficients after $\log_{10}$ transformation. For the study of zooplankton abundance one liter of mid stream surface water samples were collected in polythene cans and were preserved in 10% Lugols–Iodine solution, only 20ml sediment, were used for drop counting. The present study documents that, highest number (10 Org. ml^{-1}) of micro-zooplankton was recorded in the river Lakshmanatheertha only. The zooplanktons are recognized as the primary consumers of bacterioplankton in aquatic ecosystems and their grazing activity, play an important role in the recycling of nutrients accumulated by bacteria. Thus, positive correlation was noticed between micro zooplankton abundance with the abundance of particle bound bacteria, mean cell-lengths of free living and particle bound bacteria Further, the Chloride, TASA and Calcium were the micro nutrients; their increased concentration favored the good growth and abundance of micro zooplankton. However, the low dissolved oxygen indirectly suggests the occurrence of more organic matter in the water column. Further, the implication of mineral turbidity showed adverse consequences for zooplankton population, thus in this study the DO, Turbidity, were negatively correlated with the abundance of micro zooplankton. Thus, it can be evidenced that, river Lakshmanatheertha comparatively contain more micro-zooplankton abundance. The low water level, indiscriminate anthropogenic activities, contamination of sewage, agricultural wastes and untreated effluents, and eutrophic nature of water, all of which enriches the nutrient level in the water, might be the reason.

Key words: Primary consumers, Eutrophication, bacteria, Rainfall, Anthropogenic activity. Dissolved Oxygen.

INTRODUCTION

Micro zooplanktons are primary consumers; and are critically important mediators of organic matter. Fresh water zooplankton acts as primary and secondary links in the aquatic food chain **[1].** They are ecologically important heterogeneous group of tiny aquatic organisms and their weak power of locomotion is with the mercy of water currents. They play a role of converting phytoplankton into food, suitable for fish and aquatic animals and are also important in indicating the presence or absence of certain species of fishes **[2].** Thus, they constitute an important link of secondary production and play a vital function in energy flux in the plankton based food web causes them to become an important element in functioning of aquatic ecosystems **[3].** Further, the knowledge of their seasonal qualitative and quantitative fluctuation has been considered always essential for a proper understanding of the factors influencing biological productive and fisheries development **[4].** Due to their grazing impact they can control phytoplankton production **[5]**, and bacterial abundance **[6]** and this could be expected to be significant in aquatic habitat **[7]**. Generally, zooplankton release nutrients, the released nutrients may enhance the growth of bacteria and phytoplankton, both of which serve as prey for heterotrophic nano flagellates (HNF) and ciliates. Further, the bacteriovorous flagellates could dramatically affect the rate of nitrification in aquatic systems by consuming nitrifying bacteria **[8]**. They also recognized as the primary consumers of bacterioplankton and picoplankton in both marine and fresh water ecosystems **[9]**. Because of their grazing activity, bacteriovorous flagellates can play an important role in the recycling of nutrients accumulated by bacteria **[10]**. On the other hand the heterotrophic flagellates are consumed by metazoan zooplankton thus form an important pathway for energy **[11]**. Micro zooplankton are able to select food, based on size and nutritional value **[12]**, and play a significant role in structuring plankton communities and determining the fate of phytoplankton production **[13]**. Most of the zooplankton survives under a wide range of environmental conditions, their growth and abundance depends to a great extent upon a number of physical, chemical and biological features (Choudhary and Rajashree Gouda, 2000) **[14]**. For instance, the changes in zooplankton composition and abundance were correlated with changes in water transparency, water renewal and temperature (Dirnburger and Threlkeld 1986) **[15]** and increased concentration of suspended sediments **[16]**. The feeding rate of zooplankton was low during high turbidity, because light limitation of phytoplankton production intensifies in turbid waters. Under such conditions zooplankters with chemosensory food selection capabilities might be expected to predominate **[17]**. Zooplankton, a vital and major fish food community is severely affected by pollutants and it is being reported that only few resistant species survived in affected waters **[18]**. Thus, zooplankton community can be useful as an indicator of environmental variability **[19, 20 & 21]**. However, there are many zooplankton which play important part in biological control for example, cyclopoids such as species of *Microcyclops*, *Megacyclops* and *Mesocyclops* attack mosquito larvae **[22]**.

