

Non-equilibrium Interactions of a Zooplankton Community on Olero Creek, Benin River, Nigeria

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The Olero creek Zooplankton was sampled in wet season from 13 stations across a conductivity range of 150 μ mhos to 8000 μ mhos. The abundance of Copepods, some Cladocerans (*Daphnia* sp. and *Ceriodaphna* sp.) and Rotatoria did not vary together with conductivity in a correlation analysis. Correlation was high ($p < 0.05$) only among the Ciliata where abundance of *Opecularia* sp. and *Vorticella* sp. were closely related to variations in conductivity values while *Opisthostyla* sp. exhibited marginal correlation with values of conductivity. However, among Rotatoria abundance variable for *Brachionus* sp., *Euchlanis* sp., *Notholca* sp. and *Asplanchna* sp. was not explained by variations of single variable of conductivity. The occurrence of only three genera of Cladocera, three genera of Ciliata and four genera of Rotatoria with relatively lower abundances than Copepod group recorded, suggest in this tidal creek the non-significance of freshwater Zooplankton. The diversity values were low ranging from 0.7 to 1.3 in addition to low evenness ranging from 0.1 to 0.2 across all stations. Copepods dominated by 92% followed by Rotatoria 3%; Cladocerans 1.2% and Ciliata 0.5%. The observed non-equilibrium in abundance of Copepods with significant low numbers of Rotatoria, Cladocerans and Ciliata suggest biological interactions that support ecological principles of a trophic cascade. The low numerical abundance of Ciliates was in sharp contrast to their ubiquity, rapid reproductive rate and capacity to survive in extreme environments, including adaption to anaerobic conditions. This fact provided surrogate information

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of a cascade effect and intraguild competition. The observed numerical relationship within trophic levels shows that top-level consumers (copepods) were operating a top-down system driven by predation and competition. The top-down cascading of this inverse correlation in numerical density between copepods and other zooplankton should be included in directions of future research. A more appropriate basis of cross system explanation of top down trophic cascades in many natural systems is required for marine, estuaries and freshwater systems.

Keywords: Olero creek; zooplankton; trophic cascade; copepods.

1. INTRODUCTION

The productivity of any water body is determined by amount of plankton it contains, as they are major primary and secondary producers [1]. Among plankton, Zooplankton are important components that provide feeding resources to higher order consumers like macro crustaceans, insects, and omnivorous fishes. They are considered good indicators of trophic and environmental status of water bodies because of their sensitivity [2]. A knowledge of Zooplankton community of any water body is therefore, not only important in assessing its productivity but would permit a better understanding of trophic structure [3,4,5,6,7,8] and [9,10,11,12]. Many early studies starting from nineteen hundreds have shown that Zooplankton can be used to indicate trophic status of a water body [13,14,15,16] and [17,18,19,20]. Many studies have also used relationship between Calanoids, Cyclopoids, Cladocerans and in some cases Rotatorians to classify systems as oligotrophic, mesotrophic or eutrophic [21,22,23]. The presence of Cyclopoids which are predators have been shown to affect the abundance of Calanoid copepods accounting for the increase or decrease in Calanoid/Cyclopoid ratio reflecting a trophic state at time of sampling effort [24,25,26] and [27,28,29,30]. However, many of these studies have carried out in freshwater habitats with very little information on river systems influenced by tidal movements, which daily circulate physical and chemical characteristics of marine and freshwater systems affecting plankton distribution. The resultant environmental and biological factors produce organisms that have peculiar distributional patterns and trophic relationships. The present study therefore examines abundance quotient of zooplankton community through a tidal cycle on Olero creek, a tidal freshwater creek that discharges into Benin River. The numerical abundance of components of zooplankton was used to adduce standing trophic status at sampling time.

2. STUDY AREA

Olero creek is located off Benin river channel approximately 16 kilometers from Atlantic Ocean. Olero creek is approximately 41 kilometers long and is bordered on both sides by a 500-meter riparian corridor of mangrove vegetation and freshwater swamp. The creek drains from its northwest extensions by a myriad of creeklets receiving waters from extensive freshwater swamp forest. The conductivity values of the creek ranged from 150 μ mhos to 8000 μ mhos. The creek was flushed on both sides with pipelines and associated activities of oil and gas that maintain and sustain operational performance of an oil and gas company.

3. METHODS

The study was conducted during wet season month of July in 2014. Subsurface water samples (5 – 20 cm) were collected from thirteen stations with aid of a two-liter plastic container in which 1ml of Lugol's solution was added. Samples were collected during spring and neap tides at 5-hour intervals. The samples were stored in dark cool boxes and transported to laboratory. In laboratory, samples were allowed to stand for 48 hours to settle before supernatant was carefully pipetted to obtain a 50 ml concentrated sample. One milliliter of properly homogenized sub-sample was transferred on to a Sedgewick Rafter counting chamber using a Stempel pipette. From each sample, five replicates were evaluated by identifying and enumerating organisms using a Brunel Microscope at 40x magnification and with aid of a Plankton identification key.

Once identified and counted, population densities were calculated and expressed as number of individuals per liter of water.

3.1 Data Analysis

Data was analyzed using methods such as mean, variance and coefficient of variation.

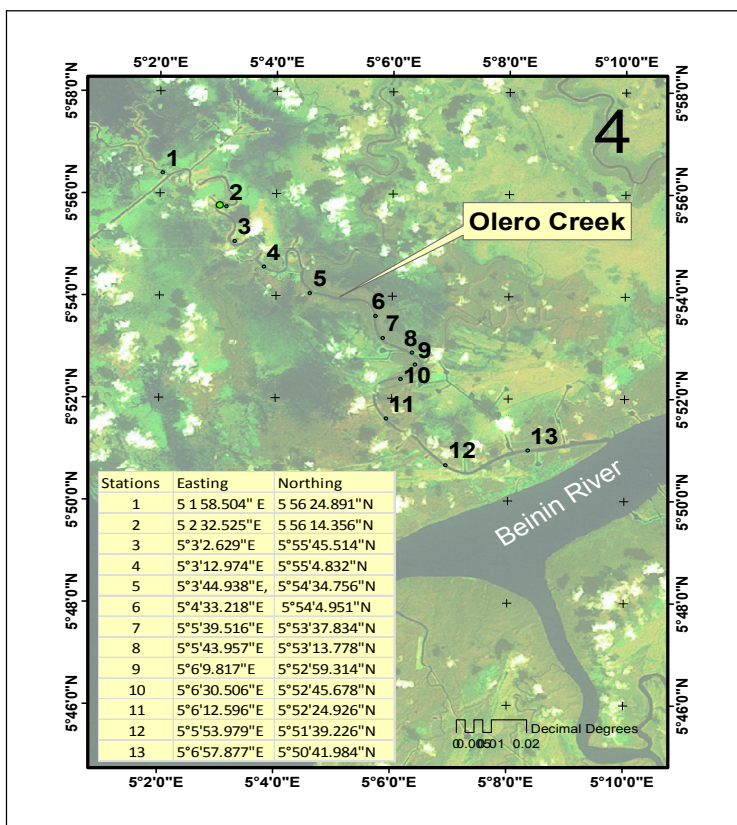


Fig. 1. Olero creek study area with stations

An analysis of variance (ANOVA) together with Student's t was further used to compare differences among the class of zooplankton in study area. A correlation matrix was applied to test relationships between conductivity values and abundance of four groups of zooplankton and between dominant group Copepods and Rotatoria, Cladocera and Ciliata. The diversity and evenness indices were applied to test assemblage health in study area. The diversity indices used were Shannon Weiner (H) and Margalef (Da) and Pielou's evenness (E). The two indices rely on different concepts to measure diversity. The Shannon-Wiener Index heavily relies on uncertainty. The indices were give below as:

$$H = -\sum[(p_i) \times \ln(p_i)]$$

SUM = summation pi
= proportion of total sample represented by species

Where H' is Shannon Weiner diversity and S is the total number of species in a sample, across all samples in dataset.

$$Da = (S - 1) / \log_{10} e N$$

Where Da = Margalef index, S = number of species and N = total number of individuals.

