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CARBON, NITROGEN AND PHOSPHORUS CONTENT OF THE COPEPOD EUTERPINA ACUTIFRONS IN THE COASTAL WATERS OF ALEXANDRIA, EGYPT.

By

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ABSTRACT

The Carbon, Nitrogen and Phosphorus content of the harpacticoid copepod Euterpina acutifrons has been studied along the coastal waters of Alexandria. Samples were collected during summer 1989 to spring 1990 from 15 stations representing different areas subjected to different types and quantities of pollutants.

Annual average of E. acutifrons of carbon, nitrogen and phosphorus content during the period of study was 43 + 1.80, 5.6 + 0.97 and 0.34 + 0.06 respectively. The annual average of C/N ratio at the different localities being remarkably higher than that expected for marine organisms. The N/P ratio in the different stations fluctuated between 11.6 (autumn) and 24.3 (summer) with an annual average of 17.5 + 1.3.

INTRODUCTION

The increasing importance of studying the biogeochemical cycles of elements have devoted several researchers to study the chemical composition of plankton community to evaluate its role in these cycles. Marshall et al. (1934); Nakai (1942); Harris and Riely (1956) and Krey (1958) leads the first studies in this approach.

Curl (1962 a & b) and Beers (1966) studied the total carbon and chemical composition content of plankton. The various fractions of zooplankters have been considered earlier in the work of Fudge (1968) Raymont et al. (1967) and Omori 1969

On the other hand, Tande (1982) investigated the generation cycles, seasonal variations in length, body weight and body contents of carbon and nitrogen related to the overwintering and reproduction in the copepod Calanus finmarchicus from northern Norway. For the N.W. Mediterranean Sea (Hardstedt-Romeo, 1982) presented the concentration of carbon, nitrogen and phosphorus as well as other metals in natural populations of zooplankton collected during 1979/80. Kerambrun (1987) investigated the carbon, hydrogen and nitrogen contents in natural populations of the copepod Acartia clausi collected during 1980-82 from different areas near Marseille, France.

In the present study, the total carbon, nitrogen, and phosphorus of the harpacticoid copepod Euterpina acutifrons were analyzed and compared in samples of five different localities along the coastal waters of Alexandria. An examination of the seasonal variation of each content was also attempted.

MATERIAL AND METHODS

The area investigated extends along the coast of Alexandria about 60 km between Agami in the west (Longitude 29° 45' E and Latitude 31° 8' N) and Abu-Qir Bay (Boughaz El-Maadia) in the east (Longitude 30° 5' and 30° 22' E, and Latitude 31° 16' and 31° 21' N) (Fig. 1).

During the period from summer 1989 to spring 1990, zooplankton samples were collected for 4 cruises, 15 stations were sampled covering the costal waters of Alexandria region. Stations were chosen to represent different areas varying in their exposure to different types and quantities of pollutants discharged.

Samples for chemical composition were collected using a zooplankton net of 1m mouth diameter and 120 u mesh size. The net was towed horizontally for about 20 minutes at the lowest ship speed (about 0.25 m S^{-1}). The net was completely submerged below the water surface. Samples after discharging gross contaminating particles (paint, tar balls, wood pieces,...etc) were preserved into 250 ml glass containers previously soaked in 3 M pure HCl, washed with double deionized distilled water and rinsed with filtered sea water before sampling. Samples were kept in ice box and were deep frozen at -20°C immediately upon reaching the laboratory. The whole horizontal haul samples were placed in a Petridish, microscopically examined and adult **Euterpina acutifrons** was identified and sorted.

In the present experiments, E. acutifrons were gently rinsed with deionized water following the method of Williams and Robins (1982). Only undamaged specimens were used for analysis, because if exoskeleton membranes are ruptured by freezing, then internal fluids could be washed out, when specimens were rinsed with deionized water. Specimens were dried in an oven at 65°C until constant weight and stored in glass scintillation vials. Dried samples were