MATERIALS AND METHODS

One liter of mid stream surface water samples from rivers Lakshmanatheertha, Harangi, Hemavathy, Lokapavani and Cauvery were collected in polythene cans for the study of micro Zooplankton fortnightly during study period. The water samples were preserved in 10% Lugols–Iodine solution. Micro Zooplankton, from one liter preserved samples was concentrated by sedimentation method for 24 hours. The sedimentation was concentrated to only 20ml, by siphoning off the remaining 980ml of the supernatant. Their abundance was counted by **[23]** drop method by using Epifluorescence microscope (BX40, Olympus, Japan). The number of micro zooplankton was calculated by using the following formula **[24]**.

$$\text{Number of Organisms ml}^{-1} = \frac{A \times 1/L \times n / V}{1000}$$

Where A= Number of organisms per drop.

V= Volume of one drop (0.05 ml)

n= Total volume of concentrated sample (20 ml)

L= Volume of original sample (1 liter).

After log $_{10}$ transformed values of micro-zooplanktons data were used for Kolmogorov-Smirnov test, Student–Neuman-Keuls test, one-way ANOVA, Pearson's correlation coefficients and stepwise multiple regression analysis.

RESULT AND DISCUSSION

The mean values with different superscripts are significantly different ($p<0.05$) as shown by one-way ANOVA post hoc nonparametric Student-Newman-Keuls test (SNK test). Interrelationship between the abundance of micro-zooplankton and other microbial and physico-chemical (water quality) variables were investigated by calculation of Pearson's Correlation Coefficients after $\log_{10}$ transformation are given in Tables (2 and 3). The mean abundance of micro zooplankton was similar in river Cauvery (2 Org. ml^{-1}) and in river Lokapavani (2 Org. ml^{-1}), but it was less in the rivers Harangi and Hemavathy (1 Org. ml^{-1}). However, in the surface water of river Lakshmanatheertha it was more (4 Org. ml^{-1}) and also significantly different. Further, in this investigation the highest number (10 Org. ml^{-1}) of micro-zooplankton was also recorded in the river Lakshmanatheertha only (Table 1). The indiscriminate human activities, reduced water level, discharge of sewage, agricultural wastes and other untreated effluents contamination, eutrophic nature of water, all of which enriches the nutrient level in the water, might be the reason that, increased abundance of micro zooplankton was recorded in the river Lakshmanatheertha. Similarly, **[25]** was reported that higher concentration of nutrient discharge causes increased abundance of micro zooplankton. Further, presence of more phytoplankton and diverse zooplankton abundance in water was mainly due to eutrophication, **[18]**. The abundance of micro-zooplankton showed few correlations with the other microbial variables (Table 2). The mean abundance of micro zooplankton was positively correlated with the abundance of particle bound bacteria in the river Lakshmanatheertha, and with the mean cell-length of free living and particle bound bacteria in the rivers Lakshmanatheertha and Hemavathy, and with the mean length of free living bacteria in the river Cauvery. Similarly, a significant positive correlation was also noticed between bacterial cell-size and that of heterotrophic zoo-flagellates in the water column of Sep reservoir **[26]**, and in wide variety of pelagic **[27]** and Benthic **[28]** ecosystems. The zooplankton act not only as predators in a classical sense, but also have an indirect effect on resource competition between algae and bacteria, and forms the major nutrient supply to the primary producers at certain times **[29]**. The correlations between micro-zooplankton and physico-chemical (water quality) variables showed more correlations in the river Lakshmanatheertha, than the other four water courses studied (Table 3). Interestingly, the micro zooplankton was positively correlated with the Field pH, Conductivity, Carbon di-Oxide, Chloride, Total Anions of Strong Acids and Calcium in the river Lakshmanatheertha, and with the Chlorophyll-a in the rivers Lakshmanatheertha and Harangi, there were no positive relations was noticed in the remaining three water courses. This implies that, higher the above mentioned water quality parameters, higher will be the abundance of micro-zooplankton. For instance, Chloride, TASA and Calcium were the micro nutrients; their increased concentration favored the good growth and abundance of micro zooplankton in the river Lakshmanatheertha. This in agreement with the similar findings of **[30][4]** and **[8]**. However, the abundance of micro zooplankton showed significant negative correlation with Dissolved Oxygen and positive correlation with the Carbon di-Oxide in the river Lakshmanatheertha. The low dissolved oxygen indirectly suggests the occurrence of more organic matter in the water column **[31]**. Further, in the presence of more sewage and eutrophic condition in the water, the dissolved oxygen may be consumed quickly by the heterotrophic micro-organisms for the degradation of organic matter, which in turn results in the increased concentration of CO_2 in the water **[32]**. Similarly, the Turbidity and Surface Water Velocity in the rivers Lakshmanatheertha and Harangi, and rainfall in the rivers Harangi and Hemavathy, Sulphate in the rivers Harangi and Cauvery was negatively correlated with the abundance of micro zooplankton. The implication of mineral turbidity showed adverse consequences for zooplankton population, because the conventional algal food resources available to zooplankton tend to decline with high turbidity because, the light limitation to phytoplankton production intensifies in turbid waters **[33]**. Further, in turbid water planktivorous fishes were dominated, this may declines the zooplankton abundance **[34]**. Similar observation was also noticed in Ohio River by **[35]**. In rivers, flow is probably one of the most important factors associated with the abundance of zooplankton **[30]**. Because, turbidity may attain very high values in the rivers, particularly during high flow. This may reduce the food availability for zooplankton through reduction of phytoplankton by light limitation **[30]**. Negative correlation of zooplankton abundance with river flow and the positive correlation with Chl-a in the Hawkesbury-Nepean river **[30]**, tidal fresh water portion of Hudson River **[36]**, in the Ohio River by **[35]**, and in polymictic shallow Muggelsee **[37]** are consistent with the similar findings obtained in the present study. Further, high rainfall and hydrodynamics effect of wind, produces high turbulence in the water, which inturn might have disfavored the development of zooplankton population **[38]**, this may be the reason for negative relations between rainfall and abundance of micro-zooplankton in the rivers Harangi and Hemavathy. The extent of the potential dependence of micro-zooplankton abundance on environmental (water quality) variables was further investigated by step-wise multiple regression analysis (Table 4). The regression analysis revealed that, several key environmental variables were potentially responsible for much of the abundance of micro-zooplankton, but their influence varied with the sampling stations. The notable environmental variables were Chlorophyll-a, Conductivity, Temperature, pH, Surface water velocity, BOD, Carbon di-Oxide, Chloride, Calcium, DO, CO_2, Rainfall, Total Anions of Strong Acids, Chloride, Nitrate and Sulphate. Further, only few (1-15) correlations were found to be affecting the abundance of micro-zooplankton in the present investigation. However, no environmental variables entered the regression equation in the river Lokapavani with respect to abundance of micro-zooplankton. Interestingly, in this study more abundance of micro-zooplankton was noticed in the river Lakshmanatheertha, generally this may be due to increased concentration of micro-nutrients and other water quality variables, which influences the biological productivity. Several studies have shown that the inorganic nutrients and other water quality variables can stimulate abundance of micro-zooplankton directly **[39 & 40][30] [4] [8]**.

