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Selective grazing on phytoplankton in El-Dekhaila Harbour (Alexandria)

Broutage sélectif du phytoplancton dans le port d'El-Dekhaila (Alexandrie)

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ABSTRACT

Ismael A.A., N.E. Abdel-Aziz - Selective grazing on phytoplankton in El-Dekhaila Harbour (Alexandria). Mar. Life, ***13*** *(1-2): 21-30.*

The role of zooplankton grazing on the "green tide" in El-Dekhaila Harbour near Alexandria was studied over a one year cycle. Multiple regressions were used as a tool to investigate the effects of feeding selectivity of micro- and meso-zooplankton species on specific phytoplankton forms. Heterotrophic dinoflagellates, particularly Protoperidinium *spp., the major micro-zooplankton grazers, accounted at times for 45% of the grazing pressure. Most effective among the meso-zooplankton grazers were the two copepods* Acanthocyclops americanus *and* Paracalanus parvus*; the copepod nauplii and the Cirriped larvae, feeding on* Euglena acus*, c.f.* Chlorella *sp., cyanobacteria and diatoms. Selective feeding caused considerable density fluctuations of the "green tide" at times and its final decline, but also strong alterations of its community structure, corresponding to the species succession of the grazers.*

RÉSUMÉ

Ismael A.A., N.E. Abdel-Aziz - [Broutage sélectif du phytoplancton dans le port d'El-Dekhaila (Alexandrie)]. Mar. Life, ***13*** *(1-2) : 21-30.*

Le rôle du zooplancton dans le broutage de la "marée verte" a été étudié durant un cycle annuel dans le port d'El-Dekhaila près d'Alexandrie. Les régressions multiples ont servi d'outil pour l'investigation des effets du broutage sélectif des espèces du micro-plancton et du meso-zooplancton sur certaines espèces du phytoplancton. Les dinoflagellés hétérotrophiques, en particulier les espèces du genre Protoperidinium*, les plus importants brouteurs du micro-zooplancton, sont responsables, à certaines périodes, de 45% de l'effet du broutage. Parmi les brouteurs du méso-zooplancton, les plus importants sont les deux copépodes* Acanthocyclops americanus *et* Paracalanus parvus*, les nauplii des copépodes et les larves de cirripèdes, se nourrissant d'*Euglena acus*, c.f.* Chlorella *sp., de cyanobactéries et de diatomées. Par moments, le broutage sélectif est à l'origine d'importantes fluctuations de la densité de la "marée verte" et de sa disparition finale, mais aussi d'une forte altération de la composition de la communauté, correspondant à la succession des espèces brouteuses.*

INTRODUCTION

Phytoplankton levels are controlled by a balance between "bottom-up" nutrient limitation and resource competition and "top-down" processes such as grazing (Keller *et al.*, 1999). Grazing by herbivores is a primary factor that reduces phytoplankton biomass (Officer *et al.*, 1982; Hily, 1991; Mellina *et al.*, 1995; Prins *et al.*, 1995). The fate of phytoplankton is a combination of grazing by micro and meso-zooplankton, remineralization of nutrients, loss by sedimentation and advection (Sautour, Castel, 1999).

Zooplankton in the water column consumes particles of appropriate size and nutritional quality by filter feeding and/or raptorial feeding (Montanari *et al.*, 1996). The direct effect depends on zooplankton composition since the nature of food selection varies among herbivore taxa (Havens, 1993) and selective grazing has a significant impact on the structure of the phytoplankton community (James, Salonen, 1991).

The role played by protozooplankton (heterotrophic dinoflagellates and ciliates) in pelagial food webs is generally regarded as important (Smetacek, 1981). The heterotrophic dinoflagellates can make up a substantial biomass, which at times even exceeds that of other zooplankton groups (Lessard, 1991).

Abnormally dense phytoplankton blooms regularly develop in the warm season in El-Dekhaila Harbour causing a "green tide" which shows some fluctuations. The present work was carried out as an attempt to test the usefulness of multiple regressions as a tool in the investigation of selective feeding by meso- and micro-zooplankton in El-Dekhaila Harbour. The objective is to assess the effect of zooplankton prey selectivity on the abundance, structure and dynamics of the phytoplankton community in El-Dekhaila Harbour.

MATERIAL AND METHODS

El-Dekhaila Harbour occupies the western part of Mex Bay (figure 1). It is an important center for the maritime import and export of a variety of goods. The marine environment in the harbour is affected largely by anthropogenic factors, which cause alternate inhibition and promotion of the plankton growth (Abdel-Aziz, 2001 and Ismael, Dorgham, unpublished).

