

PHYTOPLANKTON-ZOOPLANKTON RELATIONSHIP IN THE NERITIC WATER OFF ALEXANDRIA

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ABSTRACT

Phytoplankton and zooplankton quantitative and qualitative estimations are continuously variable in the eutrophic neritic waters off Alexandria. Their relationship apparently was under multi-factorial control with temperature, salinity being the most important factors, phosphate and grazing at times. Three different patterns of co-existence of phyto-zooplankton were distinguished. The positive top-bottom relationship was observed at intermittent periods during the different seasons, and with diatom predominance. The negative top-bottom pattern seems to be strongly influenced by specific phytoplankton community structure and or diatom composition. The paralleled increasing phyto-zooplankton pattern occurred at times, with fast growing diatom species. Zooplankton grazing pressure affects the relative abundance of the phytoplankton community structure and species composition, offering some advantage to non-diatom species to dominate. Meanwhile, reduced grazing has been implicated as primary phytoplankton bloom trigger.

INTRODUCTION

Zooplankton assemblage appears to be closely related to the importance of the relative densities of predator and prey (Carpenter and Kitchell, 1993), the environmental changes that occur regularly in the water column, such as surface heating, cooling, stratification, mixing, currents (Roemmich and McGowan,

The correlation matrix and statistical model were computed to define the relation between physico-chemical parameters measured, phytoplankton and zooplankton abundance and their relationship.

RESULTS

The phytoplankton crop attained an annual average of 1.32×10^6 cell l^{-1} , mainly of diatoms (66% of the total, average 0.88×10^6 cell l^{-1}), followed in abundance by dinoflagellates (17 %, 0.22×10^6 cell l^{-1}), microflagellates (10.4%, 0.14×10^6 cell l^{-1}), and euglenophytes (5.3 %, 0.07×10^6 cell l^{-1}). The major phytoplankton peaks occurred in April, May, August and September (Fig. 1).

Zooplankton population ranged between 15×10^3 - 621×10^3 org. m^{-3} , with an annual average of 178.3×10^3 org. m^{-3} . The population structure declared copepods to be the most representative group (average 86×10^3 org. m^{-3} , 48.8 %), followed by Protozoa (11.6 %), Annelida (9.6%), cirriped larvae (6.3%) and rotifers (1.1 %). The major zooplankton peak was observed in mid-September and there were other small ones in April, July, August, October and November (Fig. 2). Adult copepods (51.8 % of the total Copepoda) contributed its highest of 81.2 % of the total copepods on 11 June. Nauplius larvae (11.9-49.2 %, average 25.87 %) dominated in March (46.6-49.2 %) and early January (36.87 %), and copepodite stages ranked the third level (9.6-36 %, average 22.28 %, with three major peaks in late April, mid-September and November, Fig. 3).

Different patterns of phytoplankton-zooplankton relationship are recognised in the present relatively short-term sampling in an area of heavy eutrophication. These include mainly three types: positive top-bottom relationship which indicates increased zooplankton population to be associated with distinct phytoplankton drop; negative pattern indicating the reverse case; and tops of co-existing increased phytoplankton and zooplankton abundance.

Seasonal variations

During spring the phytoplankton gained an average of 2.29×10^6 cell l^{-1} , mainly of diatoms, 63.2 %. Two major peaks were triggered on 13 April (5.2×10^6 cell l^{-1}) and 12 May (4.24×10^6 cell l^{-1}), and a smaller one by the end of this month (2.13×10^6 cell l^{-1}). Diatoms were responsible for the first one. *Rhizosolenia delicatula* (44.7 %), *Chaetoceros curvesitus* (21 %), and

Skeletonema costatum (19.2 %), *Euglena granulata* (1.5×10^6 cell l^{-1} , 35.53 %); *S. costatum* (28.1 %) and *Prorocentrum triestimum* (18.75 %) were the dominant forms on 12 May, while *Pyramimonas* spp. (28.15 %), *Prorocentrum minimum* (18.9%) and *Thalassionema nitzschioides* (12.4%) on 26 May. Accompanied physico-chemical parameters showed surface temperature of 16.5°C on 13 April, raised distinctly to 21.2-21.5 °C in May, salinity range of 37.5-38 ppt, nitrate 1.2-2.6 μ M, silicate 0.9-1.8 μ M, and phosphate of 1.3-3 μ M, the higher phosphate on 12 May

Zooplankton ranged between 80×10^3 - 287×10^3 org. m^{-3} (average 131×10^3 org. m^{-3}), with its major peak on 27 April. Copepoda (mainly nauplius larvae, 46.6-49.2 %) dominated with Protozoa (tintinnids, 27.3 %) in March and with annelid species (polychaete larvae) in April, and contributed 77.1% in May. *Acartia* species, mostly *A. grani* and *Oithona* species formed most of adult Copepoda.

