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SPECIES COMPOSITION AND SEASONAL POPULATION DYNAMICS OF THE BENHIC FAUNA IN KHOR KALABSHA, LAKE NASSER, EGYPT

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ABSTRACT

Seasonal population dynamics of the benthic fauna and nature of sediment at Khor Kalabsha, Lake Nasser, have been investigated between October 1989 and September 1990. The benthic fauna in Khor Kalabsha was rich in density and biomass. They were dominated by aquatic insects followed by gastropod molluscs and oligochaete annelids. The khor sediments are sandy or silty sand at littoral localities (sand content 87.37%), forming sandy silt at the offshores (53.58% silt and 25.92% clay). The average annual density of benthic fauna at the littoral stations amounted to 10,292 organisms/m^2, with 33.9 gm wet wt./ m^2. The offshore stations harboured lower densities of benthic organisms that averaged 908 organisms/m^2, with 4.0 gm wet wt./ m^2. Aquatic insects constituted 85.1% by number (8757 insects/m^2) at the littoral stations. These values declined to 63.0% (average = 574 insects/m^2) at the offshore stations. Benthic fauna attained their maximum persistence in winter while the spring and summer sustained lowest densities. Gastropod molluscs constituted 11.1% by number (1138 organisms/m^2) at the littoral stations. Their occurrence at the offshore stations was very rare and constituted 6.6% by number (60 organisms/m^2). Oligochaetes constituted 3.8% at the littoral stations. At the offshore stations, they formed numerically 30.4% of the total benthos. Spearman Correlation Coefficient revealed negative relationship between the density or biomass of benthic fauna at littoral stations and organic carbon, inorganic phosphorus and total carbonate. In contrast, a positive correlation was recorded for organic phosphorus. At the offshore stations, Spearman Correlation Coefficient indicated

negative relationship between the density of benthic fauna and organic carbon, inorganic phosphorus and total carbonate. In contrast, a positive correlation was documented between the density and organic phosphorus as well as between the biomass and above mentioned physicochemical parameters.

INTRODUCTION

Lake Nasser or High Dam Lake represents the second largest man-made lake in Africa. The morphometry of the lake has been given by Entz (1973, 1974 and 1979) and Latif (1984). The lake extends southwards for about 480 km, of which 300 km lie in Egypt as Lake Nasser, and 180 km in Sudan forming Lake Nubia. An important feature of Lake Nasser is the presence of side extensions, namely the khors. The number of important khors is about 85 and some of these khors attain markedly great surface area, and consequently converted to auxiliary semi-isolated lakes. The surface area of Lake Nasser ranges from 3084 km^2 at 160 m above the mean sea level and 6276 km^2 at 180 m above the mean sea level (Latif, 1984). Entz (1979) demonstrated that some of the khors in Lake Nasser such as Kalabsha, Allaqi and Tushka are wider, shallower than others and have sand or sandy loamy bottom.

Benthic invertebrate populations are important factors in the productivity of lakes (Welch, 1952) and are frequently used to evaluate overall ecosystem health (Flint, 1979; Rosenberg & Resh, 1993; Reynoldson *et al*., 1995) because these communities are important to material cycling and secondary production, and are sensitive to environmental contaminants. Benthic fauna feed mostly upon detritus including sedimentary phytoplankton and zooplankton organisms. The bottom fauna in turn furnishes a direct food supply for some aquatic organisms including fish. Populations of the benthic organisms attain marked fluctuations at both spatial and temporal scales in relation to changes in the physical, chemical factors of water (Cyrus & Wepener, 1993; Dermott & Kerec, 1995; Reynoldson *et al*., 1995; Palmer & Poff, 1997; Vivier & Cyrus, 1999; Breneman *et al*., 2000; Nalepa *et al*., 2000; Bass & Potts, 2001) and/or biotic interactions such as predation and competitive exclusion (Gomez *et al*., 1989; Guimaraes *et al*., 2001).

Several limnological studies have been made of the chemistry of Lake Nasser (for example Nessiem, 1972; Elewa, 1976, 1980, 1985; Mancy, 1978). Other reports have been given of the texture of bottom sediments of the lake (for example Smith and Mancy, 1978; Hassan *et al.*, 1979; El-Dardir, 1984). In contrast, little quantitative estimations have been given of the benthic fauna of the lake. The first survey on the bottom fauna in Lake Nasser was carried out by Entz (1978), who found a gradual change in the components of benthic fauna, particularly molluscs and oligochaetes, with the development of the lake. Iskaros (1988) conducted further studies on the distribution and seasonal variations of benthic fauna in Lake Nasser and adjacent waters in relation to the prevailing environmental conditions. The author identified 38 species belonging to the aquatic insects, molluscs, annelids and platyhelminthes.

Due to the paucity of ecological data available and in view of the increasing industrial, agricultural and urban development in the catchments of Lake Nasser, the need for obtaining basic ecological data was recognized. The present investigation aimed to perform qualitative and quantitative estimation of the benthic community (bottom fauna) in four selected sectors of Khor Kalabsha and to throw light on its seasonal population dynamics and abundance of individual species. The present study aimed also to determine the annual ranges of selected physico-chemical environmental parameters in the sediment of the khor and to correlate between the density (organisms/m^2) and biomass (gm wet wt./m^2) of the benthic organisms and environmental parameters.

MATERIALS AND METHODS

Study area and sampling localities :

Khor Kalabsha is one of the largest khors in Lake Nasser. Four sampling stations or sectors represent the major habitats were selected in the khor. The sampling area and the four studied sectors of the khor were described by El-Tantawy *et al.* (in press). Moreover, water sampling and water analysis (temperature, transparency, oxygen content and pH) at each sector were measured by El-Tantawy *et al.* (in press). At each station macroinvertebrates and sediment samples were collected monthly between October, 1989 and September, 1990.

Sediment analysis:

Twenty four samples were collected at both the littoral and offshore stations using a Ponnar grab and the following parameters were analyzed:

1. **Grain size analysis:**

Determination of the grain size of sediments was carried out according to Krumbein and Pettjohn (1938). About 30 gm of the dried prewashed quartered samples were placed in the topmost sieve and the entire column of sieves was shaken on a mechanical shaker for 20 min. The sieves meshes give the class intervals 4.0, 2.5, 2.0, 1.0, 0.8, 0.5, 0.2, 0.125, 0.09, and 0.06 mm. Some samples were subjected to pipette analysis according to Trask (1932).

2. **Organic carbon and total organic matter:**

The organic carbon was determined according to the method described by El-Wakeel & Riely (1957). About 200 mg of the dry sample were oxidized with 10 ml of chromic acid in a boiling tube (15 x 2.5 cm). The contents were then boiled on a water bath for 15 min and cooled. Subsequently, about 200 ml of distilled water were added to the contents. Titremetric determination of the oxidant consumed was performed against 0.2 N ferrous ammonium sulphate, using ferrous-phenonthroline as an indicator. The percentage of total organic matter was evaluated by multiplying the percentage of organic carbon by 1.8 (see Trask, 1939).

3. **Inorganic and organic phosphorus:**

Determination of inorganic and organic phosphorus from sediments was carried out according to Aspila *et al.* (1976). The inorganic phosphorus was estimated after its extraction from the unignited dry sediments with 1.0 N hydrochloric acid for 16 hrs. then determined colourimetrically using Schimadzu double beam Spectrophotometer UV-150-02.

To determine total phosphorus, the dry sediment samples were ignited at 550°C and digested with nitric acid and perchloric acid. Then, the total phosphorus was estimated colourimetrically using Schimadzu double beam Spectrophotometer UV-150-02. The organic phosphorus was then calculated as the difference between total and inorganic phosphorus.

