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Temporal and spatial dynamics of rotifers in the Rosetta Estuary, Egypt

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Abstract

The spatial and temporal distribution of rotifers in Rosetta Estuary of the River Nile, Egypt, was monthly investigated from April 2007 to April 2008. Samples were taken at eight stations from Rosetta Branch to the upstream limits of the brackish water zone. Ecological parameters were determined and correlated with rotifers abundance to gain information about the forces that structure the rotifer community in this dynamic environment. The results showed that Rotifera was the first important zooplankton group in the Estuary (46.9 % and 42.3 %) with an annual average count of 11300 and 11000 organisms/m^3 at the surface and subsurface layers respectively. A maximum density of 45800 and 53300 organisms/m^3 were observed at the two layers respectively during December 2007. During March rotifers appeared at low density (487 and 575 organisms/m^3 at the two layers). 22 rotifer species were identified during the whole period, but only a few of them appeared at significant densities. The predominant species were *Keratella cochlearis,* which accounted for over 43.2 % and 46.8 % of the total abundance at the two layers respectively, *Brachionus calyciflorus* (12.7 % and 10.1 %), *Brachionus urceolaris* (12.2 % and 11.6 %) and *Brachionus plicatilis* (6.4 % and 8.5 %). Salinity and temperature were the most important environmental factors controlling the abundance of rotifers in Rosetta Estuary. Shannon -Weaver diversity index reflects relatively pronounced changes in biodiversity of rotifers.

Keywords: Rotifera; Rosetta Estuary; environmental conditions, temporal variations, spatial distribution.

1. Introduction

Rotifers are important components of planktonic communities because of their rapid heterogenetic reproduction, they are the first metazooplankters to cause an impact by grazing on the phytoplankton. Furthermore, rotifers influence various interactions within the microbial food-web which occur at several trophic levels (Arndt, 1993). While many studies have dealt with rotifers in lentic systems, considerably fewer have provided data about them in lotic environments, especially estuaries. Only about 4 % of all publications on flowing waters concern large rivers (Hynes, 1989), and in these, little attention has been paid to the "potamoplankton", which has often focused on crustaceans (Thorp *et al.*, 1994).

Nevertheless, rotifers are well adapted to river ecosystems, where zooplankton abundance is often regulated by advective losses, and population densities are maintained by rapid heterogenetic reproduction with short generation times (Stemberger and Gilbert, 1985). Recent detailed studies dealing only with rotifers in estuarine environments are rare such as Papinska (1990); Dolan & Gallegos (1991, 1992); Neumann-Leitao *et al.* (1992); Egborge (1994); Green (1995); Telesh (1995); Holst *et al.* (1998), Park and Marshall (2000) and Aoyagui and Bonecker (2004). The studies dealing with rotifers in Egyptian estuarine environments have received but little attention (Zaghloul, 1988; Soliman, 1994; Abdel-Aziz, 2000; El-Shabrawy and Khalifa, 2002; and El-Naggar, 2008).

The present study was carried out to characterize the rotifer fauna and their temporal and spatial dynamics in relation to environmental parameters at different locations in Rosetta Estuary.

2. Material and methods

2.1. Study site

The Rosetta Estuary is semi – enclosed coastal area having a free connection with the Mediterranean Sea and within which the sea- water is always diluted with freshwater coming from the River Nile (Figure 1).The Rosetta Estuary is the classical example of a transitional environment between the river and the sea. The geographical position and morphometric features of this estuary are influenced by several factors, with the most important being climatic variations, the impact of human activities, and sea hydrodynamics. The annual discharging capacity of the river into an estuarine environment is related not only to the rainfall density in the river catchments area, but also to natural and artificial barriers to river flow encountered between the river source and its point of discharge (Ibrahim *et al*., 2007). The Egyptian Nile water budget is 55.5 billion cubic meters according to agreement on Full Utilization of the Waters of the Nile, while the Nile water loss is estimated to be about 53 % of Egypt Nile water budget (DRI, 2004).

2.2. Sampling

Samples were collected monthly from April 2007 to April 2008, from eight stations (Figure 1). A shallow water upstream at stations I, II and III (3 – 4.5 m), then the depth increased gradually at the Rosetta branch from about 5 m at station IV to reach about 11 m at station VIII. Station V lies in front of irrigation drain.

Surface water temperature was measured directly by a usual thermometer, graduated to 0.1 ^{0}C and water transparency by white enameled Secchi disc, pH by a digital standardized pH meter. The surface and subsurface salinities were determined argentometrically, and dissolved oxygen by Winkler s method (APHA, 1980). The phytoplankton biomass (Chlorophyll *a*) was measured according to procedures described by Strickland and Parsons (1975).

For zooplankton analysis, at each station, two vertically samples were taken, one from 1.5 m to the surface using a standard plankton net (55µm mesh size), and the other by using a standard zooplankton closed net with the same mesh size, lowered near the bottom up 1.5 m then closed and pushed up. The organisms were fixed in 100 ml of 5% formalin. Rotifer species were identified following Edmondson (1959); Koste and Shiel (1987 and 1989); Shiel and Koste (1992), and the standing crop was estimated as organisms/m^3 from the average of three counts of 5 ml concentrated samples. To evaluate seasonal differences (i.e. three months for each season, except spring 4months) considered as spring = March- May, summer= June – August, autumn = September – November, and winter = December – February). The data were subjected to statistical treatment to find biological indices. Diversity index was calculated according to Shannon and Weaver (1963). Correlation coefficients (r) and multiple regression analysis were computed using MINITAP for rotifers with the ecological measured parameters and chlorophyll *a* concentration at $p \leq 0.05$.