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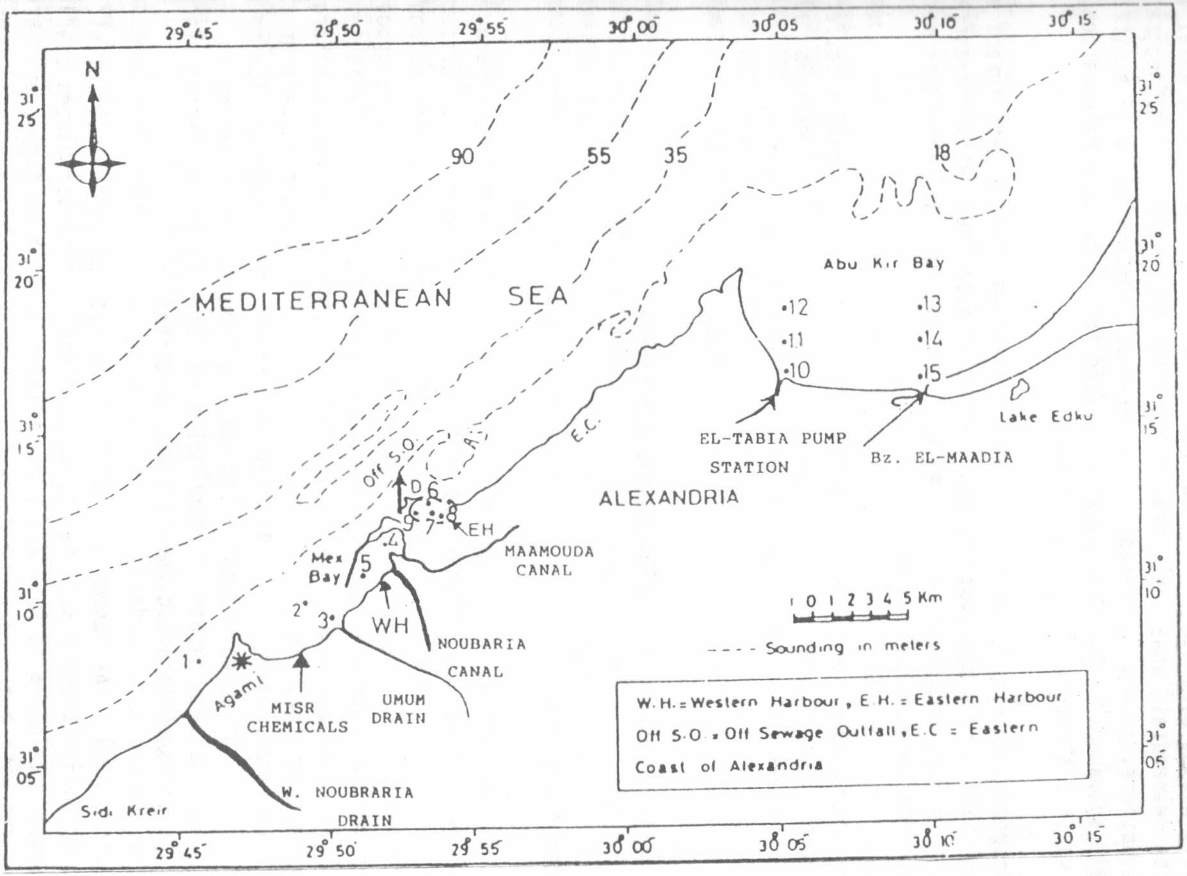

Figure 1: Area of study and sampling stations.

stored in a desiccator, with silica gel as desiccant, for subsequent analyses. All weighings for chemical and biochemical analysis were performed at accuracy of 5×10^{4} and sensitivity and readability of 0.1 ug.

The carbon and nitrogen concentrations were determined using Model 1104 Carlo Erba elemental analyzer located in the Department of Oceanography, Liverpool University, using Acetanilide as standard containing 10.73 % nitrogen and 71.09 % carbon. The mean relative errors for duplicate calculations of standard was + 3 % carbon and + 6 % nitrogen.

For phosphorus determination, 5 to 20 mg of dried adult E. acutifrons were fused with NaOH in a platinum crucible and then dissolved with concentrated HCl. In this solution, phosphorus was analyzed using the Molybdate method according to Murphy and Riley (1962).

Samples for nitrate, phosphorus, chlorophyll a were simultaneously collected and analyzed using the methods described by Strickland and Parsons (1972) while salinity was determined using the RSC-76 induction salinometer.

RESULTS AND DISCUSSION

Carbon content :

The carbon content (as percentage of dry weight) of E. acutifrons showed, not only variation between the different localities, but also within the different sampling sites of the same area (Figure 2). In Abu Qir, the lowest carbon of the copepod was generally observed during summer at the inshore sites opposite to El-Tabia pump station discharging the industrial waste of about 36 factories (st. 10). The same results was also recorded for Boughaz El-Maadia discharging brackish water from Lake Edku (St. 15). The dissolved oxygen content at this station was extremely low 1.31 ml/l. However, in the other seasons, the carbon content at this location was normally low varying from 30.9 % in spring to 36.1% in winter. The maximum carbon content observed for El-Tabia sector reached 48.4 % at the offshore location (st. 12) during winter.

On the other hand, the carbon content of E. acutifrons in the coastal st. 15 of Boughaz El-Maadia sector, affected by agricultural discharge, varied over the same magnitude like those of El-Tabia i.e. between 32.6 % in summer and 38.6 % in winter, but with a slightly higher range. Similarly, the carbon content in this sector increased gradually offshore at st. 13 (range 41.8 % - 52.8 %), far from the discharge point (Fig. 2). The carbon content in both sectors showed a peak in winter with a general average of 44.6 + 7.4 % for El-Maadia sector and 41.4 + 6.3 % for El-Tabia sector (Fig. 2).

The carbon content of E. acutifrons in the E.H. (sts 6-9) and W.H. (st. 4 and 5) (Fig. 2) are significantly ($p < 0.01$) higher than those recorded for Abu Qir Bay i.e. annual averages 48.3 + 5.5 % and 46.6 + 3.9 %, respectively

(Table 1). Carbon was characteristically high at the central station of E.H. reaching 61.9 % during autumn (Fig. 2). Stations affected by sewage discharge (st. 6 and 8) showed characteristically the lowest carbon contents (annual av. 44.9 + 6.8 % and 43.7 + 3.9 %, respectively). The minimum value for carbon in the E.H. was recorded at st. 8 in spring, i.e., 38.3 %. The overall average calculated for the mid W.H. station, i.e. 42.4 + 4.4 % was significantly lower ($p < 0.05$) than that located opposite to the agricultural discharge i.e. 47.5 + 5.1 %.

