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SPECIES COMPOSITION, ABUNDANCE AND BIOMASS OF COPEPODA IN PLANKTON OF THE NORTHERN LEVANTINE BASIN (EASTERN MEDITERRANEAN)

BY

Z. UYSAL[1,3]) and A. A. SHMELEVA[2])
[1]) Institute of Marine Sciences, Middle East Technical University. P.O. Box 28,
Erdemli, Mersin 33731, Turkey
[2]) Institute of Biology of the Southern Seas, National Academy of Sciences of Ukraine,
2 Nakhimov Avenue, Sevastopol 335011, Ukraine

ABSTRACT

Changes in species composition, abundance and biomass of copepods were monitored weekly over the year 1998 in shelf waters of the northern Levantine Basin. A total of 192 copepod species belonging to 61 genera were identified during the course of this study. Thirty-six species are reported for the first time from the region, including three new species. Copepod abundance ranged from 215 individuals m^{-3} in early March to 2220 individuals m^{-3} in late March, whereas the biomass ranged from 4 mg m^{-3} in mid-January to 22 mg m^{-3} in mid-February. The copepod fauna was found to be most species-rich on 4 November (Margalef's Index $d = 7.4$) and least on 10 March ($d = 3.3$). The index was found low during spring and autumn with lowest levels obtained during the stratification period from September to October. The diversity was found to be highest on 18 February (Shannon-Wiener Index $H' = 2.9$) and lowest on 31 March ($H' = 1.6$). Higher index values were characteristic of the winter period. A proportional representation of the species among their populations was well established during February whereas the best situation was met on 3 March and the most unbalanced situation at the end of March. Multivariate analyses have shown the formation of distinct seasonal communities of copepod species throughout the year. The observed seasonality in community structure is suggested to be a result of wide range changes in temperature throughout the year. The dominant species observed during late winter and spring were *Oithona nana*, *Oithona* sp., *Oncaea media*, *Oncaea* sp., *Calocalanus elegans*, *Euterpina acutifrons* and *Oncaea zernovi*, respectively. *Calocalanus* sp., *C. elegans*, *Triconia dentipes*, *Oncaea* sp., *Oithona nana*, *Clausocalanus furcatus*, and *Temora stylifera* were dominant during summer, whereas *Oncaea* sp., *Calocalanus* sp., *Oithona nana*, *Clausocalanus paululus*, *C. furcatus*, *Parvocalanus* sp., and *Calocalanus elegans* dominated the autumn and early winter populations. Sharing similar species with the Indo-Pacific region gives the copepod fauna of the Levantine Basin, at least in part, a subtropical affinity.

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[3]) e-mail: uysal@ims.metu.edu.tr

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RÉSUMÉ

Les variations de la composition en espèces, de l'abondance, et de la biomasse des copépodes ont été suivies chaque semaine au cours de l'année 1998 dans les eaux du plateau continental du Bassin du Levant septentrional. Un total de 192 espèces de copépodes appartenant à 61 genres ont été identifiées au cours de cette étude. Trente six espèces ont été trouvées pour la première fois dans la région, incluant trois espèces nouvelles. L'abondance des copépodes allait de 215 individus m^{-3} au début mars à 2220 individus m^{-3} à la fin mars, tandis que la biomasse allait de 4 mg m^{-3} à la mi-janvier à 22 mg m^{-3} à la mi-février. La faune des copépodes était la plus riche en espèces au 4 novembre (indice de Margalef $d = 7{,}4$), et la plus pauvre le 10 mars ($d = 3{,}3$). L'indice était faible au printemps et en automne, avec les niveaux les plus bas durant la période de stratification de septembre à octobre. La diversité était la plus élevée le 18 février (indice de Shannon-Wiener $H' = 2{,}9$) et la plus faible le 31 mars ($H' = 1{,}6$). Des valeurs d'indice plus élevées caractérisaient la période hivernale. Une représentation proportionnelle des espèces au sein de leurs populations a été bien établie en février, avec la situation la meilleure le 3 mars, et la plus déséquilibrée à la fin mars. Des analyses multivariées ont montré la formation d'assemblages saisonniers distincts d'espèces de copépodes tout au long de l'année. La saisonnalité observée dans la structure des communautés est suggérée comme étant le résultat des variations de grande amplitude de la température au cours de l'année. Les espèces dominantes observées à la fin de l'hiver et du printemps étaient *Oithona nana, Oithona* sp., *Oncaea media*, *Oncaea* sp., *Calocalanus elegans*, *Euterpina acutifrons* et *Oncaea zernovi*, respectivement. *Calocalanus* sp., *C. elegans*, *Triconia dentipes*, *Oncaea* sp., *Oithona nana*, *Clausocalanus furcatus* et *Temora stylifera* étaient les espèces dominantes en été, tandis que *Oncaea* sp., *Calocalanus* sp., *Oithona nana*, *Clausocalanus paululus*, *C. furcatus*, *Parvocalanus* sp. et *Calocalanus elegans* dominaient dans les populations de l'automne et du début de l'hiver. Le fait de partager des espèces similaires avec la région Indo-Pacifique confère une affinité subtropicale, au moins en partie, à la faune des copépodes du Bassin du Levant.

