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Hydrography and Crustacean Zooplankton as Determinants of Rotifer Distribution and Density in Damietta Coast, Egypt

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Abstract: Samples were collected seasonally from Damietta Coast during summer 2013-spring 2014 at five sites to assess the relative importance of environmental variables and crustacean zooplankton as determinants of rotifer distribution. Redundancy analysis showed that 44.1% and 43.6% of the variance in rotifer density was explained by environmental variables and crustaceans respectively. The maximum crustacean density appeared at site III with the higher densities of saltwater copepods as the cyclopoid *Oithona nana* and the harpacticoid *Euterpina acutifrons*. Larger rotifer density appeared at site V with the higher concentration of phytoplankton biomass and lower salinity. All the recorded species except *Synchaeta* spp. are freshwater forms and showed their maximum density at site V (Located at the mouth of Gamsa Drain west to the mouth of the River Nile branch) opposite to salinity gradient. *Ascomorpha saltans*, *Brachionus urceolaris* and the euryhaline *B. plicatilis* were the most abundant. The carnivorous *Cyclops vernalis* and the herbivorous *Bosmina longirostris* were the most effective in rotifer species distribution. Variation partitioning analysis demonstrated that the variances explained by pure crustaceans and pure environmental variables were 16.7 % and 14.2%, respectively. Rotifer species distribution in the study area was strongly associated with salinity variation, chlorophyll-a and their defense against potential predators and competitors of planktonic crustaceans.

Key words: Rotifera · Crustacean zooplankton · Variation partitioning · Damietta coast

INTRODUCTION

Rotifers are important component of planktonic communities because of their rapid heterogonetic reproduction; they are the first metazooplankters to cause an impact by grazing on phytoplankton. Furthermore, rotifers influence various interactions within the microbial food-wed which occur at several trophic levels [1]. Algae and bacteria are among the major food resources for rotifers which play a significant role as grazers, suspension feeders and functional predators within the zooplankton community [2] and comprise a significant portion of the annual production of freshwater zooplankton communities [3]. Because of short generation times, rotifer species commonly display extreme rates of population growth during periods of suitable conditions, but often rapidly decline when conditions worsen [4]. Unfortunately, it is difficult to determine thoroughly the ecological factors that set limits on population abundance and produce such rapid changes in rotifers community. Two views have appeared: 1- competition and/or predation with crustaceans, as most rotifers and cladocerans and some copepods compete for the same food resources and some cyclopoid copepods are effective predators on rotifers [5, 6]. Many studies have revealed a clear negative correlation between abundances of crustaceans and rotifers in natural environments [7, 8]. 2- Other environmental factors such as pH [9], salinity [10, 11], oxygen and temperature [11, 12] and food availability [13].

Although rotifers have been reported in numerous studies on zooplankton community along the Egyptian Mediterranean coast [14, 15, 16], there has been very limited information on the interactions of rotifers with environmental variables and crustacean zooplankton. Thus this work aimed to determine the relative importance of these two forces in regulating the rotifer density and species distribution.

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MATERIALS AND METHODS

Study Area: Damietta coast lies at the eastern part of the Nile Delta on the south eastern Mediterranean Coast, between longitude 31°51 and 31°33 E and latitude 31°31 and 31°26 N. Five sites were selected for samples collection, representing different habitats in Damietta coast (Fig. 1).

Site I lies in the front of a canal connecting Manzala Lake to the Mediterranean Sea. Site II is located at the mouth of the Damietta Nile estuary. Site III is located in the Damietta harbor barge canal at the connection between barge canal and Nile River. Site IV lies at the mouth of Seta drain which sometimes receives considerable amounts of untreated agricultural, industrial and sewage discharge from the City of New Damietta and its neighboring villages. Site V located at the mouth of Gamsa Drain west to the mouth of the River Nile branch which receives huge amounts of untreated domestic and agricultural waste waters from the eastern part of Damietta Governorate and the south of Dakhlia Governorate.

Methods: Study at five sites was carried out seasonally from summer 2013 to spring 2014. Specifically, in August & November 2013; February & May 2014, theses sampling were designated as: summer, autumn 2013 and winter, spring 2014 respectively.

Samples of hydrological and chemical parameters in addition to phytoplankton biomass (Chlorophyll-a) were taken from surface water, while zooplankton samples were collected using a 54-µm mesh plankton ring-net of 45 cm mouth diameter. Net collections were preserved in 5% neutralized formalin and after setting they were concentrated to 100 ml. Abundances were expressed as the number of individuals per cubic meter (individuals × m^{-3}). Zooplankton samples were identified to species using a combination of Koste and Shiel [17, 18], Shiel and Koste [19], Edmondson [20], Gonzalez and Bowman [21] and Boltovskoy [22].

The water temperature was measured with thermometer sensitive to 0.1°C, the pH with a pocket pH meter (model 201/digital pH meter) and the water salinity to the nearest part per thousand with a refractometer. Dissolved oxygen and phytoplankton biomass (chlorophyll-a) were determined according to the methods described by Strickland & Parsons [23].