$$\text{Evenness} = E = H / \ln(S)$$

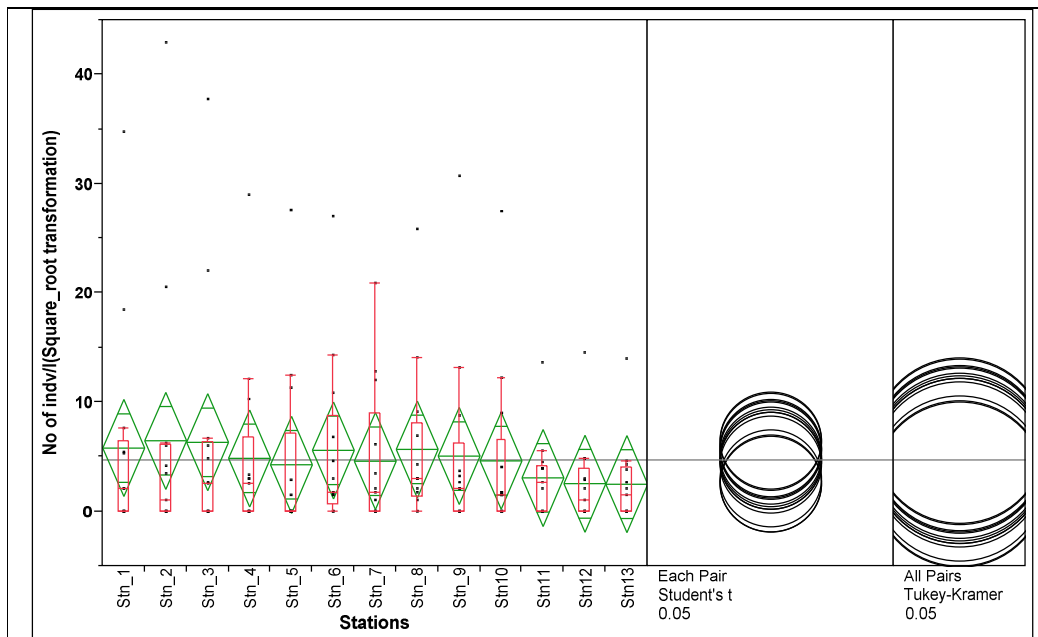
Pielou's or species evenness (E) refers how close in number each species in an environment. If E is close to 1.0, this means that equitability is higher.

4. RESULTS

Tables 1 and 2 presents total Zooplankton groups, individual counts per liter, and relative composition in the stations of the study area. Four groups namely Copepoda, Cladocera, Ciliata and Rotatoria were identified with a total of 13 species and 14,298 organisms. The distribution among stations of Zooplankton shown in Figs. 2 to 4. Total Zooplankton density varied from 292 to 2366 indiv/l with significantly lower values at stations 11, 12 and 13, which were stations close to Benin River estuary. Fig. 2 shows no significant differences ($t = 1.9753$ $p = 0.05$; $q^* = 3.3649$ $p = 0.05$) in total abundances between stations.

Table 1. Total zooplankton, mean, standard deviation and coefficient of variation (CV)

Statistics	Station_1	Station_2	Station_3	Station_4	Station_5	Station_6	Station_7	Station_8	Station_9	Station_10	Station_11	Station_12	Station_13
Total	1671	2366	2028	1129	1055	1132	798	1047	1229	1012	292	279	260
Mean	128.5	182	156	94.1	81.2	87.1	61.4	80.5	94.5	77.8	22.5	21.5	20
Standard deviation	337.1	511.9	404	240.1	211.5	201.3	125.6	184.1	259.4	208.2	50.1	57.6	52.8
Coefficient of variation	2.6	2.8	2.6	2.6	2.6	2.3	2.0	2.3	2.7	2.7	2.2	2.7	2.6



Connecting Letters Report

Level	Mean
Stn_2 A	6.4723077
Stn_3 A	6.3330769
Stn_1 A	5.8046154
Stn_8 A	5.6823077
Stn_6 A	5.5869231
Stn_9 A	5.0753846
Stn_4 A	4.8607692
Stn10 A	4.6415385
Stn_7 A	4.6030769
Stn_5 A	4.2753846
Stn11 A	3.0653846
Stn12 A	2.5353846
Stn13 A	2.5038462

Levels not connected by same letter are significantly different.

Fig. 2. One-way ANOVA analysis of zooplankton across stations

Table 2. Total individuals among zooplankton

Groups	Zooplankton	Total individual (individuals/l)
COPEPODA	<i>Copepod nauplii</i>	10196
COPEPODA	Calanoid copepod	2031
COPEPODA	Cyclopoid copepod	1370
CLADOCERA	<i>Daphnia</i> sp.	106
CLADOCERA	<i>Bosmina</i> sp.	61
CLADOCERA	<i>Ceriodaphnia</i> sp.	9
CILIATA	<i>Opisthostyla</i> sp.	1
CILIATA	<i>Vorticella</i> sp.	63
CILIATA	<i>Operculariasp.</i>	4
ROTATORIA	<i>Asplanchna</i> sp.	295
ROTATORIA	<i>Branchionus</i> sp.	117
ROTATORIA	<i>Euchlanis</i> sp.	40
ROTATORIA	<i>Notholca</i> sp.	5
	Total	14298

The most abundant group was the Calanoid nauplii (Fig. 3) varying from 186 to 1843 indv/l. The Calanoid copepod was significantly more abundant in stations 1, 2 and 3 which were stations located with inner sections of creek away from estuary influence of main channel of Benin River. Following Calanoid nauplii copepods in abundance (Fig. 3) which varied from 9 to 419 indv/l. Their abundance also follows Copepod nauplii pattern being most abundant in stations 1, 2 and 3. The abundance of Cyclopoid copepods was also significant as shown in Fig. 3. Their numbers were however lower than the other copepods varying from 8 to 204 indv/l. The pattern of abundance contrasted with those of Copepod nauplii and Calanoid copepods with abundance highest between stations 4 and 10 and significantly low between stations 1 to 3.

Fig. 3 shows the abundance of the various groups of Zooplankton throughout the stations.

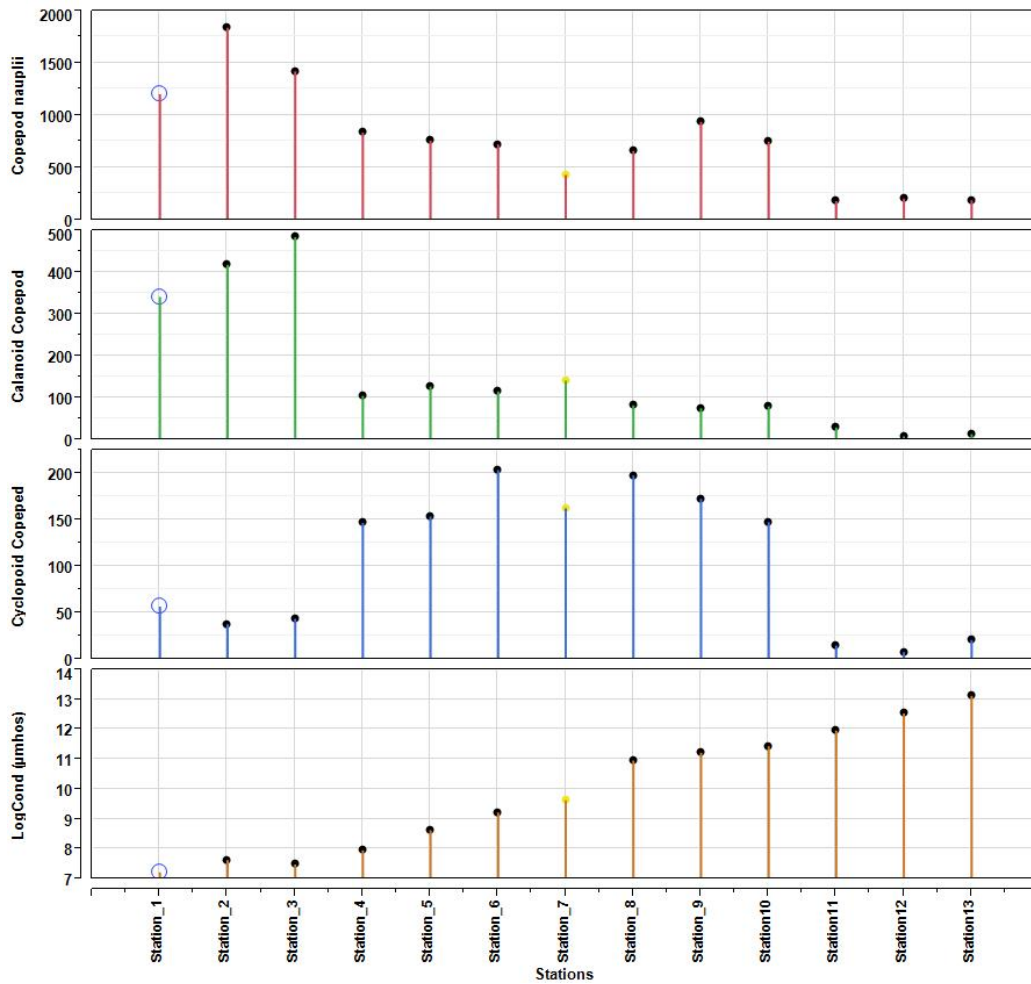


Fig. 3. Numerical abundance (indv/l) of copepod community among zooplankton

The Cladoceran abundance is shown in Fig. 4. *Daphnia* sp. shows high abundance (varying from 0 to 36 indiv/l). The highest abundance occurred in inner sections of creek in stations 1 to 3. Following in abundance was *Bosmina* sp. with 0 to 23 indiv/l. The abundance pattern contrasts with *Daphnia* sp. abundance in stations 11 to 13 in outermost section of creek closest to the influence of Benin River. The *Ceriodaphnia*

sp. represented lowest abundance (0 to 4 indiv/l) and in contrast to *Daphnia* sp. and *Bosmina* sp. occurred in central section of creek in stations 7, 8 and 10. Fig. 5 shows Ciliata abundance in sampling stations. In this group *Vorticella* sp. was most abundant (0-23 indiv/l). Both *Opisthostyla* sp. and *Opercularia* sp. had no significant occurrence in numbers and station being only observed in single stations.