INTRODUCTION

Information on the distribution and ecology of copepods in the eastern Mediterranean is scarce when compared to the western basin (Vives, 1978; Furnestin, 1979; Kouwenberg & Razouls, 1990; Mazzocchi & Ribera d'Alcala, 1995; Fernandez de Puelles et al., 2004, 2007, 2009) including the Adriatic (Regner, 1985; Baranovic et al., 1993) and the Aegean seas (Christou, 1998). Although over relatively short time scales, certain regions of the eastern Mediterranean, such as the coast of Libya (Zorgani, 1984), Egypt (El Maghraby, 1965; El Maghraby & Halim, 1965; Halim et al., 1967; Halim, 1976), Israel (Kimor & Wood, 1975; Pasteur et al., 1976), Lebanon (Lakkis, 1973, 1976a, b, 1990a, b, 1995a, b; Lakkis & Zeidane, 1990), the Ionian Sea (Greze, 1963), Aegean Sea (Pavlova, 1966; Moraitou-Apostolopoulou, 1972), the seas of Sirt and Levant (Delalo, 1966), the region Sicily to Cyprus (Mazzocchi et al., 1997; Siokou-Frangou et al., 1997), and the eastern Mediterranean (Kimor & Berdugo, 1967) have been studied in more detail. Being a sub-domain of the eastern Mediterranean, the northern Levantine basin, at present, can be considered as the least studied region with respect to zooplankton. Among the few studies concerned with the dynamics and composition of zooplankton in this basin are those of Akyuz (1957), Gokalp (1972), Siokou-Frangou

& Pancucci-Papadopoulou (1990), and of Pancucci-Papadopoulou et al. (1992). Similar to this study, a time series study (biweekly) based solely on species composition and dynamics of zooplankton over a year-long period in the same study area was conducted earlier by Gucu et al. (1991).

The coastal ecosystems of the easternmost part of the basin itself have changed greatly from major changes in the drainage systems, such as the construction of the Aswan High Dam in the upper Nile. Following construction, terrestrial nutrient input to the receiving Mediterranean waters was greatly blocked and resulted in a non-fertile, more saline, oligotrophic water system. Shortage of nutrients first diminished phytoplankton productivity, and hence the zooplankton as the second step in the marine food chain. Similar threats were also observed from the northern Levantine Basin. A dramatic increase in human population, intense marine traffic to/from Mersin and Iskenderun harbours, pollutants of industrial and domestic origin, and agricultural and atmospheric loads make the ecosystem of the region extremely vulnerable to the imposed environmental burdens. The most predominant anthropogenic impact is the severe eutrophication experienced in Iskenderun Bay and Mersin Bay. Eutrophication is considered to play a key role in the ecosystem, causing substantial alterations in the structure and function of the marine flora and fauna, both qualitatively and quantitatively (Uysal et al., 2003; Gucu & Bingel, 2011). Recent studies have shown an alarming expansion of the threat in all dimensions. Compared to the Black Sea, the region may be regarded as one of the least studied environments under stress. Recent studies indicate that changes are occurring rapidly in the northern Levantine basin across different trophic levels (Uysal & Mutlu, 1993; Gucu et al., 1994; Gucu & Bingel, 1995; Kideys & Gucu, 1995; Cinar, 2006, 2009; Cinar et al., 2006; Cinar & Altun, 2007). Introduction of extraneous species represents anthropogenic effects through Lessepsian migration from the Red Sea. The identification of many previously unknown non-native species in the region suggests that their invasion and acclimatization in the area is a phenomenon that necessitates further studies. Taking all these aspects into account, the present paper aims to provide a regional taxonomic description of the copepod community and to evaluate sequential changes in the abundance, biomass and community structure in relation to concurrent changes in physical properties of the basin waters over a year-long period. Moreover, it aims to highlight factors such as transport of both Atlantic and Indo-Pacific originated species via prevailing current regimes and Lessepsian immigration, which effectively altered the copepod species composition in the basin.