Stations sampled at El-Mex Bay showed significantly considerable variations in their carbon content of Euterpina depending on their position relative to agricultural/industrial mixture discharge location. Opposite to the discharge point, the carbon content fluctuated between 30.8 % and 36.4 % in autumn and summer, respectively. On the other hand, despite of the relative oligotorophic nature of st. 1 sampled at the western coast, the average carbon content of Euterpina acutifrons was 51.2 ± 2.6 % (Table 1). Generally, seasonal variations in sampling sites were related principally to the seasonal amplitudes in the discharge from landbased sources as well as its reflection on the productivity and biomass of phytoplankton in the different localities.

Coastal stations that are highly affected by either industrial or agricultural discharge indicated by low salinity values reaching 16.41 % at El-Maadia opening in Winter showed low carbon contents (Fig. 2). Industrial disposal seemed to have a higher impact on the carbon content (st. 3 and 10).

On the other hand, the chlorophyll a in the Eastern Harbour (av. 7.67 mg chl.. a/m^3) corresponds to the maximum carbon content of the organisms for locations subjected to land discharge (av. 48.3 %, Table 1).

Correlation between the carbon content and chlorophyll a in this basin was statistically significant ($r = 0.9686$, $p < 0.001$) while for the whole coastal area was ($r = 0.7103$, $p < 0.01$) indicating the importance of food supply in building up the carbon content of the organism.

Hardsted-Romeo (1982) observed high carbon values (48 %) in plankton samples from the N. western Mediterranean. He concluded that phytoplankton are richer in mineral elements and carbohydrates than zooplankton which are characterized by low mineral content. Curl (1962 a & b) reported 29.8 % C (dry weight) in samples of mixed copepods and phytoplankton and an average of 38.3 % carbon in crustaceans. Beers (1966) observed 41.6 % C (dry weight) in copepods from Sargasso Sea off Bermuda. Among 4 copepod species from the N.W. Mediterranean, Champalbert and Kerambrun (1978) found carbon ranging from 32.4 % to 43.3 %.

For the inland sea of Japan, Hirota (1981) estimated the total carbon for different copepod species and observed concentrations varying from 45.85 % for Acartia erythraea and A. pacifica to 51.96 % for the harpacticoid Microstella norvegica. The carbon content of Oithona bervicornis, Oncea media and Corycaeus sp. was 49.51 % and 48.14 % respectively. For 128 organisms of Pontella mediterranea, Champalbert and Kerambrun (1979) recorded carbon concentrations between 40.6 and 46.0 %.

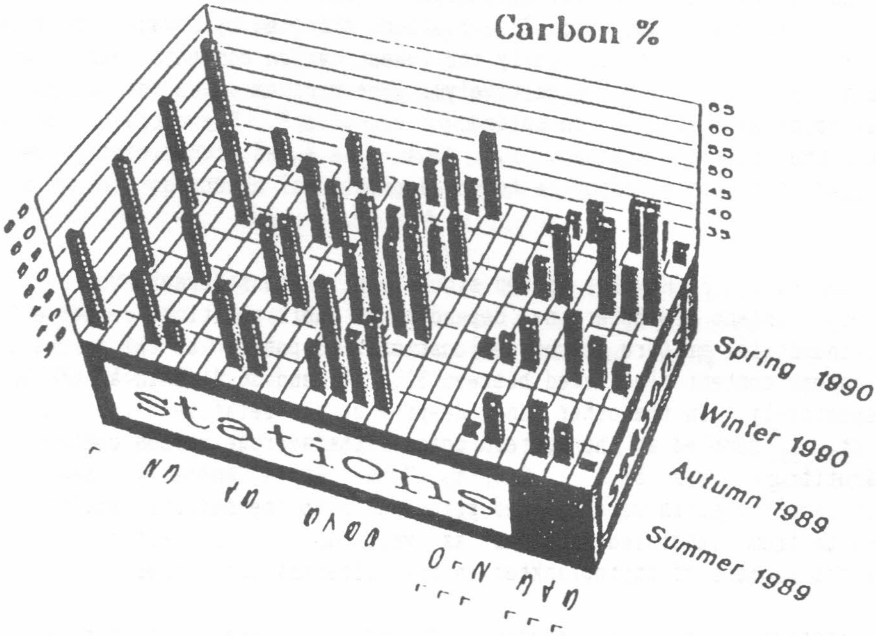

Figure 2: Carbon content (% of dry wt) of E. acurifrons in the coastal waters of Alexandria.

Table (1): Average carbon content (%) of E. acutifrons in the different regions of the coastal waters of Alexandria.