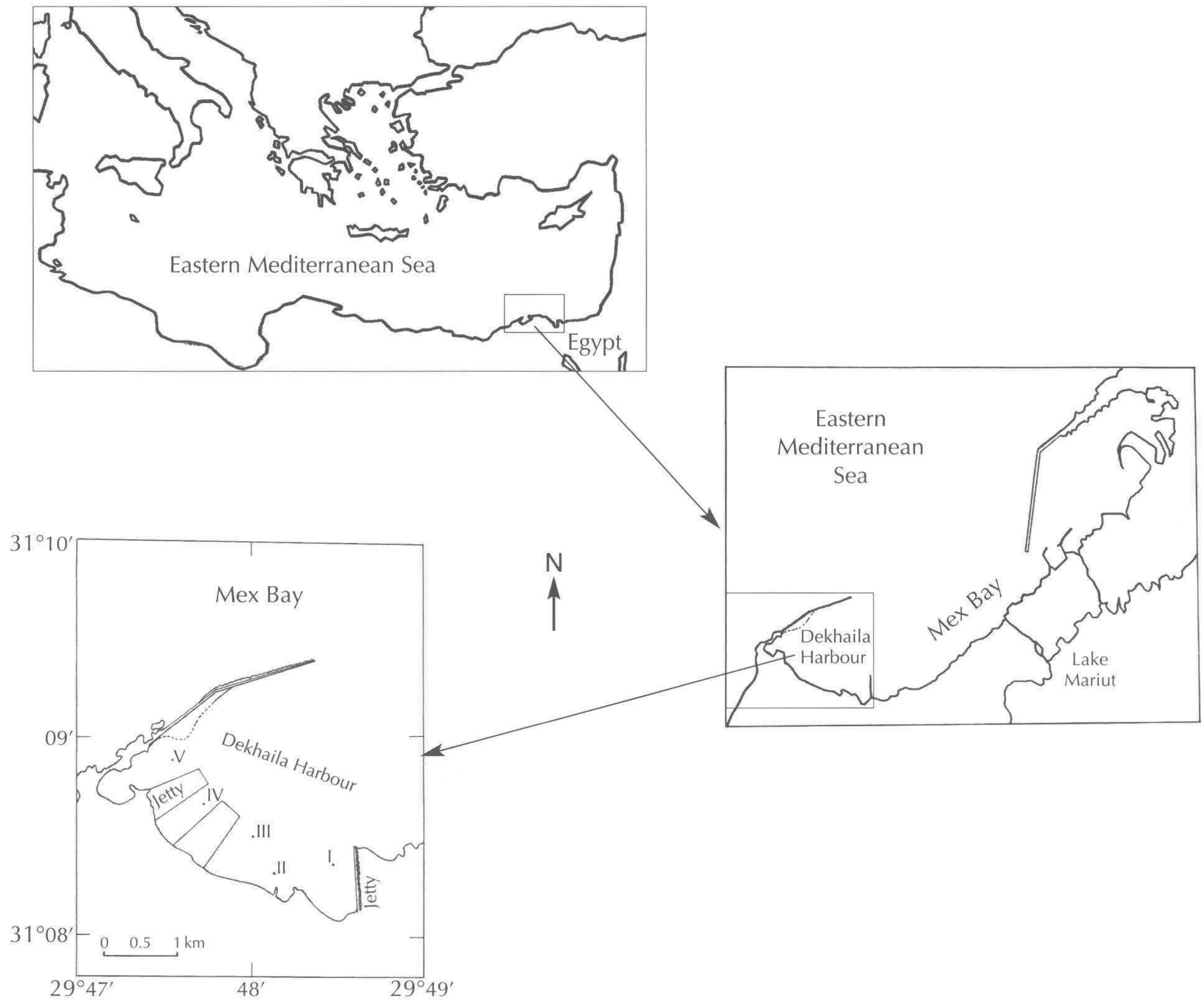


Figure 1 - Investigated area (El-Dekhaila Harbour) and position of stations. / *Aire étudiée (port d'El-Dekhaila) et position des stations.*

Quantitative phytoplankton samples were collected from surface water and zooplankton samples were collected by vertical net hauls from the bottom to the surface. Sampling was carried out monthly at five stations from April 1998 to March 1999. In all, 60 samples of phytoplankton and an equal number of zooplankton samples were collected.

Multiple regression between the total zooplankton groups and the dominant species of phytoplankton and between selected meso-zooplankton, micro-zooplankton species and the dominant species of phytoplankton were performed on SPSS Programme.

RESULTS

The phytoplankton community in El-Dekhaila Harbour consisted of 88 brackish and tolerant marine species (the heterotrophic dinoflagellates excluded). They belong mainly to the diatoms and dinoflagellates. Brackish water cyanobacteria, chlorophyte, euglenophyte and dictyophyte species were much less diversified. However, the cyanobacterial genera *Oscillatoria* sp. and *Spirulina* sp., the euglenophyte *Euglena acus* and a c.f. *Chlorella* sp. were particularly abundant at times. The zooplankton population comprised 49 meso-zooplankton belonging to the copepods, larvae, coelenterates, rotifers, nematods, ostracods and appendicularia and 43 species of micro-zooplankton belonging to the tintinnids, foraminifera, heterotrophic dinoflagellates and other protozoans. The abundance of the dominant species from both phytoplankton and zooplankton is given on table I.

The phytoplankton cycle went through three phases. An abnormally dense bloom, forming a "green tide", developed from June to October with a peak in August, the standing crop ranging from $17.8.10^6$ to $46.4.10^6$ cells.L^{-1} (phase II). The bloom was preceded in April-May (phase I) and followed in November through February (phase III) by a comparatively very low standing crop (phase I, $0.081\text{-}0.91.10^6$ cells.L^{-1}, phase III, $0.036\text{-}0.095.10^6$ cells.L^{-1}). An increase in cell density is observed the following March (5.10^6 cellsL^{-1}) (figure 2).