Generally, the negative top-bottom phyto-zooplankton relationship was common in spring. The phytoplankton community structure and species composition seem affecting the grazing pressure. The reverse pattern occurred on 27 April (Fig. 4).

During summer, diatoms (77.6 %), and dinoflagellates (20 %), mainly represented the phytoplankton (average of 1.19×10^6 cell l^{-1}). The highest density was recorded on 13 August (2.65×10^6 cell l^{-1}) at 27.2 °C, low salinity 34 ppt, and 3.3, 1.8, and 2 μ M for nitrate, silicate and phosphate, respectively. The dominant species progressed as: *S. costatum* (0.27×10^6 - 0.4×10^6 cell l^{-1} , 32.1- 65.15 %) with *P. minimum* and *Scrippsiella trochoidea* in June; *T. nitzschioides* and *Cyclotella nana* in July (57.9 % and 30.15 %, respectively); *Nitzschia longissima* in mid-August (2.2×10^6 cell l^{-1} , 83.12 %); and *Bellarochea malleus* with the end of the month (74.15 %).

Zooplankton increased compared with spring (average 216×10^3 org. m^{-3}), yet, copepods were still dominating (83×10^3 org. m^{-3} , 38.5 %), mainly of adult species (68.9 %). Three zooplankton peaks ($>252 \times 10^3$ org. m^{-3}) were recorded on 10 July, 13 and 29 August. Protozoa contributed 16 % of the total in the first day (mainly of tintinnids and polychaete larvae) and about 15 % on 29 August and annelids on 13 August (17 %) *Oithona* and *Acartia* species dominated in August.

Table 1. Correlation matrix

	Tem	Sal	NO ₃	SiO ₄	PO ₄	Diat	Dino	Micr	Ph.	Co	Pro	Ann	C.L	Rot	T.Z	A.C	C.S	N.L	
Tem	1.00																		
Sal	<u>-0.87</u>	1.00																	
NO ₃	-0.20	-0.04	1.00																
SiO ₄	-0.15	-0.06	0.37	1.00															
PO ₄	-0.05	-0.02	0.18	<u>0.58</u>	1.00														
Diat	0.25	-0.31	0.19	-0.01	0.07	1.00													
Dino	<u>0.51</u>	-0.37	0.17	-0.07	0.13	0.25	1.00												
Micr	0.21	-0.08	-0.07	-0.01	0.14	0.00	<u>0.46</u>	1.00											
Ph.	0.37	-0.35	0.22	-0.02	0.16	<u>0.83</u>	<u>0.67</u>	<u>0.43</u>	1.00										
Co	0.39	-0.27	-0.13	0.14	0.27	0.32	0.17	0.22	0.32	1.00									
Pro	0.28	-0.11	-0.15	0.18	<u>0.45</u>	0.06	0.05	0.29	0.09	<u>0.61</u>	1.00								
Ann	<u>0.52</u>	-0.39	-0.14	0.19	0.27	0.15	0.36	<u>0.67</u>	0.37	<u>0.47</u>	<u>0.50</u>	1.00							
C.L	0.19	0.05	-0.02	-0.11	0.14	-0.06	-0.03	0.38	0.02	0.23	0.37	<u>0.40</u>	1.00						
Rot	-0.10	0.04	-0.17	0.16	0.08	<u>-0.42</u>	-0.10	-0.32	<u>-0.41</u>	-0.38	-0.26	-0.15	-0.13	1.00					
T.Z	<u>0.56</u>	-0.39	-0.17	0.08	0.21	0.23	0.25	0.37	0.31	<u>0.93</u>	<u>0.66</u>	<u>0.62</u>	0.38	-0.38	1.00				
A.C	<u>0.60</u>	<u>-0.46</u>	-0.13	0.12	0.35	0.35	0.31	0.32	<u>0.40</u>	<u>0.90</u>	<u>0.59</u>	<u>0.64</u>	0.31	-0.30	<u>0.92</u>	1.00			
C.S	0.02	0.10	-0.02	0.20	0.37	0.09	-0.01	0.14	0.08	<u>0.75</u>	<u>0.62</u>	0.33	0.28	-0.30	<u>0.60</u>	<u>0.51</u>	1.00		
N.L	0.03	0.06	-0.13	0.23	0.30	0.21	-0.09	0.02	0.13	<u>0.84</u>	<u>0.59</u>	0.21	0.08	-0.25	<u>0.63</u>	<u>0.60</u>	<u>0.84</u>	1.00	