4. **Total carbonate** :

About 0.4 gm of the dried sediment sample were attacked with 2.0 N hydrochloric acid in a Calcimeter "Dietrich-Fruhling" and the volume of the evolved carbon dioxide was measured. A standard curve was developed using selected weights of standard calcium carbonate. The percentage of the total carbonate in the sediments was then calibrated from the standard curve.

Collection and treatment of bottom fauna :

At each of the four studied sectors in Khor Kalabsha, four dredges were sampled either at the littoral or offshore stations. A Ponnar bottom grab with an opening of 234 cm^2 was used. Collected samples were washed thoroughly in a metalic sieve with mesh size of 0.4 mm. Organisms with smaller size were picked up from the surface water after stirring the sample. The bottom organisms were sorted directly in the field and then preserved in 5% formaline solution. In the laboratory, the number of different species or genera was recorded. The wet weight of bottom organisms was determined. The shells of molluscs were removed gently to estimate the weight of their soft tissues.

For an accurate identification, special treatment was performed to chironomid larvae. The head capsule or entire body was placed in a crucible containing 5-10% KOH solution and heated until the muscle tissue was digested. Cleared specimens were then rinsed in distilled water, transferred to absolute alcohol and mounted on a slide with its ventral side upwards and then mounted in Canada balsam by pressing gently on the coverslip (see Mason, 1973). The stomach content of different fish species was examined searching for benthic fauna preyed by the fish.

The bottom fauna were identified using the following references; for insects (Wirth & Stone, 1968; Smith & Pritchard, 1968; Usinger, 1968; Mason, 1973; Hilsenhoff, 1975; Dumont & Martens, 1984), for Mollusca (Demian, 1959; Brown, 1980; Brown *et al.*, 1984) and for Oligochaeta (Brinkhurst & Jamieson, 1971; Pennak, 1978).

Statistical analysis:

Probability values less than 0.05 were defined as significant. Spearman Correlation Coefficient (SPSS version 6.0) was used to show the nature of the relationship between the density or biomass of benthic organisms and abiotic (physicochemical) factors of the sediments in Khor Kalabsha.

RESULTS

Species composition

The benthic fauna in Khor Kalabsha was rich, diversified and comprised three invertebrate phyla, namely Arthropoda, Mollusca and Annelida. According to their relative abundance, they constituted 85.1%, 11.1% and 3.8% of the total benthos respectively. Phylum Arthropoda was represented by Class Insecta, which comprised the following species: *Procladius* sp., *Clinotanypus* sp., *Coelotanypus* sp., *Conchapelopia* sp., *Ablabesmyia* sp., *Dicrotendipes* sp., *Nilodorum* sp., *Tanytarsus* sp., *Polypedilum* sp., *Cryptochironomus* sp., *Microtendipes* sp., *Chironomus* sp. and *Cricotopuis* sp. (Order: Diptera); *Pseudagrion niloticum*, *Perithemis* sp. and *Libellula sp.* (Order: Odonata); Nymphs of Ephemeroptera (Order: Emphemeroptera); Larvae of Trichoptera (Order: Trichoptera); and Adult forms of Order: Hemipera. Phylum Mollusca was represented by Class Gastropoda, which comprised the following species: *Valvata nilotica* and *Melanoides tuberculata* (Order: Prosobranchia) and *Bulinus truncatus* and *Physa acuta* (Order: Basomatophora). Phylum: Annelida was represented by two classes, namely Oligochaeta and Hirudinea. Class Oligochaeta comprised *Branchiura swerbyi*, *Limnodrilus udekemianus* and *Limnodrilus hoffmeisteri* (Order: Plesipora) whereas Class Hirudinea comprised *Helobdella conifera* (Order: Rhynchobdellidae).

Distribution and seasonal dynamics

The average annual density of benthic fauna at the littoral stations of Khor Kalabsha amounted to 10,292 organisms/m^2, with 33.9 gm wet wt./ m^2. The highest value was recorded at sector IV, which lies nearly in the main Nile Channel of Lake Nasser. The density of benthic organisms decreased gradually towards the inner parts of the khor. On the other hand, the offshore stations harboured lower densities of benthic organisms that averaged 908 organisms/m^2, with 4.0 gm wet wt./ m^2.

Regarding their seasonal dynamics at the littoral stations, benthic fauna attained a slight increase in autumn followed by another one during winter with a peak in February. The standing crop decreased again gradually throughout spring and summer. Regarding their density, aquatic insects were the most dominant among bottom organisms at both the littoral and offshore stations. At the littoral stations, gastropod molluscs came second, followed by annelids (Figs. 1 and 2). On the other hand, at the offshore stations, oligochaetes attained the highest density followed by aquatic insects and gastropod molluscs.

On the other hand, at offshore stations, benthic fauna showed relatively low densities during most of the year, with a tendency of a pronounced increase in late autumn and during winter when the water was vertically homothermal. The lowest densities of benthic fauna at offshore stations were documented in summer. Aquatic insects prevailed throughout winter and spring whereas oligochaetes prevailed in summer and autumn.

The total biomass of the benthic fauna at the littoral stations was nearly proportional to their numerical values during the different months. Thus, their highest biomass recorded in winter, while the lowest was in autumn. On the other hand, the monthly variations of benthic biomass at the offshore localities showed certain deviations concerning their peak which appeared in winter at stations I and II in November, 1989 and March, 1990 at stations IV and III, respectively.

A- Distribution and seasonal dynamics of Aquatic Insecta:

Aquatic insects constituted 85.1% by number (8757 insects/m^2) and 66.4% by weight (22.5 gm wet wt./m^2) at the littoral stations. These values declined to 63.0% and 574 insects/m^2 and 17.5% of the total biomass (0.7 gm wet wt./m^2) at the offshore stations. Their maximum distribution at the littoral stations was recorded at sector IV and decreased gradually towards the inner parts of the khor. At the offshore localities, they remained at comparable lower values within the four sectors. Regarding their seasonal dynamics at the littoral stations, they showed their maximum persistence in winter (January-March), while the spring and summer sustained lowest densities (Figs. 3 and 4). They were less abundant at the offshore stations during most of the year, being more common in winter, while they were missed at most stations during summer (Figs. 3 and 4). Generally, Diptera (Chironomidae) were dominant throughout the different months followed by Ephemeroptera and Odonata nymphs. However, Trichoptera larvae and Hemiptera appeared as rare forms. Their biomass was linearly proportional to their numbers.

1- Distribution and seasonal dynamics of Chironomid larvae:

Chironomid larvae constituted 87.6% by number (average = 7671 larvae/m^2) and 45.3% by weight (10.2 gm wet wt./m^2) of the total aquatic insects at the littoral stations. These values declined to 543 insects/m^2 and 0.7 gm wet wt./m^2 at the offshore stations. The maximum distribution of chironomid larvae appeared at the littoral zone of sector IV, while the lowest was recorded at the offshore of sector II.

Concerning their monthly variations, the numbers of chironomid larvae recorded at the littoral stations showed a rapid increase in winter (January and February), followed by a sharp drop throughout March and April and they remained rare in summer at most stations. On the other hand, at the offshore localities, their maximum density was also recorded in winter and early spring. Moreover, their biomass was generally proportional to their numbers during the different months.

Pupae of Chironomidae were very rare in Khor Kalabsha, constituting only 2.3% of the total number of aquatic insects at the littoral stations (average 201 pupae/m^2) with an average biomass of 0.4 gm wet wt./m^2. At the offshore localities, their average numbers and biomass amounted to 14 pupae/m^2 and 0.1 gm wet wt./m^2. With respect to their monthly variations, the pupae were present in parallel frequency with the abundance of their larvae.

