The diversity and dynamics of Calanoida (Copepoda) in the Northern Gulf of Elat (Aqaba), Red Sea

Copepoda Calanoida,
Zooplankton
Vertical migration
Seasonality in plankton
Gulf of Elat, Red Sea
Copépodes calanoïdes
Zooplancton
Migration verticale
Variations saisonnières
Golfe d'Elat, Mer Rouge

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ABSTRACT

The species diversity, numerical abundance and dynamics of the Copepoda Calanoida in station A, Northern Gulf of Elat (Aqaba) (29°30′N/34°57′E) are analysed. 31 species were identified from seasonal samples obtained from stratified tows in 1975. This fauna is composed of tropical species; since the environment shows marked seasonal fluctuations, individual numbers are highest in March and lowest in July. At depths below 300 m, numbers of species and individuals decrease rapidly. The different groups of species are characterized according to abundance frequency, seasonal dynamics, vertical distribution and dietary habits. Calanoid plankton, which is both quantitatively and qualitatively poor, is dominated by small herbivores, among which two species of *Ctenocalanus* are the most important. There is a relative abundance of omnivorous species. Carnivores are limited for most of the year to a single species of *Paracandacia*. Comparison of day and night samples provides some evidence of vertical migration.

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RÉSUMÉ

Diversité et dynamique des copépodes calanoïdes dans le nord du Golfe d'Elat (Aqaba), Mer Rouge.

La diversité et la dynamique des populations de copépodes Calanoïdes dans le nord du Golfe d'Elat (Aqaba) sont étudiées sur la base de prises saisonnières verticales effectuées sur une station, station A (29°30′N/34°57′E), en 1975. 31 espèces de Calanoïdes ont été identifiées. La population est typiquement tropicale, malgré une distribution saisonnière marquée avec un maximum de specimens en mars et un minimum en juillet. Généralement, la faune est qualitativement et quantitativement pauvre. La population se concentre dans les 300 premiers mètres, et diminue brusquement au-delà. Des groupes d'espèces sont individualisés selon plusieurs critères : abondance, fréquence, dynamique saisonnière, distribution verticale et régime alimentaire. La biomasse des Calanoïdes est dominée par les petits herbivores avec deux espèces de *Ctenocalanus*, qui sont les plus abondantes. La représentation des espèces omnivores est assez diversifiée. Les carnivores sont représentés pendant la plus grande partie de l'année par une seule espèce : *Paracandacia truncata*. Enfin, en comparant des prises effectuées le jour et la nuit, quelques aspects de la migration verticale des copépodes ont été étudiés.

Oceanol. Acta, 1983, **6**, 2, 139-145.

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INTRODUCTION

In the only review of the zooplankton of the Red Sea, Halim (1969) summarizes all the previous records of Calanoida from the main Red Sea, the Gulf of Suez and the Suez Canal. More recent data from Delalo (1966) and Weikert (1980; 1982) may be added to this earlier information. Schmidt (1973) provides preliminary data on the displacement volume and numerical abundance of the total copepod population in one station in the Northern Gulf of Elat.

Virtually nothing is known about the planktonic Calanoida of the Gulf of Elat (Aqaba). To my knowledge, there is only one reference to *Acartia negligens*, by Richman *et al.* (1975), and a reference to *Rhincalanus nasutus* in Halim (after Furnestin, 1958).

For the present study, I used the preserved collections sampled by the Data Collecting Programme of the Gulf of Elat (DCPE), carried out by the Marine Biology Laboratory of the Hebrew University at Elat under the direction of Pr. Z. Reiss from that university. The present paper, intended as the first in a series, analyses the diversity, seasonal and depth distribution of Calanoida in the northernmost station covered by this programme, namely station A (see Klinker *et al.*, 1976).

MATERIALS AND METHODS

The methodology of plankon collection during the DCPE has been described by Klinker *et al.* (1975). Samples were collected once a month, using a Viillefranche-type net with a 58 cm opening and a mesh size of 200 μ. Collection was carried out vertically, at intervals of 50 m in the uppermost 100 m, and of 100 m down to a maximum depth of 500 or 600 m. The depth of the water column at station A (29°30′N/34°57′E) is 700 m. The samples analysed in the present study are those from January, March, July and September 1975. Tows were not performed at fixed hours; the March and September samples were taken during the night and the other two under full daylight conditions.

