

VERTICAL MIGRATION OF ZOOPLANKTON GROUPS IN AN EUTROPHIC BAY, DEKHAILA HARBOR, ALEXANDRIA, EGYPT

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ABSTRACT

Diel vertical migration of different zooplankton groups in Dekhaila Harbor was studied monthly from May 2003 to April 2004. Generally, more groups were found in the surface layer (0-10 m.) than the deeper one (10-20 m.). Some zooplankton groups undergo significant vertical migration at certain time of the year, others showed no clear differences in distribution patterns and exhibited no directed movement patterns. Some species stayed a part of the day within certain layer of the water column, others were randomly dispersed in the whole water column during different hours. Responses appear to depend also on the life stages of each zooplankton group, as well as other ecological conditions such as temperature, light and amount of food. Population budget indicates that the abundance of some groups was greater at the morning time, others at the sunset time. While the noon time often showed lower density. The time of the day which showed the lowest count of each group is known as the day deficit, which is probably due to diel horizontal migrations.

1. INTRODUCTION

The diel vertical migrational (V.M.) behavior of zooplankton, is closely related to the adaptive strategies of organisms and to the degree of competition for food resources between species. V.M. has been of interest to both oceanographers and limnologists from essentially the inception of each discipline. Numerous explanations for this behavior have been proposed (Hutchinson, 1967). Metabolic constrains (Orcutt and Porter, 1983) and food availability (Dini and Carpenter, 1992) may affect V.M. in some cases. Predator avoidance is another factor causing zooplankton to vertically migrate on diel basis to seek less risky habitats (Ohman, 1990; Neill, 1990 Bollens and Frost, 1991). Some major adaptations include changes in size (Black and Hairston, 1988), shape (De

Stasio *et al.*, 1990), life history patterns and demographics (Ohman, 1990), and swimming behavior (Ramcharan and Sprules, 1991). Fewer animals are found in the water surface during the day than during the night (Bollens and Frost, 1989). In the Egyptian Mediterranean waters, no studies have been so far conducted on zooplankton Vertical migration.

The present paper includes results of a study on the diurnal V.M. of different marine zooplankton components for a year cycle in El Dekhaila Harbor, on Alexandria sea coast.

2. MATERIAL AND METHODS

Monthly zooplankton samples, from May 2003 to April 2004 were collected vertically from two depth ranges (0-10 and 10-20 m) every two hours during the day time at fixed

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station in Dekhaila Harbor (Fig.1). The samples were taken with a plankton net of 55 μm mesh size and 0.23 m^2 mouth surface area and were fixed in 5% formaldehyde. Densities expressed as organisms/ m^3 were calculated from the average count of three

aliquots of 5 ml each. The species identification was done following Rose (1933), Tregouboff and Rose (1957), Edmondson (1959), Hutchinson (1967), Dussart (1969), Marshall (1969), Bradford (1972) and Malt (1983).

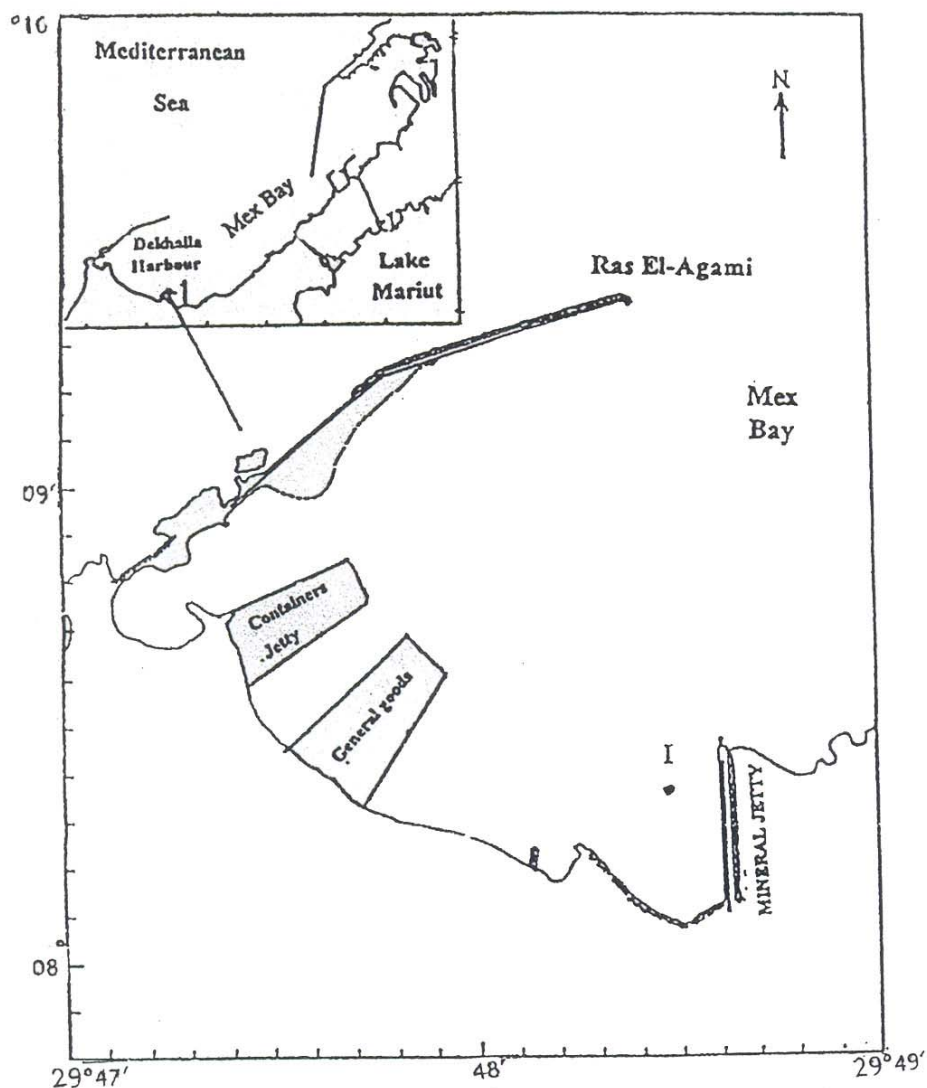


Fig. 1. Location of sample collection in Dekhaila Harbour

3. RESULTS

In order to understand the V.M. of zooplankton in the study area, the distribution of each group along the water column was considered monthly every two hours, during the different day times from sunrise to sunset all the year round. The results indicated different models of behaviors for the different zooplankton groups.

Copepoda

The vertical distribution of copepodite stages (Fig.2a) showed different patterns at the two depths. At the upper layer (0-10m.) the highest densities were at morning (9 AM) and at afternoon (3-8 PM) during the period of May-July. From August to December, more animals were found either at the morning (9 AM) or afternoon (3-5 PM), while from January to April, the population densities were greatest during afternoon morning time (3-8 PM). On the other hand noon time (1 PM) was considered as the day deficit most of the year. At the deeper layer (10-20 m), densities were greatest at (5 PM) during the period from May to July, but within the period from August–December, more animals were found mostly at the morning (9 AM), and from January to April, higher numbers of organisms were observed afternoon (5 or 8 PM). On the other hand, the day deficit was recorded mostly at the morning (11 AM) or at noon (1 PM) all the year.

As shown in figure 2b, nauplii larvae attained their lowest density in the upper layer (0-10 m) at noon (1 PM) except in May and January, while the maximum density was observed at the morning, from June to August, and afternoon from September to November and they showed different timing of peaks, at morning (9-11 AM) or evening

(5-8 PM), during February and March. At the deeper layer (10-20 m.), greater density of nauplii larvae was observed afternoon (1-3 PM) or (3-5 PM) during summer and autumn respectively, and at noon or before sunset during winter, while in spring its highest density appeared at 11 AM or 5 PM. These patterns reflect different seasonal behaviors of dominant copepods towards the vertical migration.

The dominant copepod species

Oithona nana

During most of the year, *Oithona nana* was found to prefer the upper layer (0-10 m) where it sustained the greatest density during most of day times (Fig. 3). However, its standing crop demonstrated wide variations during the day hours particularly in summer months, as the greatest density was recorded at morning and sunset hours, while during most of winter and spring months, the greatest density was recorded at noon (1 PM). This means that this species prefers low light intensity. However, during autumn the diurnal variation was less pronounced between the different hours. Such pattern may be attributed to variations in the environmental conditions in the harbor.