MATERIAL AND METHODS

Zooplankton samples for this study were collected from a single shelf station about 12 km offshore from the Institute of Marine Sciences of Middle East Technical University, located on the northeastern coast of the Mediterranean (fig. 1). This station (36°30′N 34°22′E), has a depth of 150 m. In order to collect zooplankton, vertical tows were performed using a Nansen net with a mouth opening of 0.385 m^2 and 112 μm mesh size from a fixed depth of 100 m to the surface on board R/V "Erdemli" during the year 1998. Shortly thereafter, the net materials were preserved in a 4% borax buffered formaldehyde solution in seawater. In the laboratory large and rare species were identified and counted for the whole sample using a Bogorov counting chamber. Mass species were sorted by taking duplicate sub-samples of 1 or 2 ml using a stempel pipette. Biomass estimates of copepods were made taking into account formulas provided by Gruzov & Alekseeva (1970).

In addition to net sampling, temperature and salinity were measured using a Sea-Bird model CTD probe. CTD data were processed utilizing the standard Sea-Bird data processing software.

Analytical methods

For the analysis of multispecies copepod data and the associated environmental variables both STATGRAPHICS (Univariate Statistics Package) and PRIMER (Multivariate Analyses Package, Plymouth Routines in Multivariate Ecological

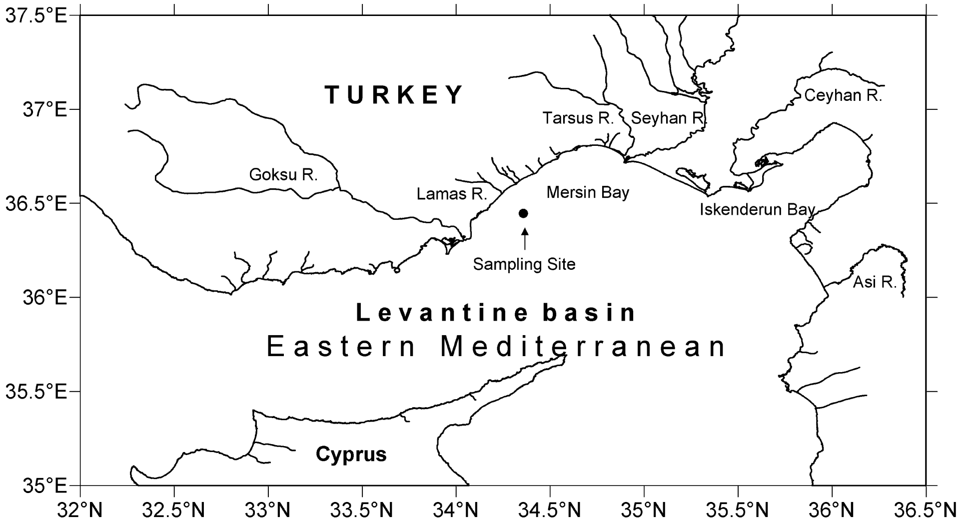

Fig. 1. Map showing the location of the zooplankton sampling station in the Turkish coastal waters of the northern Levantine Basin.