Location / Season	AG	MX	WH	EH	AQ (TB)	AQ (MD)	Seasonal average
Summer, 1989	50.1	42.2	44.9	49.5	36.2	37.5	43.3 + 8.02
Autumn, 1989	48.6	38.7	48.2	55.6	37.0	41.1	44.9 + 9.45
Winter, 1990	51.1	42.5	46.5	44.7	41.4	44.6	45.1 ± 6.90
Spring, 1990	54.8	35.5	40.3	43.4	35.4	38.2	41.3 + 7.73
Annual averag	51.2	39.8	45.0	48.3	37.5	40.4	43.7 + 1.80
S.D.	± 2.6	± 3.4	± 3.4	± 5.5	± 2.7	± 3.2	

* AG = AGAMI MX = MEX BAY WH = WESTERN HARBOUR
EH = EASTERN HARBOUR AQ (TB) = ABU QIR/EL-TABIA SECTTOR
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S.D. = Standard Deviation.

The present investigation reveal an average carbon content for E. acutifrons of 43.7 + 1.80 % (Table 1) of dry weight which is accepted for inshore tropical species and considered within the range recorded by most investigators.

Nitrogen content :

Available information on the nitrogen content of copepods, are scarce (Beers, 1966; Champalbert and Kerambrun, 1978; 1979; Hirota, 1981; Williams and Robins, 1982).

The present data revealed a nitrogen level (av. 5.6 ± 0.97 %) which is at least one order magnitude lower than those recorded in other localities (Table 2). Comparatively, in this study, the nitrogen content of E. acutiforms covered the range between 2.0 % and 10.4 %. Such wide variation reflects the effects of LBS on decreasing of increasing the body contents of the organisms sampled opposite to the effluents. The lowest value i.e. 2.0 % was observed opposite of El-Tabia pumps in spring (Fig. 2). However, this season was characterized with a common low nitrogen contents in all sampled areas, leading to the lowest seasonal average i.e. 4.2 % (Table 2). Even the E.H. which normally showed the higher nitrogen levels during the study period (av. 6.2 % ± 2.1), showed the lower average during the season i.e. 4.0 % (Table 2).

For the E.H., the mid harbour station generally recorded the highest values especially in summer and autumn (absolute maximum). Stations affected by the external sewage discharge from Kayet Bey pump station (st. 6) and that sampled in the ship anchorage (st. 9) normally showed high levels while st. 8 directly affected by sewage discharge inside the harbour recorded low values ranging between 3.2 % in spring and 8.7 % in autumn, respectively. Similar to Abu Qir Bay, the nitrogen levels of E. acutifrons increased seaward in Mex Bay, as the organism is apart from the direct discharge, reaching nearly half the value example: winter (Fig. 3).

It is interesting to note that the highest average recorded for the study area including the western station (Agami) (6.4 ± 0.89 %) are observed during winter 1990, except for the E.H. where the maximum average occurred during autumn i.e. 9.1 ± 1.1 %. Williams and Robins (1982) measured nitrogen in Calanus helgolandicus collected from the Cetlic Sea and observed levels around 10.89 ± 0.73 %, 10.36 ± 1.5 % and 9.28 + 1.61 % for fresh, frozen and fixed specimens. For Pontella mediterranea, Champalbert and Kerambrun (1979) reported an average nitrogen content of 11.4 %. Beers (1966) observed 9.62 % N (dry weight) in copepods and 7.83 % N in other crustaceans from samples collected from the Sargasso Sea. Among 4 species of copepods from The NW Mediterranean, Champalbert and Kerambrun (1978) found nitrogen concentrations ranging from 9.3 from 9.3 % N and 11.5 % N. For Inland Sea of Japan, Hirota (1981) reported nitrogen contents of different copepods varying between 9.78 % and 13.14 %.

Table (2): Average nitrogen content (%) of E. acutifrons in the different regions of the coastal waters of Alexandria.

Location Season	AG	MX	WH	EH	AQ (TB)	AQ (MD)	Seasonal average
Summer, 1989	6.5	5.0	5.3	6.3	5.2	5.6	5.7 + 0.91
Autumn, 1989	7.1	4.2	6.3	9.1	4.6	5.1	6.1 + 2.12
Winter, 1990	7.8	6.3	7.1	5.5	5.6	6.1	6.4 + 0.89
Spring, 1990	6.8	3.4	4.2	4.0	3.3	3.6	4.2 + 1.07
Annual average S.D.	7.1 + 0.6	4.7 + 1.2	5.7 + 1.3	6.2 + 2.1	4.7 + 1.0	5.1 + 1.1	5.6 + 0.97 -