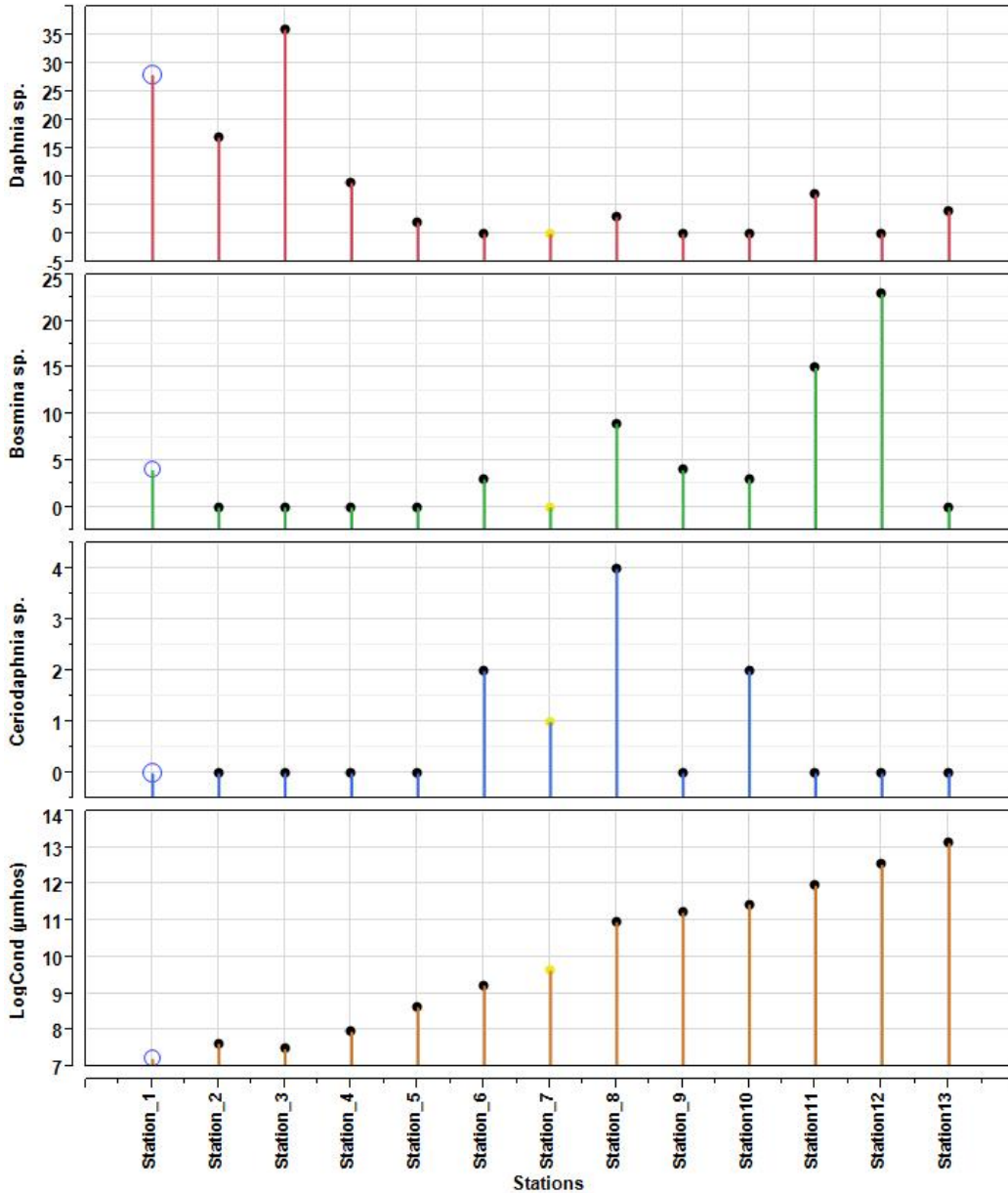


Fig. 4. Numerical abundance (indiv/l) of cladoceran community among zooplankton

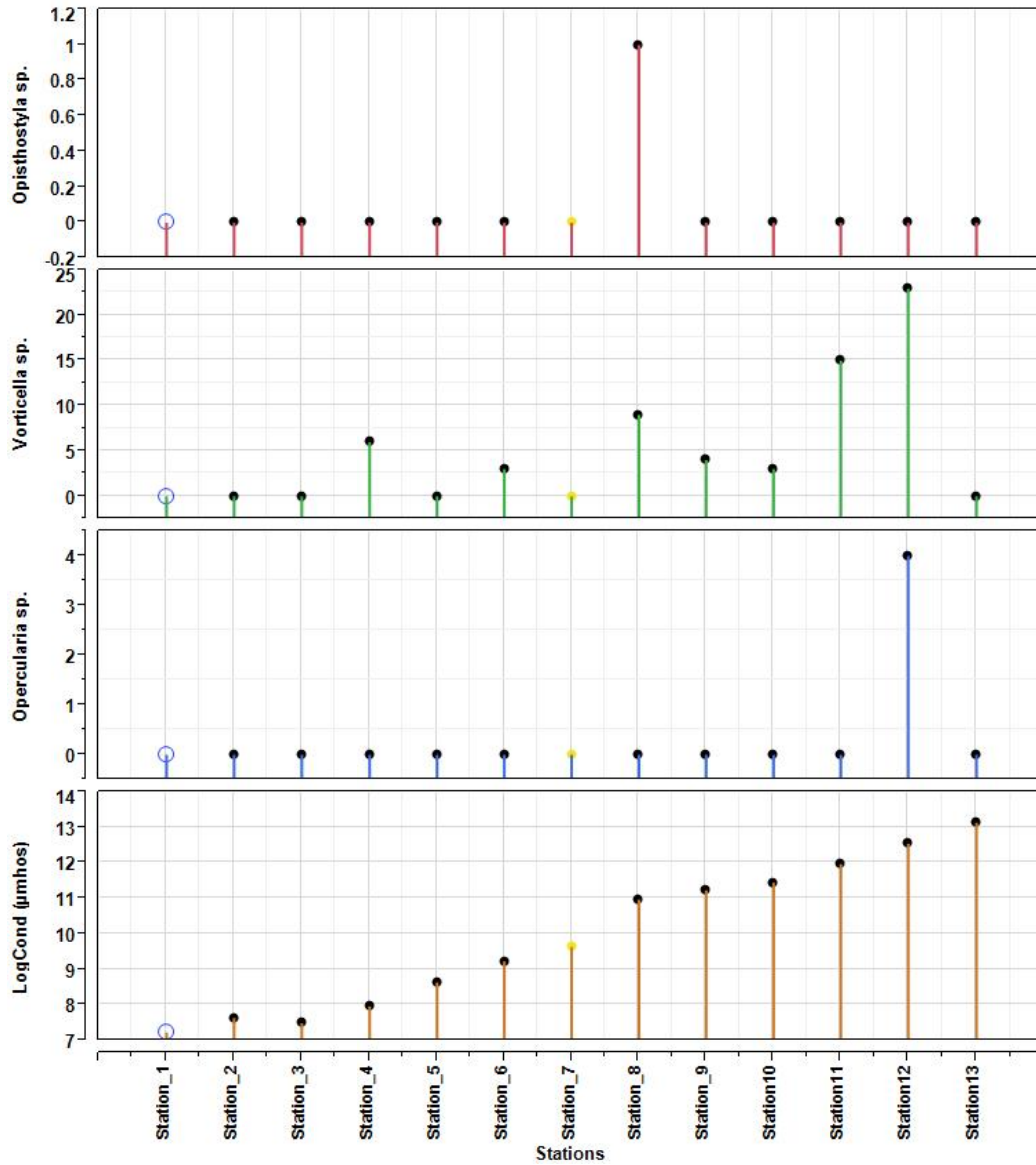


Fig. 5. Numerical abundance (indv/l) of ciliata community among zooplankton

Fig. 6 presents occurrence of Rotatoria among sampling stations. *Asplanchna* sp was most abundant (1 to 48indv/l). Abundance was high at inner section of creek in stations 1 and 2. In middle sections of creek at stations 6, 7 and 8 and at outward section in station 11. The next in abundance was *Brachinous* sp. with 0–21 indv/l density in middle sections of creek in stations 6, 7, 8 and 9 and in most outward section in station 13. The *Euchlanis* sp. was moderately abundant (0–9 indv/l). Occurring mostly in middle section of creek in stations 6 7 8 and 9. Low abundance was observe for *Notholca* sp. (0 to 3 ind/l) which occurred in stations 6 and 7.