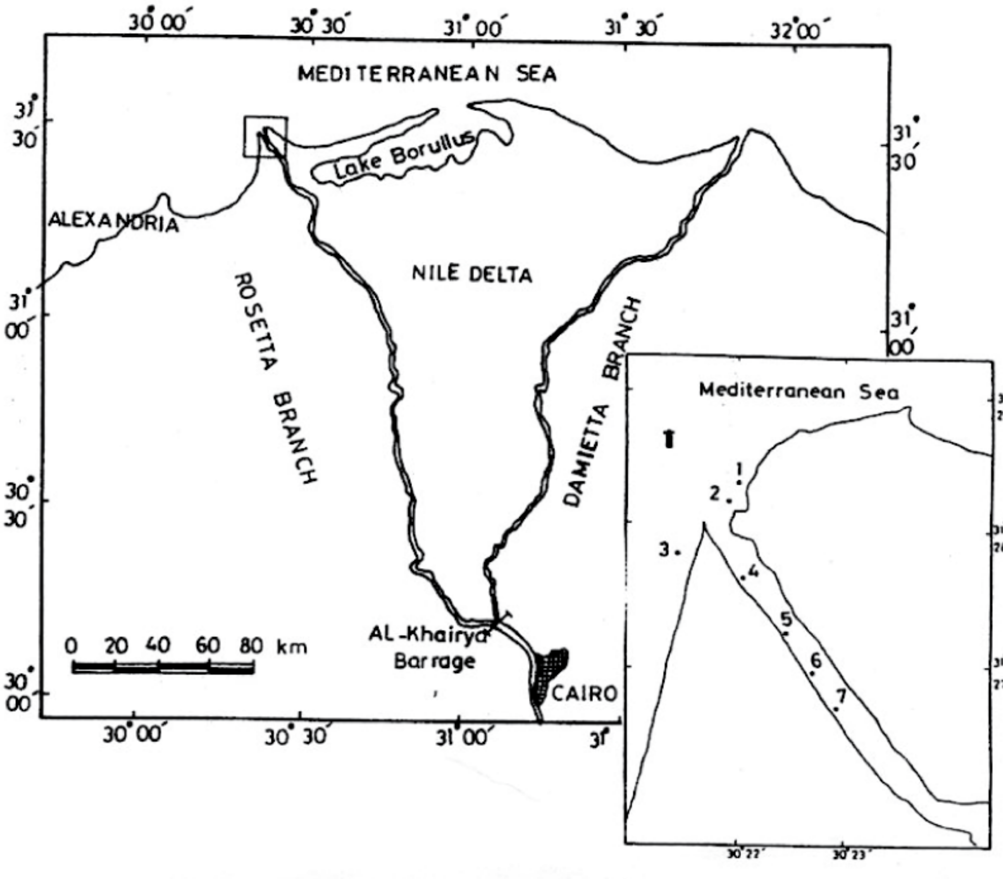

Figure 1. Rosetta Estuary and locations of sampling stations.

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3. Results

Surface water temperature varied from a minimum of 16.5 ^{0}C in December to a maximum of 30.5^{0}C in July (Figure 2). The spring and autumn months demonstrated wide temperature variations (18.6 – 23.4 ^{0}C and 19.1 – 25.6 ^{0}C respectively), while summer and winter showed markedly narrow variations (29.3 – 30.5 ^{0}C and 16.5 – 21.5 ^{0}C respectively).

The Rosetta Estuary characterized by high transparency most of the year with the highest readings of 2.1 – 2.3 m during February to April. On spatial scale, transparency decreased gradually from station IV (average 1.3m) to reach an average of 90 cm at station VIII, while stations I and III demonstrated the highest transparent water (average 1.7 & 1.5 m respectively) (Table 1).

The pH values of the surface water pointed out alkaline tendency, varying between a minimum of 7.5 during October and March to a maximum of 8.1 and 8.2 during May and June respectively (Figure 2).

The high salinity values were recorded during summer, (July) being 18‰ at the surface layer and 27.6‰ at the subsurface layer, and the peak was noticed during spring (March) with the averages of 33 and 37.5 ‰ for the two layers respectively. On the other hand the minimum salinity was noticed during September, October and January (<1‰) at the surface layer, and December – January (<8‰) at the subsurface layer.

Two levels of dissolved oxygen were reported in the Estuary (Figure 2), the first one >5 ml/L was appeared during the months April 2007, July, and from December to April. The second was <5 and >4 ml/L during the rest of the year, except during August (3.5 ml/L). The spatial difference in dissolved oxygen was less than 0.8 ml/L.

The annual average chlorophyll *a* concentration was 17.8 µg/L, three levels were noticed; the lowest concentrations (<3µg/L) was recorded from April – June 2007, the highest concentrations (33 – 78.5 µg/L) from July – September 2007, and the moderate concentrations (6.2 – 17.7 µg/L) from October – March. On spatial scale, stations 2, 3 and 4 showed the lowest concentrations (averages 15.7, 13.3 and 15.8 µg/L respectively), while the other stations showed higher annual averages (16.1 – 22.6 µg/L) (Table 1).