Statistical Analysis: Shannon's (H') index [24] and species Dominance index [25] were used to estimate the community structure for both rotifers and crustacean zooplankton. One-way ANOVA with Tuckey's-b test was employed to test the spatial and temporal differences between the environmental variables, species number and diversity of rotifers and crustaceans. Simple correlations

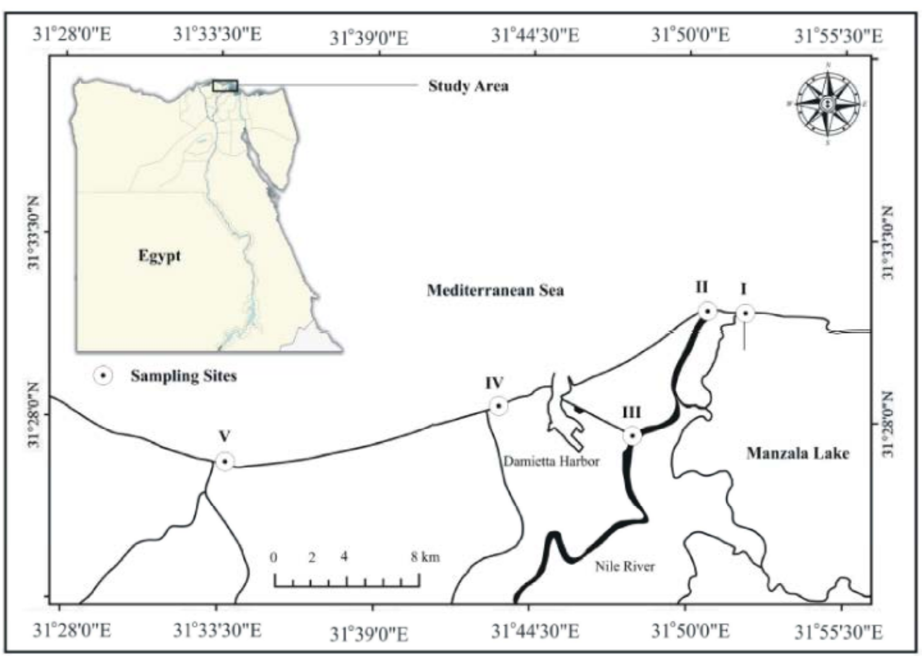

Fig. 1: Study area with sampling sites

were determined to define the relationship between abundance, species number and Shannon diversity of rotifers and environmental variables and dominant crustaceans. The data were tested for normality prior to analysis and transformed to natural logarithms where necessary to satisfy the homogeneity of variances and normality of analysis. ANOVA and Correlations were performed using SPSS 18.

Redundancy analysis (RDA) was performed to assess the association of rotifer species with environmental factors and the most important planktonic crustaceans. A Monte Carlo test was used to evaluate the significance of RDA axes and the different variables by using 999 unrestricted permutations. Variation partitioning was performed according to Galbraith and others [26] by using Canonical correspondence analysis CCA, which permits to single out the individual effects of environmental variables and crustaceans. This analysis was accomplished using statistically significant variables in three explanatory data sets individually as coverable and after that remaining the combined effects of the two matrices. CANOCO 4.5 package for windows was used for multivariate analyses (RDA and CCA) [27].

RESULTS

Hydrographic Conditions: Water temperature followed the expected annual dynamics with winter minimum (14.7-16.5°C) and summer maximum (28-29.4°C) (Table 1). No spatial variations in water temperature could be detected (Table 2). Dissolved oxygen and pH values for site V were significantly lower than those of other sites. Seasonally, there were no significant variations in dissolved oxygen and pH values. Salinity values varied between 5.9 and 39.4 ppt. There were no significant seasonal variations in salinity (Table 1). Spatially, salinity showed the most noticeable spatial significant variations .In accordance with the salinity gradient, the sampling sites could be ranked as follows: site I = site II > site III= site IV > site V. Chlorophyll-a concentrations were significantly greater at site V (18 μgl^{-1}) than at the other sites (averaged between 8- 11.8 μgl^{-1}), indicating higher trophic status at site V when comparing to other sites (Table 2). Seasonally, Chlorophyll-a concentrations were significantly lower during winter (5.1 μgl^{-1}) than the other seasons which showed a relatively similar values of Chlorophyll-a (Table 1).

Zooplankton Community Structure and Composition: A total 27 crustacean species were identified during the present study; 19 copepods and 8 cladocerans. One way ANOVA with Tuckey's-b test revealed a significant differences between the number of species present per site (*F ratio* = 3.7, p <0.05), however the Shannon index values revealed no significant differences (*F ratio* = 1.5, p >0.05). Accordingly, site III sustained the highest species number, while sites II and V were the lowest (Fig. 2A). Crustacean density ranged from 1.6 to 144.4 × 10^3 individuals m^{-3}. The highest density (144.4 × 10^3 individuals m^{-3}) was recorded at site III during spring and the lowest recorded at site II (1.57 × 10^3 individuals m^{-3}) during Autumn (Fig. 3).