Dicrotendipes sp. represented the most important chironomid larvae at the littoral stations and it formed about 39.9% of their total numbers (average = 3059 larvae/m^2) while it was missed from the offshore localities. The maximum distribution of *Dicrotendipes* sp. was recorded at sectors III and IV, while the lowest value was recorded at sector I. The winter was the most productive season for the species at most stations, otherwise it remained rare throughout most of the year.

Procladius sp. constituted about 29.3% of the total chironomid larvae (average = 2251 larvae/m^2) at the littoral stations. On the other hand, at the offshore stations, although the number of the species remained relatively low, yet it represented the most dominant chironomid larvae and formed 96.5% (average = 524 larvae/m^2) of their total numbers. The maximum distribution of *Procldius* sp. was recorded at the littoral station of sector II while the lowest value was recorded at the offshore of the same sector. The species attained its maximum density during winter (February and March). however it remained infrequent or rare in the other seasons.

Nilodorum sp. represented 15.3% of the total chironomid larvae (average = 1172 larvae/m^2) at the littoral stations while it was very rare at the offshore localities (average = 10 larvae/m^2). The maximum distribution of *Nilodorum* sp. was recorded at the littorals of sector IV and decreased gradually towards the inner parts of the khor. The species was more abundant during autumn and early winter, while it remained very rare in spring and early summer. On the other hand, at the offshore localities, *Nilodorum* sp. was scarcely recorded in winter and totally disappeared in the other months.

Tanytarsus sp. formed 10.9% of the total chironomid larvae (average = 835 larvae/m^2) at the littoral stations. The species was not encountered at the offshore localities. The maximum distribution of *Tanytarsus* sp. was recorded at the littorals of sectors I and IV. The species was rather common during the period October-November, however, it persisted as a rare form in the other months.

Other members belonging to Order Diptera such as *Clinotanypus* sp., *Coelotanypus* sp., *Conchapelopia* sp., *Ablabesmyia* sp., *Polypedilum* sp., *Cryptochironomus* sp., *Microtendipes* sp., *Chironomus* sp. and *Cricotopuis* sp. were infrequent or rare and showed irregular pattern in their population dynamics. These insects constituted small fraction of the total chironomid larvae in the khor.

2- Distribution and Seasonal dynamics of Ephemeroptera Nymphs:

The distribution of nymphs of Ephemeroptera were confined to the littoral stations where they constituted 6.8% by number of the total aquatic insects (average = 594 nymphs/m^2) and 6.7% by weight (average = 1.56 gm wet wt./m^2). Their annual averages fluctuated within a narrow range between 795 nymphs/m^2 and 1.8 gm wet wt./m^2) at sector III and 437 nymphs/m^2 and 1.7 gm wet wt./m^2) at sector II.

Concerning their monthly variations, Ephemeroptera nymphs appeared more frequent in late autumn and/or early winter as well as in early summer. Their average monthly biomass were linearly proportional to their numbers except in January at sectors III and IV and in May and June at sector III when the increased numbers of the nymphs coincided with lower biomass, indicating the presence of a new small sized generation.

3- Distribution and Seasonal dynamics of Odonata Nymphs:

The distribution of nymphs of Ephemeroptera was confined to the littoral stations. Although their average annual numbers amounted to 229 nymphs/m^2 of the total insects, yet their biomass increased to 44.4% of their total weights (average = 10.0 gm wet wt./m^2). This is attributed to the big size of anisoptera nymphs. They showed wide distribution in the outer parts (III and IV) of the khor than in inner ones (I and II).

Concerning their monthly variations, nymphs of zygoptera were encountered throughout most of the year showing higher values in winter, in late spring and during summer. Their biomass was in general proportional to their numbers. The major occurrence of nymphs of anisoptera was in May at sectors I, II and III and during March at sector IV, while autumn and summer were the least productive seasons.

4- Distribution and Seasonal dynamics of Trichoptera larvae:

Larvae of the order Trichoptera were very rare in the khor. Their average annual numbers at the littoral stations amounted to 37 larvae/m^2 and 0.1 gm wet wt./m^2. These values further decreased to 1 larvae/m^2 and 0.04 gm wet wt./m^2 at the offshores. They showed a maximum persistence at the littoral station of sector II. Otherwise, they remained rare in the outer sectors with annual averages fluctuating between 30 larvae/m^2 with 0.05 gm wet wt./m^2 (littoral of sector II) and 7 larvae/m^2 with 0.02 gm wet wt./m^2 (offshore of sector III).

Regarding their monthly variations, larvae of Trichoptera appeared mostly between October, 1989 and January, 1990. They remained very rare or completely absent in the other months. The highest value of 516 larvae/m^2 was recorded at the littoral of sector II in November.

5- Distribution and Seasonal dynamics of adult corixid Hemiptera:

These insects were scarcely observed at the littoral stations and appeared during most of the year except in October, 1989 and January, 1990. Their maximum persistence was recorded in April, which harboured an average of 81 insects/m^2. Their annual average density amounted to 24 insects/m^2 with 0.3 gm wet wt./m^2.

B- Distribution and Seasonal dynamics of gastropod molluscs:

Gastropod molluscs constituted 11.1% by number (1138 organisms/m^2) and 20.6% by weight (average = 7.0 gm wet wt./m^2) at the littoral stations. Their maximum distribution appeared at sector III, while the lowest was at sector I. Their occurrence at the offshore stations was very rare attaining annual averages of 60 organisms/m^2 and 0.3 gm wet wt./m^2.

Regarding their monthly variations at the littoral stations, their numbers increased rapidly in winter and spring at most stations, reaching their peaks in May and/or June (Figs. 5 and 6). Another peak was recorded at sector III during August (Figs. 5 and 6). On the other hand, at the offshore stations, they remained infrequent in winter and spring and very rare or completely absent during autumn and summer (Figs. 5 and 6).

1- Distribution and seasonal dynamics of *Physa acuta*:

This species belongs to Family Physidae and represented the most important gastropod inhabiting the khor. It constituted 49.4% by number (average = 523 organisms/m^2) and 37.1% by weight (2.9 gm wet wt./m^2) of the total molluscs at the littoral stations. The species was missed at the offshore stations. The maximum persistence was attained at station III (average = 855 organisms/m^2), decreasing to a lowest value at station I (average = 412 organisms/m^2).

2- Distribution and seasonal dynamics of *Valvata nilotica*:

The gastropod *Valvata nilotica* belongs to Family Valvatidae and represented 25.6% by number (average = 291 organisms/m^2) and 8.6% by weight (average = 0.6 gm wet wt./m^2) of the total molluscs at the littoral stations. Its maximum distribution was at the littoral zone of sector III with an annual average density of 982 gastropods/m^2 while it was less abundant in the other sectors. The species was the only gastropod inhabiting the offshore stations with average values fluctuating between 50 and 81 gastropods/m^2 and an annual average of 60 gastropods/m^2 and 0.3 gm wet wt./m^2.

Valvata nilotica appeared at the littoral stations during spring and summer, showing maximum density in June and August and it mostly disappeared throughout autumn and winter. At the offshores, its main occurrence was in winter and spring and it remained very rare in autumn and summer.

3- Distribution and seasonal dynamics of *Bulinus truncatus*:

The gastropod *Bulinus truncaus* belongs to Family Planorbidae and was confined to the littoral stations, where it constituted 21.3% by number (average = 242 gastropods/m^2) and 48.6% by weight (average = 3.4 gm wet wt./m^2) of the total molluscs. The species remained more or less equally distributed within the different sectors. Its maximum density appeared in winter and spring, however it was less abundant in autumn and summer.