Rotifera contributed about 47% and 42.3% to the total zooplankton counts at the surface and subsurface layers with averages 11.3X10^3 and 11X10^3 organisms/m^3 respectively. Twenty two rotifer species were recorded in the investigated area (Table 2) belonging to 9 genera within 7 families. The monthly pattern of species diversity at the surface layer showed pronounced variations. The highest diversity was reported during April, 2007, October and November (14 species) decreased to a minimum during August and March (5 species) as represented in Figure (3). For the subsurface layer, the highest diversity was recorded during October - December (14, 14 and 15 species respectively). The diversity index demonstrated similar pattern at the two layers where it ranged from 0.9 – 1.6 during all months except June, August and March it ranged from 0.3 – 0.7 (Figure 3).

During April 2007, May and June the rotifer density was below 5X10^3 organisms/m^3, in July the numbers had reached 10.5 X10^3 and 11.9 X10^3 organisms/m^3 at the two layers respectively, followed by a sharp decrease to 3.3 X10^3 and 5.3 X10^3 organisms/m^3 at the two layers during August. A gradual increase was noticed from September to reach its maximum density during December, then it began to decrease again till March, another increase began during April 2008 (Figure 2).

A significant negative correlation between the total rotifer abundance and both temperature and salinity was observed (r = -0.379 and r = 0.467 respectively at $p \leq 0.05$) at the surface layer, and there was a negative correlation between rotifer abundance and salinity (r = 0.424, $p \leq 0.05$) at the subsurface layer.

A relatively homogeneous zonal distribution of the total rotifer abundance was observed in the two layers. All rotifers encountered, except *Monostyla lunaris* and *M. quadridentatus*, were recorded in the two layers (Table 2). On the other, hand 6 species dominated all stations with percentage 83.5% and 85.1% at the two layers respectively (Figure 4). At the subsurface layer *Brachionus plicatilis, Synchaeta pectinata* and *S. tremula*, a typical brackish water forms increased towards the sea at stations I, II, and III. On the other hand *B. urceolaris* a fresh water species decreased towards the sea at the two layers. Station V showed the maximum abundance of rotifers at the two layers (15.3 X10^3 and 16.3 X10^3 organisms /m^3 respectively) due to the abundance of *Keratella cochlearis, B. calyciflorus* and *B. urceolaris*.

At the two layers, the numerically dominant rotifer was *K. cochlearis* which accounted for over 43 % of the total rotifer community, its density reached for over 90% of the total counts during December. Other very common species included *B. calyciflorus*, *B. urceolaris*, *Brachionus plicatilis*, *Polyarthra vulgaris* and *K. valga* species. These accounted for over 10%, 11%, 6%, 3% and 3 % of the total number of individuals, respectively (Figure 5).

At the beginning of the investigation during spring and early summer (April– July), *B. urceolaris* and *B. plicatilis* were the dominant rotifers and the abundance of each taxon reached its maximum during July (Figure 6). *B. calyciflorus* and *K. cochlearis* were the most common rotifers during September at densities 54X10^2 and 17X10^2 organisms/m^3 respectively for the surface layer. From October to November *B. calyciflorus* and *B. urceolaris* increased in their counts gradually; also *K. cochlearis* increased during this period but its abundance increased more to reach its maximum during December (407.8 X10^2 and 482.8 X10^2 organisms/m^3 for the two layers respectively). *B. calyciflorus*, *K. cochlearis* and *Synchaeta oblonga* were the most common species during January (Figure 6). The peak of total rotifers during December coincided with the maximum abundance of *K. cochlearis*, including *Polyarthra vulgaris*. The density of *K. cochlearis* accounted for over 90% of the total rotifer community. After the sharp decline in total abundance was observed after December, a new rotifer community developed, including, *K. quadrata* with a peak of about 23 X10^2 organisms/m^3 at every layer during February. Other species such as *Synchaeta pectinata, S. tremula* and *S. oblonga* also increased in abundance during April 2008.