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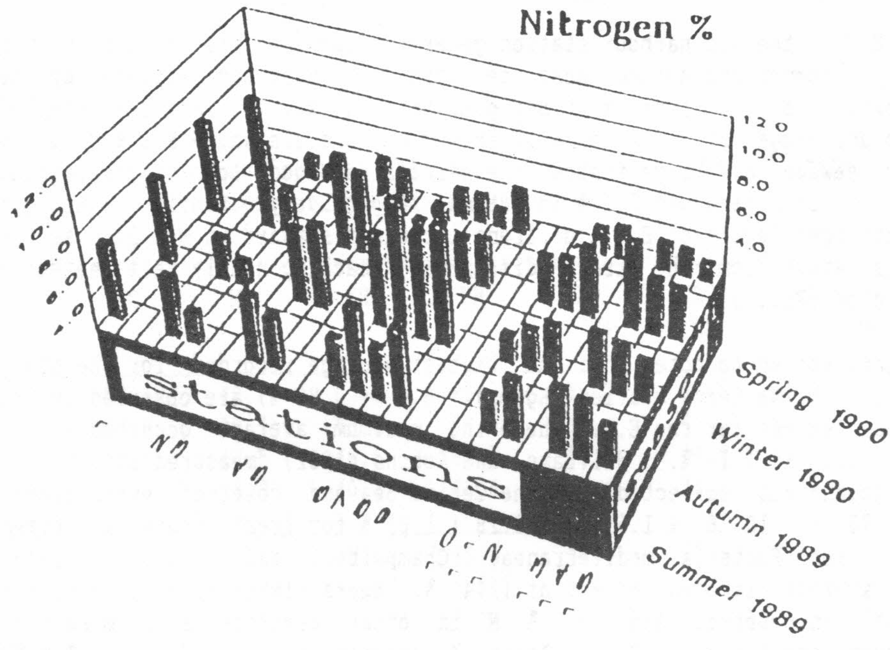

Figure 3: Nitrogen content (% of dry wt) of E. acutifrons in the coastal waters of Alexandria.

The nitrogen content of the E.H. copepods is highly related to the chlorolyll a biomass of the harbour showing strong coincident peaks ($r = 0.9668, 9 < 0.001$). In other areas like W.H. (st. 4 and 5) and El-Maadia sector (station 13 to 15) a negative correlation was observed between chlorophyll a content and the nitrogen content of the copepod ($r = -0.5300$, $p < 0.1$ and $r = -0.1339$, insignificant) indicating that factors other than the available food regulates the nitrogen content of the organism.

Using the data for nitrogen content of the copepod in a relation with the nitrate content of water; it was clearly evident that a negative, not highly significant relationship exists. The general regression equation was:

$$N (\%) \text{ orgs.} = 6.145 + 1.00 \pm 0.0947 \pm 0.0467 \, NO_3 \text{ (uM)}$$

with a regression coefficient of -0.3985, $p < 0.0153$. Regressions for different seasons showed insignificant differences, all showing an inverse relationship indicating the use of nitrate for Euterpina body nitrogen synthesis which appeared through a mediator i.e. Phytoplankton. The intercept in the equation indicates that the organism in addition to nitrate, depends on other sources in building up its body nitrogen. Ammonia, which was not measured by that time could be an additional and/or substitutional source. When nitrogen sufficient media prevails, indicated from the concentrations in water, the organism contained a consistent amount of nitrogen. However, the organism could suffer nitrogen starvation with a total decrease in cellular nitrogen, internal decrease of NO_3 and amino acids followed by a drastic reduction of protein and NO_3 normally used to sustain growth when nitrogen source is depleted, constituting the nitrogen store when N is plentiful (Dortch, 1982).

Phosphorus content :

The annual average concentration of content of Phosphorus E. acutifrons collected from the coastal waters of Alexandria was 0.34 $\pm$ 0.06 % (Table 3). A minimum value was recorded in spring at st. 10 (0.1 %) opposite to the industrial outfall in Abu Qir Bay whereas the maximum value was observed at st.7 (E.H.) during autumn (0.64 %) (Fig. 4). During summer and autumn the highest average values were recorded at the E.H. (0.38 % and 0.57 %), although in summer, nearly similar values were noticed at AG (0.37 %) and Maadia sector of AQ (0.36 %); (Table 3). Similar annual averages of phosphorus content (0.32 %) were noticed at both Mex and W.H. stations (Table 4). The highest annual average of phosphorus % was recorded at AG (0.46 $\pm$ 0.09 %), whereas the two sectors of AQ Bay were represented by the lowest annual average values of phosphorus % which ranged from 0.27 $\pm$ 0.07 % to 0.29 % $\pm$ 0.09 % (Table 3).

Generally, E. acutifrons collected from stations affected by direct discharge of industrial wastes showed remarkably low phosphorus contents especially at times of high discharge periods (st. 10, spring and st. 3, summer). However, the discharge of agricultural runoff from Lake Edku through Boughaz El-Maadia enriched with reactive phosphorus during Winter i.e. 2.767 uM and salinity 16.41%.. Lead to a corresponding elevation in the phosphorus levels in E. acutifrons during this season. (0.34 %). Sewage disposal to the E.H. seems

Table (3): Average phosphorus content (%) of E. acutifrons in the different regions of the coastal waters of Alexandria.