Oithona plumifera

The species showed clear vertical migration during certain months, it attained its maximum count at the deeper layer during some hours of the day (June–August, October and April) (Fig. 4). In September and March, homogenous vertical distribution was observed during afternoon hours and clear upward migration to the upper layer at 11 AM. During the relatively cold months (November and December), the species sustained its highest count in the upper layer.

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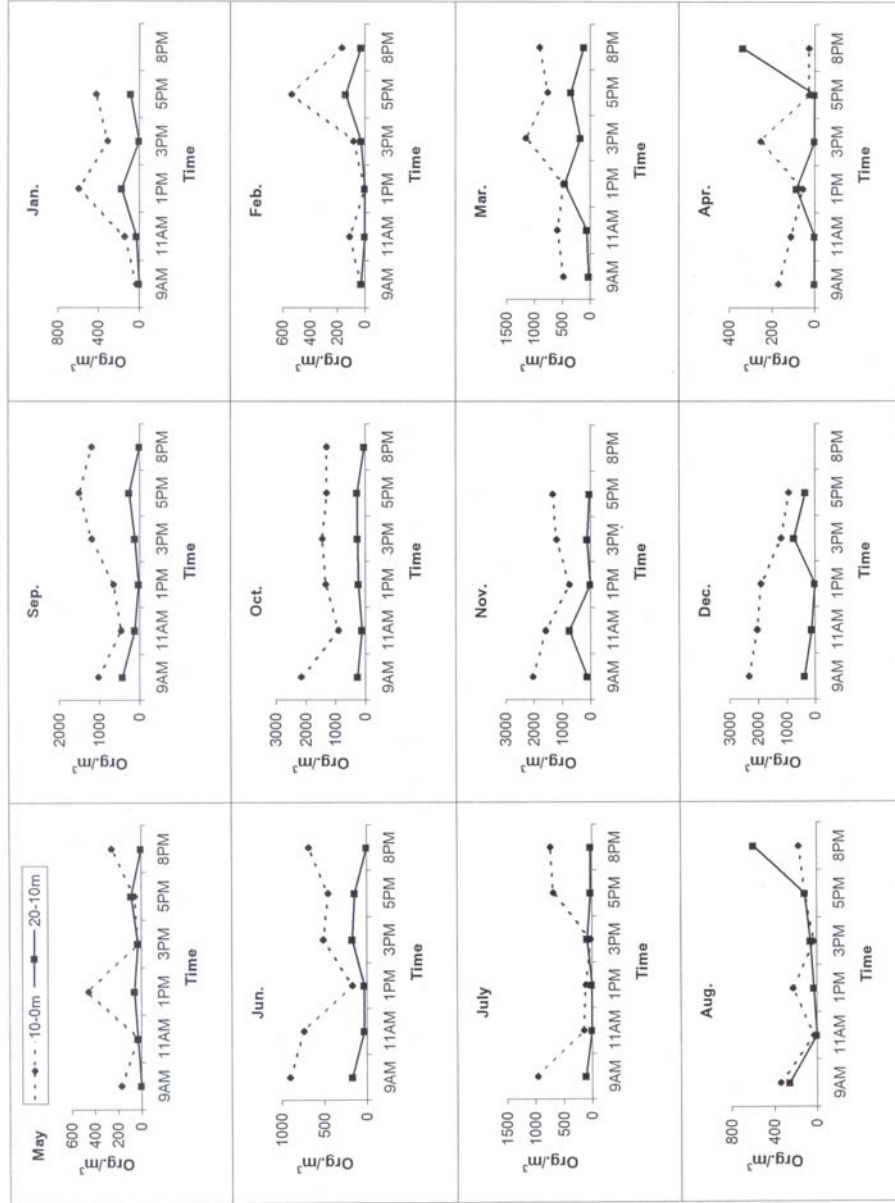


Fig. 2a- Diel vertical distribution of copepodites Org./m³ in Dekhaila Harbor during different months.

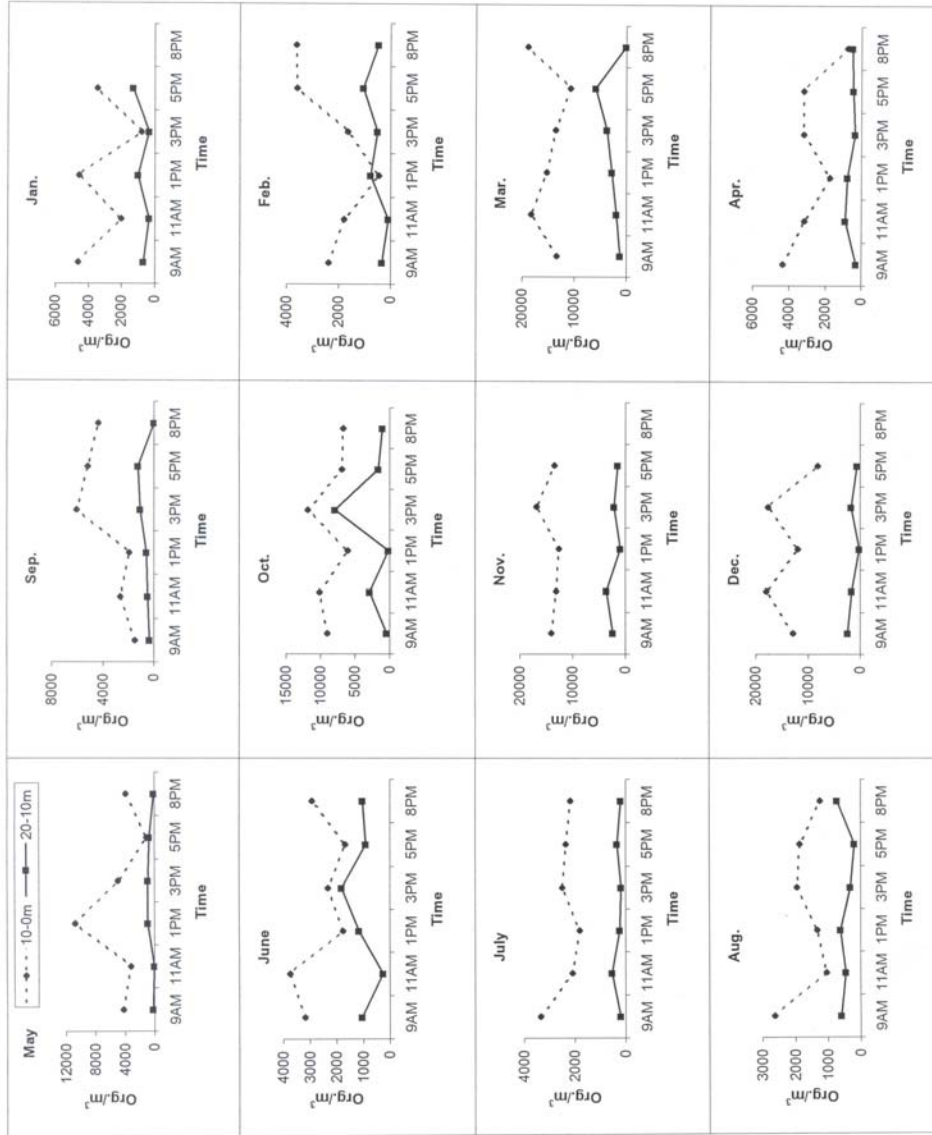


Fig. 2b. Diel Vertical distribution of copepod nauplii Org./m³ in Dekhaila Harbor during different months.