Among four groups of Zooplankton abundance with respect conductivity is shown in Figs. 8 and 9. In Fig. 8 copepod abundance was negatively correlated with conductivity ($r = -0.7017$; -0.6377 ; -0.4652 $p < 0.05$) which suggest that abundance do not vary together with respect conductivity. In Fig. 9 among Cladocerans conductivity values was correlated only with *Bosmina* sp. abundance ($r = 0.4986$, $p < 0.05$) and did not correlate with *Daphnia* sp. and *Ceriodaphna* sp. ($r = -0.4044$; $r = -0.0965$, $p < 0.05$). Fig. 10 shows that among Ciliata, abundance of *Opecularia* sp. and *Vorticella* sp. are closely related to variations in conductivity

values ($r=0.4824$, $r=0.4626$ $p<0.05$) while *Opisthostyla* sp. exhibited no correlation with values of conductivity ($r=-0.0164$, $p<0.05$). In Fig. 11 among Rotatoria the abundance variable for *Brachionus* sp., *Euchlanis* sp., *Notholca* sp. and *Asplanchna* sp. were not explained by conductivity variations across stations ($r=0.0203$; $r=-0.1810$; $r=-0.2449$; $r=-0.5146$; $p<0.05$).

4.1 Numerical Coherence and Diversity

The numerical coherence of dominant Copepods and other groups of Zooplankton among stations are shown in Figs. 12 to 14. In Fig. 12 there was

moderate to strong correlation in numerical Copepods abundance (Copepod nauplii and *Calanus* Copepods) and Cladocera- *Daphnia* sp.; $r = 0.6680$ and $r = 0.8766$ $p < 0.05$). A moderate correlation was observed between Cyclopoid copepod and Cladocera-*Cerodaphnia* sp. ($r = 0.6311$ $p < 0.05$). In Fig. 13 correlation between Copepod group and Ciliata was low with *Opisthostyla* sp. ($r = 0.3710$ $p < 0.05$). The correlation values in Fig. 14 show low to moderate relationship between Copepods and Rotatoria. Moderate correlation values were observe between Copepods (Copepod nauplii, Calanoid Copepods and Cyclopoid Copepod)

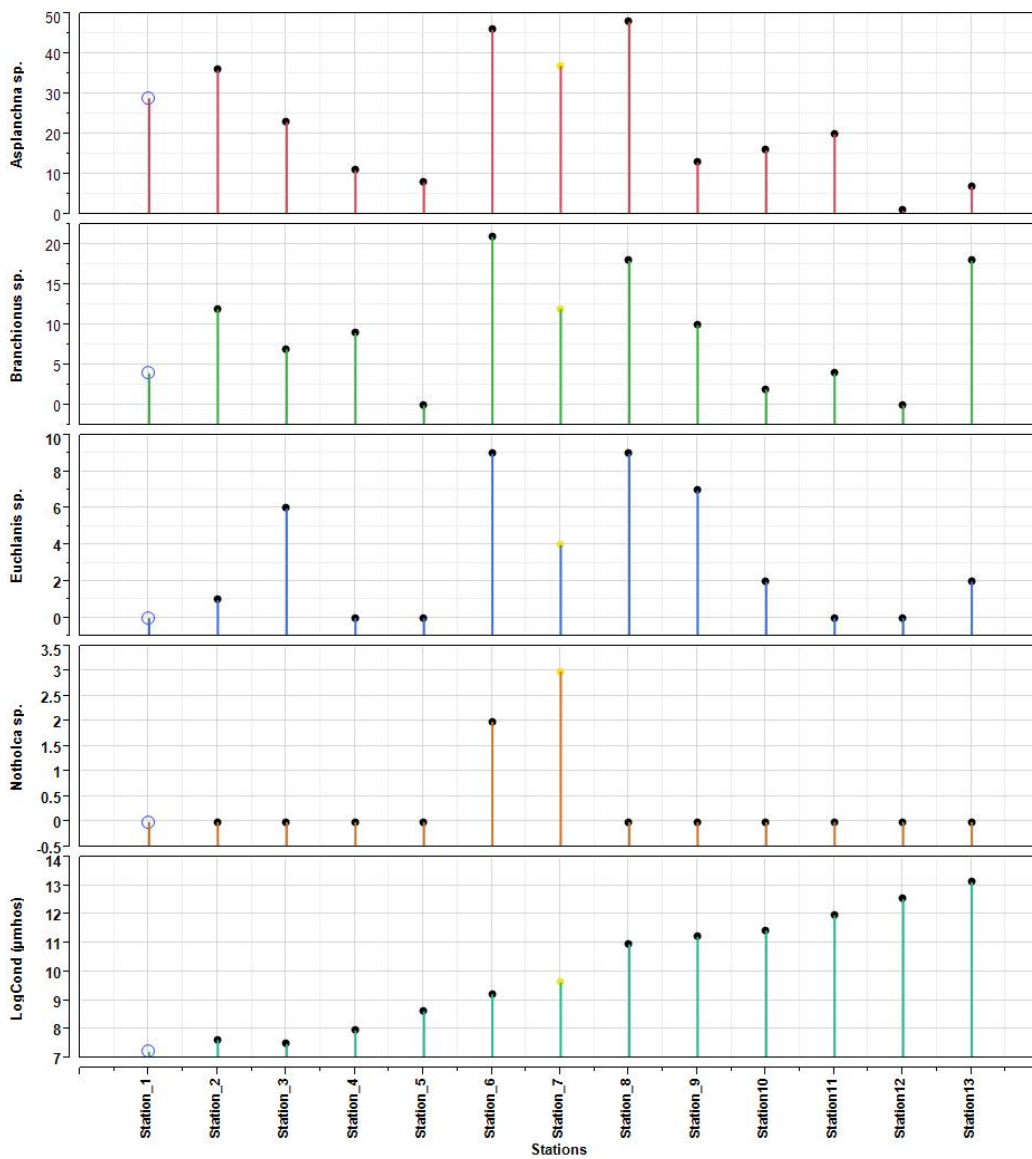


Fig. 6. Numerical abundance (indv/l) of rotatoria community among zooplankton

and *Asplanchna* sp. ($r= 0.3222$; $r= 0.3423$; $r=0.4191$ $p<0.05$). The numerical abundance in *Rotatoria Brachionus* sp., *Euchlanis* sp. and *Notholca* sp. expressed low to moderate correlation with Cyclopoid copepods ($r = 0.3569$; $r=0.6009$; $r=0.4279$; $p<0.05$).

Fig. 7 show diversity of Zooplankton presented as Shannon–Weiner index (H), Margalef index (S) and Pileou (E) evenness. The SWi value of 1.1 and 1.2 occurred in middle section of creek in stations 6, 7, 8 with highest value of 1.3 in outward section of creek at station 11. Lowest SWi diversity was mostly in innermost sections of creek where diversity varied from 0.7 to 0.9. The Margalef index (S) values of 0.1 and 0.2 were low for most stations. The Pileou evenness vary from 0.1 to 0.2 and corresponds with profile of Shannon-Weiner index.

5. DISCUSSION

The study has shown evidence of a standing crop of Zooplankton with a dominance of copepods. Among stations there was no

significant difference ($p<0.05$) in abundance between stations from conductivity value of 150 (μmhos) at station 1 to conductivity value of 8000 (μmhos) at station 13. There was also no pattern in the correlation of conductivity to abundance of Copepods, Rotatoria, Cladocera and Cilliata. The occurrence of only three genera of Cladocera, three genera of Cilliata and four genera of Rotatoria with relatively lower abundances than the Copepod group recorded, suggest that in this tidal creek, freshwater Zooplankton are not significant components. The observed significant Copepod dominance (72-96%) and the low diversity and evenness patterns reflect a Zooplankton community operating under non-equilibrium [31] conditions.

The non-equilibrium conditions expressed as high abundance of Copepods (95%) and significant low numbers of Rotatoria (3.2%), Cladocerans (1.2%) and Cilliata (0.5%) suggest biological interactions that support ecological principles of a trophic cascade [32,33,34,35,36]. Copepod induced trophic cascades have been implicated in a number of studies [37,38,39,40].