Three phytoplankton communities, corresponding to the three phases, alternate during this one year cycle. During phase II, the community was composed mainly of brackish water species, namely *Oscillatoria* sp., *Spirulina* sp., *Euglena acus* and c.f. *Chlorella* sp., causing the outstanding bloom of this phase. The first and third communities, which developed respectively before and after the bloom (phases I and III) were dominated by diatoms and dinoflagellates. The three phases are also characterized by distinct salinity-temperature conditions. The "green tide" developed at the highest temperature (26-29°C) and lowest salinity (22.5-24.5 PSU), indicating stable stratification of the brackish surface layer. Both pre-bloom and post-bloom phases occurred at lower temperatures and

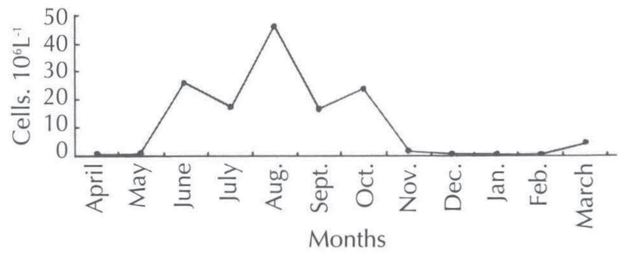


Figure 2 - Average phytoplankton standing crop in El Dkhaila Harbour during the periods April 1998-1999. / *Moyenne du stock disponible en phytoplancton au port d'El-Dekhaila entre avril 1998 et avril 1999.*

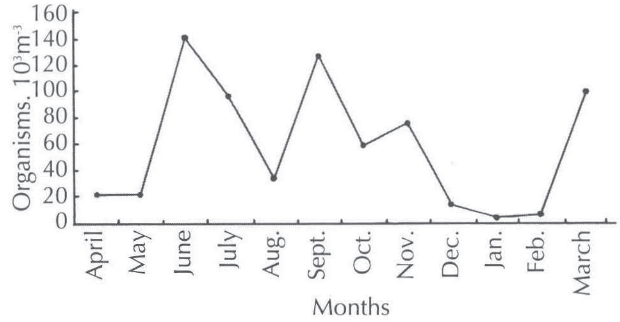


Figure 3 - Average zooplankton standing crop in El-Dkhaila Harbour during the periods April 1998-1999. / *Moyenne du stock disponible en zooplancton au port d'El-Dekhaila entre avril 1998 et avril 1999.*

higher salinities, respectively 21°C and 31.8-32.3 PSU and 15-18 °C and 28.4-38.3 PSU.

In contrast to phytoplankton, the zooplankton standing crop, including meso- and micro-zooplankton, showed four pulses, in June, September, November and March reaching respectively $141.2.10^3$, $126.9.10^3$, 75.10^3 and $99.7.10^3$ ind.m^{-3} (figure 3). Zooplankton density was relatively low during the rest of the year, ranging from $3.7.10^3$ to $21.8.10^3$ ind.m^{-3}.

Assuming that grazing pressure is responsible for the fluctuating trend in phytoplankton abundance during the blooming phase, multiple regressions between the major groups of zooplankton (both meso- and micro-zooplankton) and the dominant phytoplankton species were computed to detect which zooplankton groups are responsible for the grazing stress.

Copepods as a group were significantly and negatively correlated with c.f. *Chlorella* sp. at $p<0.05$, but protozoa, tintinnids, rotifers, nematodes, larvae and ostracodes were significantly and positively correlated with most of the dominant phytoplankton species. On the other hand heterotrophic dinoflagellates as a group were significantly and negatively correlated with *Euglena acus*, c.f. *Chlorella* sp. and *Cerataulus smithii* but positively correlated with the other dominant phytoplankton species (table II).

Table I - Abundance of dominant species of both phytoplankton (cells.10^3.L^{-1}) and zooplankton (number.10^3.m^{-3}) in El-Dekhaila Harbour (1998- 1999). Monthly average of the five stations. / *Abondance des espèces dominantes du phytoplancton (cellules.10^3.L^{-1}) et du zooplancton (nombre.10^3.m^{-3}) dans le port d'El-Dekhaila (1998-1999). Moyenne mensuelle des cinq stations.*