Location / Season	AG	MX	WH	EH	AQ (TB)	AQ (MD)	Seasonal average
Summer, 1989	0.37	0.29	0.34	0.38	0.33	0.36	0.35 ± 0.06
Autumn, 1989	0.40	0.36	0.28	0.57	0.26	0.28	0.36 ± 0.13
Winter, 1990	0.51	0.43	0.42	0.31	0.31	0.34	0.39 ± 0.08
Spring, 1990	0.55	0.19	0.23	0.22	0.17	0.16	0.75 + 0.11
Annual average	0.46	0.32	0.32	0.73	0.27	0.29	0.34 + 0.06
S.D.	± 0.09	± 0.10	+ 0.08	+ 0.15	± 0.07	± 0.09	

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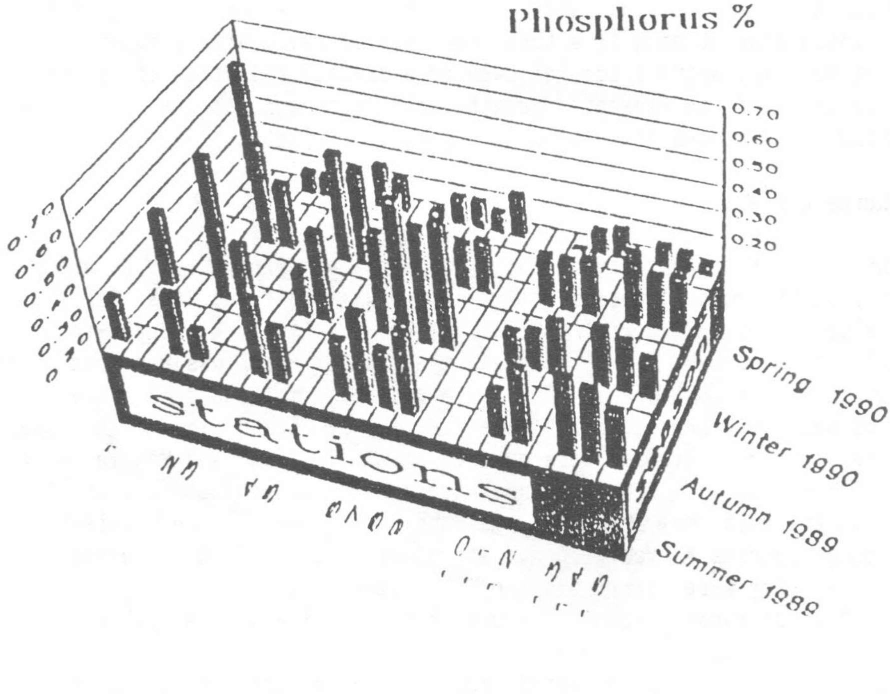

Figure 4: Phosphorus content (% of dry wt) of E. acutifrons in the coastal waters of Alexandria.

generally to increase phosphorus levels in the organism as recognized from the highest annual average recorded at the harbour (0.37 %, Table 3). during the study period. In spite of this, maximum discharge periods are not accompanied by high P contents probably because most of the P is discharged in the organic form (Aboul-Kassim, 1987). It seems likely that the phosphorus content of the organism is slightly affected by reactive phosphorus concentration in water. A regression equation described such relationship. This relation though not highly significant was negative for both seasons. The general regression is :

$$P\ (\%\ dwt)\ orgs. = 0.3467 \pm 0.094 - 0.0377 \pm 0.02\ P\ water(uM)$$

$$(r = -0.1985,\ P < 0.063).$$

Similar to nitrogen, Euterpina use phosphorus in water through phytoplankton uptake to build body phosphorus, though still other sources like Dissolved Organic Phosphorus, (Dop) could be of considerable importance. DOP in the coastal waters of Alexandria constituted between 20 and 65 % (Aboul-Kassim, 1987). However, the phosphorus content of water is not only a factor of discharge but also of the amount of chlorophyll a (chosen as a phytoplankton biomass indicator) concentration.

Table (4): Average C/N ratio for E. acutifrons in the different regions of the coastal waters of Alexandria.

Location Season	AG	MX	WH	EH	AQ (TB)	AQ (MD)	Seasonal average
Summer, 1989	7.9	8.7	8.1	8.0	7.0	6.7	7.7 ± 0.74
Autumn, 1989	7.4	7.0	7.0	6.1	8.1	8.1	7.3 ± 0.80
Winter, 1990	6.9	6.7	6.3	8.2	7.4	7.3	7.1 ± 0.70
Spring, 1990	8.6	10.6	9.3	11.0	11.6	10.7	10.3 ± 1.10
Annual average	7.7 ± 0.7	8.3 ± 1.8	7.7 ± 1.3	8.3 ± 2.0	8.5 ± 2.1	8.2 ± 1.8	8.1 ± 1.50

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Copepods sampled at st. 1 located at the Alexandria western coast, were characterized by high phosphorus content especially during winter and spring and to a lower extent in autumn (0.51 %, 0.55 % and 0.4 %, respectively).

Reactive phosphorus levels in this station were extremely low (range 0.08-0.32 uM), thus a negative relation between water phosphorus and organism phosphorus appeared ($r = -0.8802$, $P > 0.01$). On the other hand, a significantly positive relation ($r = 0.9525$, $P < 0.01$) appeared between the phosphorus content of the organisms and phytoplankton biomass in water. This condition indicates that despite the low phosphorus content of water, phytoplankton can assimilate these low concentrations, forming a phosphorus rich diet to copepods. Unavailable data on phytoplankton phosphorus content in the area make it impossible to reach a concise conclusion.