Calanoids were counted from total samples, with the exception of the large samples of March, which were divided with the aid of a Motoda box, only half of the sample being counted. Only adults and 5-th copepodites were counted; but moults were disregarded.

HYDROGRAPHIC FRAMEWORK

The topography and circulation of the Gulf of Elat are amply described by Klinker *et al.* (1976). The region is desertic and hot; the Gulf waters receive only an occasional freshwater influx as a result of winter flooding. Evaporation is extremely high, exceeding the annual mean of 300 mm. The shelves are very narrow and maximum depths reach almost 2 000 m. The Gulf receives an inflow from the Red Sea at the surface, over a sill of 252 m depth, while deeper countercurrent returns to the Red Sea. The salinity of the waters is high and relatively constant, ranging from 40.2 to 41 °/₀₀. The minimum (20°C) temperature is reached in winter.

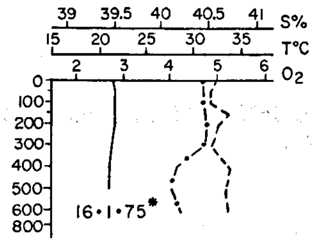


Figure 1
Hydrographical data station A 16.1.1975 (salinity, temperature, oxygen) (after Klinker et al., *1975).*

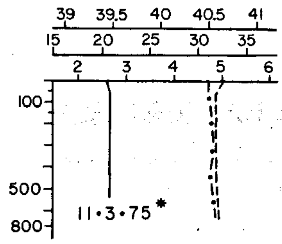


Figure 2
Hydrographical data station A 11.3.1975 (salinity, temperature, oxygen) (after Klinker et al., *1975).*

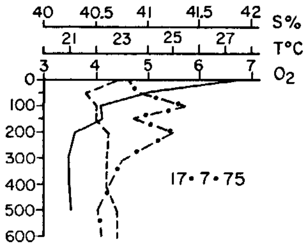


Figure 3
Hydrographical data station A 17.7.1975 (salinity, temperature, oxygen).

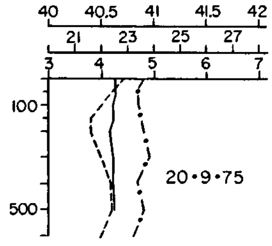


Figure 4
Hydrographical data station A 20.9.1975 (salinity, temperature, oxygen).

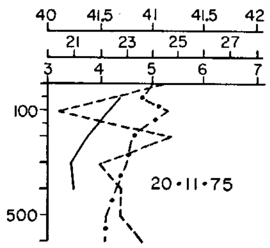
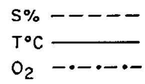


Figure 5
Hydrographical data station A 20.11.1975 (salinity, temperature, oxygen).



The seasonal and bathymetric range does not exceed 6°C. Oxygen content at the surface amounts to 6.0 ml/l, and to 3.75 ml/l in the deepest waters. There is no oxygen minimum layer in the Gulf. Where they exist, the thermocline and the halocline are weak. In summer, a thermal stratification separates an upper layer of 200 m; in winter (January to March), the temperature is uniform throughout the water column.

Hydrographical data at station A, representative of the 5-month period from which the samples have been analysed, are provided in Figures 1-5.

Nutrient content and primary production are very low in the Gulf of Elat, though illumination is strong and light penetration is deep throughout the year (Levanon-Spanier *et al.*, 1979). Phytoplankton consequently occurs to a depth of more than 300 m (Kimor, Golandsky, 1977; Winter *et al.*, 1980).

RESULTS

The species diversity of Calanoida in the Northern Gulf of Elat is very low, a total of 31 species having so far been identified from station A (Table). The dominant species are *Ctenocalanus tageae* and *C. campaneri* (two new species, see Almeida Prado-Por, in press),

Table
List of Calanoida species at station A (Northern Gulf of Elat) and their occurrence in adjacent waters.