4- Distribution and seasonal dynamics of *Melanoides tuberculata*:

The gastropod *Melanoides tuberculata* belongs to Family Theiaridae (Melaniidae) and was infrequently recorded at the littoral stations of Khor Kalabsha. The species showed an annual average count of 43 gastropods/m^2 with 0.4 gm wet wt./m^2. This gastropod appeared during the period June-September at all sectors with maximum density in August.

C- Distribution and seasonal dynamics of oligochaetes:

Oligochaetes represented the third most important component among the benthic community at the littoral stations of Khor Kalabsha. They constituted 3.8% by number (average = 396 organisms/m^2) and 13.0% by weight (average = 4.4 gm wet wt./m^2) at the littoral stations. On the other hand, they ranked the second important constituent at the offshore stations where they formed numerically 30.4% (average = 276 organisms/m^2) and 75.0% of the biomass (average = 3.0 gm wet wt./m^2) of the total benthos. Their maximum distribution was recorded at both the littoral and offshore stations of sector IV, while the lowest density appeared at sector III.

Regarding their monthly variations, their distribution at the littoral stations was confined to the period May-September. However, they were missed during autumn and winter except of scattered specimens observed in October (Figs. 7 and 8). The highest value of 4042 organisms/m^2 was observed in June at sector IV and it consisted mainly of *Branchuira sowerbyi*. On the other hand, at the offshore stations, they were abundant throughout most of the year (Figs. 7 and 8), showing highest density in November at station IV, during the period March-April at most stations as well as in August at stations I and II.

1- Distribution and seasonal dynamics of *Branchiura sowerbyi*:

This species belongs to Family Tubificidae and represented the most important oligochaete inhabiting the khor. It constituted 93.9% (average = 372 organisms/m^2) and 59.8% (165 organisms/m^2) of the total number of oligochates at the littoral and offshore stations respectively.

At the littoral stations, the species appeared more abundant during the period from May to August with a peak in June. The species persisted as a rare form in early autumn and spring and totally disappeared between November and March. At the offshore stations, *B. sowerbyi* was encountered during most of the year, showing higher values in November and during the period March-April, however it persisted as a rare form in the other months. The highest counts of 1561 and 4042 organisms/m^2 were recorded at the offshore of sector IV in November and the littoral of the same sector in June respectively.

2- Distribution and seasonal dynamics of *Limnodrilus* spp.:

The genus *Limnodrilus* was represented by two species, namely *L. hoffmeisteri* and *L. undekemianus*. The former species was rarely encountered at the littoral stations, where it appeared only in July at sectors II and III and in September at sector IV. At the offshore stations, it ranked to the second in importance, constituting about 36.6% (average = 101 organisms/m^2 of the total oligochaetes, being more abundant during the period March-May and in August at the offshores.

The species *L. undekemianus* remained very rare at both the littoral and offshore stations (average = 19 and 10 organisms/m^2 respectively). The distribution of *L. undekemianus* was mostly confined to summer and early autumn.

D- Distribution and seasonal dynamics of Hirudinea:

This invertebrate taxon was scarcely represented by the species *Helobdella conifera*, which belongs to the Family Glossiphoniidae. The species appeared once at the littoral station of sector III in May with 43 organisms/m^2.

Some characteristics of bottom sediments

1. **Grain size analysis:**

The nature of bottom sediments in the four sectors ranges from medium sand to sandy silt. These sediments are generally characterized by homogeneous grain size distribution.

2. **Carbon and Phosphorus content** :

The average values of organic carbon, organic phosphorus, inorganic phosphorus and total carbonate are generally higher in the sediments of the offshore stations than those of littorals. The highest average concentration of organic carbon (3.08%), organic phosphorus (153.64 ppm), inorganic phosphorus (317.81 ppm) and total carbonate (26.87%) were recorded at the offshore sediments in autumn, which reflects their gradual accumulation during spring and summer. In contrast, the winter sustained the lowest values coinciding with winter convection. The reverse occurred at the littoral stations, where the maximum average concentration of these elements was recorded in autumn (organic carbon 0.56%, inorganic phosphorus 15.74 ppm and total carbonate 0.83%) except for organic phosphorus, which attained its lowest value of 73.42 ppm in summer.

Correlation analysis

Spearman Correlation Coefficient revealed a negative relationship between the density or biomass of benthic fauna at littoral stations and organic carbon, inorganic phosphorus and total carbonate. Statistically, the relationship was significant between the biomass of benthic organisms and organic carbon ($r^2 = -0.6040$, $P = 0.037$), inorganic phosphorus ($r^2 = -0.6040$, $P = 0.037$) or total carbonate ($r^2 = -0.6040$, $P = 0.037$). In contrast, a positive significant correlation was recorded between the biomass and organic phosphorus ($r^2 = -0.57$, $P = 0.05$). On the other hand, at the offshore stations, Spearman Correlation Coefficient indicated a negative non significant relationship between the density of benthic fauna and organic carbon, inorganic phosphorus and total carbonate. In contrast, a positive non-significant correlation was documented between the density of benthic fauna and organic phosphorus as well as between the biomass of benthic fauna and each of the above mentioned physico-chemical parameters ($P > 0.05$ in all cases).

DISCUSSION

The present study revealed that Khor Kalabsha is rich in species, density and biomass of benthic fauna. Aquatic insects were the most dominant group followed by gastropod molluscs and oligochaete annelids. The annual average of the density and biomass of total bottom fauna at the littoral stations amounted to 10292 organisms/m^2 and 33.9 gm wet wt./m^2 respectively. On the other hand, at the offshore stations, these values decreased to 908 organisms/m^2 and 4.0 gm wet wt./m^2. Benthic fauna showed their maximum peaks during autumn and winter, however they attained their lowest values during summer at both littoral and offshore stations. Chironomid larvae dominated insect fauna. Molluscs were represented mainly by *Physa acuta* followed by *Valvata nilotica* and *Bulinus truncatus*. Oligochaetes were dominated by *Branchiura sowerbyi*.

Benthic organisms are important keys in the primary production of natural lakes. Officer *et al.* (1982) and Stanczykowska and Lewandowski (1993) reported that benthic filtering bivalves can sequester much of the pelagic primary production, thereby altering the balance between pelagic and benthic food webs. Johannsson *et al.* (2000) suggested that conditions that favour bivalve dominance include a high proportion of suitable substrate, lack of stratification of the overlying water, and good water flow. The authors compared the benthic and pelagic secondary production in Lake Erie between 1979 and 1993 and demonstrated that the benthic biomass increased greatly between the two study periods because of the invasion of lake by *Dreissena* species (Mollusca: Bivalvia). They also reported that Dreissenids affect zooplankton production by reducing algal biomass and primary production by decreasing rotifer abundance, and hence biomass, and production of veligers which contribute to 10-25% of the zooplankton production.

Chironomid larvae flourished well in winter, however they were rare in summer at littoral stations. Similarly, at offshore localities, chironomid larvae attained their maximum density in winter and early spring. A similar winter peak was previously recorded for chironomid larvae in the Blue Nile (Lewis, 1957). White Nile (Monakov, 1969) as well as in the Delta Lakes of Egypt (Samaan, 1977; Aboul-Ezz, 1984; Gharib, 1991). The time required for the growth and maturation of the chironomid larvae varies according to several environmental parameters such as water temperature. The latter is regarded as one of the most important determinants that regulate the growth and population dynamics of aquatic organisms. Increasing of water temperature during spring and summer in Khor Kalabsha appears to accelerate the rate of development of chironomid larvae by increasing their metabolic activities (Konstantinov, 1958; Sweeney *et al*., 1986). Konstantinov (1958) suggested that elevation in water temperature leads to rapid metamorphosis from larval to pupal stage that in turn produces adult forms within a short duration. In contrast, the decrease in water temperature during cold seasons of the year (autumn and winter) may inhibit or reduce the rate of development of chironomid larvae by decreasing their metabolic activities.