Table 1. Mean values of Micro-Zooplankton variable in the surface water of the rivers Lakshmanatheertha, Harangi, Hemavathy, Lokapavani and Cauvery.

Micro plankton variable	River Lakshmanatheertha			River Harangi			River Hemavathy			River Lokapavani			River Cauvery		
	Mean	(Range)	CV (%)	Mean	(Range)	CV (%)	Mean	(Range)	CV (%)	Mean	(Range)	CV (%)	Mean	(Range)	CV (%)
Zooplankton ($Org\ ml^{-1}$)	04.00*	(00.00 - 10.00)	66	01.00^{b}	(00.00-04.00))	91	01.00^{b}	(00.00-04.00)	92	02.00^{c}	(00.00-05.00)	69	02.00^{c}	(00.00-05.00)	75

Mean Values with different superscripts are significantly different ($P<0.05$, Student-Newman-Keuls test, after $\log_{10}$ transformation).
CV = Coefficient of Variation.

Table 2: Relationships between Micro-zooplankton ($Org\ l^{-1}$) and other Microbial variables.

Sampling sites	DC-FLB	DC-PBB	DC-TB	CFUs Phytoplankton	%CCFUs of AODCs	CFUs as% Total plankton	SGR	ML-FLB	ML-PBB		
Zooplankton											
River Lakshmanatheertha	NS	0.30*	NS	NS	NS	NS	NS	0.43***	0.36*	0.57***	0.69***
River Harangi	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.45***	0.56***
River Hemavathy	NS	NS	NS	NS	NS	NS	NS	0.31*	0.29*	NS	NS
River Lokapavani	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.42**
River Cauvery	NS	NS	NS	NS	NS	NS	NS	0.29*	NS	0.33*	0.51***

DC-FLB= Directly Counted Free Living Bacteria, DC-PBB= Directly Counted Particle Bound Bacteria, DC-TB= Directly Counted Total Bacteria, CFUs=Colony Forming Units, CCFUs = Chromogenic Colony Forming Units, CFUs as% AODCs= Colony Forming Units as Percentage of Acridine Orange Direct Counts, SGR = Specific Growth Rate, ML-FLB = Mean length of Free Living Bacteria, ML-PBB= Mean length of Particle Bound Bacteria.