Research), a number of PC programs written at the Plymouth Marine Laboratory (Plymouth, U.K.) were used. Net zooplankton samples consisted mainly of copepods. Copepod counts required root-root transformation to adjust the weight of abundant species. To calculate similarities between samples the Bray-Curtis coefficient is used. Similarity between the j-th and k-th samples is given by:

$$S_{jk} = 100\left\{1 - \sum_i |y_{ij} - y_{ik}| / \sum_i (y_{ij} + y_{ik})\right\}$$

where y_{ij} is the score (count) for the i-th species in the j-th sample, and y_{ik} the score for the i-th species in the k-th sample.

Then the similarity matrix was formed between every pair of samples in a lower triangular array for further clustering and ordination. For a graphic representation of relations among samples, a dendrogram showing clustered groups at an arbitrary cut-off level was constructed. Among the various hierarchical sorting strategies the group-average sorting was preferred to produce a dendrogram from the similarity matrix. This joins two groups of samples together at the average level of similarity between all members of one group and all members of the other. In order to visualize sample relationships, ordination was done by delineating dendrogram classes on the corresponding ordination via Multi-Dimensional Scaling (MDS).

To identify discriminating species responsible for groupings among the community, the contribution to average dissimilarity ($\overline{\delta}$) or similarity ($\overline{S}$) from the i-th species was calculated. Higher $\overline{\delta}_i$ and high ratio of $\overline{\delta}_i/\mathrm{SD}(\delta_i)$ revealed the discriminating species. Further, contribution of the i-th species ($\overline{S}_i$) to the average similarity within a group ($\overline{S}$) were computed similarly (Anon., 1992). This indicated that the species concerned is consistently prominent in that group.

For a better description of the community structure of copepods, community diversity indices including Margalef's Index (d);

$$d = (S - 1)/\ln N$$

where S is the number of species, and N the number of individuals, and the other most commonly used diversity measure, the Shannon-Wiener Index (H') is calculated (Anon., 1992). This index incorporates both the species richness and equitability components;

$$H' = -\sum_i P_i(\ln P_i)$$

where P_i is the proportion of the i-th species of the whole sample.

To express the degree of evenness in the distribution of individuals among different species the Pielou's Evenness Index (J') is calculated as a measure for proportional representation (Equitability).

$$J' = H'(\text{observed})/H'_{\max}$$

where $H'_{\max}$ is the maximum possible diversity (ln S).

RESULTS

Changes in temperature and salinity

Pronounced seasonality in the water column temperature is a permanent feature of the basin. Surface temperature ranged between 16.0 and 29.9°C over the year, being the coldest in March and the warmest in late August (fig. 2). Surface salinity varied in the range 38.5-39.4 over the year, being the lowest in May and the highest in September. The magnitude of the change in salinity was little compared to the temperature, being less saline in spring due to increasing runoff from local rivers and most saline in September due to evaporation during summer. Increased