	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Phytoplankton												
Oscillatoria	5.9	0	9096	8126	8309	3463	10625	51.3	0	0	0	0
Spirulina	3.3	0	15428	7056	18035	3877	1534	387	13	0	0	0
Euglena acus	34.1	7	65.2	43.5	13322	335	692.5	31.8	5.6	3.2	3.2	6.6
Prorocentrum triestinum	10.4	19.3	61.3	113	203	353	2455.7	46	4.8	4.1	0.08	50.3
Cyclotella meneghiniana	3.2	13.3	185.8	68.1	291.2	1383	1040	5.8	3.6	0.7	0.1	1.8
Cerataulus smithii	0	0	0	99	59.8	371	292.5	0	0	0	0	0
Chlorella sp.	41.5	3.3	966.8	914	3774	7135	724.3	186	0	0	0	0
Skeletonema costatum	42	1.2	0	655	274.6	300	4.2	0	0	2.9	10.5	468.5
Prorocentrum minimum	10.3	0.4	133.5	476	466.7	545	66.9	60.9	5	6	0.3	9.1
Prorocentrum micans	3.1	37.6	4.3	5.7	5.6	0	0	0.5	0	0	0	5.9
Coscinodiscus radiatus	0.6	5.1	34.3	11	8.2	13.6	23.3	6.2	0.4	0	0	0
Pseudonitzschia sigma	0.7	0	6.2	0	0	0	13.5	25.7	3.7	3	3	0.3
Zooplankton												
Protozoa	0.01	0	0	0.02	0.01	2.3	0	0.01	0	0.23	0.02	0
Tintinnids	0.22	1.9	0.09	0.60	0.10	89	3.5	1.8	0.11	0.05	0.11	79
Foraminifera	0.09	0.05	0.06	0.01	0.01	0.01	0.01	0.03	0.02	0.08	0.02	0.07
Heterotrophic Dinoflagellates	10.8	4.5	0.14	0.08	31.1	33	44.9	61.3	4	0.98	0.52	13.8
Coelenterates	0.02	0.03	0.02	0.09	0	0.01	0	0	0	0	0	0.02
Rotifers	0.01	0.02	0.18	0.07	0	0.10	0.83	0.01	0	0.02	0.01	0
Nematods	0.09	0	0.08	0.03	0	0.07	0.09	0.01	0	0	0	0
Larvae	1.3	2.4	1.1	2.5	0.93	0.74	1.9	1.2	0.6	0.46	0.55	0.64
Copepods	7.6	10.9	4.7	8.2	1.3	1.6	6.6	9.9	9	1.9	4.6	5.7
Appendicularia	0.99	0.81	0.06	0.26	0.02	0.01	0.04	0.6	0.32	0.01	0.17	0.31

Table II - Multiple regressions between dominant species of phytoplankton and zooplankton groups in El-Dekhaila Harbour at $p < 0.05$ and $R^2=0.57$. In bold: the significant values. / *Régressions multiples entre les espèces dominantes du phytoplancton et les groupes du zooplancton au port d'El-Dekhaila, à $p<0,05$ et $R^2=0,57$. En gras : les valeurs significatives.*

	Oscillatoria	*Spirulina*	*Euglena acus*	*Prorocentrum triestinum*	*Cyclotella meneghiniana*	*Cerataulus smithii*	*Chlorella*	*Skeletonema costatum*	*Prorocentrum minimum*	*Prorocentrum micans*	*Coscinodiscus radiatus*	*Pseudonitzschia sigma*
Protozoa	-0.012	-0.018	-0.083	0.019	**0.748**	**0.730**	**0.856**	-0.056	**0.569**	-0.176	0.120	-0.199
Tintinnids	-0.148	-0.141	-0.132	-0.019	0.496	0.481	**0.564**	**0.653**	0.310	-0.101	-0.048	-0.257
Foraminifera	-0.389	-0.226	-0.360	-0.353	-0.504	-0.546	-0.502	0.249	-0.540	0.130	-0.175	-0.158
Heterotrophic Dinoflagellates	0.485	**1.554**	**-3.080**	-0.034	0.775	**-0.732**	-0.471	**0.863**	**0.890**	-0.070	**3.488**	**0.822**
Coelenterates	0.263	0.148	-0.204	-0.187	-0.220	-0.055	-0.116	0.062	0.358	0.330	0.146	-0.208
Rotifers	**0.637**	0.005	-0.087	**0.975**	**0.616**	**0.611**	0.026	-0.147	-0.029	-0.166	**0.611**	0.341
Nematodes	0.473	0.145	-0.210	0.495	0.532	0.489	0.223	-0.230	0.119	-0.234	**0.640**	0.107
Larvae	0.395	0.044	-0.101	0.305	0.036	0.157	-0.149	-0.172	0.173	**0.583**	0.292	0.034
Chaetognatha	-0.108	0.060	-0.212	-0.235	-0.285	-0.364	-0.271	0.547	-0.334	-0.006	0.104	-0.146
Copepods	-0.271	-0.454	-0.468	-0.032	-0.403	-0.326	**-0.595**	-0.033	-0.436	0.425	-0.137	0.389
Cladocera	-0.308	-0.246	-0.128	-0.154	-0.210	-0.219	-0.213	-0.142	-0.278	**0.927**	-0.172	-0.241
Ostracods	-0.211	-0.132	-0.130	-0.137	-0.202	-0.221	-0.197	**0.961**	-0.241	-0.008	-0.173	-0.179
Pteropods	-0.356	-0.286	-0.149	-0.182	-0.250	-0.255	-0.247	-0.151	-0.313	0.590	-0.263	-0.266
Appendicularia	0.435	0.279	-0.116	-0.093	-0.132	0.037	-0.039	0.017	0.474	0.008	0.234	-0.178

In a second step, in order to further specify the respective grazing role of copepod species, larval types, rotifers and tintinnids, multiple regressions were again computed, this time between selected species from the respective groups and the dominant phytoplankton species. Five dominant copepods, four larval types, one rotifer, two tintinnids and six heterotrophic dinoflagellates were selected. Nematode, protozoan and ostracode species were not considered, as the respective standing crops of their species were comparatively insignificant (table I).