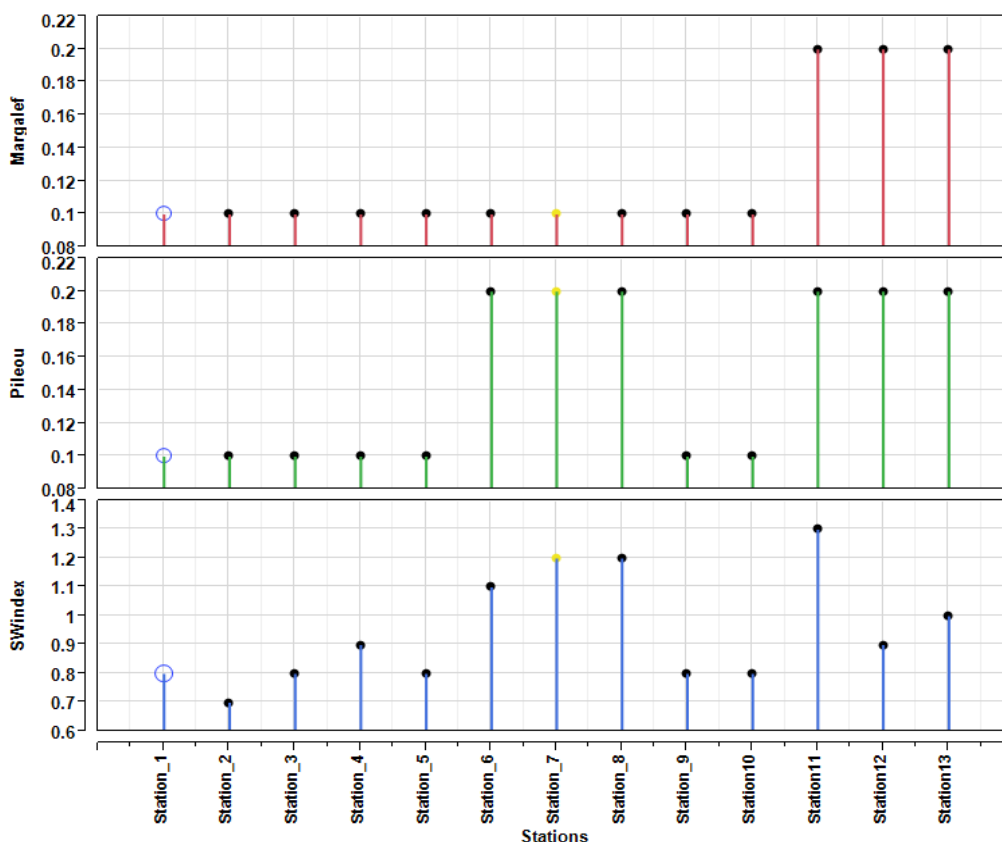


Fig. 7. Diversity values as Shannon Weiner Index (H), Margalef Index (S) and Pileou evenness (E)

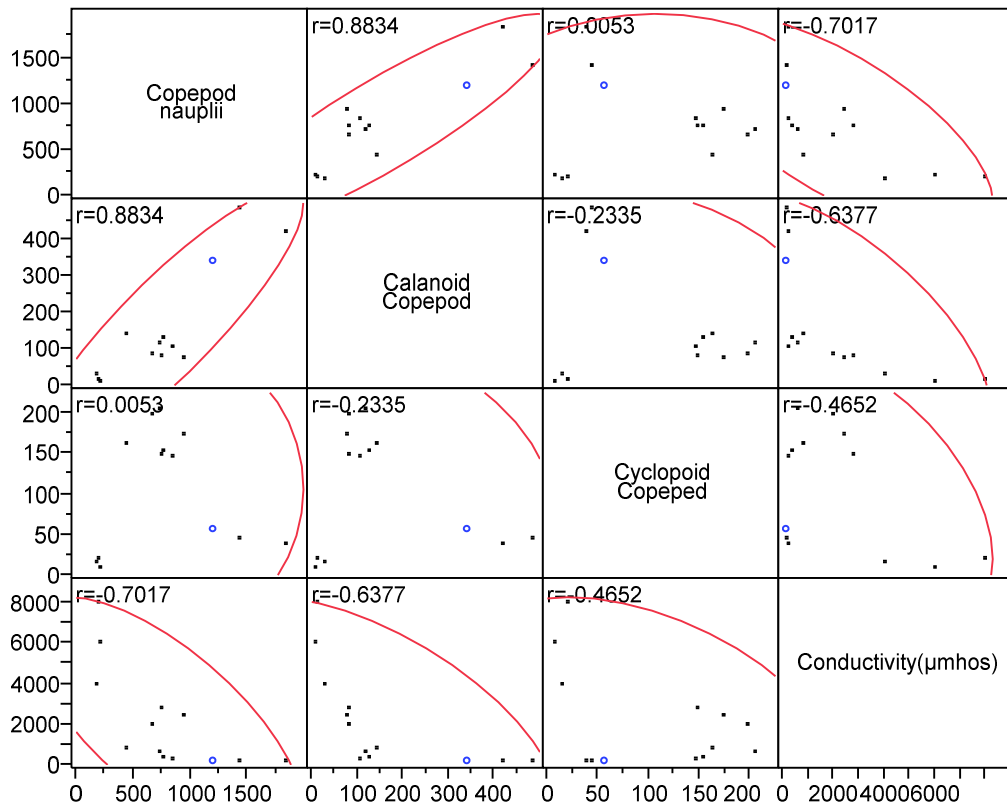


Fig. 8. Scatterplot matrix of correlations between copepods and conductivity (µmhos)

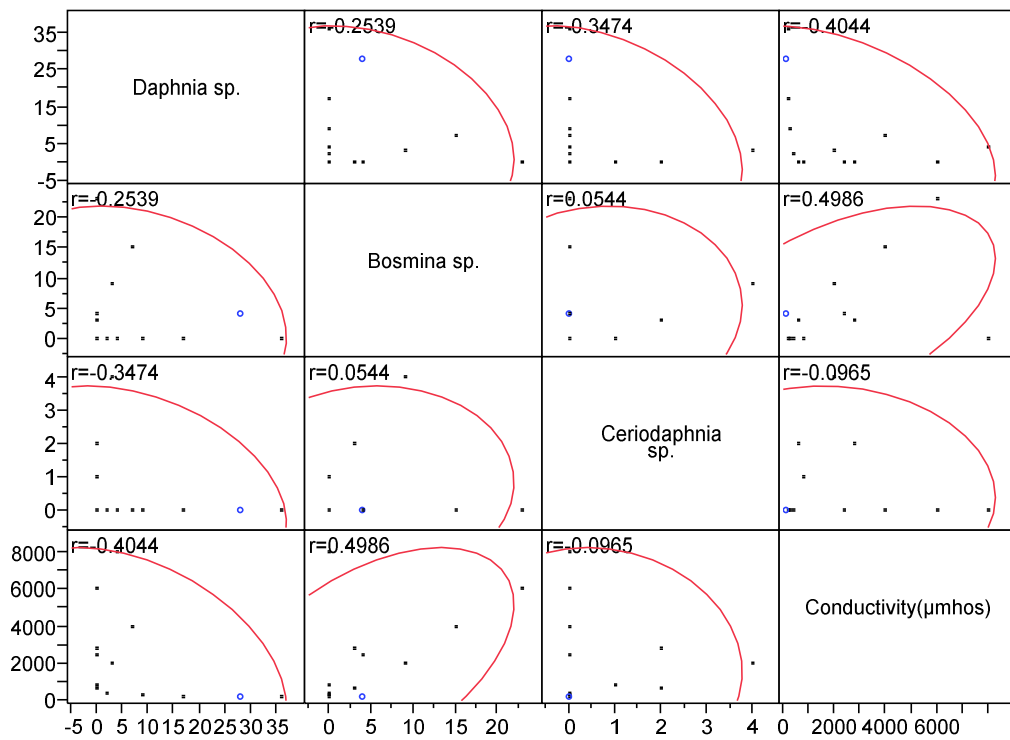


Fig. 9. Scatterplot matrix of correlations between Cladocera and conductivity (µmhos)