As shown in Table 3, only copepod nauplii and copepodites were dominant at all sampling sites. *Oithona nana* and *Euterpina acutifrons* dominated the crustacean community at all sampling sites except at site V. *Oithona simplex* and *Paraclanus* spp. were dominant at site III. Freshwater species like *Acanthocyclops americanus, Cyclops vernalis*, *Halicyclops magniceps*, *Bosmina longirostris* and *Moina macrocarp* dominated the crustacean zooplankton community at site V.

A total of 31 rotifer species were identified in the study area (Table 3). As shown in Figure 2B and based on the results of one way ANOVA analysis with Tuckey's-b test, sites I, II, III and IV showed a similar values of species number which were considerably lower than those at site V. The rotifers diversity according to the Shannon diversity index was in arrangement relatively similar to that of the species number (Fig. 2B). Rotifers density showed a wide range of variation, ranged from 58.5 to 28.45× 10^3 individuals m^{-3}. As shown in figure 3, site V showed higher densities of rotifers in all season with the maximum record in summer (28.45 × 10^3 individuals m^{-3}). The lowest densities of rotifers were recorded at site I in winter

As shown in Table 3, *Brachionus plicatilis* was recorded as dominant species at all sampling sites. *Synchaeta okai* and *S. pectinata* were dominant at all sites except at site V. *Synchaeta oblonga* dominated the rotifers community at sites II, III and IV. All other dominant species like *Anuraeopsis fissa*, *Ascomorpha saltans*, *Brachionus angularis*, *B. urceolaris*, *Keratella cochlearis* and *Proales daphnicola* were found at site V (Table 3).

Rotifers Species Distribution in Relation to Both Environmental Variables and Crustacean Zooplankton: The results of redundancy analysis (RDA) applied to the two sets of explanatory variables indicated that both dominant crustaceans and environmental variables had significant influences on rotifer distribution (p<0.001; Monte Carlo permutation test, 999 unrestricted

Table 1: Mean, range and one-way ANOVA of the five variables measured seasonally in the study area

Parameters	Summer	Autumn	Winter	Spring	*F*	*P*
T (°C)	28.6 (28-29.4)^a	22.3 (21.6-23.9)^b	15.7 (14.7-16.5)^c	22.5 (22-23)^b	265.6	<0.001
pH	8 (7.7-8.3)	7.9 (7.8-8.2)	7.9 (7.7-8.1)	7.9 (7.7-8.3)	0.23	>0.05
DO (mg l^{-1})	5.4 (1.3-7.2)	6.9 (5.2-8.6)	7.6 (7.3-8.5)	7.1 (3.8-8.6)	1.5	>0.05
Sal (ppt)	25 (7.8-36)	24.5 (7.3-35.3)	21.3 (6-32.2)	23.4 (5.9-39.4)	0.11	>0.05
Chl-a (µg l^{-1})	14.8 (9.8-21.2)^a	12.7 (9.8-18.3)^a	5.1 (2.5-9.8)^b	13.4 (10-22.1)^a	5.562	<0.05

The letters indicate significant differences based on one-way ANOVA with Tuckey's-b test where a>b>c. T= temperature, Sal= Salinity, Chl-a= Chlorophyll-a

Table 2: Mean, range and one-way ANOVA of the five variables measured in waters of 5 sites of the study area

	Site I	Site II	Site III	Site IV	Site V	*F*	*P*
T (°C)	22.1 (15.4-28.5)	22.2 (14.7-28)	22.7 (16.5-29.4)	22.2 (16.2-28.7)	22.3 (15.8-28.7)	*0.08*	>0.05
pH	7.96 (7.83-8.15)^b	8.18 (8.08-8.25)^a	7.97 (7.9-8.01)^b	7.75 (7.69-7.81)^c	7.74 (7.68-7.86)^c	17.4	<0.001
DO (mg l^{-1})	7.1 (6.4-8.1)^{ab}	7.7 (6.5-8.6)^a	7.9 (7.2-8.6)^a	6.6 (5.7-7.4)^{ab}	4.4 (1.3-7.4)^b	4.2	<0.001
Sal (ppt)	33.8 (31.5-36)^a	31.6 (25.2-39.4)^a	23.3 (19.6-26.8)^b	22.3 (20.4-24.3)^b	6.8 (5.9-7.8)^c	42.2	<0.001
Chl-a (µg l^{-1})	8.5 (2.5-11.2)^b	11.8 (6-14.5)^b	10.8 (4.2-16.8)^b	8.4 (3-10.7)^b	18 (9.8-22.1)^a	3.1	<0.05

The letters indicate significant differences based on one-way ANOVA with Tuckey's-b test where a>ab> b>c. T= temperature, Sal= Salinity, Chl-a= Chlorophyll-a