The results show a significant negative correlation at $p<0.05$ between the brackish water copepod *Acanthocyclops americanus* and c.f *Chlorella* sp. (figure 4). No correlation was found between *Acartia clausi, Oithona nana* and *Euterpina acutifrons* and any of the phytoplankton species examined. *Paracalanus parvus* is negatively correlated to *Oscillatoria* sp., though weakly so. Cirriped larvae showed also a significant negative correlation with *Cyclotella meneghiniana, Spirulina* sp. and c.f. *Chlorella* sp. (figure 5), while copepod nauplii were also negatively and significantly correlated to *Cyclotella meneghiniana, Cerataulus smithii* and c.f. *Chlorella* sp. (figure 6, table III). On the other hand, the microzooplankton seems to play an important role at times as the correlation between most dominant microzooplankton and the dominant species of phytoplankton is significant (table IV). There is a negative correlation between *Protoperidinium curvipes* and *Cerataulus smithii*, c.f. *Chlorella* sp., *Skeletonema costatum, Pseudo-nitzschia sigma*, between *P. nipponicum* and c.f. *Chlorella* sp., and *Euglena acus*, between *P. diabolus* and *Euglena acus, Oscillatoria* sp., between *P. breve* and *Euglena acus* and finally between *P. pellucidum* and *Cerataulus smithii*. On the other hand, the tintinnid *Tintinnopsis beroidea* does not seem to feed on the micro-phytoplankton species considered.

During the present one year cycle, the interrelation of phytoplankton and zooplankton, as a whole, showed three trends:

- In April-May (phase I), grazing is weak but still effective. Grazing in this phase is restricted to the heterotrophic *P. diabolus*, feeding on *Oscillatoria* sp. and *Euglena acus, P. curvipes* on *Skeletonema costatum*, the copepod *Acanthocyclops americanus* and copepod nauplii on c.f. *Chlorella* sp. Their combined grazing pressure accounts for a reduction in total phytoplankton density of 44% (table I). In the mean time, the population of *P. diabolus* increased by 68%, that of the copepod nauplii by 45% and *Acanthocyclops americanus* by 105%. It is to be noted that the total density of zooplankton (both micro and meso-zooplankton) is misleading, as it appears to remain constant.
- During the blooming phase, the phytoplankton density showed fluctuations, both phytoplankton and zooplankton communities changing in

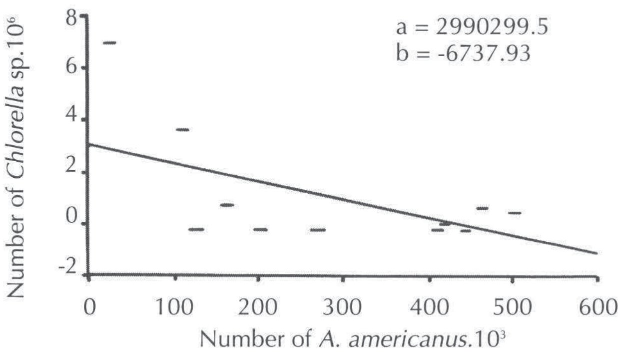


Figure 4 - Regression between *Acanthocyclops americanus* and c.f. *Chlorella* sp. (r^2=0.44). / *Régression de* Acanthocyclops americanus *sur c.f.* Chlorella *sp. (r^2=0,44).*

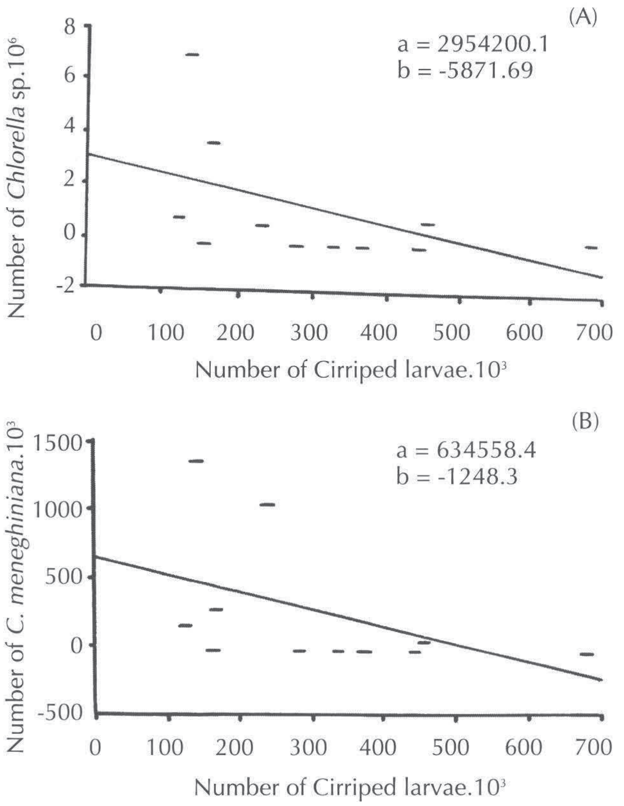
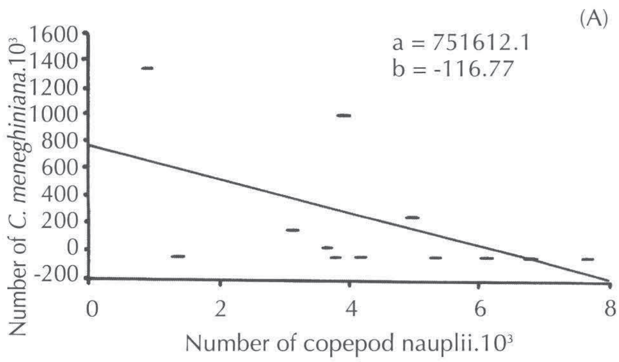