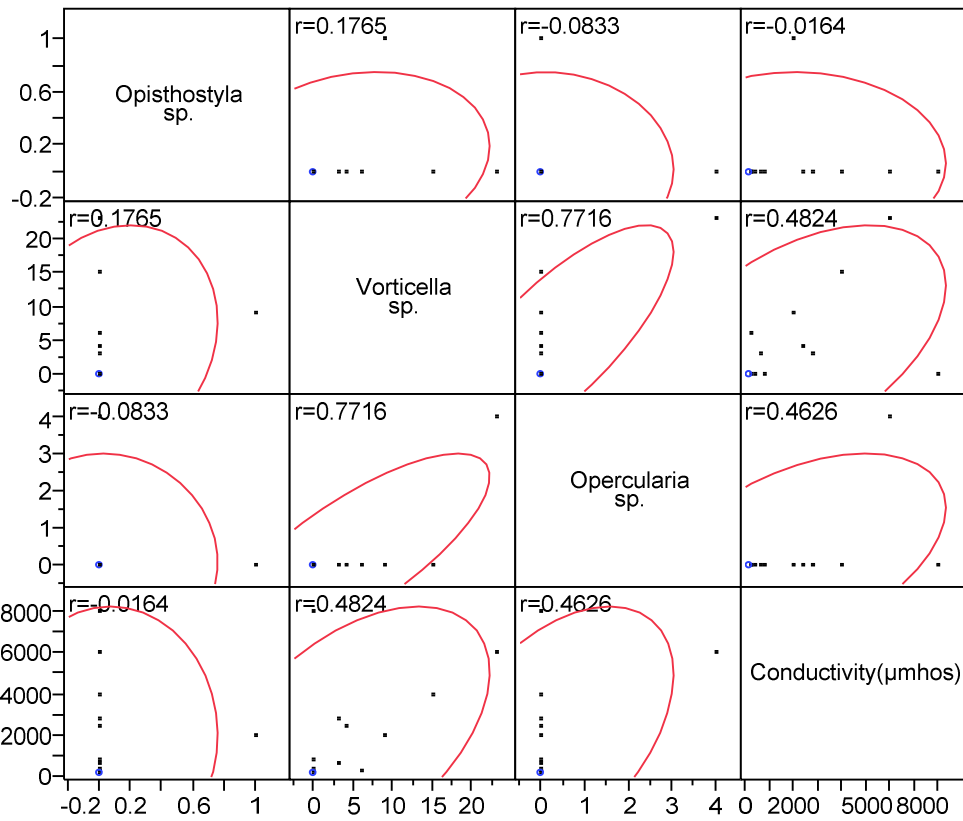


Fig. 10. Scatterplot matrix of correlations between Ciliata and conductivity (µmhos)

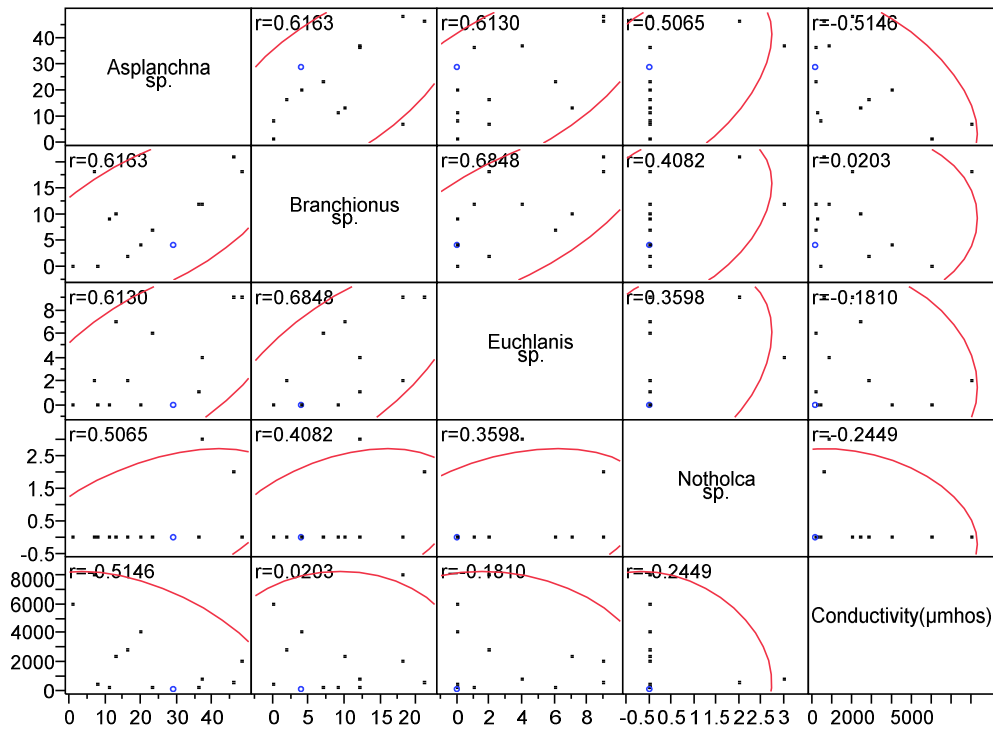


Fig. 11. Scatterplot matrix of correlations between Rotatoria and conductivity (µmhos)

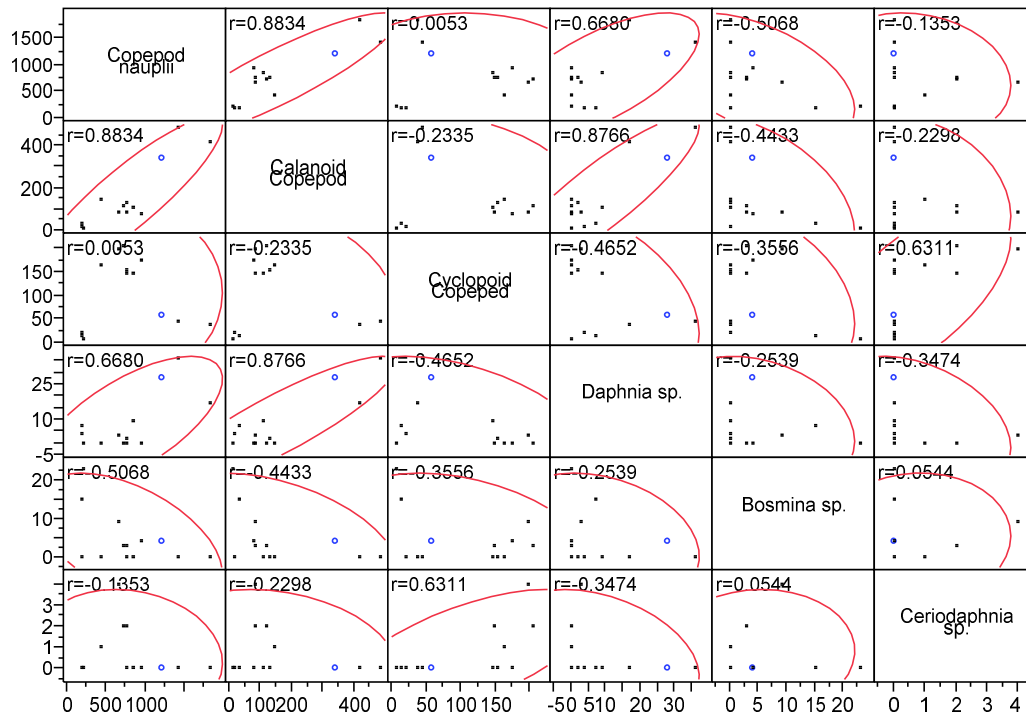


Fig. 12. Scatterplot matrix correlation of abundance between copepod and cladocerans