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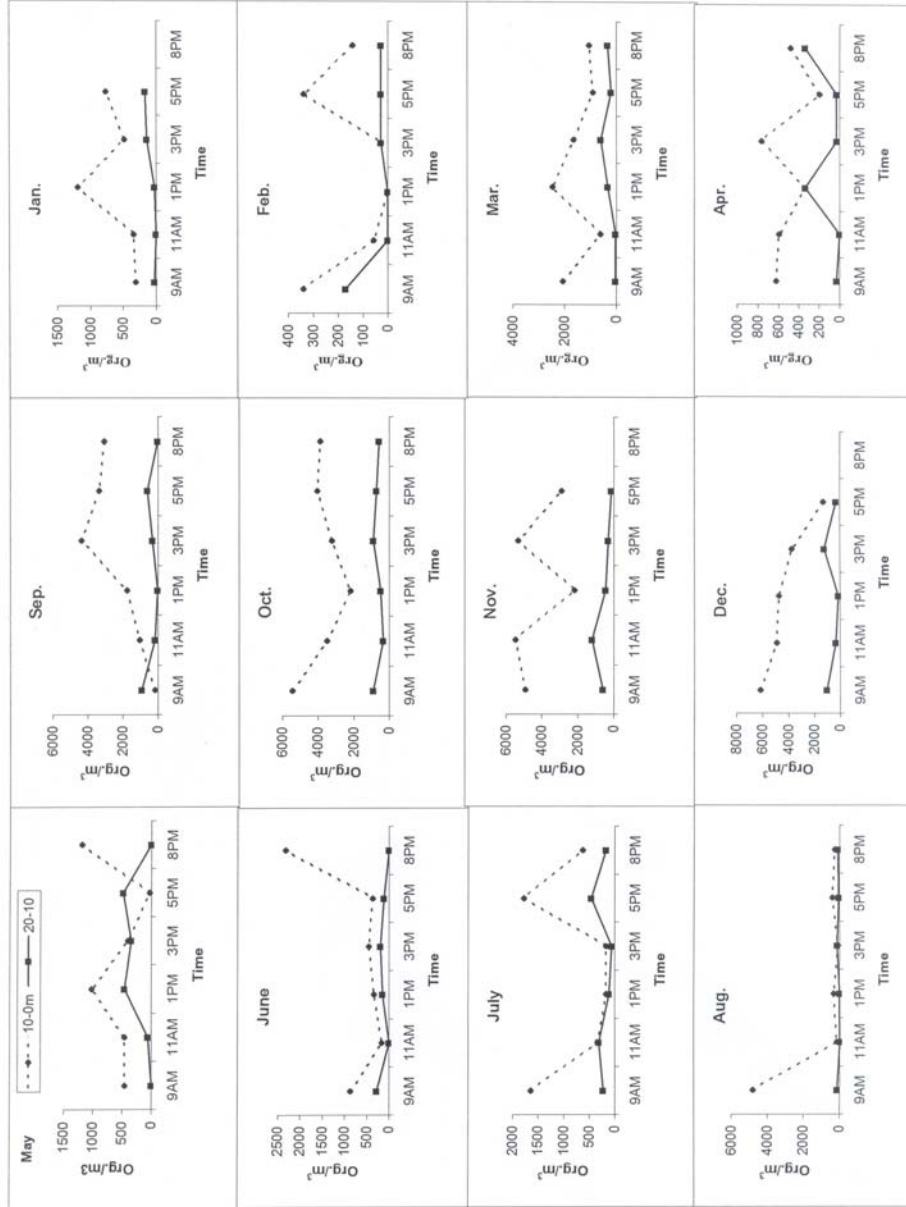


Fig. 3. Diel vertical distribution of *Oithona nana* Org./m³ in Dekhaila Harbor during different months.

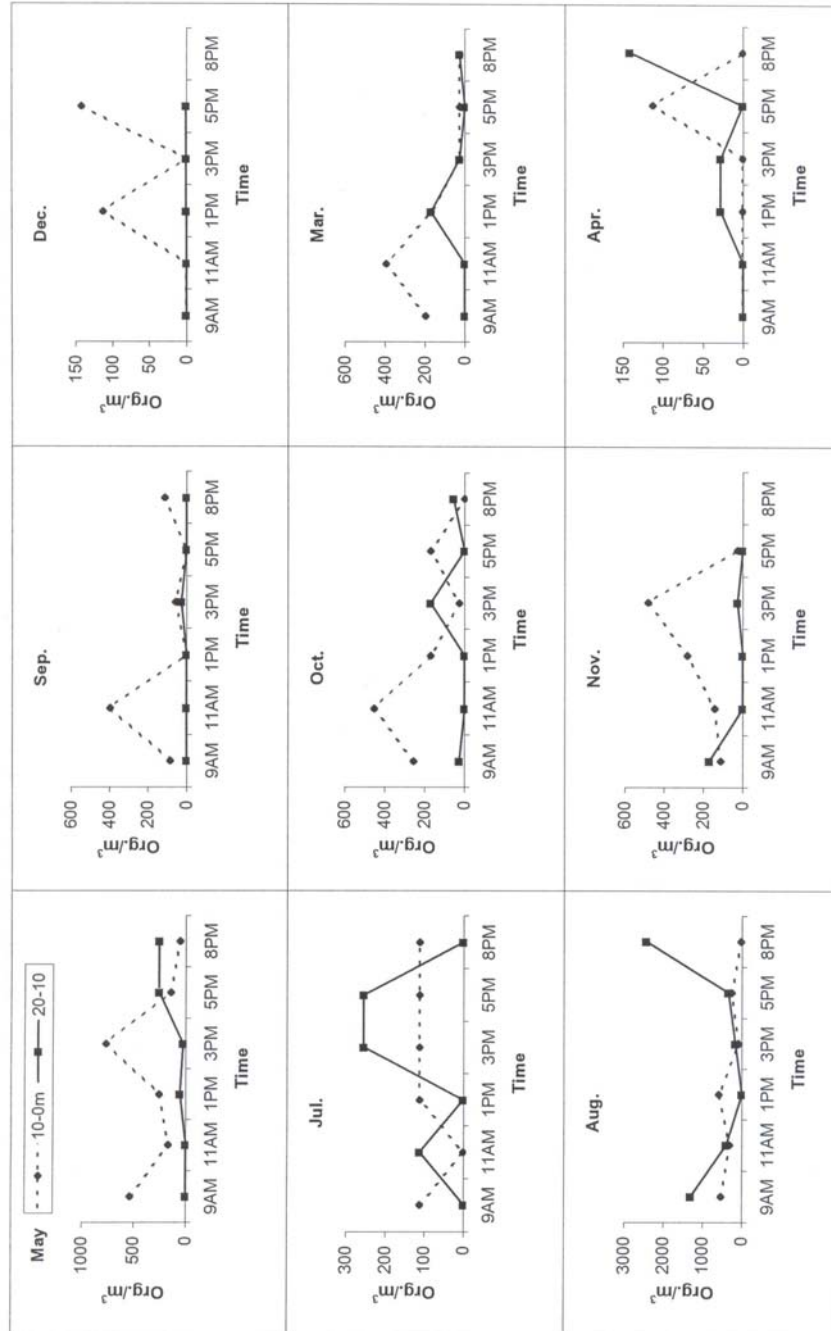


Fig. 4. Diel Vertical distribution of *Oithona plumifera* Org./m³ in Dekhaila Harbor during different months.

Acartia clausi

Acartia clausi showed different patterns of vertical distribution (Fig.5) which means its variations in response to light intensity according to the seasonal conditions. In late spring and summer, *A. clausi* attained its maximum counts at the upper layer during afternoon hours, and in few cases at the morning (9AM) in November and February-April or at 9AM-1 PM in December. The species showed also homogenous distribution in the two layers during the rest of the day hours from February to April. Although the differences between the upper and lower layers are limited most of the year, during the whole day, relatively wider differences were observed between the two layers, during most of the day hours in autumn and winter (October – January) with alternating light and darkness. These results indicate that the species is phototactic.

Paracalanus parvus

This species showed different daily patterns of vertical distribution all the year round (Fig. 6). The maximum density of the species was mostly found in the upper 10m layer. In a few occasions, the deeper layer contained higher density of *P. parvus* at the midday time particularly in summer. In February, higher density was also observed in the deeper layer at morning and noon hours.

Euterpina acutifrons

This species was generally abundant during the period from March to May (Fig. 7), especially in the upper layer. The daily distribution showed different patterns during different months, the maximum count was reported at 9 AM in February, and at 11AM in May, July and April. The species became most abundant in the upper 10 m by the end of the day (3 - 8 PM) in cold months (November – January).