	Red Sea	Gulf of Suez	Suez Canal	Levant Coast
Calanidae :				
Calanus minor Claus, 1863	X	X		X
Rhincalanus nasutus Giesbrecht, 1888	X			
Mecynocera clausi Thompson, 1888	X			X
Eucalanus sp.				
Paracalanidae :				
Acrocalanus spp.				
Calocalanus pavo (Dana, 1849)	X	X		X
Calocalanus pavoninus Farran, 1934	X			
Calocalanus styliremis Giesbrecht 1888				X
Paracalanus indicus Giesbrecht 1888				
Pseudocalanidae :				
Clausocalanus farrini Sewell, 1929				X
Clausocalanus furcatus Brady, 1883	X	X		X
Ctenocalanus campaneri Almeida Prado-Por 1982				
Ctenocalanus tageae Almeida Prado-Por 1982				
Euchaetidae :				
Euchaeta concinna Dana, 1849	X			
Phaennidae :				
Phaenna spinifera Claus, 1863	X			X
Scolecithricidae :				
Scolecithricella auropecten Giesbrecht, 1892				
Temoridae :				
Temora stylifera Dana, 1852	X	X		X
Temoropia mayumbaensis T. Scott 1894	X	X		X
Metridinidae :				
Pleuromamma indica Wolfenden, 1905	X			
Centropagidae :				
Centropages elongatus Giesbrecht, 1896	X			
Lucicutidae :				
Lucicutia flavicornis Claus, 1863	X	X	X	X
Lucicutia sp.				
Augaptilidae :				
Haloptilus longicornis Claus, 1863	X			X
Haloptilus ornatus Giesbrecht, 1892	X			
Candaciidae :				
Candacia curta Dana, 1849	X			
Candacia tenuimana Giesbrecht, 1889				
Paracandacia truncata, Dana, 1849	X	X		
Pontellidae :				
Pontellina plumata Dana, s. l. 1849	X	X		X
Acartiidae :				
Acartia negligens Dana, 1849	X	X		X

Data from the Red Sea, according to Halim (1969), Delalo (1966) and Weikert (1982). Data from the Suez Canal, according to Halim (1969). Data from the Mediterranean coast, according to Berdugo (1969) and Lakkis (1971).

Clausocalanus farrani, Mecynocera clausi, Paracalanus indicus, Calocalanus pavoninus and *C. styliremis.*

The density of the Calanoida is very low, amounting to a maximum mean concentration of 76.3 individuals/10 m^3 in March, and to a minimum of 27.0 in July, in the 600 m water column (Fig. 6). The highest concentration of animals was found in the upper 300 m (Fig. 6). The samples collected at night, i. e. during March and September, suggest a diurnal vertical migration into the 100 m surface layer, although seasonal variation cannot be excluded.

The seasonal and bathymetric occurrence of single species is presented below, in order of abundance and frequency and arranged according to the three dietary groups suggested by Ito (1970). Although this dietary classification is far from absolute, it may provide some useful information.

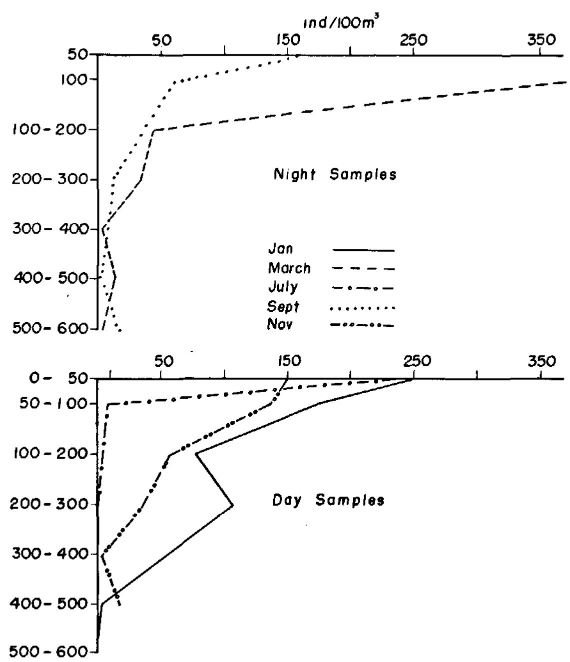


Figure 6
Vertical distribution of Calanoida at station A in January, March, July, September and November 1975.