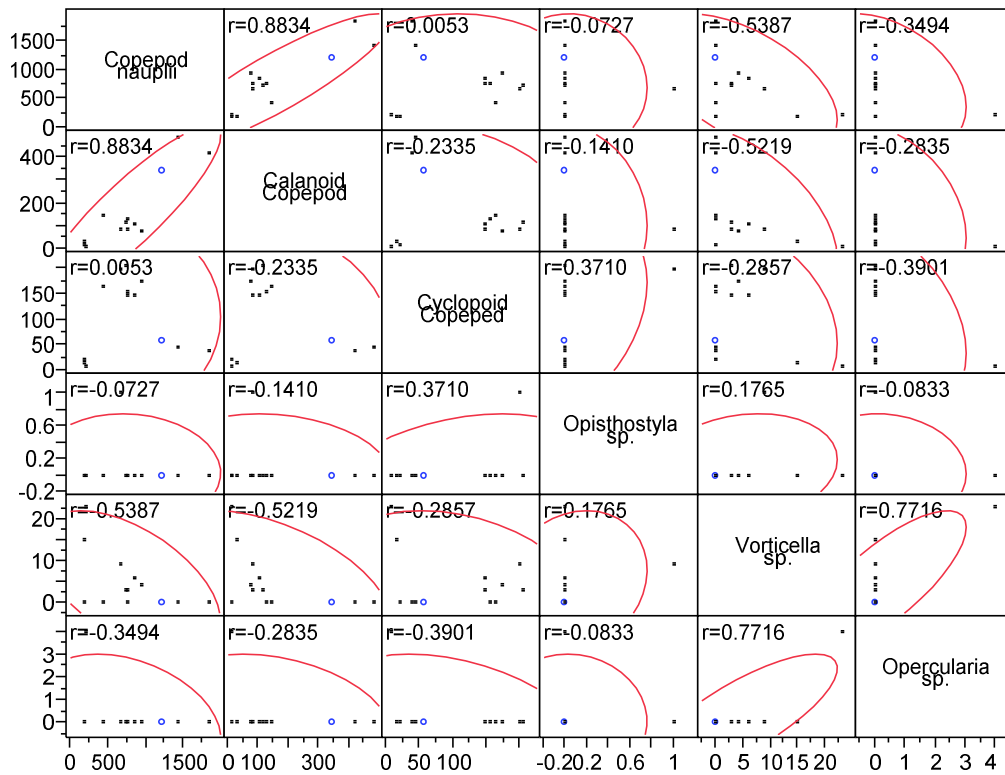


Fig. 13. Scatterplot matrix correlation of abundance between copepod and ciliata

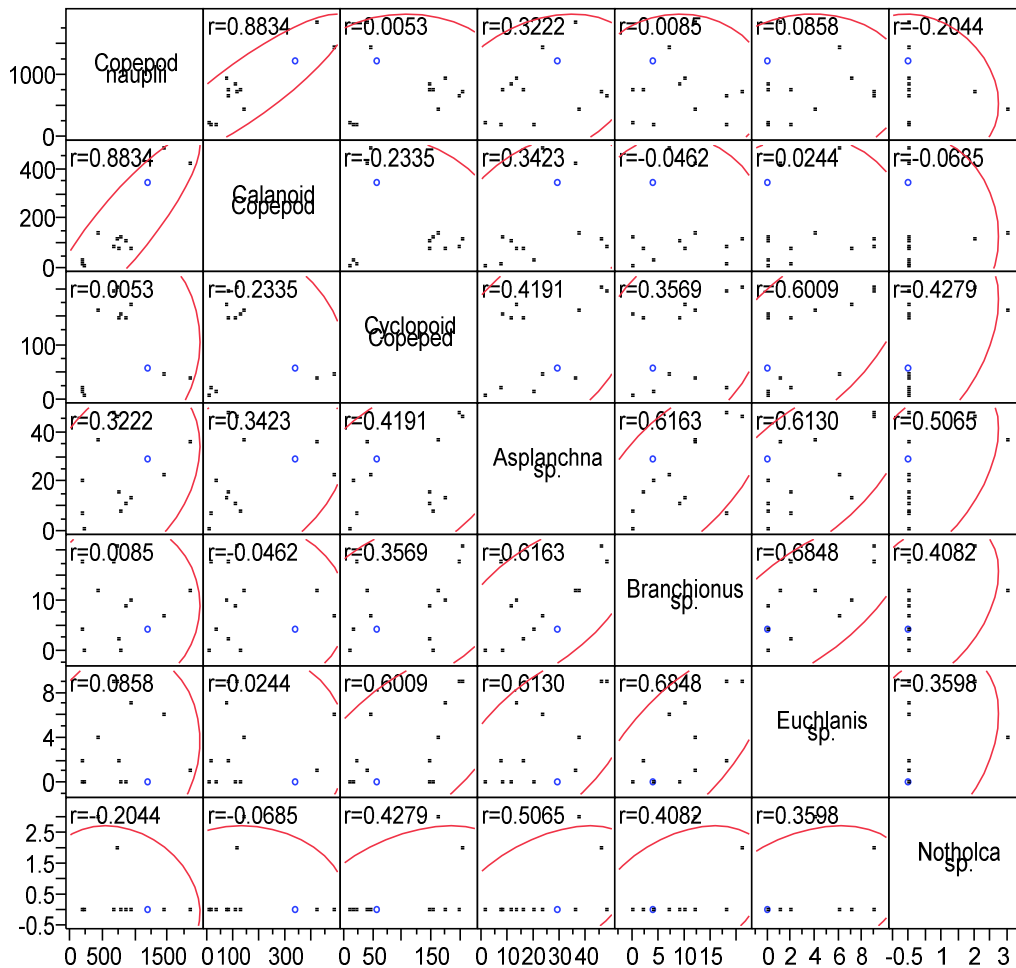


Fig. 14. Scatterplot matrix correlation of abundance between copepod and rotatoria

The observed trophic cascade is plausibly from depletion of Ciliata who is an intermediate competitor with copepods for same basal resources. Ciliates are known as an important component of aquatic ecosystems by consuming autotrophic and heterotrophic pico and nano plankton and function as prey Zooplankton at higher trophic levels [41-44].

Ciliates were characterized with ubiquity, rapid reproductive rate and capacity to survive in extreme environments, including adaption to anaerobic conditions. Their significantly low numbers strongly suggest a cascade effect. Only one Ciliate namely *Vorticella* sp. was observed to have occurred in seven (7) stations out of 13 stations with other Ciliates, *Opisthostyla* sp. and *Opercularia* sp. occurring in single stations. Similarly Cladocerans which were represented in an asynchronous pattern across 13 stations by

Daphnia sp. (8 stations); *Bosmina* sp. (7 stations) and *Ceriodaphnia* sp. (4 stations) were significantly low compared to Copepods. Copepods are known practice omnivory switching from one intermediate predator such as Ciliates that compete for common resources from primary production [45-48] and [49-51].

Studies have also shown suppression of Cladocerans by Copepods through direct effect of numerical abundance and indirect effect by release of chemicals or kairomones [52,53,54,55,56] and [57,58,59,60,61]. From the foregoing, it is plausible to infer the existence of intraguild interactions among Zooplankton community at sampling time. Copepods through a combination of predation and competition were maintained by existence of alternative prey as they drive their preferred prey to low numbers while they feed across trophic levels.

6. CONCLUSION

The study shows evidence that at sampling time a trophic cascade and intraguild competition was standing trophic status among Copepods, Rotatoria, Cladocera and Ciliata on Olero creek. The observed numerical relationship within trophic levels shows Copepods who as top-level consumers were operating a top-down system driven in principle by predation and competition. The typology of this top-down cascade system between Copepods and other Zooplankton should be included in directions of future research to enable a more appropriate basis of cross system explanation in marine, estuaries and freshwater systems.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Davies OA, Abowei JFN, Tawari CC. Phytoplankton community of Elechi Creek, Niger Delta, Nigeria - A nutrient polluted tropical creek. *American Journal of Applied Sciences*. 2009;6(6):1143-1152.
2. Iloba KI, Ruejoma MGO. Physico-chemical characteristics and zooplankton of Ekpan River, Delta state, Nigeria. *International Journals of Applied Biological Research*. 2014;6(1):8-30.
3. Holden MJ, Green J. The hydrology and plankton of River Sokoto. *Journal Animal Ecology*. 1960;29:65-84.
4. Williams VN. The Seasonal distribution of the teleost fish fauna in Lagos harbour, creek and Lagoon in relation to salt tolerance. M.Sc. Thesis, University of Wales; 1962.
5. Olaniyan CIO. The seasonal variation in the hydrology and total plankton of the lagoons of South West-Nigeria. *Nigerian Journal of Science*. 1969;3(2):101-119.
6. Fagade SO, Olaniyan CIO. Seasonal distribution of the fish fauna in Lagos Lagoon. *Bulletin de l'Institut Français d'Afrique Noire. Series A*. 1974;36:245-252.
7. Adebisi AA. The physicochemical hydrology of a tropical seasonal river – upper Ogunriver. *Hydrobiologia*. 1981;179: 157-165.
8. Egborge ABM. The composition, seasonal variation and distribution of Zooplankton in lake Asejire, Nigeria. *Revue de Zoologie Africaine*. 1981;95:136-163.
9. Nwankwo DI. Phytoplankton of a sewage disposal site in Lagos Lagoon. I. The Algae. *Nigerian Journal of Biological Sciences*. 1986;1(2):89-96.
10. Abohweyere PO. Study of limnological parameters and potential fish yield in Kigera reservoir (extensive system) in Kainji, New Bussa, Nigeria. *Journal of Aquatic Sciences*. 1990;5:53-58.
11. Ugwumba AAA. Food and feeding habit of *Orochromis niloticus*, *Sarotherodon melanotheron* and *Heterotis niloticus*. (Pieces Osteichthyes) in Awba reservoir Ibadan. PhD Thesis, University of Ibadan, Ibadan; 1990.
12. Ajuonu N, Ukaonu SU, Oluwajoba EO, Mbawuike BE, Williams AB, Myade EF. The abundance and distribution of plankton species in the bonny estuary; Nigeria. *Agriculture and Biology Journal of North America*. ISSN Print: 2151-7517, ISSN Online. 2011;2151-7525.
13. Muhlen Mand Schneider G. Der See Wirzjerw in Livland. *Archivfur die Naturkunde des Ostbaltikums*. 1920;14:1–156.
14. Gulati RD. Zooplankton and its grazing as measures of trophy in the Loosdrecht lakes. *Verhandlungen des Internationalen Verein Limnologie*. 1984;22:863-867.
15. Gulati RD. Structural and grazing responses of zooplankton community to biomanipulation of some Dutch water bodies. *Hydrobiologia* 1990;200-201:99-118.
16. Ivanova MB. Productivity of planktonic crustaceans in freshwater water bodies. *Nauka*. 1985;220.
17. Jeppesen E, Jensen JP, Søndergaard M, Lauridsen T. Trophic dynamics in turbid and cleanwater lakes with special emphasis on the role of zooplankton for water clarity. *Hydrobiologia*. 1999;408-409: 217-231.
18. Marneffe Y, Comblin S, Thomé J. Ecological water quality assessment of the Bûtgenbachlake (Belgium) and its impact on the River Warche using rotifers as bioindicators. *Hydrobiologia*, 1998;387-388:459-467.
19. Nöges T, Agasild H, Haberman J, Kangur A, Kangur K, Kangur P, Timm H, Zingel P, Nöges P. Food webs in lake Vörtsjärv. In: J. Haberman, E. Pihu, A. Raukas (eds.),