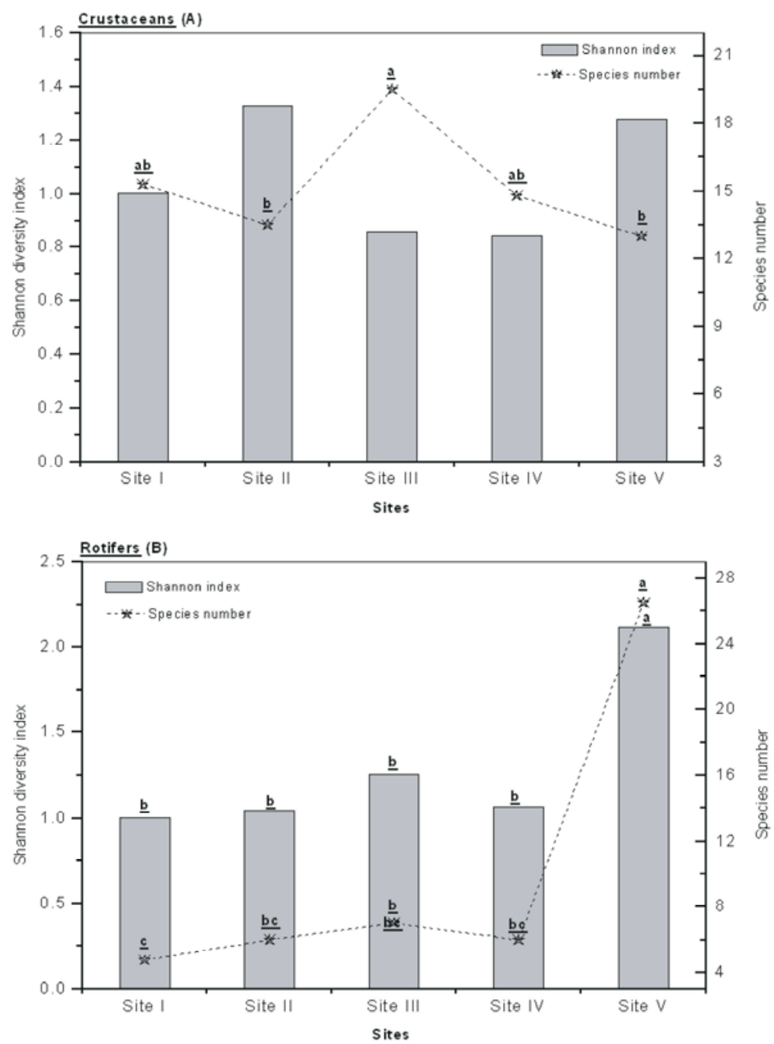

Fig. 2: Spatial variations of crustaceans(A) and rotifers (B) species number and diversity (Note the letters indicate the significant differences based on the results of one way ANOVA and Tuckey's-b test where: a>ab>b>bc>c)