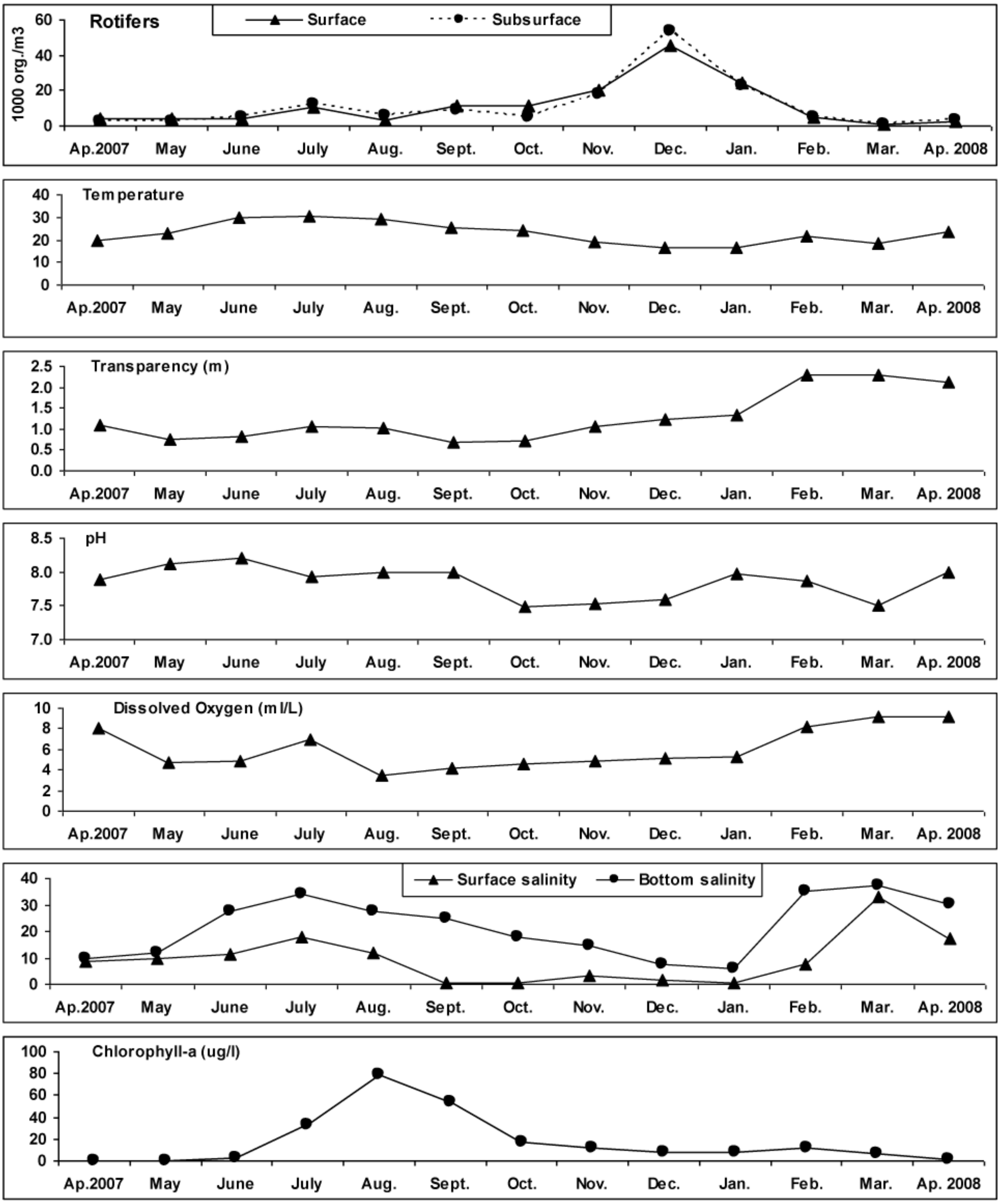

Figure 2: Monthly average variations of rotifers, hydrographic parameters and chlorophyll *a* in Rosetta Estuary during April, 2007- April, 2008.

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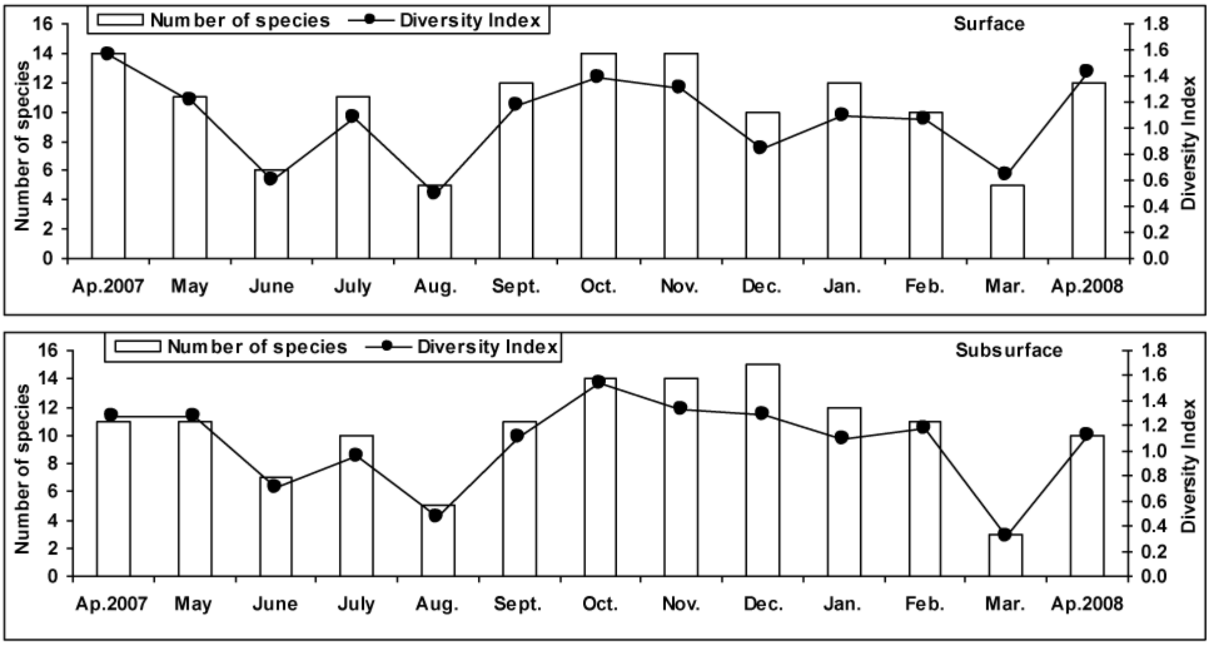

Figure 3. Monthly variations of species numbers and diversity index of rotifers in Rosetta Estuary during April, 2007 - April, 2008.