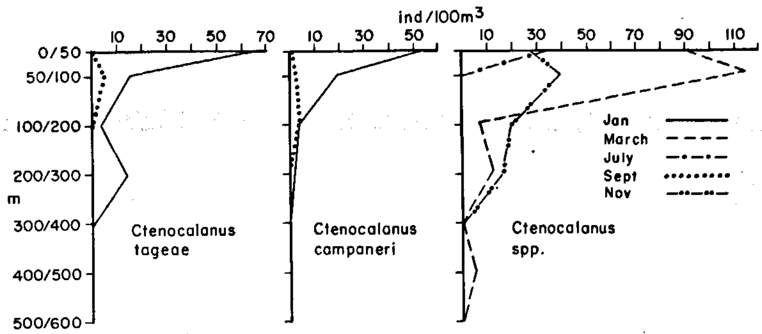


Figure 7
Vertical distribution of Ctenocalanus *spp. station A in March, July and November 1975 and of* C. campaneri *and* C. tageae *in January and September 1975.*

Herbivores

Ctenocalanus tageae and *C. campaneri* are the most common species in the northern Gulf of Elat. While the results for January and September are presented separately for the two congeneric species, for the other 2 months they are plotted together (Fig. 7). There is evidence that both species occur together throughout the year and exhibit a similar bathymetric distribution, neither species predominating over the other. This result must be considered as preliminary, and the significance of the phenomenon remains to be investigated. As a rule, the two species are concentrated in the upper 200 m, but they are occasionally found to a depth of 500 m – unless contamination is responsible for this finding. The seasonal fluctuation of the *Ctenocalanus* species presents a pattern typical for most of the calanoids of the Gulf, i. e. a maximum density in March and a minimum in July. The genus *Clausacalanus* is represented by *C. farrani* and *C. furcatus*, which have different distribution partterns :*C. farrani*, which is much more abundant than *C. furcatus*, occurs throughout the year and is numerous especially in January and in March (Fig. 8). *C. furcatus* was absent during the *C. farrani* peak in March, and showed its own small peak in January (Fig. 9). Unlike *C.farrani*, which is concentrated in the upper layers, particularly during July, *C. furcatus* has a much uniform bathymetric distribution. This was especially evident in January.

Mecynocera clausi (Fig. 10) occurs throughout the year in fairly constant numbers. Its vertical distribution is more homogenous than that of the other species, reaching a depth of 400 m, with a peak at 200 m.

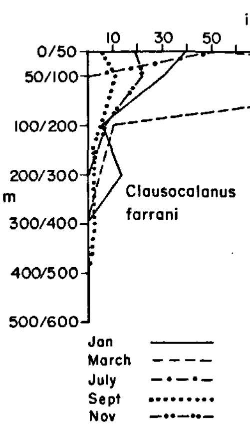


Figure 8
Vertical distribution of Clausocalanus farrani, *station A in 1975.*

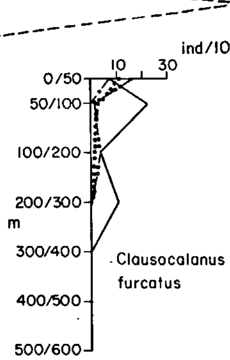


Figure 9
Vertical distribution of Clausocalanus furcatus, *station A in 1975.*

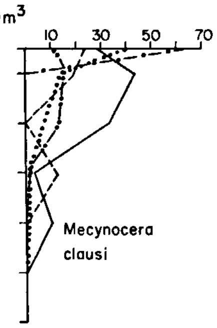


Figure 10
Vertical distribution of Mecynocera clausi, *station A in 1975.*

Among the herbivorous species, *Mecynocera clausi* has the broadest vertical distribution.

Paracalanus indicus (Fig. 11) has the same seasonal pattern as *Ctenocalanus* spp. and *Clausocalanus farrani*, but displays a special vertical distribution, which is discussed below.

The genus *Calocalanus* is represented by *C. pavo*, *C. pavoninus* and *C. styliremis*. *C. pavo* exhibits a scattered distribution throughout the year, never appears in concentrations of more than 5 individuals per 10 m^3, and is limited to the uppermost 300 m. *C. pavoninus* and *C. styliremis* (Fig. 12), which occur together, neither predominating, are abundant in the uppermost 50 m but may appear to a depth of 500 m. Two co-existent and unidentified species of *Acrocalanus*, found in the upper 300 m, reached significant numbers in January and especially in November.