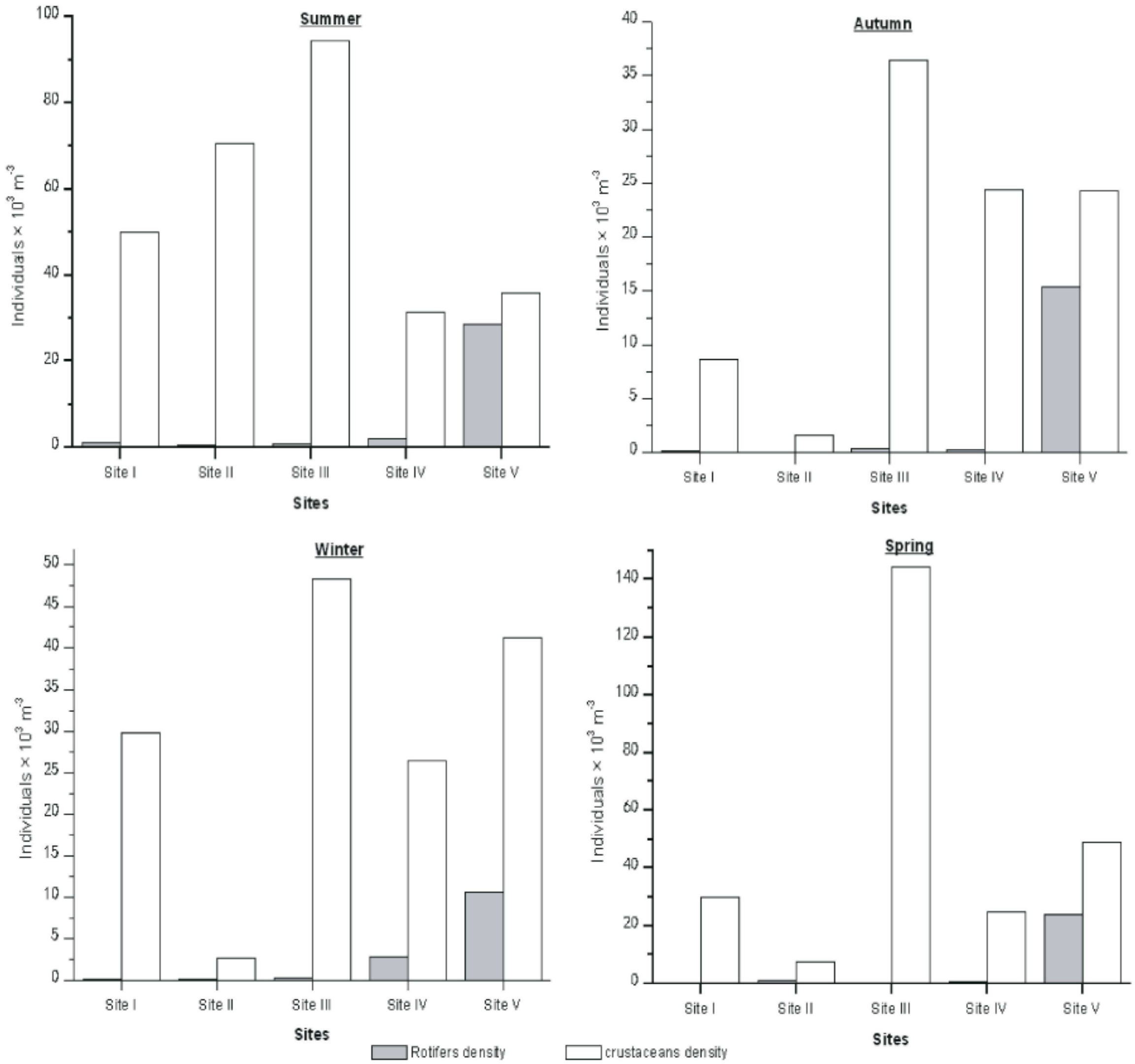

Fig. 3: Seasonal densities of crustaceans and rotifers at the sampling sites

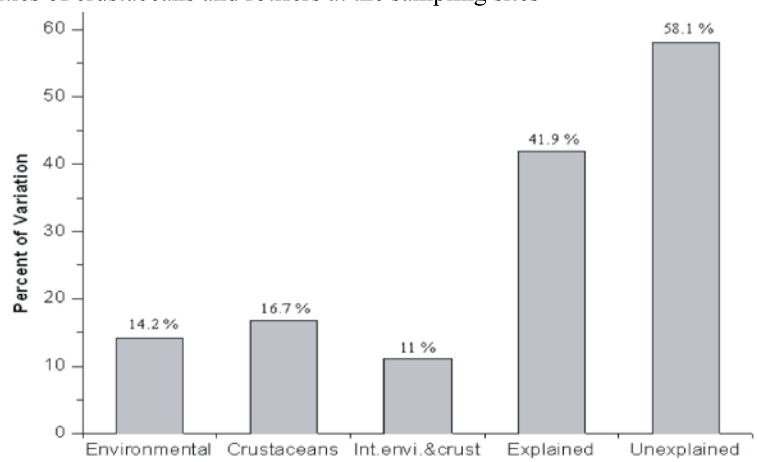

Fig. 4: The relative portion explained by pure hydrographic conditions, pure crustaceans and the interaction between the two explanatory data sets (Int.envi. & crust)

Table 3: Abundance-(averaged individuals m^{-3}) and dominancy of the species of rotifers and the most important crustacean zooplankton at Damietta coast during the study period

	Abb.	Site I	Site II	Site III	Site IV	Site V
Rotifera						
Anuraeopsis fissa (Gos.)	Anfi					1362.75*
Ascomorpha saltans (Bar.)	Assa					1866.75*
Asplanchna herrickii (de Gue.)	Asher					42.5
A. priodonta (Gosse)	Aspr					189
Brachionus angularis (Gos.)	Bran					981.315*
B. calyciflorus (Pal.)	Brca	2	1	12.25	4.75	42.75
B. plicatilis (Mül.)	Brpl	221*	104.25*	222*	254.25*	7969*
B. quadridentatus (Ehr.)	Brqu					102.75
B. urceolaris (Mül.)	Brur					2643.25*
Cephalodella gibba (Ehr.)	Cegi					14.25
Collotheca sp.	Colsp					138.5
Colurella adriatica (Ehr.)	Coad					70.9
Eothinia elongate (Ehr.)	Eoel					10.25
Filinia longiseta (Ehr.)	Filo					181.5
F. terminalis (Pla.)	Fite					234.75
Keratella cochlearis (Gos.)	Keco					567.25*
K. quadrata (Mül.)	Kequ		0.25	1.75		184.75
K. tecta (Gos.)	Kete					69.67
K. valga (Ehr.)	Keva					186.5
Monostyla bulla (Gos.)	Mobu					144.75
M. lunaris (Ehr.)	Molu					136.5
Polyarthra vulgaris (Car.)	Povu					356.25