Tem : Temperature PO₄ : Phosphate Ph. : Phytoplankton C.L : Cirripid larvae C.S : copepodite stages

Sal : Salinity Dia : Diatoms Co : Copepoda Rot : Rotifera N.L : Nauplius larvae

NO₃ : Nitrate Dino : Dinoflagellate Pro : Protozoa T.Z : Total zooplankton

SiO₄ : Silicate Micr. : Microflagellates Ann : Annelida A.C : Adult Copepoda

Values under line = significant Values in bold = significant at $p < 0.1$

conclusion that low temperature generally reduces grazing in temperate warm waters (Martin, 1965). Meanwhile, the increased phytoplankton and zooplankton density in early March, associated with a noticeable rise in temperature, and the initiation of a temporarily weak thermo-haline gradients of the water column, run in parallel with the results of Huntley and Lopez (1992) that zooplankton growth rates and those of their prey are positively affected by a temperature increase in spring. Most of the present zooplankton peak days occurred with relatively low surface salinity (36.7-37 ppt), except in late December and January (39-39.2 ppt). Such reduced salinity affecting zooplankton seasonal variation was demonstrated by Ojaveer *et al.* (1998). Copepod (the major zooplankton component) was mainly represented by *Acartia* spp., mostly *A. clausi*, which had been previously reported in the Eastern Harbour (e.g. Aboul Ezz *et al.*, 1990). *Acartia* species contributed the main bulk of the adult copepods in April at 15-16 °C. Deason (1980) reported *A. clausi* to exhibit a maximum filtration rate at 14-15 °C. The significant effect of increased temperature on the grazing rate of *Acartia* species feed on *Thalassiosira* spp. was proved by Wlodarczyk *et al.* (1992).

Nutrient concentrations were insignificantly correlated with the standing crop variability. Yet, some indirect positive significant correlation was found between phosphate and Protozoa, adult copepods and copepodite stages.

The statistical model applied predicts positive, significant relation between temperature and zooplankton and it was negative with salinity (Fig. 5 and 6).

A key question is whether the grazing pressure can be expected to be sufficiently high to effect the phytoplankton standing crop to the extent observed.

The statistical model reads:

$$\text{Zooplankton} = 1549.7 + 0.1616 * \text{phytoplankton}, R^2 = 0.096, p \leq 0.05, n = 24$$

The model predicts a positive insignificant correlation, in which zooplankton explains 18 % of the phytoplankton variability (Fig. 7). Yet, the correlation matrix shows significant correlation of the phytoplankton standing crop with zooplankton groups; Copepoda ($r = 0.4, p \leq 0.05$), Rotifera ($r = -0.41, p \leq 0.05$), and Annelida ($r = 0.37, p \leq 0.1$), as well as between diatoms (the main component of the phytoplankton standing crop) and Rotifera ($r = -0.42, p \leq 0.05$) adult Copepoda as well ($r = 0.35, p \leq 0.1$). Annelida was positively

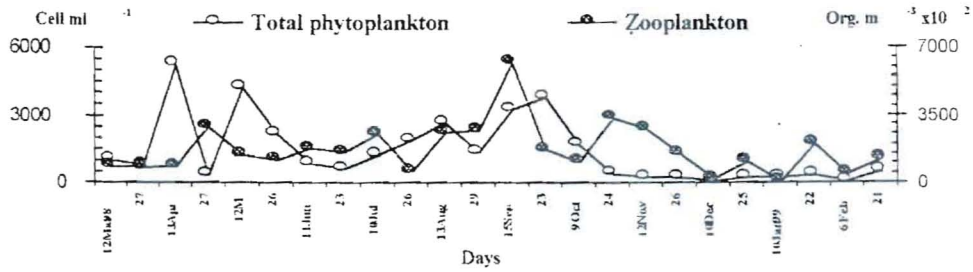


Figure 4. Phyto-zooplankton population.