Tintinnids

High densities of these protozoans were recorded in the upper layer all the year round,

but they were also found in relatively high counts in the deeper layer during autumn and spring (Fig. 8). The variations of tintinnid counts with day hours showed that the morning and sunset times (9 AM and 5-8 PM) were mostly suitable for dense population most of the year, while at the midday hours (11-13 PM), they attained comparatively moderate counts during autumn and spring.

Rotifers

Rotifers showed the greatest densities in the upper layer during all months (Fig. 9), and the lowest abundance in the deeper layer except in November which showed high counts at the morning times (9 and 11 AM).

Larvacea

The larvaceans were recorded in the upper layer during the whole daytime most of the year, (Fig. 10) except in June when their maximum count was found in the deeper layer at 5-8 PM. The daily variation of these animals in the upper layer showed different monthly patterns, from November to April, the maximum count appeared mostly at 11 AM, while in summer months (June–August), the highest count was found at 3, 5 and 8 PM for the three months respectively, but in May it was observed at noon time.

Polychaete larvae

Polychaete larvae appeared to be more abundant during morning hours in the upper layer most of the year (Fig.11), while near the sunset time (5-8 PM), they frequently attained the maximum abundance in the deeper layer during early spring and summer. In contrast to other groups, polychaete larvae demonstrated relatively high counts in the deeper layer most of the year during the whole day.

Cirriped larvae

Cirriped larvae showed had a characteristic pattern of vertical distribution (Fig. 12), whereas in summer months and

January, they reached their maximum abundance in the upper layer from 9 AM to 3 PM. In other months (October–November and February–April), they were highly abundant mostly at PM hours. On the other hand, the cirriped larvae attained the lowest diurnal abundance in the deeper layer several months.

4- DISCUSSION

The diel vertical distribution of adult copepods and copepodites in Dekhaila Harbor indicated their preference of upper layer (0-10 m) than the lower one, seeking as mainly herbivores for phytoplankton as food resources, which is usually more abundant in the surface layer (Ismael and Dorgham, 2003). Johnson and Jakobsen (1987) supposed that the food limitation can prevent zooplankton from undertaking V.M. and the optimal strategy is to stay in chlorophyll maximum layer and almost cease migration. When food is abundant the animals can afford to migrate (Dagg, 1985). However, migrational pattern of copepods in Dekhaila Harbor may coincide with the prediction of Fiksen and Giske (1995) that smaller copepods undertake diel excursions to some extent.

The increased turbidity in the study area (Secchi depth reading 40-100 cm.) during algal bloom seasons (summer and autumn) also allows aggregation of copepods near the surface at a distinct chlorophyll maximum, escaping planktivores as was also observed by Fiksen and Giske (1995) in another area. The tendency for copepods to be found at high density during certain time of the day at deeper layer may depend on the time. This indicates that the onset of vertical migration of copepods and its copepodites have been due to phenotypic behavioral flexibility (Ringelberg, 1991). Similar observations were found in the study area, where at the upper layer, densities of adult copepods and copepodites were greater at the afternoon period (3-8 PM) during late spring and

summer (24-29°C). The increased density in the upper layer in late summer, autumn (21-27°C) and early winter (19°C) was mostly recorded either at 9 AM or 3 PM, while at the lower layer during these seasons the increased counts were recorded mostly at 9 AM. During winter (15-19°C) and spring (20-27°C), the morning time sustained the great density in the upper layer, while during the afternoon, the lower layer contained higher count. Recent measurements of copepod swimming speeds varied from 0.5-1.2 mm.S⁻¹ (Ramcharan and Sprules, 1991) indicating that a migration for a distance from the surface to 20 m should take between 4 and 11 hours. Therefore, probably no individuals migrate the complete distance from surface to the 20 m depth. On the other hand, older stages descend deeper than younger stages do, and they leave the night-time habitat earlier and ascend back later in the day (Fiksen and Giske, 1995). This causes symmetrical distribution profiles during several following hours during daytime depths with developmental stages of copepods, as appeared clearly during autumn for the two species, *Oithona nana* and *Acartia clausi*, where the speed of the latter species reached 9 meter in an hour (Hardy and Bainbridge, 1954).

Noon densities were the deficit time at the upper depth, that varied at the deeper layer, to avoid visually planktivores orienting predators such as small fish, or because they undergo diel onshore-offshore migration (Mc Carty, 1990). The present study indicates that the abundance of copepod nauplii in the upper layer was greater than in the lower one and tend to behave as passive drifting particles and are good indicators of recent egg production (Lane *et al.*, 2003). Moreover, elevated abundance of copepod nauplii in the upper layer resulted from the presence of relatively higher food (Chlorophyll *a*) concentrations. The existence of high density of nauplii at noon time and lowest density at sunset most of the year in deeper layer, is in agreement with Pagano *et al.* (1993), who concluded that copepod nauplii and most

small cyclopoids do not undergo diel V.M. Franks (1992) also suggested that copepod nauplii are positively phototactic and tend to remain near the surface.

Although *Oithona nana* was concentrated in the upper layer most of the year, it undertook a downward migration at certain day hours, then up again at other day times. This behavior can be explained by its sensitivity to light variations, as the species moves downwards at the sunshine hours, during summer months and upwards at noon time in the surface layer, during winter and spring months. The difference in temperature between the two layers could be considered also in such context, whereas in summer, the deficit time is the noon time while in winter and spring, the surface is optimal habitat during noon time. Although *Oithona nana* inhabits different depths (Nishida and Marumo, 1982), it seems that it prefers autumn water temperature (18-23°C), where it showed no significant differences between day hours during the present study.

Oithona plumifera seems to prefer the strong light period in the upper layer particularly in the months with moderately light intensity (October–December). It escapes the strong light during summer, as its higher counts were reported in the deeper layer most of the day time in July. This agrees with Moore and O'berry (1957) who concluded that *Oithona plumifera* undertakes moderately extensive daytime migration to deep layer from upper one.

Acartia clausi appeared to be less sensitive to light, intensity since it showed more or less homogeneous distribution, along the water column all the day time during sunny and calm seasons (summer and spring). Kouassi *et al.* (2001) observed that a part of *Acartia clausi* population remained in the upper water during the sunny hours, with a density increase from youngest copepodites to adult stages. The abundance distribution of the species demonstrated different diurnal patterns in autumn and winter (October–January) as the maximum count was reported either during afternoon hours or at morning

time. This may be related to the light intensity and to the vertical differences in the water temperature during the two seasons. Johnson (1938) found that *Acartia clausi* was normally negatively phototactic and under constant light intensity or during increasing light intensity, such way was maintained; with a reduction in light intensity, the animal became temporarily photopositive.

Paracalanus parvus showed more or less different patterns of diel vertical distribution during different months. The high density appeared in the deeper layer, particularly in summer at midday time, indicating that the species escapes both high temperature and light at the upper layer. In February, higher density of the species was observed in the deeper layer at the morning and noon hours which may be attributed to a rapid downward migration of the species during the early hours of the day escaping the lower temperature at the surface, but at the midday, the surface layer becomes warmer and the species moves up again.

Euterpina acutifrons was reported mainly during the period of cold and moderately low temperature, from November to May, mainly in the upper layer. Such pattern may be related to the food availability near the surface, where phytoplankton was mostly abundant (Ismael and Dorgham, 2003).

Autumn and spring seems to be the optimal seasons for the richness of most tintinnid species dominated in the study area (*Favella ehrebergii*, *Metacylis Mediterranean*, *M. mereschkowskii*, *Protorhabdonella simplex*, *Tintinnopsis beroidea* and *T. radix*) at temperature 18-24°C, salinity: 19-28‰ and chlorophyll *a* 200-300 µg/L. The low temperature and chlorophyll concentration affect the life cycles of many tintinnids (Godhantarman, 2001), and seasonal occurrence of tintinnid species may be closely associated with the species-specific environmental conditions, that required to encystment or excystment (Kamiyama and Aizawa, 1992). The morning time and the sunset hours were mostly the

suitable times for maximum occurrence of tintinnids, indicating that temperature was the factor controlling migration of tintinnids. Predation loss by the high density of mesozooplankton (smaller than 1 mm.) was found in the area as *Oithona nana*, *O. plumifera* and *Euterpina acutifrons* that might be the possible reason for the low biomass of tintinnids during late spring in the present study. Also the tintinnids are suitable food sources for the first feeding fish larvae of many fishes (Edwards and Burkill, 1995).