Proales daphnicola (Tho.)	Prda					1268.25*
Proales sp.	Prsp					171.25
Synchaeta oblonga (Ehr.)	Syob	8	21.25*	33.5*	333.5*	178
S. okai (Sud.)	Syok	146.75*	125.75*	161.75*	668.75*	21.15
S. pectinata (Ehr.)	Sype	53.75*	281.75*	54.75*	125.75*	28.68
S. stylata (Wie.)	Syst	4.65	27.39	2.3475	14.22	
Testudinella patina (Her.)	Tepa					156.5
Trichocerca cylindrica (Imh.)	Trcy	4.25		72*	40.5	100.75
Rotaria sp	Rosp					102.25
Crustacea						
Copepoda						
Acartia clausi (Gie.)	Accl	69.1	30.5	212.9	84.5	0.3
Paracalanus sp.	Pasp	216.5	236.4	536.7*	477.3	38.3
Parvocalanus crassirostris (Dah. F.)	Pacr	7.3	110.3	135.5	43.4	0.1
Acanthocyclops americanus (Mar.)	Acam	0.9	18.7	34.5	4.3	1775.1*
Cyclops vernalis (Fis.)	Cyve					1275.9*
Halicyclops magniceps (Lil.)	Hama	1.7	35.7	49.6	114.8	1853*
Oithona nana (Gie.)	Oina	3357.1*	1078.7*	4570.5*	2096.7*	299.9
Oithona simplex (Far.)	Oisi	492.6	137.4	586.9*	361.4	191.5
Canthocamptus gracilis (Sar.)	Cagr	6.4	2.3	108.5	16.1	244.7
Euterpina acutifrons (Dana)	Euac	1055.2*	16211.6*	1170.9*	516.4	101.1
Nitokra lacustris lacustris (Sch.)	Nila	12.5	7.8	172.4	104.4	519.7
Onychocamptus mohammed (Bla.&Ric.)	Onmo	5.1	0.2	173.7	80.8	397.7
Copepod Nauplii	Nala	21416.7*	1131.3*	61926*	32615.3*	26321.2*
Copepodite stages	Cost	2835.6*	1601.9*	10532.7*	4381.7*	1671.3*
Cladocera						
Bosmina longirostris (O. F. M.)	Bolo	0.3		5.3	1.2	718.5*
Moina macrocarpa (Str.)	Moma	1.1		27.5	0.3	1673.7*