Table 1. Spatial changes and standard deviation in hydrographic parameters and chlorophyll a in Rosetta Estuary April 2007- April 2008**.**

	St.I	St. II	St. III	St. IV	V	St. VI	St.VII	St. VIII	SD
Temp.	22.3	22.4	22.5	22.9	23.3	23.4	23.3	23.3	0.46
Transparency(m)	1.65	1.22	1.49	1.34	1.23	1.3	1.03	0.91	0.24
PH	7.8	7.9	7.8	7.8	7.8	7.8	8	7.8	0.07
DO	5.6	6.0	6.4	6.4	6.0	6.0	5.7	6.2	0.3
Salinity Surface	10.2	11.3	12.1	9.8	8.9	8.5	8.2	7.7	1.6
Salinity Bottom	24.6	23.5	21.9	21.1	20.3	20.6	20.2	22.2	1.6
Chlorophyll *a*	17.86	15.73	13.32	15.77	18.86	16.09	22.62	22.15	3.27

Table 2: Relative abundance (% to total) and frequency of occurrence of rotifer species at the two layers in Rosetta Estuary April 2007- April 2008.

	Surface		Subsurface	
Species	%	Frequency	%	Frequency
*Asplanchna priodonta** (Gosse, 1850)	1.2	7	0.9	9
Brachionus angularis(Gosse, 1851)*	2	10	1.5	10
*B. calyciflorus** (Pallas, 1766)	12.7	10	10.2	8
B. caudatus(Barrois& Daday,1894)	0.5	4	0.4	4
B. plicatilis(O.F.Muller, 1786)*	6.4	11	8.5	12
B. quadridentatus(Hermann, 1783)	1	4	0.5	3
B. urceolaris(O.F.Muller, 1773)*	12.3	12	11.6	12
*Filinia longiseta** (Ehrenberg,1834)	1.2	4	0.8	4
Keratella cochlearis(Gosse,1851)*	43.2	9	46.8	10
K. quadrata(O.F.Muller,1786)*	3.4	9	3.4	10
K. valga(Ehrenberg,1834)*	4.3	7	3.8	7
Monostyla bulla(Gosse,1851)	0.4	3	0.4	4
M. lunaris(Ehrenberg,1832)	0.05	2	0	0
M. quadridentata(Ehrenberg,1832)	0.02	1	0	0
Polyarthra vulgaris(Carlin,1934)*	4.5	11	2.9	10
Proales daphnicola(Thompson,1892)	0.7	3	0.7	2
P. decipiens(Ehrenberg,1832)	0.1	1	0.05	1
Synchaeta oblonga(Ehrenberg,1832)*	3.4	12	4.2	11
S. Okai(Sudzuki,1964)	0.2	3	0.2	4
S. pectinata(Ehrenberg,1832)*	1.7	6	2.3	5
S. tremula(Muller,1786)	0.4	4	0.6	4
Trichocerca similis(Wierzejski,1893)	0.3	2	0.1	3
Metamorphosis of rotifers	0.07	1	0.03	1
* means species found at all stations				

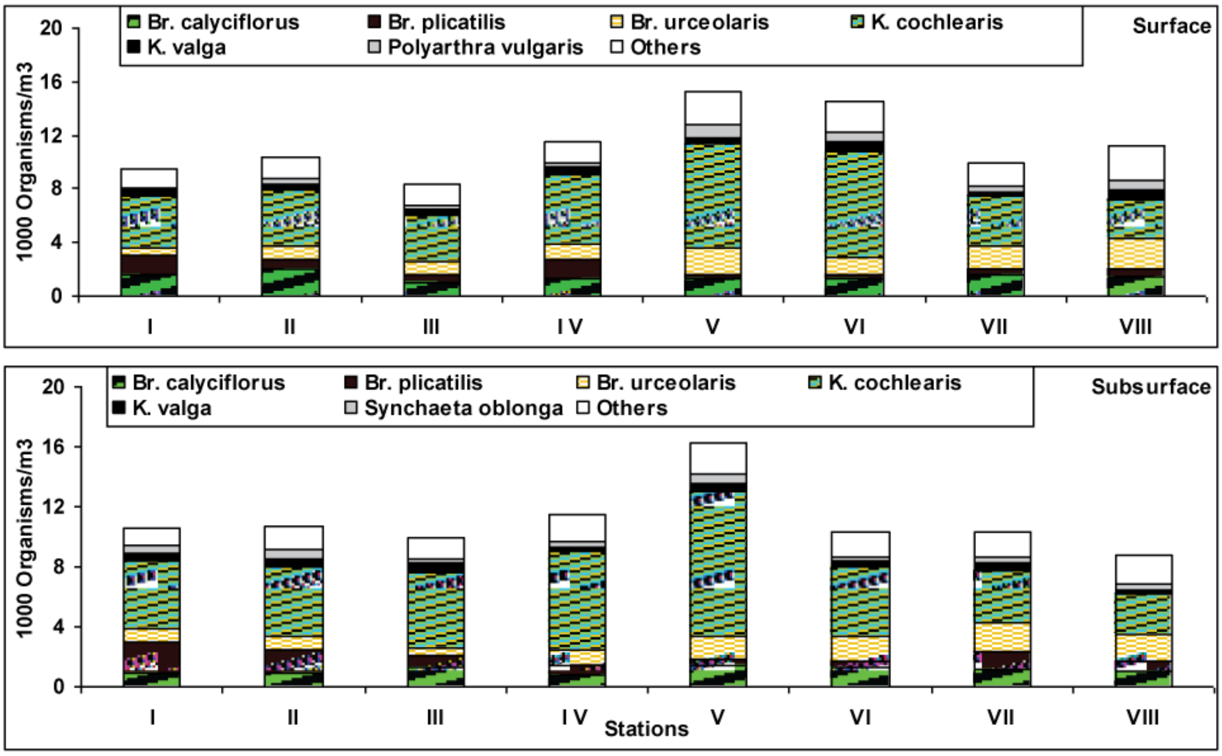

Figure 4. Spatial distribution of rotifers and its dominant species (>4%of total count) in Rosetta Estuary, April 2007 - April 2008.