- LakeVõrtsjärv. Estonian Encyclopedia Publishers. 2004;335-345.
20. Agasild H, Zingel P, Tõnno I, Haberman J, Nõges T. Contribution of different zooplankton groups in grazing on phytoplankton in shallow eutrophic Lake Võrtsjärv (Estonia). *Hydrobiologia* 2007; 584:167-177.
 21. Sampaio EV, Rocha O, Matsumura-Tundisi T, Tundisi JG. Composition and abundance of zooplankton in the limnetic zone of seven reservoir of the Paranapanema River, Brazil. *Brazilian Journal of Biology*. 2002;62(3):525-545.
 22. Sendacz S, Caleffi S, Santos Soares J. Zooplankton biomass of reservoirs in different trophic condition in the state of São Paulo, Brazil. *Revista Brasileira de Biologia*. 2006;66(1):337-350.
 23. Bini LM, Vieira LCG, Machado J, Velho LFM. Concordance of species composition patterns among microcrustaceans, rotifers and testate amoebae in a shallow pond. *International Review of Hydrobiology*. 2007;92(1):9-22.
 24. Anderson RS. Predator relationships and predation rates for crustacean zooplankters from some lakes in western Canada. *Canadian Journal of Zoology*. 1970;48:1229-1240.
 25. Confer JL. Intra-zooplankton predation by *Mesocyclops edax* at natural prey densities. *Limnological. Oceanography*. 1971;16: 663-666.
 26. Hillbricht-Ilkowska A. Trophic relations and energy flow in pelagic plankton. *Polish Ecological Studies*. 1977;3:3-98.
 27. Gannon JE, Stemberger R. Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Transactions of the American Microscopical Society*. 1978; 97:16-35,
 28. Echevarria JF, Carrillo P, Jim Cnezf, Sanchez-Castillo P, Cruz-Pizarro L, Rodriguez J. The size-abundance distribution and taxonomic composition of plankton in an oligotrophic, high mountain lake (La Caldera, Sierra Nevada, Spain). *Journal of Plankton Research*. 1990;12: 415-422.
 29. Santos-Wisniewski MJ, Rocha O. Spatial distribution and secondary production of Copepoda in a tropical reservoir: Bonita, SP, Brazil. *Brazilian Journal of Biology*. 2007;67(2):223-233.
 30. Silva WM. Potential use of Cyclopoida (Crustacean, Copepoda) as trophic state indicators in tropical reservoirs. *Oecologia Australis*. 2011;15(3): 511-521.
 31. Huston M. A general hypothesis of species diversity. *The American Naturalist*. 1979; 113:81-101
 32. Paine RT. Food webs: Linkage, interaction strength and community infrastructure. *Journal of Animal Ecology*. 1980;49:667-685.
 33. Carpenter SR, Kitchell JF, Hodgson JR. Cascading trophic interactions and lake productivity. *BioScience*. 1985;35:634-39.
 34. Pace ML, Cole JJ, Carpenter SR, Kitchell JF. Trophic cascades revealed in diverse ecosystems. *Trends in Ecology and Evolution*. 1999;14:483-488.
 35. Polis GA, Sears ALW, Huxel GR. When is a trophic cascade a trophic cascade? *Trends in Ecology and Evolution*. 2000;15: 473-475.
 36. Schmitz OJ, Krivan V, Ovadia O. Trophic cascades: The primacy of trait-mediated indirect interactions. *Ecology Letters*. 2004; 7:153-163.
 37. Fessenden L, Cowles TJ. Copepod predation on phagotrophic ciliates in Oregon coastal waters. *Marine Ecology Progress Series*. 1994;107:103-111.
 38. Katechakis A, Stibor H, Sommer U, Hansen T. Changes in the phytoplankton community and microbial food web of Blanes Bay (Catalan Sea, Mediterranean) under prolonged grazing pressure by Doliolids (Tunicata), cladocerans or copepods (Crustacea). *Marine Ecology Progress Series*. 2002;234:55-69.
 39. Sipura J, Lores E, Snyder RA. Effect of copepods on estuarine microbial plankton in short-term microcosms. *Aquatic Microbial Ecology*. 2003;33:181-190.
 40. Broglio E, Saiz E, Calbet A, et al. Trophic impact and prey selection by crustacean zooplankton on the microbial communities of an oligotrophic coastal area (NW Mediterranean Sea). *Aquatic Microbial Ecology*. 2004;35:65-78.
 41. Brook AJ. Some observations on the feeding of Protozoa on freshwater algae. *Hydrobiologia*. 1952;4:281-293.
 42. Javornick P, Prokesová V. The influence of Protozoa and Bacteria upon the oxidation of organic substances in water. *Internationale Revue der gesamten Hydrobiologie und Hydrographie*. 1963;48: 335-350.
 43. Ventela AM, Wiackowski K, Moilanen M, Saarikari V, Vuorio K, Sarvala J. The effect

- of small zooplankton on the microbial loop and edible algae during a cyanobacterial bloom. *Freshwater Biology*. 2002;47:1807-1819.
44. Blomqvist P, Jansson M, Drakare S, Bergstro AK, Brydsten L. Effects of additions of DOC on pelagic biota in a clearwater system: Results from a whole lake experiment in northern Sweden. *Microbial. Ecology*. 2001;42:383-394.
 45. Stoecker DK, Egloff DA. Predation by *Acartiatonsa* on planktonic ciliates and rotifers. *Journal of Experimental Marine Biology and Ecology*. 1987;110:53-68.
 46. Støttrup JG, Jensen J. Influence of algal diet on feeding and egg-production of the calanoid copepod *Acartia tonsa* Dana. *Journal of Experimental Marine Biology and Ecology*. 1990;141:87-105.
 47. Wootton JT. The nature and consequences of indirect effects in ecological communities. *Annual Review of Ecology, Evolution, and Systematics*. 1994;25:443-466.
 48. Gismervik I, Andersen T, Vadstein O. Pelagic food webs and eutrophication of coastal waters: Impact of grazers on algal communities. *Marine Pollution Bulletin*. 1996;33:22-35.
 49. Nejtgaard JC, Gismervik I, Solberg P. Feeding and reproduction by *Calanus finmarchicus*, and microzooplankton grazing during blooms of diatoms and the coccolithophore *Emiliania huxleyi*. *Marine Ecology Progress Series*. 1997;147:197-217.
 50. Schmitz OJ, Hambäck PA, Beckerman AP. Trophic cascades in terrestrial systems a review of the effects of carnivore removals on plants. *The American Naturalist*. 2000; 155:141-53.
 51. Hampton SE, Scheuerell MD, Schindler DE. Coalescence in the Lake Washington story: interaction strengths in a planktonic food web. *Limnological. Oceanography*. 2006b;51:2042-2051.
 52. Macháček J. Indirect effect of planktivorous fish on the growth and reproduction of *Daphnia galeata*. *Hydrobiologia*. 1991;225:193-197.
 53. Spitze K. Predator-mediated plasticity of prey life history and morphology: *Chaoborus americanus* predation on *Daphnia pulex*. *Am. Nat.* 1992;139:229-247.
 54. Pijanowska J. Diel vertical migration in zooplankton: fixed or inducible behaviour? *Archiv für Hydrobiologie–Beiheft Ergebnisse der Limnologie*. 1993;39:89-97.
 55. Pijanowska J, Weider LJ, Lampert W. Predator-mediated genotypic shifts in a prey population: Experimental evidence. *Oecologia*. 1993;96:40-42.
 56. Pijanowska J. Fish-enhanced patchiness in *Daphnia* distribution. *Verhandlungen des Internationalen Verein Limnologie*. 1994; 25:2366-2368.
 57. Reede T, Ringelber J. The influence of fish exudates on two clones of the hybrid *Daphnia galeata*, *Daphnia hyalina*. *Hydrobiologia*. 1995;307:207-212.
 58. De Meester L. Local genetic differentiation and adaptation in freshwater zooplankton population: Patterns and processes. *Ecoscience*. 1996;3:385-399.
 59. Boersma M, Spaak P, De Meester L. Predator-mediated plasticity in morphology, life history, and behaviour of *Daphnia*: The uncoupling of responses. *The American Naturalist*. 1998;152:237-248.
 60. Kumar R. Effect of *Mesocyclops thermocyclopoidea* (Copepoda, Cyclopoida) predation on population dynamics of different prey: A laboratory study. *Journal of Freshwater Ecology*. 2003;18:383-393.
 61. Kumar R, Hwang JS. Ontogenetic shifts in the ability of the Cladoceran, *Moina macrocopa* Straus and *Ceriodaphnia cornuta* Sars to utilize ciliated protists as food source. *International Review of Hydrobiology*. 2008;93:284-296.

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