The values with asterisk (*) indicate the species dominancy for each group (Rotifera and Crustacea) separately. Abb.= Abbreviation

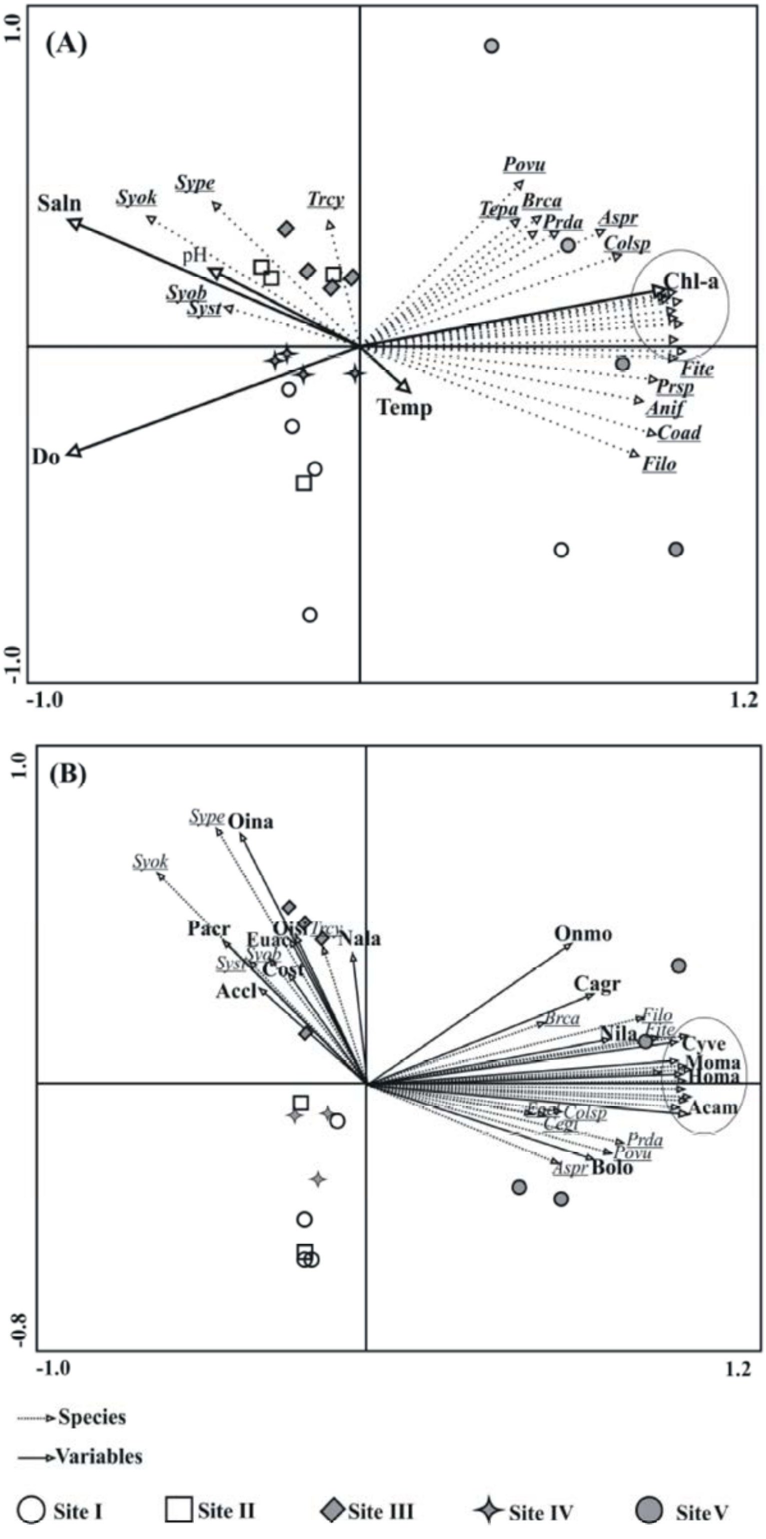

Fig. 5: Ordination diagram by RDA analysis: (A) Rotifer species association with environmental variables, (B) Rotifer species association with crustacean zooplankton. Species in cluster of figure A include: Brqu, Brpl, Brur, Assa, Bran, Keco, Kequ, Molu, Keva and Mobu. Species in cluster of figure B include: Brpl, Bran, Brur, Anfi, Mobu, Kequ, Brqu, Keva, Keco and Molu

Table 4: Results of forward selection and Monte Carlo permutation tests from RDA

	λ-A	*P*	*F*
Salinity (ppt)	0.6	0.001	26.65
Chlorophyll-a (μg l^{-1})	0.1	0.002	5.53
Temperature (°C)	0.03	0.124	1.81
Dissolved Oxygen (mg l^{-1})	0.02	0.346	1.12
pH	0.02	0.158	1.64
Cyclops vernalis	0.74	0.001	51.83
Bosmina longirostris	0.06	0.001	4.55
Acanthocyclops americanus	0.04	0.003	4.69
Moina macrocarpa	0.03	0.018	3.17
Oithona nana	0.02	0.05	2.97
Paracalanus sp.	0.01	0.349	1.07
Copepodite stages	0	0.63	0.55
Euterpina acutifrons	0.01	0.501	0.82
Halicyclops magniceps	0.01	0.755	0.36
Oithona simplex	0	0.909	0.15
Nauplii	0.01	0.319	1.7

permutation), explaining 44.1% and 43.6% of the total variance respectively. Considering the variance partitioning to explain the percentage contributed by pure environmental variables and pure crustaceans; crustaceans were more effective (explained 16.7%) than environmental variables which explained 14.2% of the variation in rotifers distribution (Fig. 4).

Considering the forward selection of environmental variables by using Monte Carlo test, two environmental variables remained significant (Table 4), salinity and phytoplankton biomass were the main factors influenced rotifers distribution. As shown in figure 5, salinity is negatively correlated with the first RDA axis, the spatial partioning of the salinity in the study area become obvious when the samples classified by sites (Fig. 5A), sample units from site V was negatively correlated with salinity and distributed in the right hand side of the biplot, whereas the sample units from other sites were positively correlated with salinity and grouped in the left hand side of the biplot. Rotifer species were negatively correlated with salinity and all species except *Synchaeta* spp. distributed in the right hand side of the biplot along the gradients of sample units from site V, indicating a great affinity of species for the fresh water conditions. Chlorophyll-a were strongly associated with axis 1 and axis 2 (Fig.5A), indicating that these two axes were mainly related to the trophic status; samples unit from site V found in this area of biplot. Along the gradient of trophic status, 13 rotifer species were found (Fig. 5A); *Ascomorpha saltans, Anuraeopsis fissa, Brachionus angularis*, *B. plicatilis*, *B. urceolaris, Keratella cochlearis* and *Proales daphnicola* were the most abundant.

Regarding the forward selection of dominant crustaceans, five crustaceans species remained significant; *Cyclops vernalis*, *Bosmina longirostris*, *Acanthocyclops americanus*, *Oithona nana* and *Moina macrocarp* were the most effective in rotifer species distribution (Table 4). The coexistence of rotifer species with crustacean zooplankton seemed to be determined by their defense against potential competitors and predators (Fig. 5B). For example, the small herbivorous *Moina macrocarpa*, *Halicyclops magniceps* and the carnivorous *Cyclops vernalis* were associated with the gradient of phytoplankton biomass, rotifer species associated with them, e.g. *Ascomorpha saltans*, *Filinia terminalis*, *Monostyla bulla*, *Brachionus angularis*, *B. plicatilis*, *B. quadridentatus*, *B. urceolaris*, *Keratella cochlearis*, *K. quadrata* and *Anuraeopsis fissa*. Markedly, *Asplanchna priodonta*, *Polyarthra vulgaris*, *Proales daphnicola* and *Cephalodella gibba* peaked with the herbivorous *Bosmina longirostris*. *Synchaeta* spp. were associated with salinity gradient and distributed in the left hand side of the biplot along the gradients of sample units from all sites except site V. *Synchaeta okai* and *Synchaeta oblonga* peaked with paracalindae and *Acartia clausi*, whereas *Synchaeta pectinata* peaked with Oithonidae and *Euterpina acutifrons*.