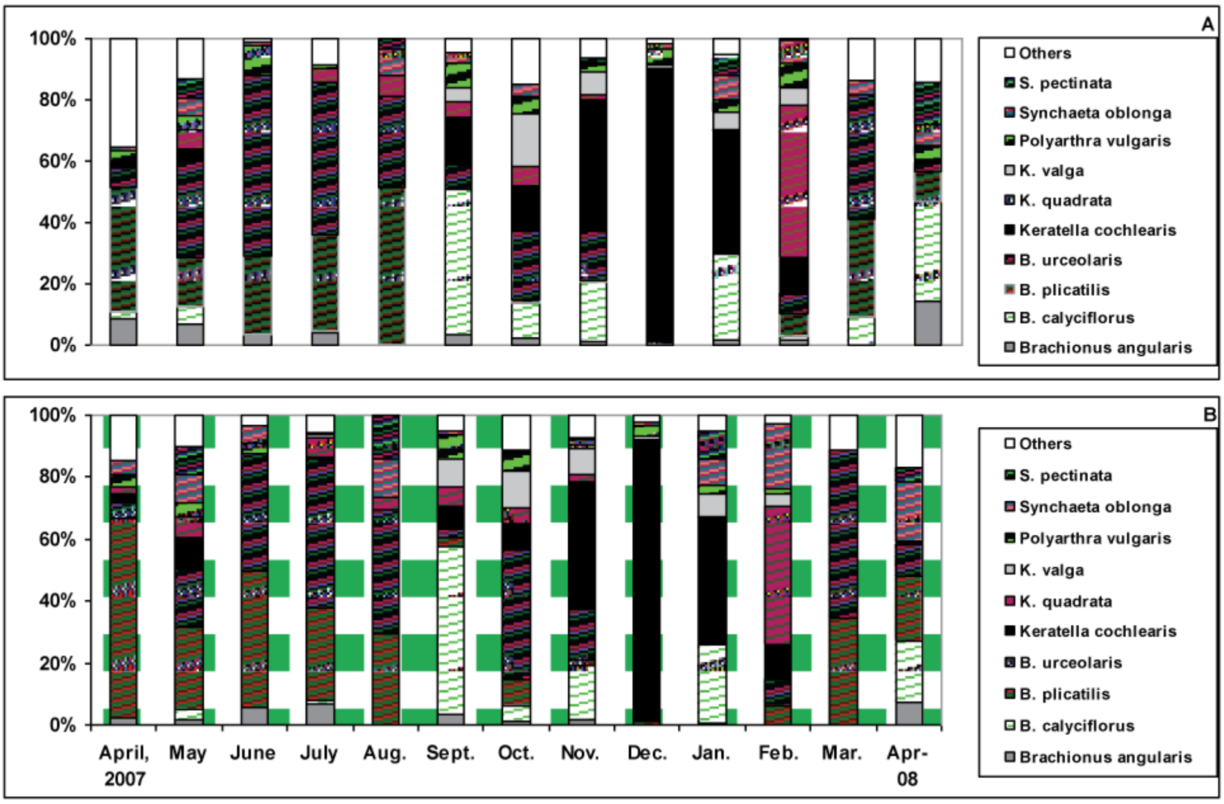

Figure 5. Relative abundance (%) of dominant species to total rotifers at surface(A) and subsurface(B) layers in Rosetta Estuary, April 2007 - April 2008