Rhincalanus nasutus appeared only sporadically, with the exception of the night profile from September, where

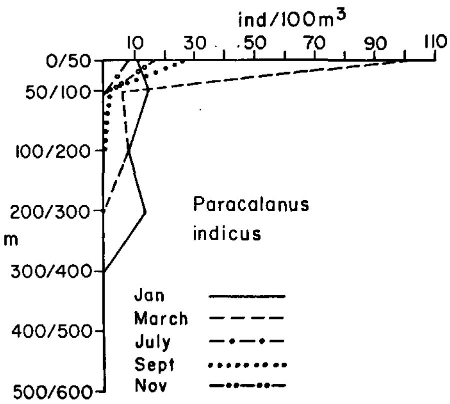


Figure 11
Vertical distribution of Paracalanus indicus, *station A in 1975.*

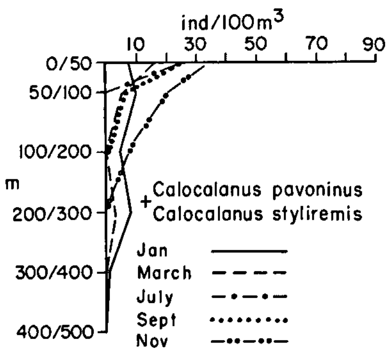


Figure 12
Vertical distribution of Calocalanus pavoninus *and of* C. styliremis, *station A in 1975.*

it reached 10 individuals per 10 m^3 at the depth of 500-600 m. Lastly, *Undinula vulgaris*, *Calanus minor* and *Eucalanus* sp. occurred very sporadically and in small numbers.

Omnivores

Acartia negligens (Fig. 13) had low densities and does not show significant seasonality. This species is relatively abundant in the upper 300 m and tends to congregate in the uppermost 50 m.

Lucicutia flavicornis (Fig. 14) appears in all seasons, with a maximum in March, and is common in the 50-200 m layer. During March, the population was more densely concentrated in the upper 100 m, possibly as a result of diurnal vertical migration. A second species of *Lucicutia* was represented by a few stray individuals.

Pleuromamma indica (Fig. 15), a deep water species, is relatively abundant and uniformly distributed down to 500 m. Like *Lucicutia, Pleuromamma* was abundant at the surface in the night profile of March.

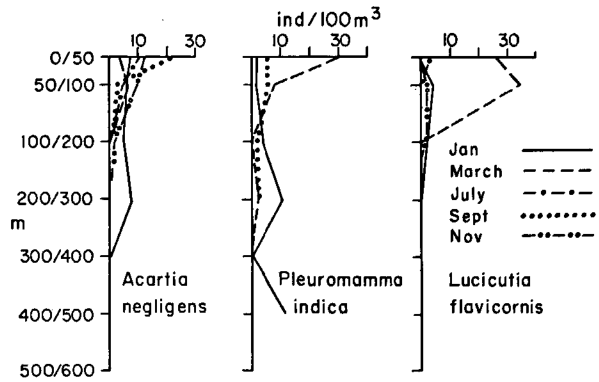


Figure 13
Vertical distribution of Acartia negligens, *station A in* 1975.

Figure 14
Vertical distribution of Lucicutia flavicornis, *station A in* 1975.

Figure 15
Vertical distribution of Pleuromamma indica, *station A in* 1975.

Euchaeta concinna, which appeared in low numbers throughout the year, had a maximum abundance of 7 individuals/10 m^3 and was found in the upper 200 m of the night profile of March.

Centropages elongatus was frequent throughout the water column, never amounting to more than 3 individuals/10 m^3. No consistent pattern could be found for the scattered appearance of *Temoropia mayumbaensis*: in January and March it reached respectively 2.5 and 3.8 individuals/10 m^3 in the uppermost 100 m. In November, it appeared only below 200 m; the maximum density of 6.6 individuals/10 m^3 was in the 200-300 m layer.

Scolecithricella auropecten, evidently a deep-water species, occurred only in the night profile of September in the 200-500 m layer. *Temora stylifera* was sampled only in November. The few stray specimens (about 1 individual/10 m^3) came probably from the littoral zone, where this species is abundant (personal observation).