DISCUSSION

Salinity was the most important factor in explaining the total variance of rotifer density during the present study. Azémar *et al.* [28] found that salinity is the main structuring of rotifer densities in Schelde estuary. The maximum rotifer density and diversity was associated with low salinity at site V which was more eutrophic. When referring to the forward selection of environmental variables by RDA analysis (Table 4), it was noticed that the phytoplankton biomass had a direct effect on rotifer community. Consequently, we can conclude that in addition to salinity, the trophic status is an important determinant of rotifer density in coastal water. This is consistent with the results of Wang and others [6] for rotifer species distribution in some Chinese lakes and also reported for other zooplankton groups in estuaries and coastal waters [29-31].

The variance in rotifer density explained by crustaceans in the study area was mainly contributed by *Cyclops vernalis*, *Acanthocyclops americanus*, *Bosmina longirostris* and *Moina macrocarpa*. Conde-Porcuna [32] and Fussmann [7] suggest that the competition of filter feeding cladocerans is an important mechanism constrain rotifer populations. *Bosmina longirostris* and *Moina macrocarpa* are generally filter feeding species [33, 34]. Most cladocerans have high filter feeding rates comparing to rotifers [35] provide them the advantages to constrain rotifers suggesting an unfair competition between cladocerans and rotifers.

The intense and selective predation of rotifers by cyclopoid copepods has been investigated by several studies [36, 37]. Birge [38] mentioned that *Cyclops* is carnivorous, mainly feeding on rotifers and nauplii. The work of García and other [39] demonstrated that the inclusion of animal diet such as the rotifer *Brachionus* is necessary for high population growth rates of the omnivorous *Acanthocyclops americanus*. Accordingly, rotifer species intensity should be declined with the peaking of their predators. However, during the present study it seems that some rotifer species (Fig. 5B) showed density peaks with predatory cyclopoids. This could be attributed to the fact that some rotifers can protect themselves through specific morphological characteristics [5, 6]. For example, species of the genus *Brachionus* and *Keratella* which have rigid lorica [27], showed density peaks with *Acanthocyclops americanus* and *Cyclops vernalis.* On the other hand the soft bodies species, e.g. *Asplanchna* and *Proales* [40, 41], showed a trend to keep away from cyclopoid predators.

Variation partitioning analysis showed that the variance of rotifer species distribution explained by pure hydrographic conditions and pure crustaceans was not significantly different. The distribution of rotifer species was predominately affected by salinity and *Cyclops vernalis*. The distribution of rotifer species in relation to salinity gradient was a reflection of the shaping of the community at different salinities. Although the majority of the recorded rotifer species during the present study belong to freshwater and showing a trend of increasing density with salinity decreasing, some genera like *Synchaeta* which described as marine in several studies [42, 43], dominated the high salinity sites. The euryhaline *B. plicatilis* was the only rotifer that appeared as dominant at all sampling sites representing a significant contribution of rotifer density. According to Telesh and Khlebovich [44], with the growing of salinity in coastal areas, the share of rotifer in the total zooplankton decreased to reach the minimum and then increasing significantly with increasing salinity due to the massive development of euryhaline rotifers.

The relatively high contribution (11%) shared by environmental variables and crustacean zooplankton may be attributed to the association between herbivorous rotifers and herbivorous crustaceans along the gradient of trophic status (high chlorophyll-a concentrations). For example, species as *Brachionus quadridentatus* and *Keratella cochlearis* which are associated with high chlorophyll-a concentrations (Fig. 5A) and the herbivorous *Halicyclops magniceps* (Fig. 5B), are known to be herbivorous [45]. Also, the association of *Moina macrocarpa* which is a common eutrophic cladocerans [46] with some rotifer species as *B. plicatilis* and *B. angularis* is an indication of the possible use of these species as indicator of eutrophication.

The variance in rotifer density and species distribution unexplained by our data was the highest, with a total of about 58.1%. Wang *et al.* [9] found that the size and nature of food are among the important factors controlling the species distribution along the trophic gradient. The majority of rotifers fed on heterotrophic components of the microbial food-web when phytoplankton density was low, such as bacteria, heterotrophic flagellates and ciliates [47]. *Keratella cochlearis* is a filter feeding rotifers with a preference for particles within the size range of approximately 1 to 12 µm, such as bacteria and small flagellates [48]. In the present work, the studied variables were only indicators of the potential food source and the competition or predation with other zooplankton species. No-size ranked algae, protozoans, nano-flagellates and bacteria were studied. Another important undetermined factor was the predation by fish larvae and planktivorous fish. The Damietta coast is considered to be an important nursery area for marine fish larvae [16]. The filter feeding round sardinella (*Sardinella aurieta*) has a wide distribution in Egyptian Mediterranean coast [49]. It feeds mostly on zooplankton; the planktonic crustaceans were preferred as the main food [50]. The direct impact of round sardinella on planktonic crustaceans may indirectly affect rotifer communities by releasing them from predation and competition.

Many other factors as toxic chemicals, metals and toxic cyanobacteria can cause a significant variations in rotifers distribution [51, 52] by affecting the growth and survival of certain rotifer species.

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