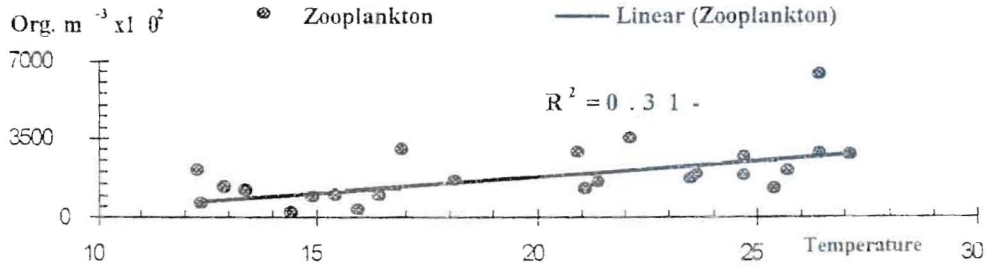


Figure 5. Zooplankton Vs Temperature

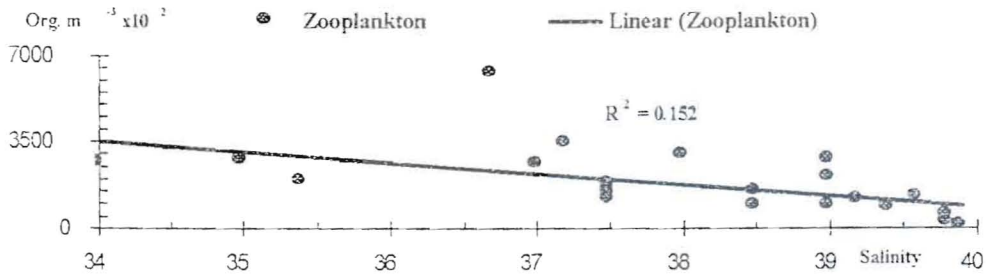


Figure 6. Zooplankton Vs Salinity

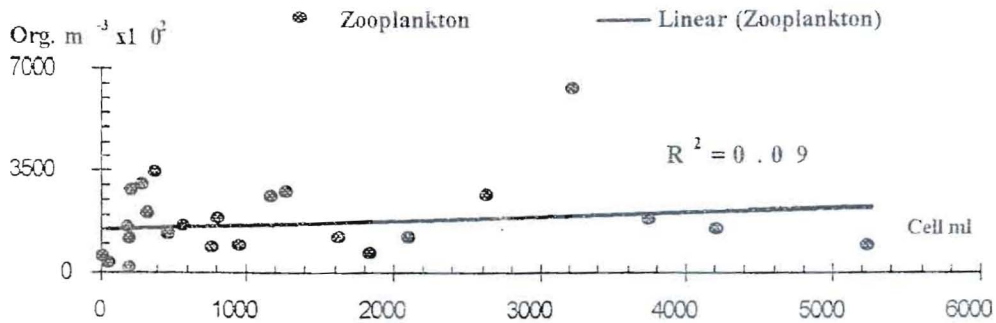


Figure 7. Zooplankton Vs Phytoplankton

significantly correlated with dinoflagellates ($r = 0.36$, $p \leq 0.1$), and microflagellates ($r = 0.67$, $p \leq 0.05$); and cirriped larvae with the latter group ($r = 0.38$, $p \leq 0.1$). Thus, the present study confirmed the ability of zooplankton grazing to play a role in regulating the phytoplankton cycle and inflicts some losses on its numerical standing crop at times.

Different patterns of the phytoplankton-zooplankton relationship could be distinguished:

1- Positive top-bottom relationship at intermittent periods during the different seasons with homothermal-homohaline/thermo-haline stratification conditions and when diatoms dominated. Such relationship was observed in late April, June, December, January and February (*S. costatum* predominated); late July (*T. nitzschioides*, *C. nana*); and autumn (*L. minimum*, *N. seriata*, *T. oestrupi*). All these small sized species of 20-50 μm length (Labib and Kamel, 2000) seem preferable for copepods grazing (Berggreen *et al.*, 1988). *Skeletonema costatum* was far known a suitable prey of *Acartia clausi* (Petipa, 1966). Such relationship has been previously noticed in the harbour throughout the vertically stratified water periods (May-October) by Aboul-Ezz and Zaghloul (1990), and in the near-shore waters off Alexandria during September 1987 - August 1988 (Zaghloul, 1994). Meanwhile, Zaghloul and Nessim (1990) reported an inverse relationship between the zooplankton density and chlorophyll *a* concentration in the area of investigation. Such relationship (e.g. Li and Smayda, 1998) was reported in the north-eastern Mediterranean (Cattani and Corni, 1992).

2- Negative top-bottom relationship, that seems to be connected with specific phytoplankton community structure. It was observed on several occasions; on 12 May with the predominance of *E. granulata* and *Prorocentrum triestinum*; in late May (*Pyramimonas* sp., and *P. minimum*); on 23 September (*Pyramimonas* sp., *N. seriata*, *G. catenatum*, and *Chaetoceros didymus*); and on 9 October when the community was comprised mainly of the dinoflagellates, *P. triestinum*, *Protoperidinium depressum*, and *S. trochoidea*. During these periods, the increased frequency observed of the non-diatom cells, and the sharp decline of the accompanied centric diatoms assume the possible avoidance of zooplankton consumers to take up the non-diatom cells as long as the smaller producer (*S. costatum*, *T. oestrupi* and *T. nitzschioides*) were present, offering some advantage to non-diatom species to dominate. Therefore,

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