Different instars of the chironomid larvae for the common species *Dicrotendipes*, *Procladius*, *Nilodorum*, *Tanytarsus*, *Microtendipes* and *Cryptochironomus* and their pupae were encountered throughout the year round. Moreover, massive emergence of adult stages was observed in Khor Kalabsha particularly in the areas covered with aquatic vegetation, mainly at the dusk. The presence of pupae and adult stages, which lasts for a few hours in their duration indicates that chironomids are breeding all over the year. Wirth & Stone (1968) concluded that the life history of Chironomidae may vary considerably according to their geographical distribution. Some species that breed in warm water may have a number of generations a year, whereas the same species may require a year for emergence when breeding in a cold lake. In Lake Victoria, *Procladius* sp. produces one generation per two months (McDonald, 1956), while the maturation of *Chironomus* sp. in Amazon waters is completed within10-12 days at 30°C and a considerable number of generations may be produced within one year (Syrjamaki, 1965). In contrast, the life cycle of chironomids in arctic waters may continue for one year or more (see Oliver, 1968).

Pringle & Msangi (1961) pointed out that the large population of *Bulinus* sp. and *Melanoides tuberculata* in the pond reflects the excess food supply, including decaying and living algae. Similarly, the highest population density of gastropod mollusca in Khor Kalabsha could be attributed to the highest phytoplankton production during spring and summer seasons. Moreover, the growth and reproduction of molluscs are apparently related to both the available food supply including decaying algae (Pringle & Msangi, 1961) and water temperature (Brown, 1980). The number of molluscs inhabiting the littoral stations in Khor Kalabsha increased gradually throughout winter and spring, reaching their maximum peak in May and/or June, corresponding to an elevation in water temperature. The present findings agree with those of Dazo *et al.* (1966) and Demian & Kamel (1972) who demonstrated that gastropod molluscs attain their maximum peak in late winter and spring, however they showed a sharp decline in their fecundity when the water temperature exceed 27.5°C.

Brown (1980) attributed the marked decline in the fecundity of pulmonate snails in summer to the high mortality as a result of low oxygen content. In the present investigation, the gastropod *Valvata nilotica* appeared at the littoral stations during spring and summer, showing a maximum persistence in June and August and disappearing mostly throughout autumn and winter. On the other hand, at the offshore stations, the species mainly occurred in winter and spring and becoming rare in summer and autumn. This indicates a downward migration of the species during the cold season, however the development of thermocline during summer appears to obligate *V. nilotica* to conduct an upward migration in the well-oxygenated water layer. The prosobranch *Melanoides tuberculata* appeared at the littoral stations during the period June-September with a maximum density in August. This pattern of occurrence coincides with the records of Samaan & Aleem (1972) in Lake Mariut and Iskaros (1988) in Lake Nasser.

The prevalence of oligochaetes at the littoral stations was confined to the period May-September while they were missed in autumn and winter except for some specimens encountered in October. On the other hand, at offshore localities, the oligochaetes were more abundant throughout most of the year, indicating that the variation of water temperature is not a determining factor for their seasonal distribution (El-Duweini & Ghabbour, 1963). Other abiotic and/or biotic factors may have a controlling effect on the distribution of oligochaetes. Pennak (1963) suggested that although temperature is not usually a limiting factor, it often determines the relative abundance of oligochaetes. Vivier & Cyrus (1999) found that oxygen content and water temperature are the most important abiotic variables determining benthic distribution. According to Ghabbour (1966), oligochaetes were ingested by the majority of wetwater benthophagic fishes.

Benthic organisms in Khor Kalabsha are considered as important food items for a variety of fish species. The chironomid larvae such as *Dicrotendipes* sp., *Procladius* sp. and *Nilodorum* sp. form the major food items for *Mormyrus kannume*, *M. caschive* and *Chrysichthys auratus* throughout different seasons. Moreover, *Synodontis shall* and *S. serratus* feed mainly on the gastropods *Bulinus truncatus* and *Physa acuta*. Latif (1974) observed that most Mormyridae feed mainly on insect larvae, while Synodontidae are adapted to consume molluscs. The author showed that *Hydrocynus forskalii* subsists mainly on insect larvae during winter. Similarly, Greenwood (1974) reported that 12 cichlid fishes are predominantly molluscivorous.

Sediment type and sediment organic content are known to have a pronounced effect on the spatial distribution of benthic organisms (Nicholas, 1970; Wu & Richards, 1981; Cyrus & Martin, 1988; Vivier & Cyrus, 1999). Boltt & Allanson (1975) and Cyrus & Martin (1988) found that more benthic animals occur in sandy sediment than in mud. Vivier & Cyrus (1999) reported that in Lake Nhlabane higher benthic densities were recorded in mud than in fine sand due to the high organic content of mud. The authors suggested that the amphipod *Grandidierella lignorum* is less adaptable to different sediment types, being more reliant on sandy substrata, while the amphipod *Corophium triaenonyx* is able to exploit a greater variety of habitats. *G. lignorum* is a benthic burrower where it constructs tubes of fine sand or silt particles on the surface objects on the substratum (Cyrus & Martin, 1988).

Khor Kalabsha sediments are sandy or silty sand at the littoral stations (sand constitutes 87.37% of sediment), forming sandy silt at the offshore localities (53.58% silt and 25.92% clay). The average values of organic carbon, organic phosphorus and inorganic phosphorus were generally higher in the offshore sediments than in littoral ones. The organic carbon in the surface sediments scaled between 0.56% at the littoral stations and 3.08% at the offshore localities during autumn. The organic phosphorus ranged between 73.92 ppm at the littoral stations during summer and 153.64 ppm at the offshore localities in autumn. The inorganic phosphorus fluctuated between 15.74 ppm at the littoral stations in winter and 317.8 ppm at the offshore stations during autumn.

Most oligochaetes probably derive the bulk of their nutritional requirements from micro-organisms grazed off plants or more commonly, ingested along with allochthonous and autochthonous organic matter in sediments (Brinkhurst & Jamieson, 1971). A linear correlation between the abundance of oligochaetes and organic carbon was recorded. Therefore, the increase of sediment organic carbon at the littoral stations during spring and summer and at the offshore localities during autumn and spring was generally concomitant with a parallel increase in the numbers of oligochaetes. Brinkhurst & Jamieson (1971) hypothesized that the total available organic matter may determine the abundance of oligochaetes, however other significant biotic factors may have a controlling effect on their distribution, particularly the predator-prey interactions. The phenomenon of predation may explain the lack of oligochaetes during autumn and winter when a high density of chironomid larvae was predominant. The predation of chironomid larvae on oligochaetes was emphasized by Loden (1974) who encountered setae of five oligochaete species in the gut content of 13 species belonging to the Chironominae and Tanypodinae.