Table 3: Relationships between Micro-zooplankton (Org l^{-1}) and Environmental variables.

Sampling sites	Ph(F)	pH (L)	Temp	Cond	Turb	SWV	RF	DO	BOD	COD	CO_2	Cl_2	NO_3	SO_4	TASA	Cal	PO_4	TSS	POM	Chl-a
Zooplankton																				
River Lakshmanatheertha	0.28*	NS	NS	0.54***	-0.42**	-0.45***	NS	-0.31*	NS	NS	0.38*	0.51***	NS	NS	0.49***	0.45***	NS	NS	NS	0.32*
River Harangi	NS	NS	NS	NS	-0.40**	-0.31*	-0.33*	NS	NS	NS	NS	NS	NS	-0.34*	NS	NS	NS	NS	NS	0.28*
River Hemavathy	NS	NS	NS	NS	NS	NS	-0.32*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
River Lokapavani	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
River Cauvery	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-0.35*	NS	-0.34*	NS	NS	NS	NS

pH(F) = pH measured in the field, pH (L) = pH measured in the lab, Temp = Temperature, Cond = Conductivity, Turb = Turbidity, SWV = Surface Water Velocity, RF = Rainfall, DO = Dissolved Oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, CO_2 = Free Carbon di-Oxide, Cl_2 = Chloride, NO_3 = Nitrate, SO_4 = Sulphate, TASA = Total Anions of Strong Acids, Cal = Calcium, PO_4 = Inorganic Phosphate, TSS = Total Suspended Solids, POM = Particulate Organic Matter, Chl-a = Chlorophyll-a.

Table 4: Multiple regression analysis between Micro-zooplankton (Org l^{-1}) and physico-chemical variables in river Cauvery and its tributaries.

Sampling sites	
Micro-zooplankton variable	Physico-chemical variables
River Lakshmanatheertha	COND (+) , (R^2 = 0.30, F = 20.22, P<0.001), FpH (+), Turb (-), SWV (-), DO(-), CO_2(+), Cl_2(+), TASA(+), Cal(+), Chl-a (+).
River Harangi	Turb (-), (R^2 = 0.16, F = 8.90, P<0.005), SWV (-), Rainfall (-), SO_4 (-), Chl-a (+),
River Hemavathy	Rainfall (-), (R^2 = 0.10, F = 5.51, P<0.05).
River Lokapavani	No environmental variables entered in the regression equation.
River Cauvery	SO_4 (-), Cal (-) (R^2 = 0.24, F = 7.36, P<0.05).

Note: pH(F) = pH measured in the field, pH (L) = pH measured in the lab, Temp = Temperature, Cond = Conductivity, Turb = Turbidity, SWV = Surface Water Velocity, RF = Rainfall, DO = Dissolved Oxygen, BOD = Biological Oxygen Demand, COD = Chemical Oxygen Demand, CO_2 = Free Carbon di-Oxide, Cl_2 = Chloride, NO_3 = Nitrate, SO_4 = Sulphate, TASA = Total Anions of Strong Acids, Cal = Calcium, PO_4 = Inorganic Phosphate, TSS = Total Suspended Solids, POM = Particulate Organic Matter, Chl-a = Chlorophyll-a.

CONCLUSION

Over all it is concluded that, in this investigation the highest number (10 Org. ml^{-1}) of micro-zooplankton was recorded in the river Lakshmanatheertha only. The mean abundance of micro zooplankton was positively correlated with most of the bacterial variables studied in this study revealed that, the zooplanktons are recognized as the primary consumers of bacterioplankton in aquatic ecosystems and their grazing activity, play an important role in the recycling of nutrients accumulated by bacteria. Further, the Chloride, TASA and Calcium were the micro nutrients; their increased concentration favored the good growth and abundance of micro zooplankton. However, the abundance of micro zooplankton showed significant negative correlation with DO and positive correlation with the Carbon di-Oxide in the river Lakshmanatheertha. The low dissolved oxygen indirectly suggests the occurrence of more organic matter in the water column. Similarly, in this investigation the Turbidity, Surface Water Velocity, rainfall and Sulphate were negatively correlated with the abundance of micro zooplankton. The implication of mineral turbidity showed adverse consequences for zooplankton population, because, the light limitation to phytoplankton production intensifies in turbid waters. The regression analysis revealed that, several key environmental variables were potentially responsible for much of the abundance of micro-zooplankton, but their influence varied with the sampling stations. Thus, it can be concluded from the present findings that the more abundance of micro-zooplankton was noticed in the river Lakshmanatheertha when compared to other water courses studied.

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