Carnivores

The Candacidae family is represented in station A by *Paracandacia truncata, Candacia curta* and *Candacia tenuimana*.

P. truncata, the most important carnivorous species, was collected throughout the study, except for September. Maxima of 2.78 and 2.1 individuals/10 m^3 occurred in the upper 300 m in January and November respectively. In September, Candacidae are represented by a few specimens of *C. curta* and *C. tenuimana* replacing *P. truncata* in the same depth layer, which is its usual habitat.

Phaenna spinifera, Pontellina plumata s. *l. Haloptilus longicornis* and *H. ornatus* appear sporadically in low densities. The four species appear together in September, when *Paracandacia* is absent. The numbers of the carnivorous species are always markedly lower than those of the omnivores and very much lower than those of the herbivores (*see* Fig. 16-20). The highest counts of carnivores occurred between 50-100 m.

VERTICAL MIGRATION

The DCPE sampling programme did not take into account the vertical migration of zooplankton. It is, however, possible to discern this phenomenon by comparing the night samples (March and September) with the day samples (Fig. 6). Individual data on the different species also provided information in this connection. During the night, *Paracalanus indicus* was more abundant at the surface, while *Ctenocalanus* spp.

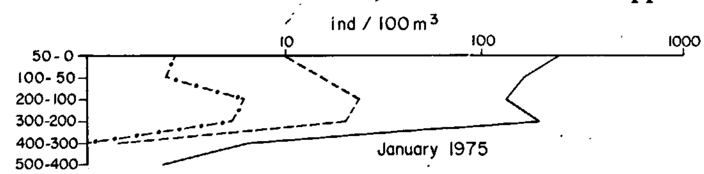


Figure 16
Vertical distribution of herbivores, omnivores and carnivores, station A, January 1975.

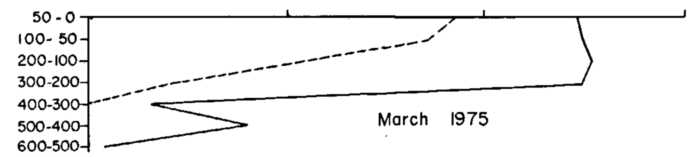


Figure 17
Vertical distribution of herbivores, omnivores and carnivores, station A, March 1975.

meters

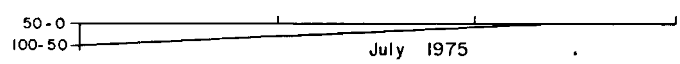


Figure 18
Vertical distribution of herbivores, omnivores and carnivores, station A, July 1975.

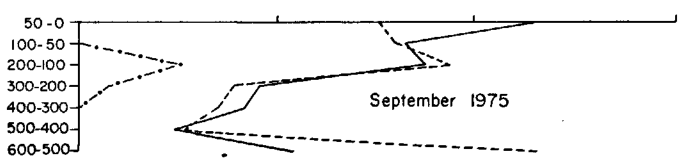


Figure 19
Vertical distribution of herbivores, omnivores and carnivores, station A, September 1975.

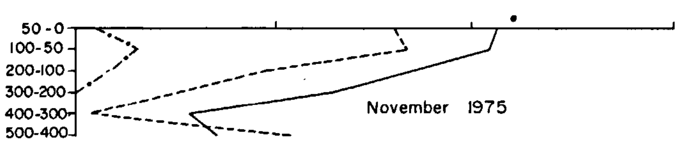


Figure 20
Vertical distribution of herbivores, omnivores and carnivores, station A, November 1975.

Omnivores ------ Herbivores ——— Carnivores -·-·-·-·

and *Clausocalanus farrani* were more concentrated in the adjacent 50-100 m layer. Deeper water species appeared in shallow layers during the night, such as *Rhincalanus nasutus* at 400-600 m and *Scolecithricella auropecten*, which was collected only at night.

A preliminary, unpublished study, carried out by the author in April 1981 at station A, showed a species-specific vertical migration pattern with a marked midnight sinking.