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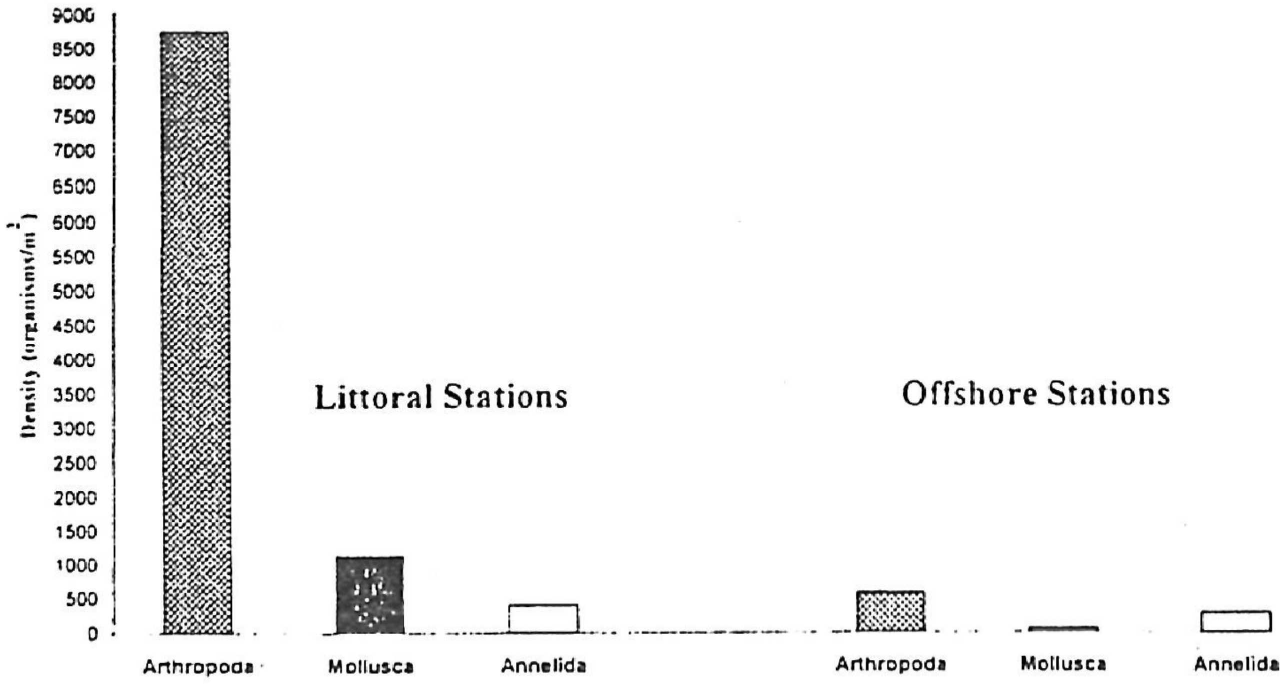

Figure 1. Total average annual density (organisms/m^2) of the benthic fauna at Khor Kalabsha during the period October 1989-September 1990.

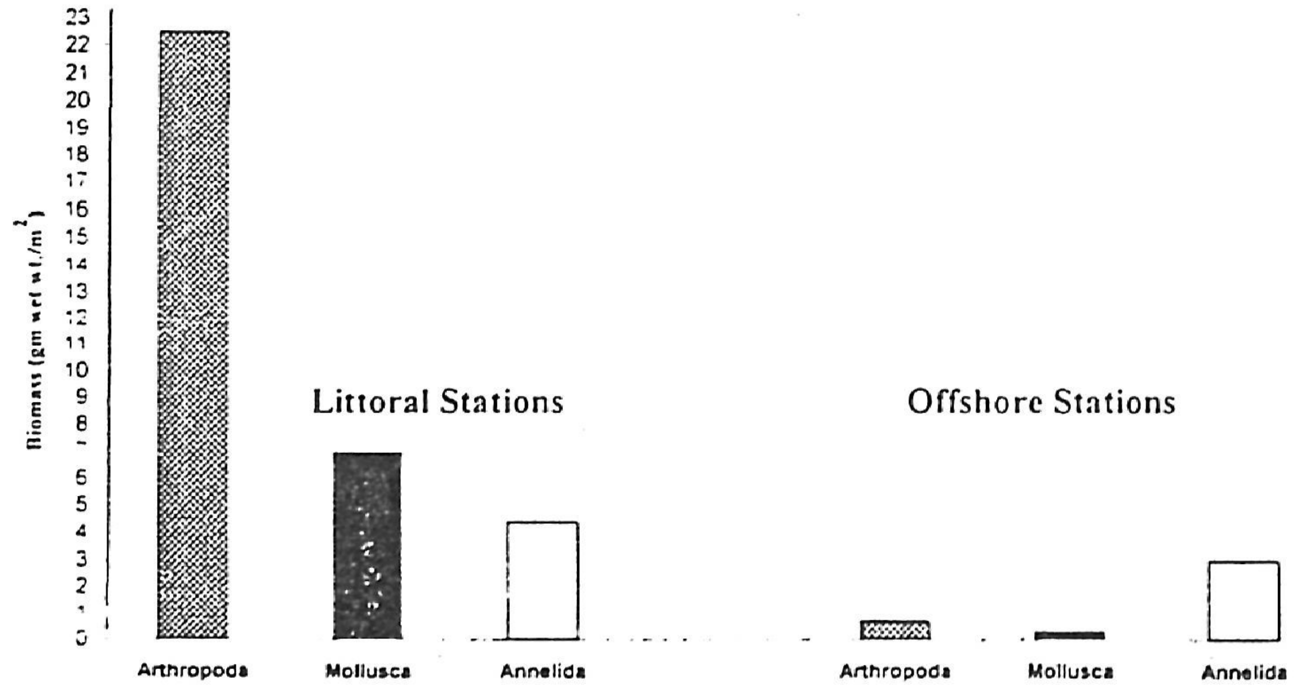

Figure 2. Total average annual biomass (gm wet wt./m^2) of the benthic fauna at Khor Kalabsha during the period October 1989-September 1990.

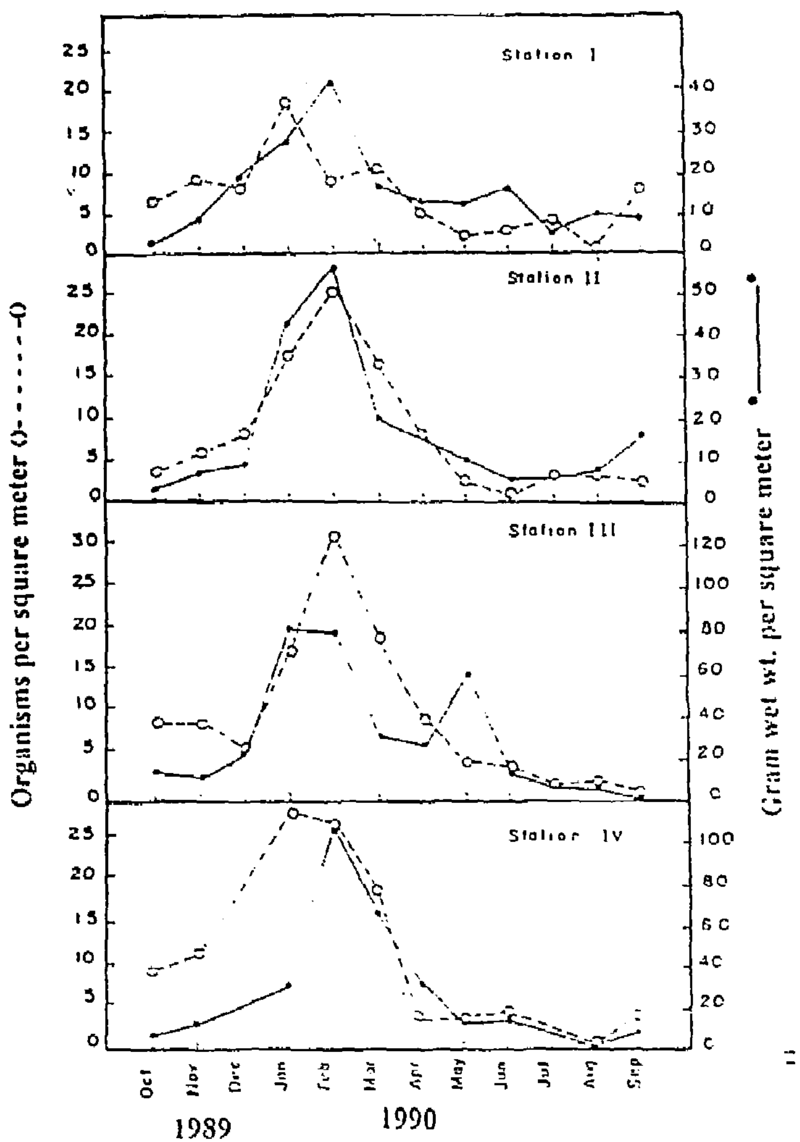

Fig. 3. Monthly variation of the density (organism/m^2) and biomass (gm wet wt/m^2) of aquatic insects at the littoral stations of Khor Kalabsha during the period Oct[illegible]