Figure 5 - Regression between Cirriped larvae (r^2=0.44) and c.f. *Chlorella* sp. (A); *Cyclotella meneghiniana* (B). / *Régression des larves cirripèdes (r^2=0,44) sur c.f.* Chlorella *sp. (A) ;* Cyclotella meneghiniana *(B).*



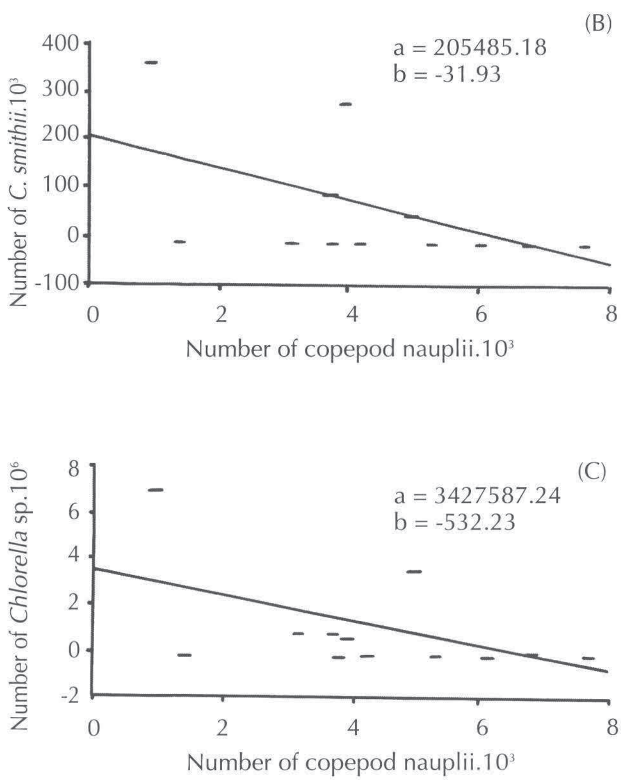


Figure 6 - Regression between copepod nauplii (r^2=0.44) and *Cyclotella meneghiniana* (A); *Cerataulus smithii* (B); c.f. *Chlorella* sp. (C). / *Régression des nauplii de copépodes (r^2=0,44) sur* Cyclotella meneghiniana *(A) ;* Cerataulus smithii *(B) ; c.f.* Chlorella *sp. (C).*

opposite directions (table IV). This is observed during July-August, August-September, September-October and October-November. There are however apparent discrepancies, the trend in both total densities seeming to be parallel at times, both communities increasing from May to June and decreasing from June to July. The major predators on *Oscillatoria* sp., *Spirulina* sp., *Chlorella* sp. and on *Cyclotella meneghiniana* are almost absent in May-June and therefore although the total zooplankton is on the increase, the lack of grazing pressure on these species allowed them to bloom (table I). On the other hand, in June-July, while there was an apparent decrease in the total zooplankton in parallel with the decrease in phytoplankton, the Cirriped larvae doubled in number and their prey, *Spirulina* sp., decreased by 8 mil-

Table III - Multiple regressions between dominant species of phytoplankton and selected dominant meso-zooplankton species in El-Dekhaila Harbour at $p<0.05$ and $R^2=0.44$. In bold: the significant values. / *Régressions multiples entre les espèces dominantes du phytoplancton et les espèces dominantes sélectionnées du méso-zooplancton au port d'El-Dekhaila, à $p<0,05$ et $R^2=0,44$. En gras : les valeurs significatives.*

	Acanthocyclops americanus	*Acartia clausi*	*Euterpina acutifrons*	*Oithona nana*	*Paracalanus parvus*	*Synchaeta*	Cirriped larvae	Spionid larvae	Copepod nauplii	Copepodite stage
Oscillatoria sp.	0.1	-0.06	-0.36	0.38	-0.40	**0.63**	-0.36	**0.45**	-0.27	-0.19
Spirulina sp.	-0.32	-0.07	-0.31	0.05	-0.28	-0.01	**-0.44**	0.16	-0.17	-0.18
Euglena acus	-0.29	-0.32	-0.26	-0.15	-0.21	-0.08	-0.28	-0.06	0.08	-0.33
Prorocentrum triestinum	0.37	-0.23	-0.30	0.17	-0.28	**0.98**	-0.19	0.21	-0.13	-0.11
Cyclotella meneghiniana	-0.17	-0.39	-0.16	-0.10	0.00	**0.62**	**-0.44**	0.07	**-0.50**	-0.01
Cerataulus smithii	-0.06	-0.33	-0.09	0.08	-0.01	**0.62**	-0.33	0.19	**-0.50**	-0.02
Chlorella sp.	**-0.52**	-0.38	-0.05	-0.20	0.10	0.03	**-0.44**	-0.02	-0.49	-0.04
Skeletonema costatum	0.02	-0.06	**0.49**	-0.12	-0.08	-0.14	0.14	-0.18	-0.06	**0.52**
Prorocentrum minimum	-0.27	-0.15	-0.02	0.28	-0.06	-0.03	-0.23	0.31	-0.40	-0.13
Prorocentrum micans	0.25	0.71	**0.53**	-0.05	-0.19	-0.18	-0.06	**0.57**	**0.54**	-0.35
Coscinodiscus radiatus	0.04	0.07	-0.34	0.17	-0.32	**0.59**	-0.38	0.33	-0.27	-0.04
Pseudonitzschia sigma	0.42	-0.13	-0.41	0.24	-0.15	0.35	**0.55**	-0.14	0.28	0.05