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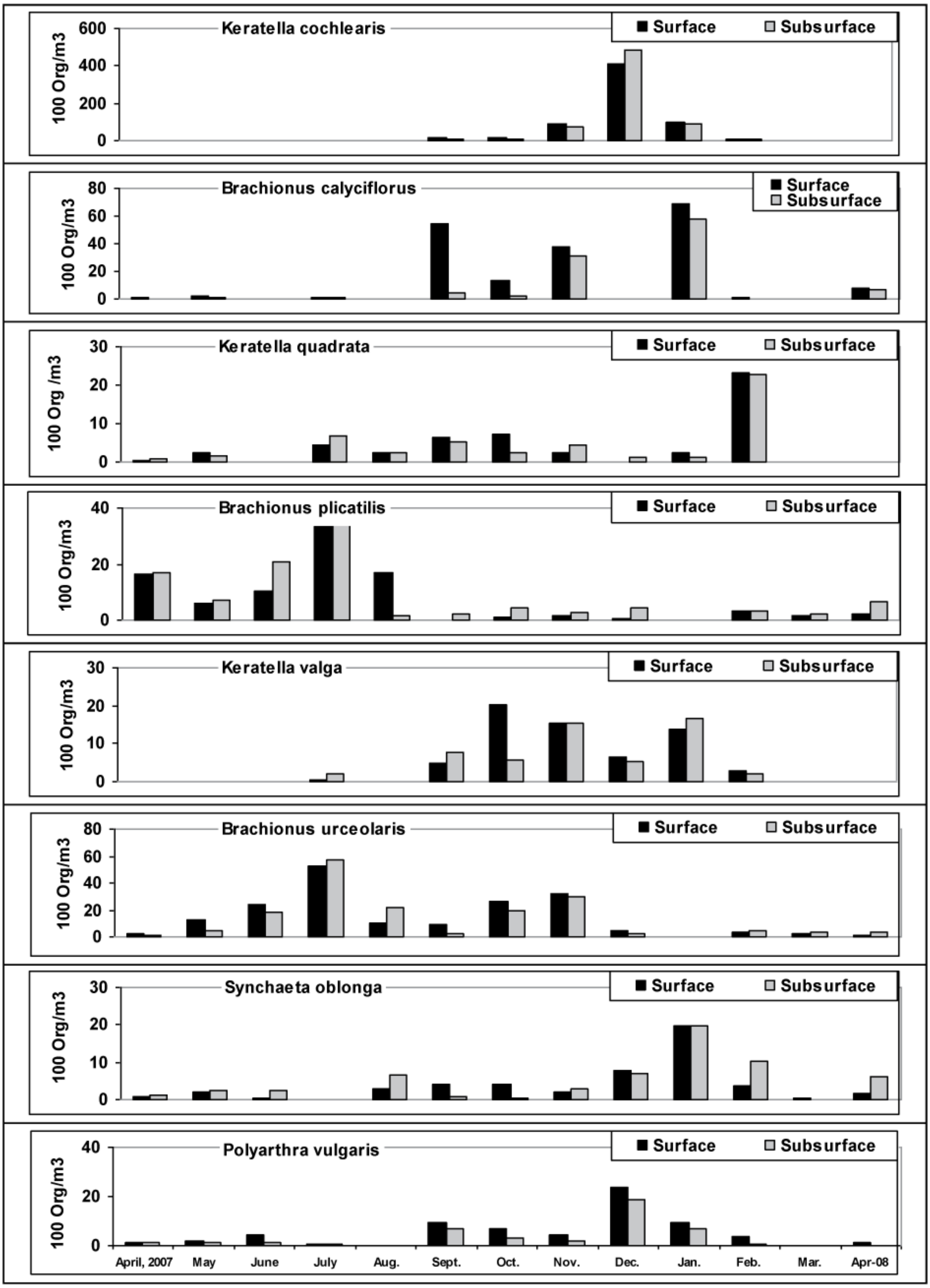

Figure 6: Variation in the abundance of the important rotifer species (>3%of total count) at surface and subsurface layers in Rosetta Estuary, April 2007 - April 2008.