DISCUSSION

The data presented in the Table indicate a marked and progressive decline in the species diversity of *Calanoida* from the Arabian Sea, through the Red Sea into the Gulfs of Elat and Suez and, finally the Suez Canal. Of the 300 bathypelagic species reported by Grice and Hulseman (1967) from the Arabian Sea, only a few were found in the Northern Gulf of Elat. These include : *Calanus minor, Rhincalanus nasutus, Mecynocera clausi, Calocalanus pavo, C. styliremis, Clausocalanus farrani, C. furcatus, Temoropia mayumbaensis, Pleuromamma indica, Lucicutia flavicornis, Haloptilus longicornis, Paracandacia truncata* and *Acartia negligens*. From the 60 species reported by Delalo (1966) from the Red Sea, 19 appear also in our samples (Table). Two very abundant species in the Gulf of Elat, *Clausocalanus farrani* and *Calocalanus styliremis*, have not yet been found in the Red Sea.

According to the earlier data of Halim (1969), the diversity of the Calanoida in the Gulf of Suez is similar to that of the Gulf of Elat. However, the species composition in the former is typically neritic (Table) and only about one third of the species are common to both gulfs. The narrow and shallow Suez Canal has no true oceanic species.

According to Berdugo (1969), species diversity in the Levant basin of the Mediterranean is also poor. The Table contains additional data from Lakkis (1971) concerning the Lebanese coast. It is interesting to note that while *Ctenocalanus vanus* is reported by this author, I myself was unable to identify any *Ctenocalanus* in the large collection of Mediterranean plankton which Pr. Kimor from OLR (Haifa) kindly placed at my disposal.

The population density of Calanoida in the northern Gulf of Elat is exceedingly low (Fig. 6). Unfortunately, and mainly for methodological reasons, I was unable to make any quantitative comparisons with nearby areas.

The Calanoida of the northern Gulf of Elat are typically oceanic, despite the fact that the distance from station A to the shore is only 2 km. The population is typical of tropical Calanoida, with a seasonal variation proper to temperate seas. However, the low diversity of species remains unchanged throughout the year : 19 in July and a maximum of 25 in September. These constantly low densities and species diversity are obviously related to the extremely low productivity of the Gulf of Elat (Klinker *et al.*, 1978; Levanon-Spanier *et al.*, 1979; Winter *et al.*, 1979; Kimor, Golandsky, 1977; 1981).

There is some evidence that the seasonal changes in the occurrence and abundance of Calanoida in the Gulf of Elat are related to the amount and quality of food. The maxima of the bigger species of small filtrators *Ctenocalanus tageae, C. campaneri* and *Clausocalanus furcatus* in March, coincide with the diatom peak (Kimor, Golandsky, 1977). The group of very small filtrators, mainly *Calocalanus pavoninus, C. styliremis* and *Mecynocera clausi*, appear to succeed the seasonal peak of the coccolithophorids, which occurs in December (Winter *et al.*, 1979). Moreover, their bathymetric distribution matches fairly well that of the coccolithophorids. Such a food relationship may also affect the distribution of *Clausocalanus furcatus*, a relatively large-sized filtrator. The small-sized *Paracalanus indicus*, on the other hand, would appear to be more opportunistic : during the peak of the diatoms in March, it concentrates at the surface; but it is evenly distributed in the water column when coccolithophorids are abundant.

The carnivorous Candacidae have a generally uniform vertical distribution, which is also always characterized by very low densities.

The important omnivorous species of station A, *Acartia negligens, Lucicutia flavicornis* and *Pleuromamma indica* are also present only in low densities; it appears, however, that they each prefer different layers : *Acartia* the surface layer, *Lucicutia* the 50-100 m range and *Pleuromamma* the deeper layers.

The pattern of occurrence of *Euchaeta concinna* and of *Centropages elongatus* shows an intermediary situation between those of the omnivores and the carnivores. Comparison of the gnathobases of the mandibles of these two species with those of typical omnivores such as *Lucicutia* and *Pleuromamma* (Fig. 21-24), suggests that *Euchaeta* and *Centropages* have much deeper cutting edges than the omnivores.