Table IV - Multiple regressions between dominant species of phytoplankton and selective dominant micro-zooplankton species in El-Dekhaila Harbour at $p<0.05$ and $R^2=0.55$. In bold: the significant values. / *Régressions multiples entre les espèces dominantes du phytoplancton et les espèces dominantes sélectionnées du micro-zooplancton au port d'El-Dekhaila, à $p<0,05$ et $R^2=0,55$. En gras : les valeurs significatives.*

	Protoperidinium curvipes	*Protoperidinium pyriforme*	*Protoperidinium nipponicum*	*Protoperidinium breve*	*Protoperidinium diabolus*	*Protoperidinium pellucidum*	*Favella*	*Tintinnopsis*
Oscillatoria	0.404	0.003	**1.16**	0.11	**-0.578**	0.04	-0.14	0.03
Spirulina	**2.008**	-0.001	-0.058	**0.909**	**0.668**	**0.98**	-0.20	0.01
Euglena acus	0.201	-0.0002	**-1.55**	**-2.049**	**-0.745**	-0.34	-0.16	-0.07
Prorocentrum triestinum	-0.272	-0.01	0.185	-0.291	0.539	-0.169	-0.04	0.05
Cyclotella meneghiniana	-0.05	-0.007	0.055	0.03	0.116	0.33	0.04	**0.77**
Cerataulus smithii	**-0.647**	-0.040	-0.099	-0.39	0.005	**-0.58**	0.08	**0.76**
Chlorella sp.	**-0.849**	-0.0002	**-1.65**	-0.09	**1.739**	**1.25**	0.03	**0.87**
Skeletonema costatum	**-0.812**	0.013	**0.637**	0.42	-0.225	0.50	-0.20	-0.05
Prorocentrum minimum	**1.522**	0.014	0.094	0.528	**1.245**	**3.07**	0.00	**0.61**
Prorocentrum micans	-0.08	-0.002	-0.181	0.16	0.062	0.236	-0.03	-0.17
Coscinodiscus radiatus	3.34	0.198	**3.09**	**1.4**	0.219	**1.15**	-0.16	0.15
Pseudonitzschia sigma	**-0.707**	0.043	**1.81**	**1.36**	-0.355	**1.49**	-0.28	-0.19

Table V - Predator selectivity and the corresponding decrease in prey density. / *Sélectivité des prédateurs et déclin correspondant à la densité des proies.*

Period	Prey	Predator	Decrease in prey
April-May	*Euglena acus*	*Protoperidinium diabolus*	27.10^3
	Chlorella sp.	*Acanthocyclops americanus*, copepod nauplii	38.10^3
	Skeletonema costatum	*Protoperidinium curvipes*	41.10^3
June-July	*Spirulina* sp.	Cirriped larvae	8.10^6
Aug.-Sept.	*Oscillatoria* sp.	*Protoperidinium diabolus, Paracalanus parvus*	5.10^6
	Spirulina sp.	Cirriped larvae	15.10^6
	Euglena acus	*Protoperidinium nipponicum, Protoperidinium diabolus, Protoperidinium breve*	13.10^6
Sept.-Oct.	*Chlorella* sp.	*Acanthocyclops americanus*	$6.4.10^6$
Oct.-Nov.	*Oscillatoria* sp.	*Paracalanus parvus*	10.10^6
	Spirulina sp.	Cirriped larvae	$1.1.10^6$
	Euglena acus	*Protoperidinium nipponicum, Protoperidinium breve*	650.10^3
	Cyclotella meneghiniana	Cirriped larvae, copepod nauplii	1.10^6
	Cerataulus smithii	copepod nauplii, *Protoperidinium pellucidum, Protoperidinium curvipes*	292.10^3
	Chlorella sp.	*Acanthocyclops americanus*, copepod nauplii, *Protoperidinium curvipes, Protoperidinium nipponicum*	600.10^3

lion cells.L^{-1} (table V). Once more, the trend in total density appears to be misleading.

• The Winter phase (phase III) is characterized by instability and turbulence in the water column following the rise in surface water density caused by the drop in temperature to 15°C and the rise in surface salinity (38.3 PSU). The conditions became unfavorable to phytoplankton growth. Its density is comparatively very low although there is no grazing pressure as shown by the very low zooplankton stock.

DISCUSSION

The present work was carried out to test the assumption that selective grazing is the major process affecting not only the total density of the phytoplankton but also its community structure in El-Dekhaila Harbour.