The great density of rotifers in the upper layer was associated with markedly low surface salinity (19-28‰) and high production of phytoplankton. Heinbokel *et al* (1988) noted that rotifers associated with the phytoplankton blooms often constitute the dominant grazer on dinoflagellates, and Gilbert and Jack (1993) reported them as the major grazers of algae and small ciliates. In the deeper layer, rotifers disappeared collectively except in November, when surface salinity dropped to lowest value (17‰). On the other hand, rotifers are prey for large crustaceans, copepods and larval fish (Conde-Porcuna and Declerck, 1998). It seems that November conditions are the optimal habitat for most rotifers recorded in this area.

Different patterns of vertical distribution of Larvacea were observed, the highest density of *Oikopleura dioica* appeared in surface layer which contained high phytoplankton production, the preferable food for these animals. This agrees with Capitanio and Esnal (1998) who concluded that *O. dioica* attained maximum density in the upper 10m, concurrently with the highest chlorophyll a value. Otherwise, the dense population of *Oikopleura* species in the upper layer may be attributed also to their ability to

form breeding aggregations near the surface as was reported by Alldredge (1982) for mature *Oikopleura longicauda*. The increase of Larvacea at certain hours of the day may be associated with its ability to attain high population densities in a very short time, so that their time-lag may not be as evident as in other zooplankters, example copepods with longer generation times. *Oikopleura dioica* has a very short generation time, approaching one day at about 29°C (Hopcroft and Roff, 1995), and higher temperature determines growth rate increments (Uye and Ichino, 1995). This indicates that densities of *Oikopleura* species varied as a function of depth and temperature.

The meroplanktonic larvae of annelids and cirripedes were found consistent with their dependence on their benthic stages. Annelids in this area seem to reproduce during spring and summer, releasing large densities of larvae. The favorable high temperature seems to enhance reproductive rate of these larvae, as indicated from the dense population of them in the deeper layer during summer and early spring. On the other hand, the distribution pattern of polychaete larvae indicates downward vertical migration at afternoon hours, particularly during the high lighted seasons (early spring and summer), while they keep themselves in the upper layer during other months. This indicates their preference to the upper lighted layer with the dense food material. The maximum abundance of cirriped larvae was recorded in the upper layer before midday, during summer months and January and afternoon during autumn and spring, indicating that the V.M. of these larvae is not affected by variation in temperature but due light intensity.

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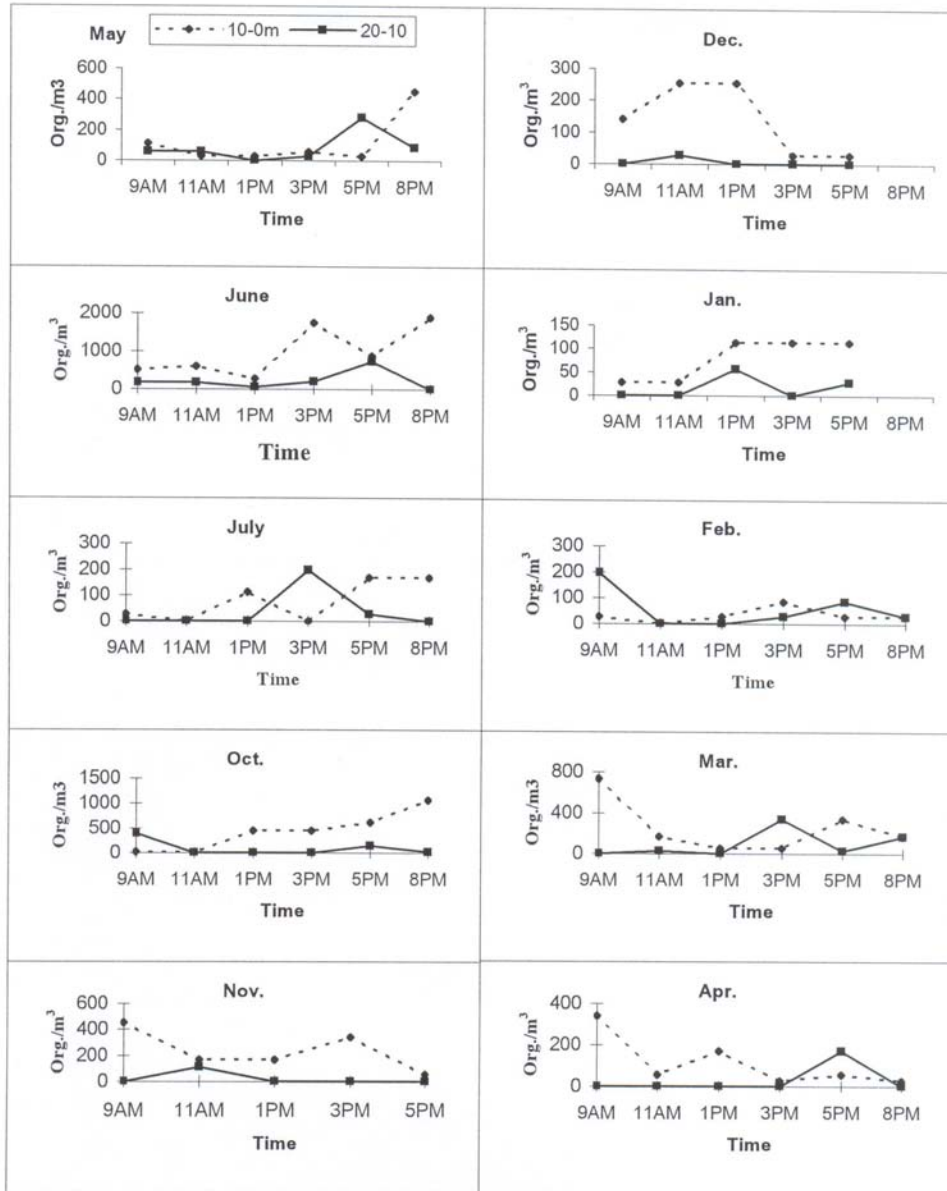


Fig. 5. Diel Vertical distribution of *Acartia clausi* Org./m³ in Dekhaila Harbor during different months.