Hardstedt Romeo (1982) for the southern French coast, observed low phosphorus content in near shore planktonic samples which were mainly composed of phytoplankton and a relatively higher content for those were mainly composed of copepods and other crustaceans. However, Mayzaud and Martin (1975), for California current, noted a value of 0.59 % for phytoplankton whereas Beers (1966) in the Sargasso Sea, reported higher levels of phosphorus for copepods (0.79 %), for Euphausiacea (1.48 %) and for other crustacea (1.26 %). In the Liguro-Provencal basin Hardstedt-Romeo, (1982) recorded an average of 0.79 + 0.11 for the total zooplankton population for March 1980 samples.

As a general trend, apart from the low average recorded in spring, i.e. 0.25 % (Table 3), variations in the average values of the phosphorus content of E. acutifrons in the coastal waters are not significant (ranging from 0.35 to 0.39 %, Table 3). The low average in spring was mainly driven from low values located opposite to areas affected by industrial discharge (Abu Qir and Mex Bays). This decrease also corresponds with the decrease in P content of the copepod food. On the other hand, the N content of Euterpina also decreased during this time of the year (Fig. 4). Therefore it is possible that changes of the Euterpina N and P contents are caused by different grazed algae. Diatoms production was high as indicated from the high average chlorophyll a recorded during this season.

C/N, C/P and N/P ratios in E. acutifrons :

C/N ratio is frequently interpreted as a gross measure of condition because of its apparent connection with proportions of lipid and protein (Conover and Corner, 1968). C and N propionate levels reflect food quantity, production cycles and trophic level (Omori, 1970; Ikeda, 1974).

In general, in Eacutifrons the estimated C/N ratio in spring (av. 10.3 + 1.1) was higher than those estimated in other seasons which showed insignificant differences in between 7.7 + 0.74 (summer), 7.3 + 0.8 (autumn) and 7.1 + 0.7 (Winter), (Table 4).

Seasonal trends of C/N does match the seasonal variations in chlorophyll a biomass ($r = -0.646$, $P < 0.01$). This could suggest that copepods could sustain themselves during periods of low phytoplankton production by feeding on detritus or microzooplankton. High C/N ratio followed to a some extent phytoplankton blooms while lower averages were observed before the bloom. In Sargasso, Sea, C/N ratio for copepods range from 5.0 to 3.8 (Beers, 1966). However, in contrast, Omori (1969) observed a fairly constant and low ratio throughout the year because of the uniformity of the environment.

Despite the variation in environmental impacts of different sampled areas, the annual average of C/N ration at the different localities showed insignificant variations (Table 4) ranging from 7.7 at both Agami and W.H. to 8.5 for El-Tabia sector. Highest averages of C/N ratio were recorded at El-Tabia sector (11.6) and E.H. (11.0) in spring.

Relative to Redfield et al., (1963), the C/N ratio observed in the present study, was remarkably higher than that expected for marine organisms. Omori (1969) found Calanus cristatus that when Copepodite V are healthy and large sized diatoms are abundant, they eat diatoms and store great reserves of fat in their bodies. As a result, the percentage of N decreases while the C/N ratio increases.

The high C/N values, which correspond to no measurable phytoplankton production, indicate that the energy requirements are met mainly from internal deposits (Tande and Hopkins, 1981).

The work of Gatten et al., (1979; 1980) and Tande (1982) supported the idea that despite the restricted external energy supply, mainly based on deficient particulate matter, copepods may to a large extent rely on internal lipid resources.

Recorded C/N ration for Acartia clausi collected from different areas near Marseille (Kerambrun, 1978) fluctuated from 3.22 to 3.80 with minimum values in summer and highest in winter. Carbon concentrations varied from 38.87 to 45.49% while nitrogen from 10.35 to 13.55 %.. He calculated energy equivalents to range from 4.28 to 5.00 cal mg^{-1} DW, using carbon levels. Applying his conversion factor for E. acutifrons, the organism could have an average energy equivalents of 4.8 ± 0.2 cal mg^{-1} DW, (The same factor, i.e. 0.09 was recommended by Salonen et al., 1976; in case of negligible inorganic carbon).

Differences in the C/N ration reflects differences in the biochemical composition of the organism. Orr (1934) and Marshall et al., (1934) declared that different factors affect C/N ration of the organism. They classified these factors to internal (Like growth rate and reproduction condition) and external (Like geographic area and season). High C/N ration indicate that metabolism was oriented by lipid and/or carbohydrate synthesis rather than protein. This could be supported also by energy equivalent values which agreed with means reported in literature for non-lipidic species, but were far below those recorded for species which are able to store lipids. On the other hand, Calanus finmarchicus have equivalent energy values of 5.232 to 7.672 k cal g^{-1}

DW (Comita and Schindler, 1963; Comita et al., 1966). Moreover, for different stages of Centropages typicus and Temora stylifera high calorofic values were obtained reaching 6 to 7 cal mg^{-1} DW.