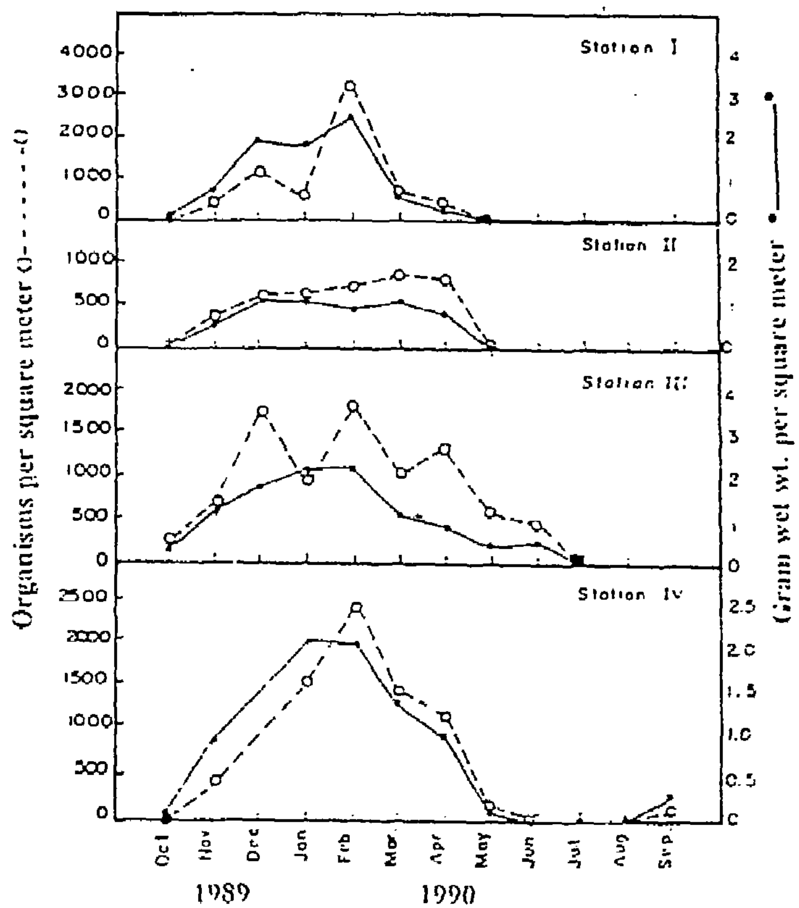

Fig. 4. Monthly variation of the density (organism/m^2) and biomass (gm wet wt./m^2) of aquatic insects at the offshore stations of Khor Kalabsha during the period October 1989-September 1990

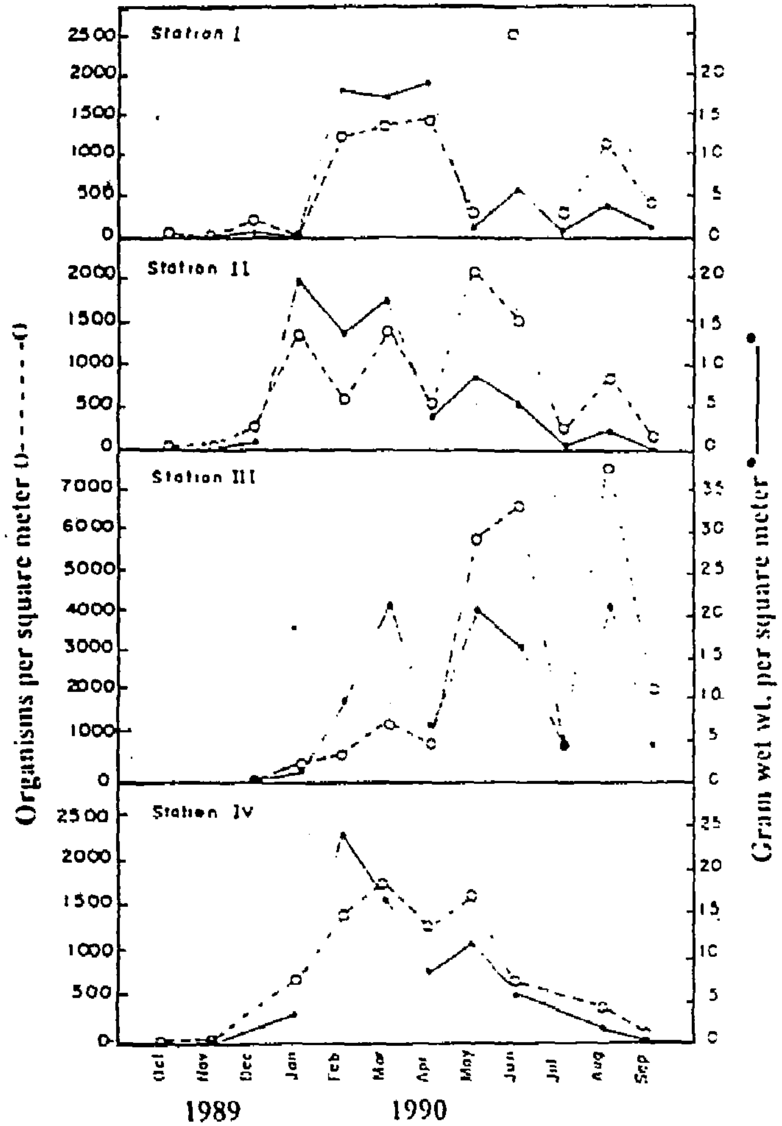

Fig. 5. Monthly variation of the density (organism/m^2) and biomass (gm wet wt./m^2) of gastropod molluscs at the littoral stations of Khor Kalabsha during the [illegible]

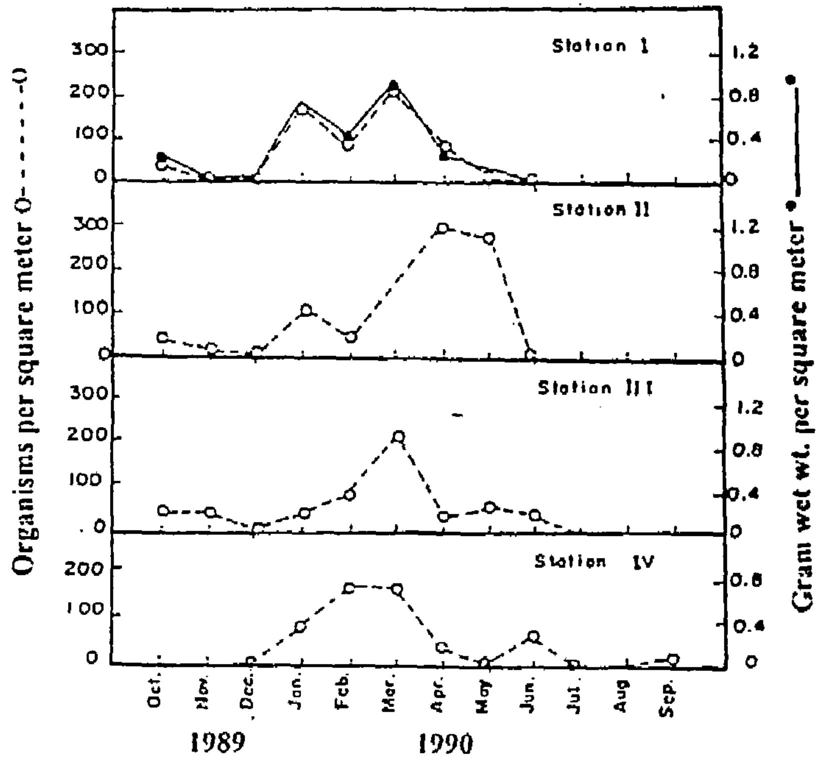

Fig. 6. Monthly variation of the density (organism/m^2) and biomass (gm wet wt./m^2) of gastropod molluscs at the offshore stations of Khor Kalabsha during the period October 1989-September 1990.