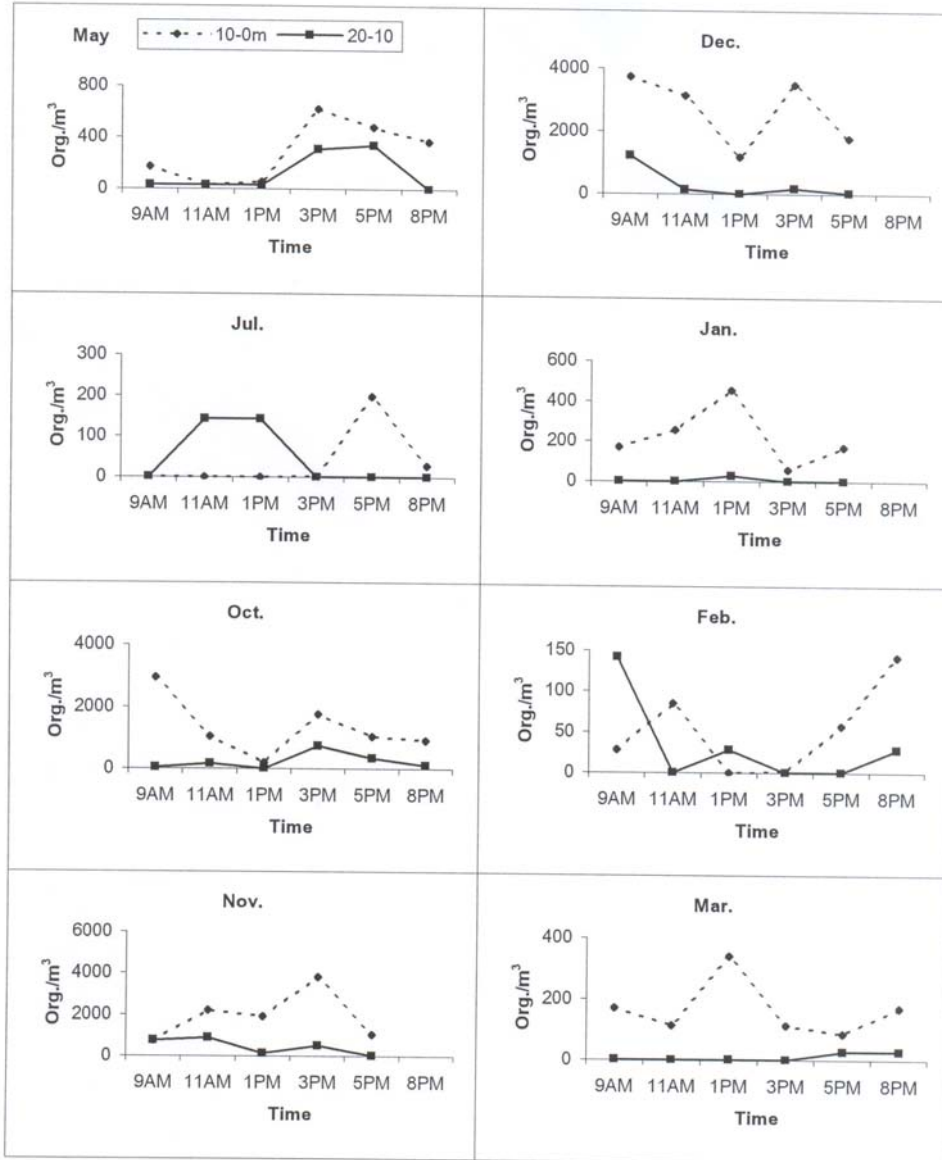


Fig.6- Diel Vertical distribution of *Paracalanus parvus* Org./m^3 in Dekhaila Harbor during different months.

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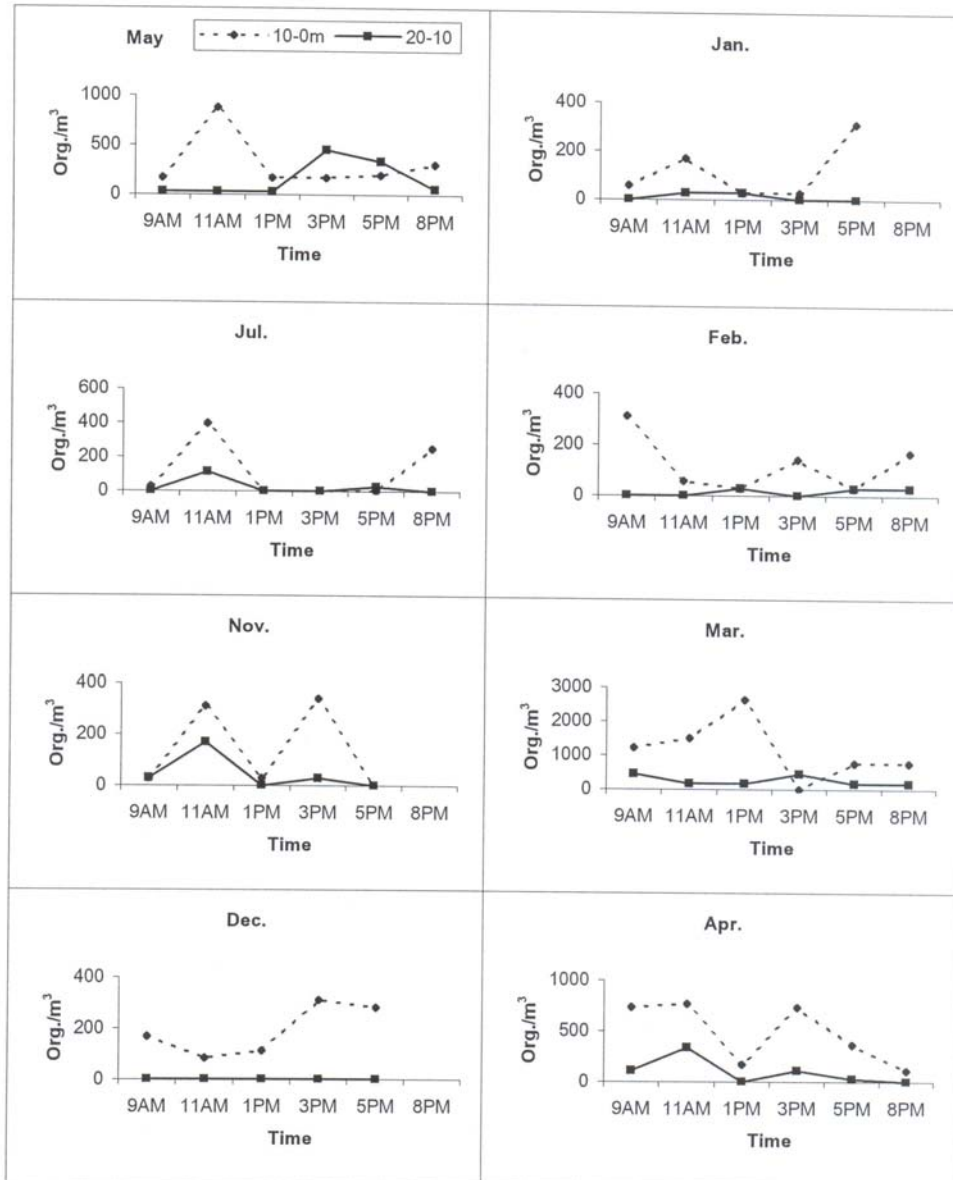


Fig. 7- Diel Vertical distribution of *Euterpina acutifrons* Org./m^3 in Dekhaila Harbor during different months.

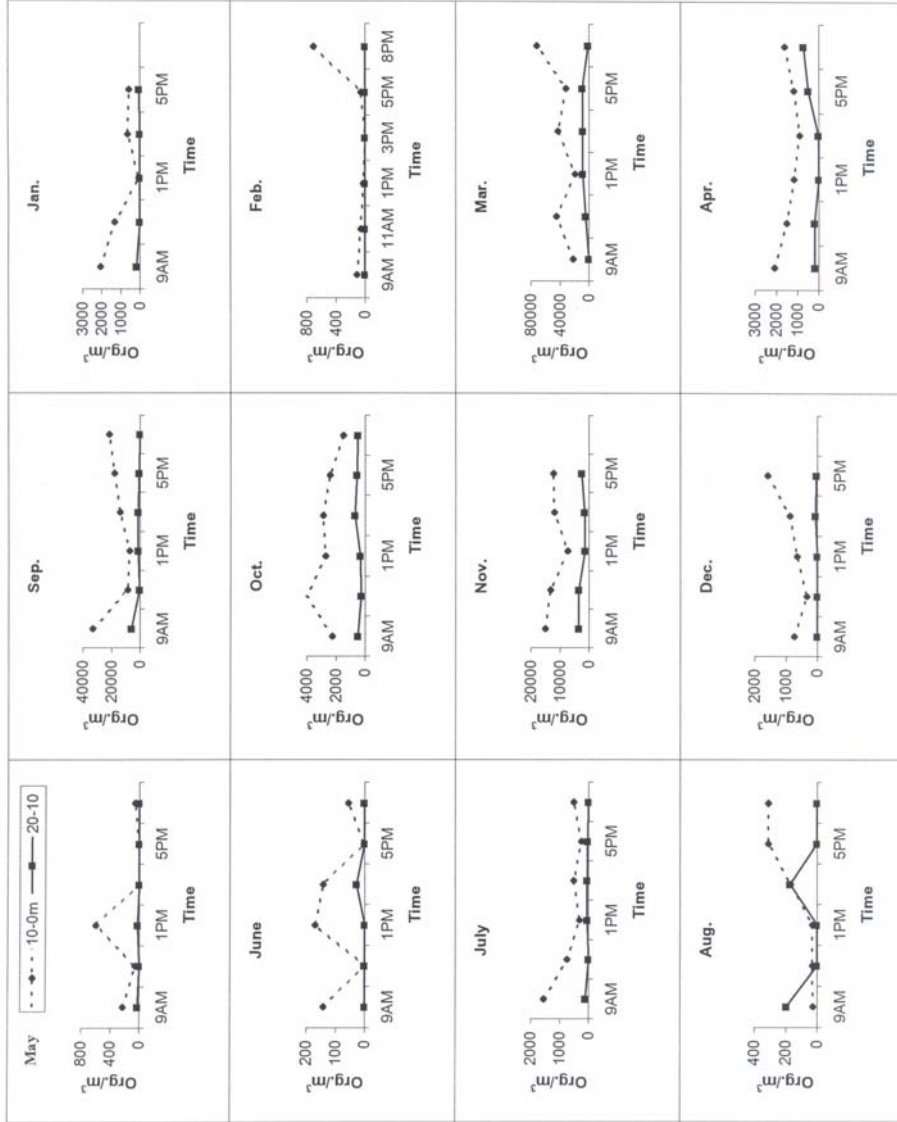


Fig. 8. Diel Vertical distribution of tintinnids Org./m^3 in Dekhaila Harbor during different months.