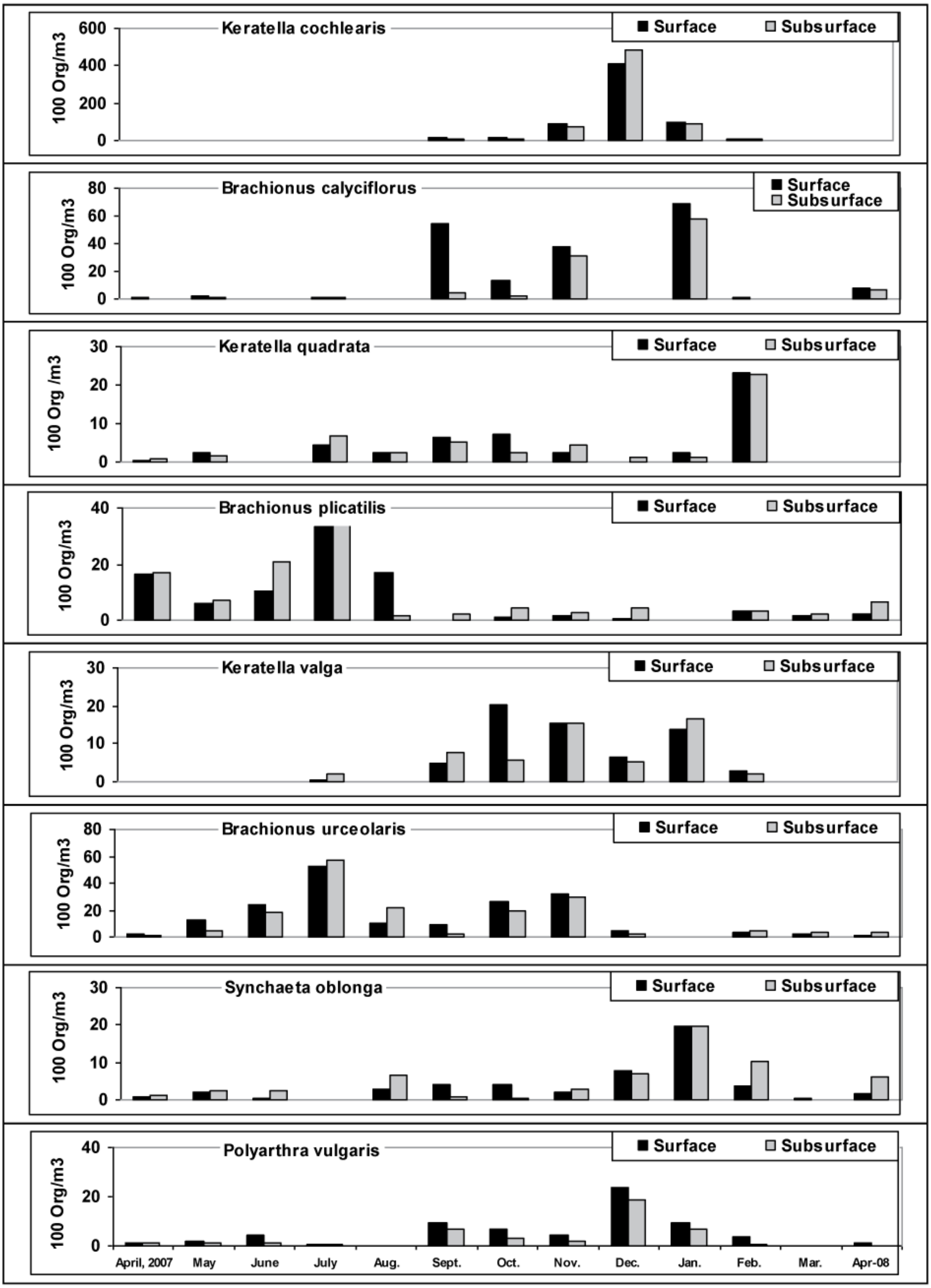

Figure 6: Variation in the abundance of the important rotifer species (>3%of total count) at surface and subsurface layers in Rosetta Estuary, April 2007 - April 2008.

priodonta was mainly phytophagous, feeding on centric diatoms and other algae. Also during April 2007 the abundance of *Asplanchna priodonta* coincided with the lowest abundance of *Keratella cochlearis*. *Asplanchna* species are predominantly carnivorous and prey on *Keratella cochlearis* and other small rotifers like *Anuraeopsis fissa* (Holst *et al*., 1998).

Brachionus calyciflorus was the second important species during January, after *Keratella cochlearis*, the reason may be the suitable of both water temperature (16.7°C) and salinity (0.8 and 5.6 at the two layers), which were the lowest during the investigation period and suitable to promote rapid reproduction of this species. This species is known to be one of the fastest growing metazoans (Bennett and Boraas, 1989). Also this species is the first dominant species during September; often described as a pioneer species (Ferrari *et al.,* 1989).

The dissolved oxygen is important in the metabolic activities of the aquatic organisms and serves as an indicator of water quality (Wetzel, 2001). During the period October – January the average value of dissolved oxygen was at the range of 5 ml/L, characterized by highest abundances of rotifers. Conversely, during August, rotifer abundances were the lowest 33 $X10^2$ and 54 $X10^2$ organisms/m^3 for the two layers respectively. This month was characterized by the lowest dissolved oxygen content (3.5 ml/L). This agrees with the opinion of Train (1979) who mentioned that the amount of dissolved oxygen required the healthy growth of freshwater biota must be over 5ml/L. Low oxygen alone could not have been responsible for this reduced abundances of rotifers during August; many conditions reduced the abundance during this month such as the high temperature (29.3°C), high salinity (12.1 and 27.3‰ at the two layers), and also the increase of pH to reach 8. Although Chlorophyll *a* was high during August (78.5 µg/L), it did not exert considerable influence on the rotifer abundance.

Salinity was important factor in controlling the density of rotifers during the present study. During September and October surface salinity was the same 0.6‰; rotifers abundances were also the same (about 11.5 $X10^3$ organisms/m^3), and at the subsurface salinity increased to 24.6 and 17.7‰ respectively during these two months correlated with clear decrease in rotifers to reach 8.5$X10^3$ and 4.8 $X10^3$ organisms/m^3 respectively. During December, when the salinity was low at the 2 layers (1.7 and 7.7 ‰ respectively), the abundances were high (45.8$X10^3$ and 53.3 $X10^3$ organisms/m^3 respectively). Another example, during March when the salinity was high at the 2 layers (33.1 and 37.5‰), the abundances of rotifers were very low (490 and 580 organisms/m^3 respectively). This can be explained by the fact that most rotifers can not tolerate high salinity.

The correlation coefficients and stepwise multiple regression analysis between the ecological parameters and rotifer abundance gave a more detailed picture about the most important factors controlling rotifer abundance in Rosetta Estuary: Salinity was the most effective factor (r = -0.467), temperature (r = - 0.379), dissolved oxygen (r = - 0.287) and pH (r = -0.226). The predicted rotifer density at the surface layer can be calculated by application the following equation:

Rotifers = 51741- 443 S‰ – 1174 temperature – 1473 dissolved oxygen.

For the most dominant species, *Keratella cochlearis*, temperature was the most important factor (r = - 0.453), followed by salinity (r = - 0.315) and pH (r = - 0.224). According to these conditions, *Keratella cochlearis* density can be calculated as follows: *Keratella cochlearis* = 47113 – 1393 temperature – 1704 dissolved oxygen.

Also for the second dominant species, *Brachionus calyciflorous* salinity was the important ecological parameter (r = - 0.453), followed by dissolved oxygen (r = - 0.292) and temperature (r = - 0.27), and *Brachionus calyciflorous* density can be calculated from the following equation :

Brachionus calyciflorous = 5046 – 110 S%o – 112 temperature.

5. Conclusion

Low water temperature between 16.5 – 19°C was the main factor in Rosetta Estuary promoted a rapid growth of rotifers. Low salinity (1- 8‰) was another controlling parameter for rotifer abundances. Chl *a* was not a limiting factor in the abundance of rotifers. A significant top – down control of rotifer populations in the estuary was not apparent. The dominant species in the estuary were *Keratella cochlearis, Brachionus urceolaris* and *Brachionus calyciflorus*. The effect of agricultural drainage water was clear in increasing the productivity of rotifers.

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