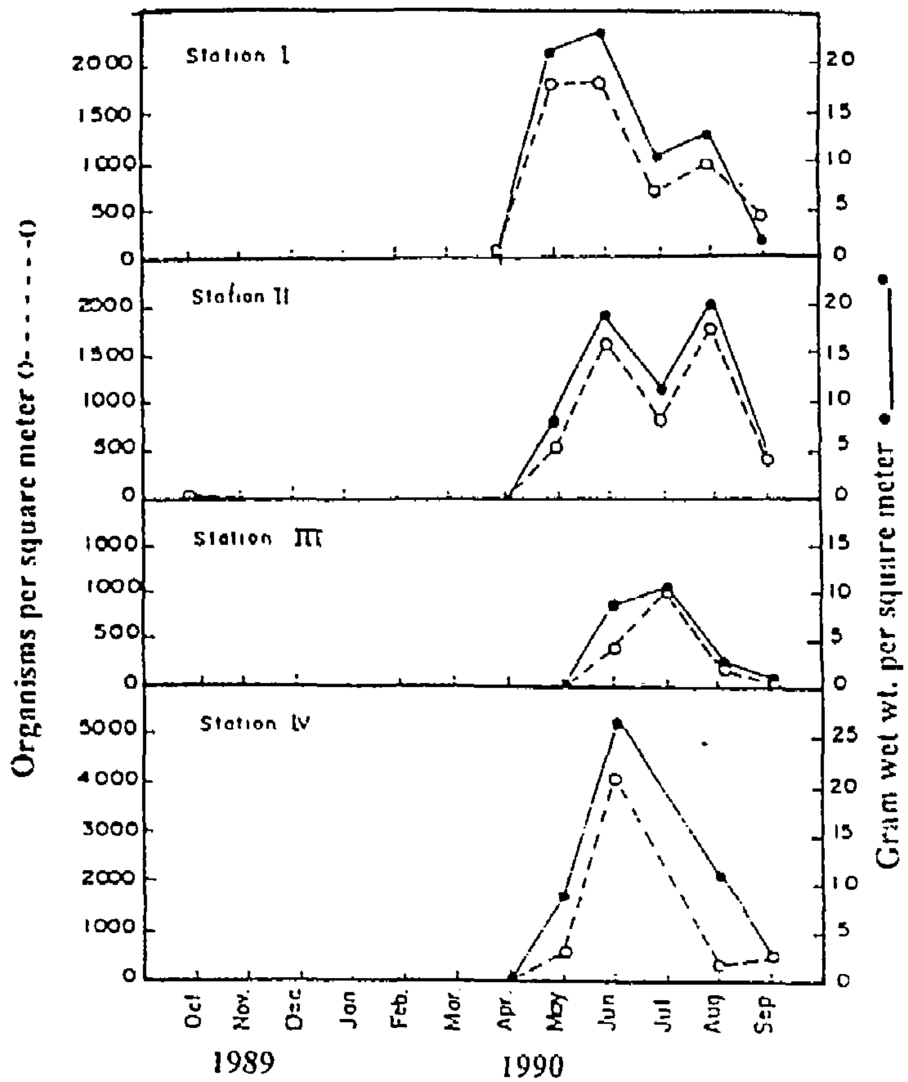

Fig. 7. Monthly variation of the density (organism/m^2) and biomass (gm wet wt./m^2) of oligochaete annelids at the littoral stations of Khor Kalabsha during the period October 1989-September 1990.

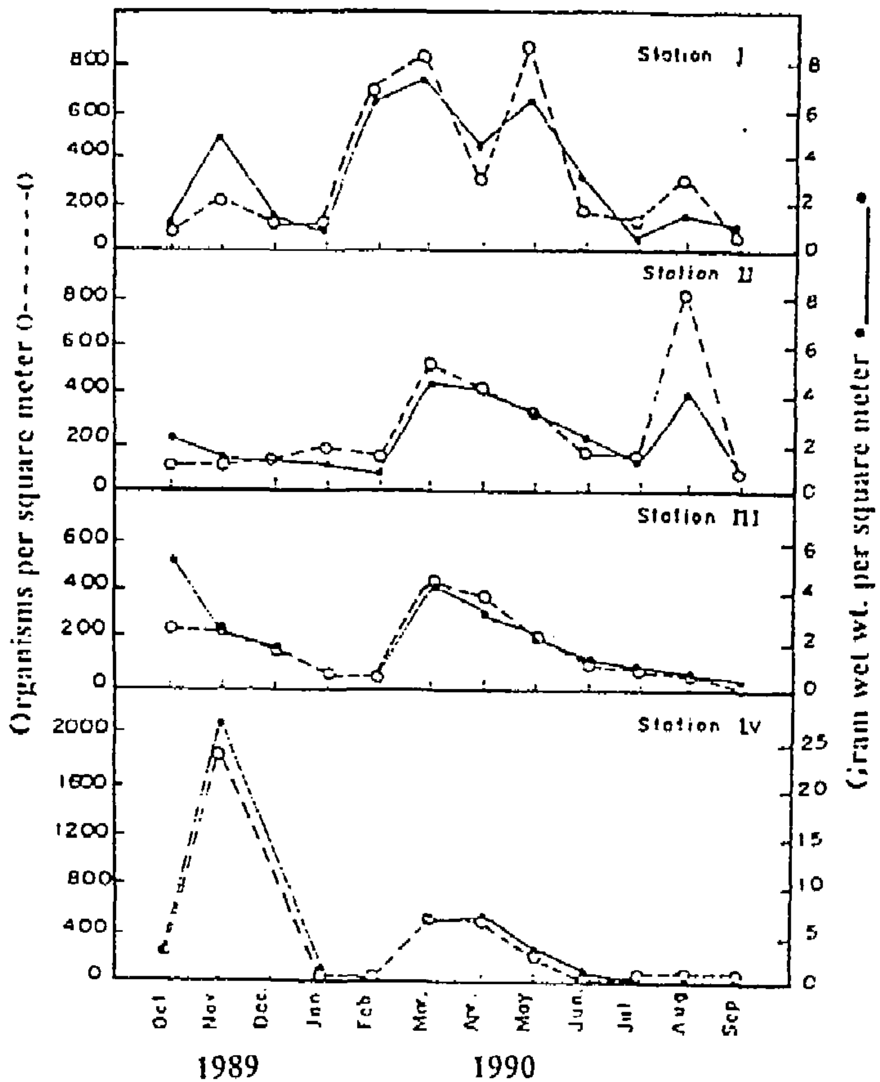

Fig. 8. Monthly variation of the density (organism/m^2) and biomass (gm wet wt./m^2) of oligochaete annelids at the offshore stations of Khor Kalabsha during the period October 1989-September 1990.