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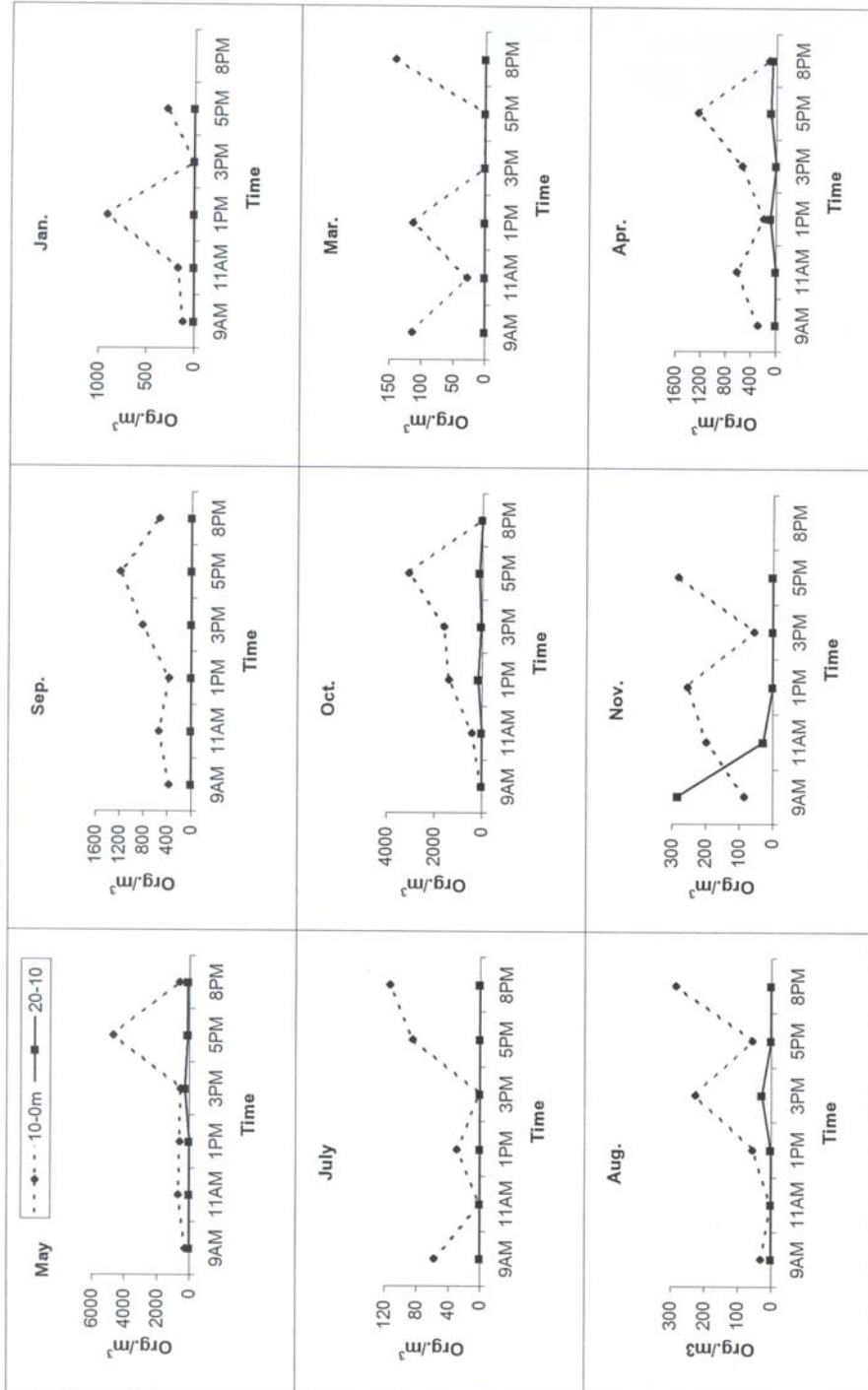


Fig. 9. Diel Vertical distribution of rotifers Org./m³ in Dekhaila Harbor during different months.

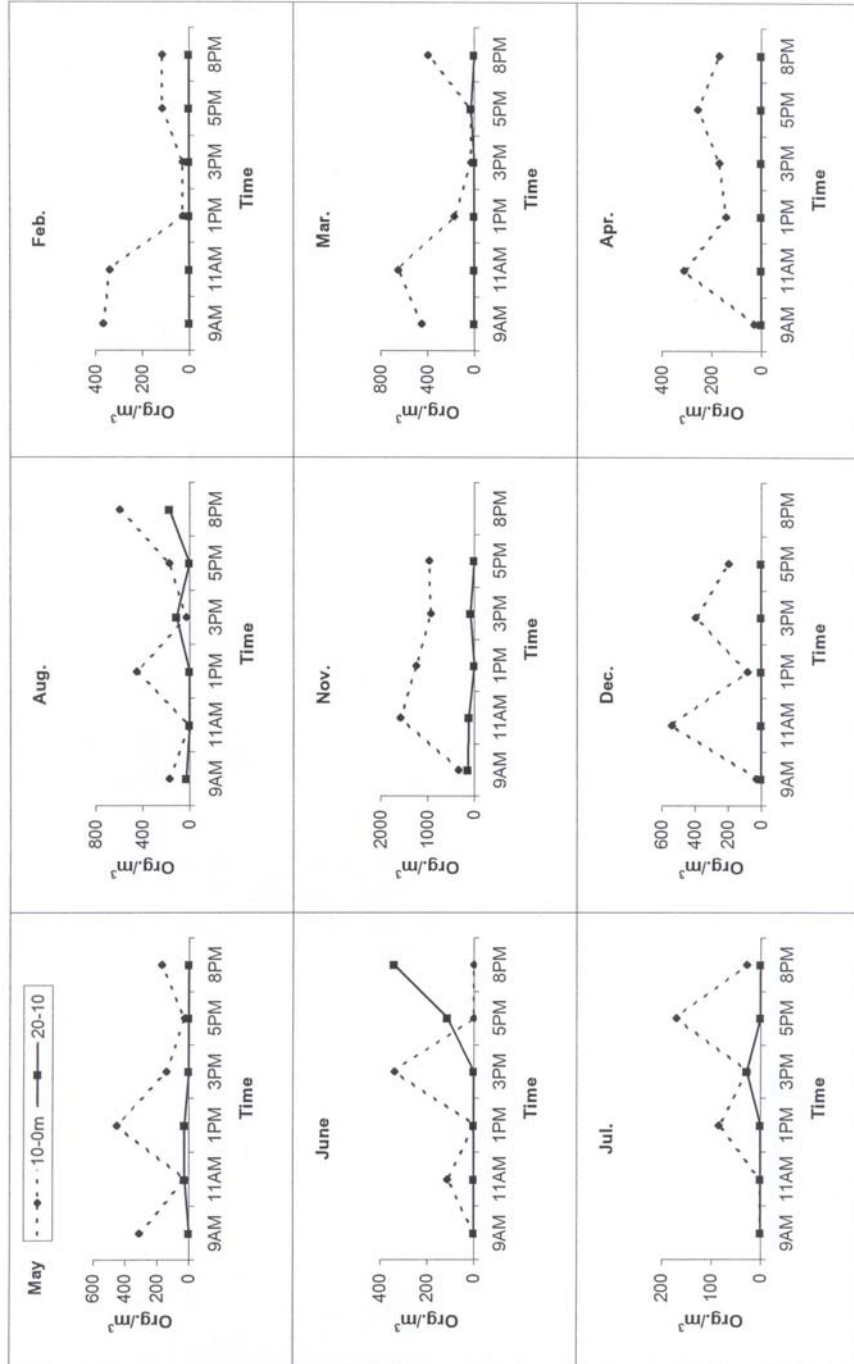


Fig. 10. Diel Vertical distribution of Larvacea Org./m^3 in Dekhaila Harbor during different months.