In marine studies, Redfield's C:N:P ratio (106:16:1 by atoms) was widely accepted as a reference (Redfield et al., 1963); however, this ratio solely cannot give a complete (elemental) composition. Spoehr and Milner (1949) estimated biomass composition in terms of protein, carbohydrates and lipids from knowledge of the elemental composition and its relation to energy aspects. Yet, no principle obstacle was found to extend their procedure to the zooplankton compartment. One of these difficulties was nitrogen, that cannot solely be allocated to protein. Further differences are: nitrogen-free polysaccharide are normally present as glycogen and a small fraction of carbon may also be incorporated in the cuticle in form of $CaCO_3$ (Spoehr and Milner, 1949).

The annual average C/P ratio of E. acutifrons collected from the coastal waters of Alexandria was 144.0 ± 28.0 (Table 5). In spring, Euterpina was characterized by the highest C/P ratios all over the localities, except that for Agami (102.2), leading to the maximum seasonal average ratio of 185.5 ± 49.2 (Table 5). Such high ratios are attributed to low phosphorus contents (Table 3), during this season which will also affect the N/P ratio during the same period. For Agami, the phosphorus content, during this season jumped to a maximum of 0.55 ± 0.18 % compared to 0.16 - 0.23 % in the other localities. Seasonal averages fluctuated between 124.1 ± 212.6 in winter and 136.7 ± 31.7 in summer. On the other hand, Euterpina of Abu Qir Bay was characterized by higher C/P ratios i.e. 153.7 ± 56.8 and 153.8 ± 51.5 for El-Maadia and El-Tabia, respectively. The absolute value of C/N ratio reached 309 at st. 10 in spring a value which is 3 times more than that mentioned by Redfield et al., (1963). Due to the inadequate data available on the phosphorus content of zooplankton organisms, render it difficult to put the present ratios in comparison with other species.

The N/P ratio of E. acutifrons fluctuated between 10.9 at st. 2 in autumn to 24.3 at st. 1 in summer and st. 4 in autumn, with an annual average of 17.5 ± 1.3 (Table 6). Though variations between different stations in the same area do not clearly appear, the seasonal pattern in each locality seemed to show some variability (table 6).

High N/P average ratio, compared to that of Redfield et al., (1963) were observed during spring in Abu Qir Bay (19.4 - 21.9), autumn in W.H. (20.4), summer (24.3) and Winter (20.2) at Agami area. The aforementioned ratios are higher than those estimated by Redfield et al., (1963). However, in Agami and Mex Bay, averages reach 11.9 and 11.6 in spring and autumn, respectively (Table 6). In the E.H. no statistically significant variation between average N/P ratio was observed. The increase in N/P ratio means an increase in nitrogen over that required for balanced growth while low ratios may suggest that phosphorus is present more than required leading to a decreased ratio in recycled nutrients.

Table (5): Average C/P ratio for E. acutifrons in the different regions of the coastal waters of Alexandria.

Location / Season	AG	MX	WH	EH	AQ (TB)	AQ (MD)	Seasonal average
Summer, 1989	190.7	152.0	130.2	133.4	110.8	103.0	136.7 ± 31.7
Autumn, 1989	145.4	106.3	143.9	97.7	141.2	145.4	130.0 ± 21.9
Winter, 1990	140.5	97.5	96.0	144.0	134.5	132.0	124.1 ± 21.6
Spring, 1990	102.2	186.0	159.5	200.6	228.5	234.6	185.3 + 49.2
Annual average S.D.	144.7 ± 36.2	135.6 ± 41.6	132.4 ± 27.1	143.9 ± 42.7	153.8 ± 51.5	153.7 ± 56.8	144.0 + 28.9

* AG = AGAMI MX = MEX BAY WH = WESTERN HARBOUR
EH = EASTERN HARBOUR AQ (TB) = ABU QIR/EL-TABIA SECTTOR
AQ(MD) = ABU QIR/EL-MAADIA SECTOR.

S.D. = Standard Deviation.

Table (6): Average N/P ratio for E. acutifrons in the different regions of the coastal waters of Alexandria.

Location / Season	AG	MX	WH	EH	AQ (TB)	AQ (MD)	Seasonal average
Summer, 1989	24.3	17.6	16.1	16.7	15.8	15.6	17.7 + 3.3
Autumn, 1989	19.7	11.6	20.4	16.0	17.5	18.0	17.2 + 3.2
Winter, 1990	20.2	14.5	15.5	17.6	18.2	18.0	17.3 + 2.0
Spring, 1990	11.9	17.6	17.2	18.3	19.7	21.9	17.8 + 3.3
Annual average S.D.	19.0 ± 5.2	15.3 ± 2.9	17.3 ± 2.2	17.2 ± 1.0	17.8 ± 2.6	18.4 + 2.6	17.5 + 1.3

* AG = AGAMI MX = MEX BAY WH = WESTERN HARBOUR
EH = EASTERN HARBOUR AQ (TB) = ABU QIR/EL-TABIA SECTTOR
AQ(MD) = ABU QIR/EL-MAADIA SECTOR.

S.D. = Standard Deviation.

In general, the changes of the copepod N/P ratio is mainly due to whether or not nutrients in certain area limits the phytoplankton growth, the main copepod food. In the present study, though N/P ratios in phytoplankton are not available, a statistical significant relationship appeared between N/P ratios in both water and organism ($r = 0.7655$, $P < 0.001$).

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