As far as vertical migration is concerned, three main groups may be characterized : the small herbivores that migrate within the upper 300 m layer; *Pleuromamma*, which migrates over a wide range, i. e. from 500 m to the surface; finally, *Rhincalanus nasutus* and *Scolecithricella auropecten*, which appear in the 600 m layer at night but probably reside deeper during the day. The vertical migration pattern of *Rhincalanus nasutus* contrasts with the behaviour of this species in the central Red Sea, where Weikert (1980) reports it as remaining permanently within the oxygen minimum layer.

In order to complete the knowledge of the Calanoida of the Gulf of Elat, further research will deal with the DCPE samples collected in the southern part of the Gulf, which differs in many respects. Preliminary data obtained recently indicate that there is no individualized neritic association of Calanoida in the lagoons and nearshore waters of the Gulf; a few coastal species may, however, be expected to enrich the small list of Calanoida of the Gulf of Elat. Round-the-clock sampling, which has already begun is expected to elucidate further the patterns of vertical migration. The relative homogeneity of the water column in the northern Gulf of Elat (Klinker *et al.*, 1976) provides ideal conditions for vertical migration.

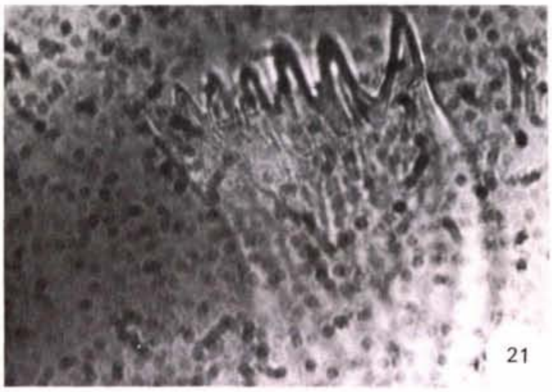


Figure 21
Gnathobasis of mandible, Lucicutia flavicornis ×630.

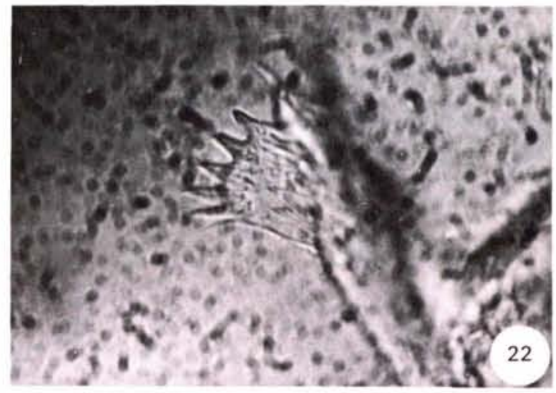


Figure 22
Gnathobasis of mandible, Pleuromamma indica ×630.

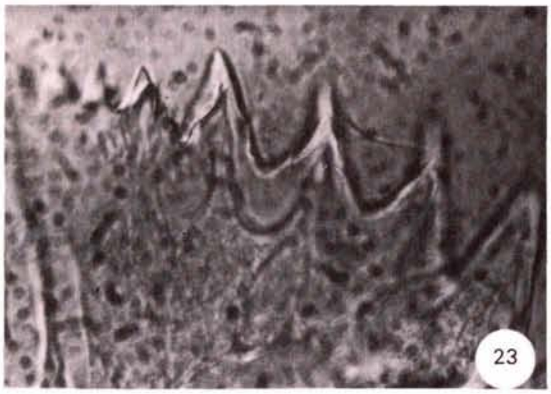


Figure 23
Gnathobasis of mandible, Centropages elongatus ×630.

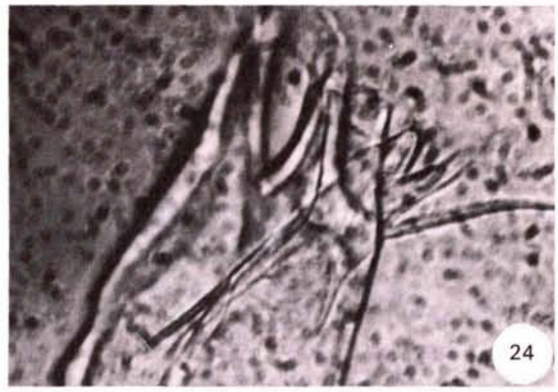


Figure 24
Gnathobasis of mandible, Euchaeta concinna ×630.

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