In this harbour, the drop in phytoplankton density during phase I is also associated with a significant alteration in community composition. The drastic reduction in the stocks of *Euglena acus, Oscillatoria* sp., *Spirulina* sp., c.f. *Chlorella* sp. and *Skeletonema costatum*, the major community components, allowed the dinoflagellate-diatoms community to develop (*Prorocentrum micans, P. triestinum* and *Cyclotella meneghiniana*, phase I). It appears from the correlations that dinoflagellate species such as *Prorocentrum micans, P. minimum* and *P. triestinum* are unsuitable as a prey for either micro-zooplankton or meso-zooplankton.

In spite of optimum conditions of nutrient availability and stable stratification, which would favour a continuous bloom during phase II, wide fluctuations are observed. The phytoplankton standing crop dropped by 9.10^6 cells.L^{-1} from June to July, by 30.10^6 cells.L^{-1} from August to September and by 23.10^6 cells.L^{-1} from October to November. Higher temperatures are known to enhance the grazing pressure, as also concluded by Keller *et al.* (1999) who found, from a mesocosm study, that in warm systems, a relatively low standing stock of phytoplankton was accompanied by high zooplankton abundance.

On the other hand, alterations in dominance of the phytoplankton community during phase II are governed by the zooplankton succession. In June-July, the Cirriped larvae increased by 270% reducing the stock and relative importance of *Spirulina* sp. (table I). In August-September and October-November, *Paracalanus parvus*, increased respectively, by 270% and 200% decreasing the stock and lowering the rank of *Oscillatoria* sp. in the community. *Acanthocyclops americanus* thrived from September to October (rising from $2.8.10^3$ ind.m^{-3} to $50.4.10^3$ ind.m^{-3}), its prey, *Chlorella* sp. dropping by six million cells in the meantime. Guergues (1979), examining the gut content of 41 specimens of *Acanthocyclops americanus* from a brackish water lagoon, found it to contain mainly the chlorophytes *Microspora* sp. and *Ulothrix tenerrima* and the diatom *Nitzschia* sp. He concluded that feeding in *A. americanus* is not indiscriminate but selective. In a totally different environment, *Calanus finmarchicus* from the Norwegian Sea showed positive selectivity for diatoms and dinoflagellates avoiding cyanobacteria and "green algae" (Meyer-Harms *et al.*, 1999). October-November sees an increase in copepod nauplii by 73% causing subsidence of the stocks of *Chlorella* sp., *Cyclotella meneghiniana* and *Cerataulus smithii*. According to Sautour, Castel (1999), the omnivory of "herbivorous" copepods is now well known and only a few groups of obligate herbivores or carnivores exist. Our results do not allow us to confirm or contradict this view. The two major copepod grazers appear to be specific and selective in their food preference.

The micro-zooplankton, represented by heterotrophic dinoflagellates is responsible for the decrease of *Euglena acus*, c.f. *Chlorella* sp., *Cerataulus smithii, Oscillatoria* sp. and *Skeletonema costatum* (table IV). Heterotrophic dinoflagellates in El-Dekhaila Harbour accounted for 45% of the total grazing pressure during August-September. They were less effective in June-July and October-November (about 6%). Reported ingestion rates by Hansen (1991) and Naustvoll (2000) indicate that heterotrophic dinoflagellates may be important grazers, sometimes having a strong impact on the phytoplankton community. Their selective grazing is known to also influence the phytoplankton species composition and could even control the abundance of key species under some conditions.

Porter (1973, 1976) showed that grazers suppress small naked cells, while rigid cells are unaffected. This would explain the low grazing rate when dinoflagellates were dominant (April-May, September-October and December-March). The behavior of the prey may also play an important role in predator selectivity. Buskey (1997) observed that *P. pellucidum* cells never lose contact with a non-motile diatom but do so when feeding on motile dinoflagellates. The selective preference for diatoms over dinoflagellates of *P. pellucidum* might be related to the motility of the prey. This is compatible with the results of the present study, as *P. pellucidum* and *P. curvipes* feed only on diatoms (table IV). However, Meyer-Harms *et al.* (1999) report that calanoid copepods showed a strong selection for motile cells, particularly small dinoflagellates, when phytoplankton biomass was low.

Although tintinnids represent the second important component among the micro-zooplankton, they have no significant role in phytoplankton grazing in El-Dekhaila Harbour. Smetacek (1981) concluded that in the pelagic environment the ciliate diet is restricted to nanoplankton and bacterioplankton.

With regard to phase III, it is obvious that grazing is not responsible for the drop in phytoplankton during this phase. The rise in salinity accompanied by a drop in temperature points to turbulence and mixing with the subsurface water mass, inhibiting both phytoplankton and zooplankton.

In conclusion, in field observations, multiple correlations can be a useful tool for the interpretation of predator-prey interrelation between zooplankton and phytoplankton. Other authors have used a pigment-based technique (Meyer-Harms *et al.*, 1999; Sautour, Castel, 1999). The correlations should be applied to selected species or taxons groups and not to zooplankton and phytoplankton as a whole. The correlations between zooplankton groups and phytoplankton are also misleading.

The zooplankton succession and its selective feeding govern the composition of the phytoplankton community either by removing the prey species or by lowering their rank in the community. The role of micro-grazers should not be overlooked, since the results evidence their key role at times.

The observations and their interpretation confirm the working assumption that selective grazing is responsible for the density fluctuations of the phytoplankton community as well as for the community structure.

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