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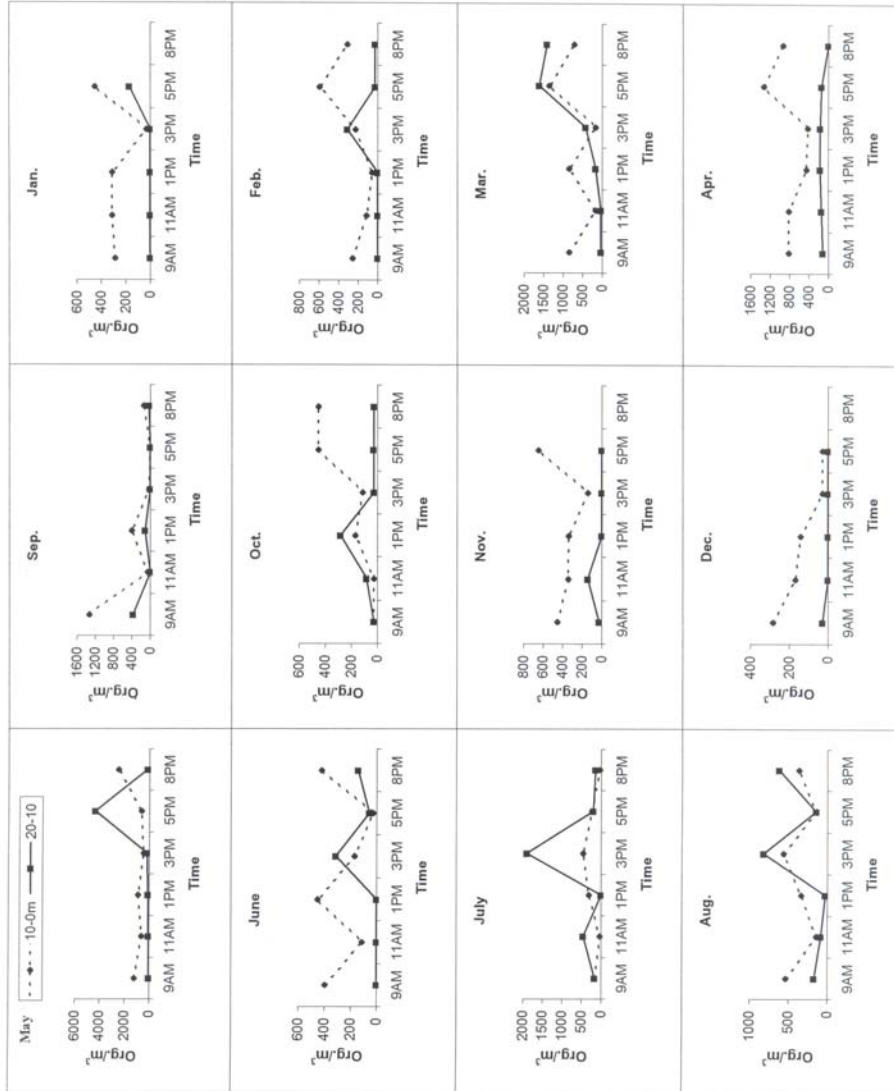


Fig. 11. Diel Vertical distribution of Polychaete larvae Org./m^3 in Dekhaila Harbor during different months.

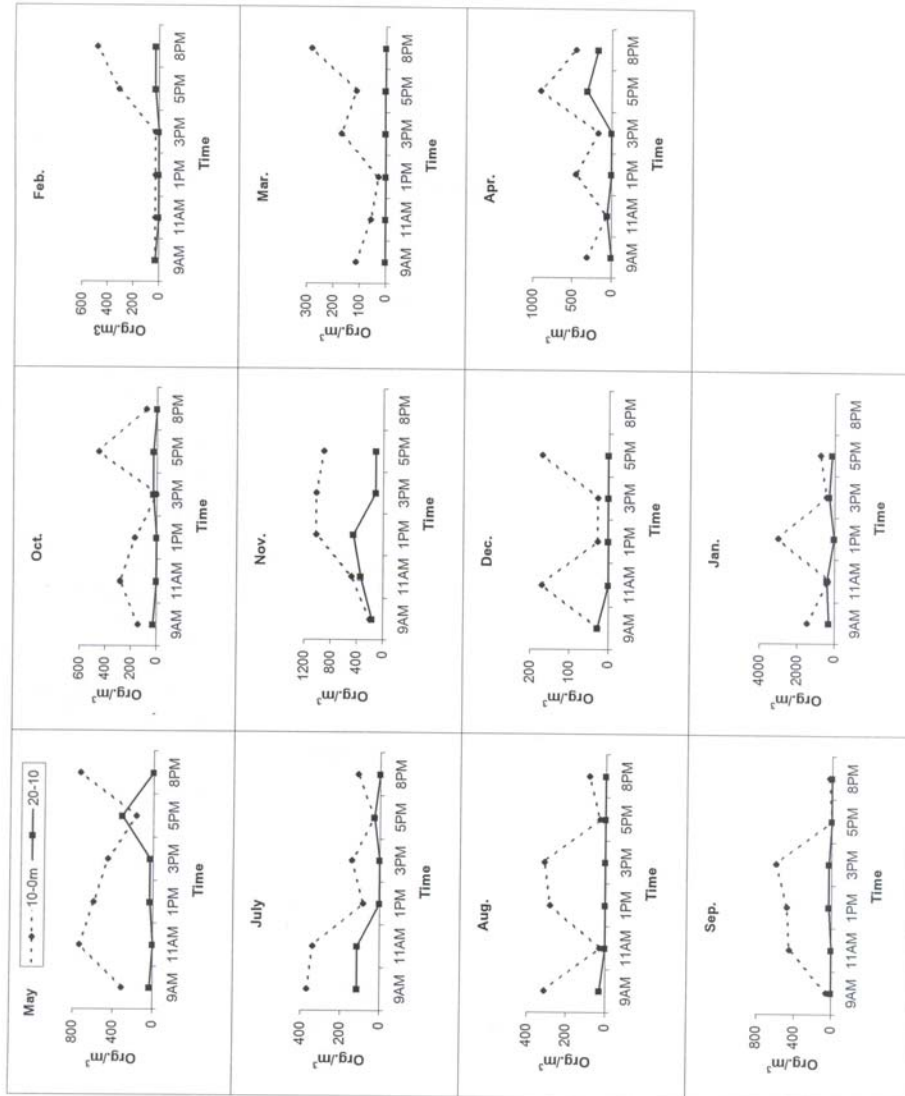


Fig. 12. Diel Vertical distribution of cirriped larvae Org./m^3 in Dekhaila Harbor during different months.

5- CONCLUSION

Many of holoplanktonic and meroplanktonic components of zooplankton in Dekhaila Harbor prefer living at higher light intensity, and high chlorophyll a concentrations in the uppermost layer. The vertical distribution of different zooplankters showed marked differences during different day hours and different seasons. Light variation was suggested to be the trigger signal, controlling the vertical movement of zooplankton populations. This was demonstrated clearly by *Oithona nana* and *Paracalanus parvus* which prefer low light intensity, escaping to deeper layer most summer hours. Temperature has also a role in the vertical movement of zooplankton species, but to a limited extent. Many species were reported more abundant in the upper layer in cloudy winter days like *Euterpina acutifrons* and *Oithona plumifera*, which in bright sunshine summer days tended to go deeper.

Responses of vertical migration appear to depend on the life history of each species, as in *Oikopleura* species, which prefers the upper layer to form breeding aggregations during its productive seasons. Sometimes there is no or little difference in the density of species between the two layers as *Acartia clausi*, that may be due to the time of triggering off, speed of each species and physiological differences between generations.

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