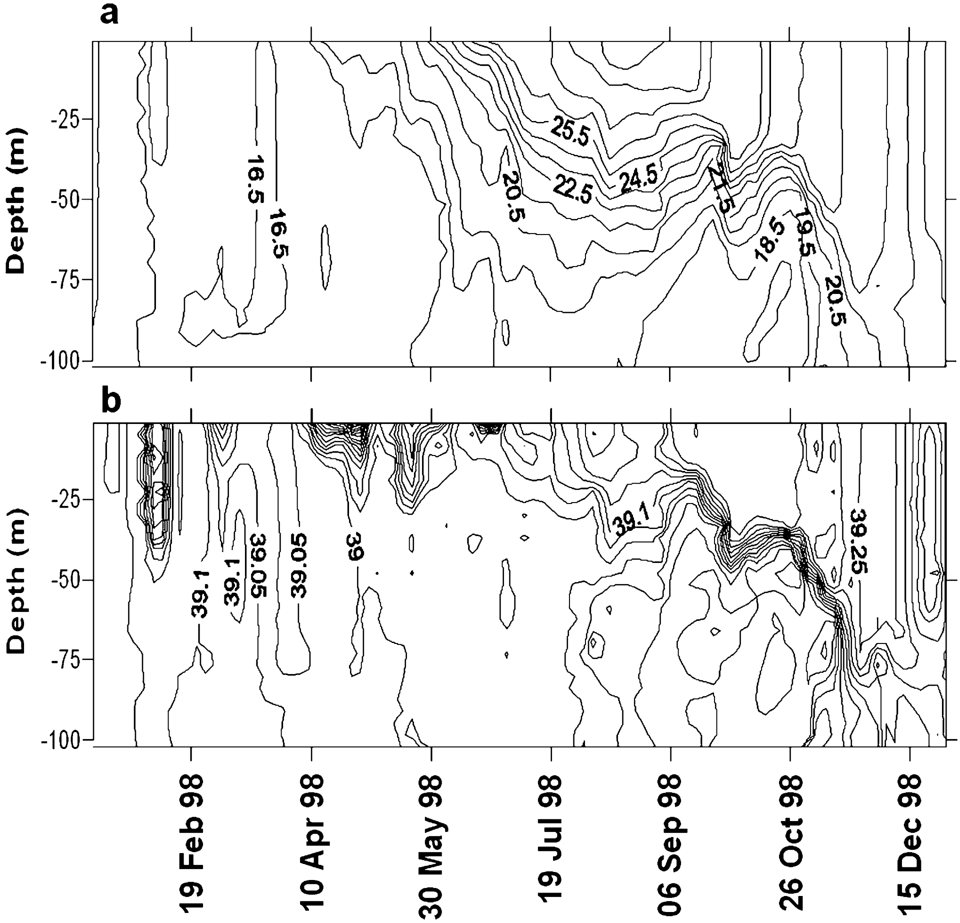

Fig. 2. Time profile of: a, temperature; and, b, salinity versus depth at the sampling site.

freshwater input from the major rivers, namely Seyhan, Ceyhan and Goksu, on a larger scale to the basin led to a gradual decrease in surface salinity with a minimum value of 38.5 observed in late May. Water column temperature and salinity sustained a homogeneous profile from surface to bottom during January, February and March as a result of convective mixing during the winter. A slight increase in temperature of near-surface waters coupled with a slight decrease in salinity due to increasing river runoff occurred during April and May. With the onset of summer, a simultaneous increase in the temperature and salinity of the surface waters was observed due to increasing radiation. Surface water temperature reached a peak value of 29.9°C in late August. A well defined surface mixed layer (the top layer where temperature and salinity and, thus, density, become uniform) developed during the autumn, which gradually deepened due to seasonal cooling and associated convective mixing. The thermocline and halocline were observed at around 20 m in September and had deepened to 35 m by October. Following further convective mixing and cooling, the water column was completely mixed by December.

Changes in copepod abundance and biomass

Significant fluctuations both in the abundance and biomass of copepods were observed throughout the year (fig. 3a, b). Copepods were most abundant during late March and early September 2221 ind. m^{-3} and 1790 ind. m^{-3}, respectively. To the lowest level was reached in early March (215 ind. m^{-3}); the annual mean level was 1057 ind. m^{-3}. Based on seasonal means, the population density fluctuated around the annual mean level during spring and summer with maximum and minimum levels of 1300 and 949 ind. m^{-3} observed in autumn and winter, respectively. Despite the lower population size observed in winter, mean biomass was found high (11.8 mg m^{-3}) in the meantime. Copepod biomass reached peak levels mid-February (22 mg m^{-3}) and in the beginning of June (16 mg m^{-3}) and dropped to a low level of 4 mg m^{-3} in mid-January. Annual mean copepod biomass was estimated as 9.6 mg m^{-3}. Seasonal mean biomass levels remained below the annual mean except in winter. A sharp increase in biomass and to a lesser extent in abundance from mid-January to mid-February was followed by a sudden decrease in both until the end of February. Compared to biomass, a more pronounced increase in abundance was observed during March.

Changes in community structure over the year

Analysis of total 34 zooplankton samples has shown the presence of 192 copepod species of which 36 are reported for the first time in the study area (marked with * in table I).

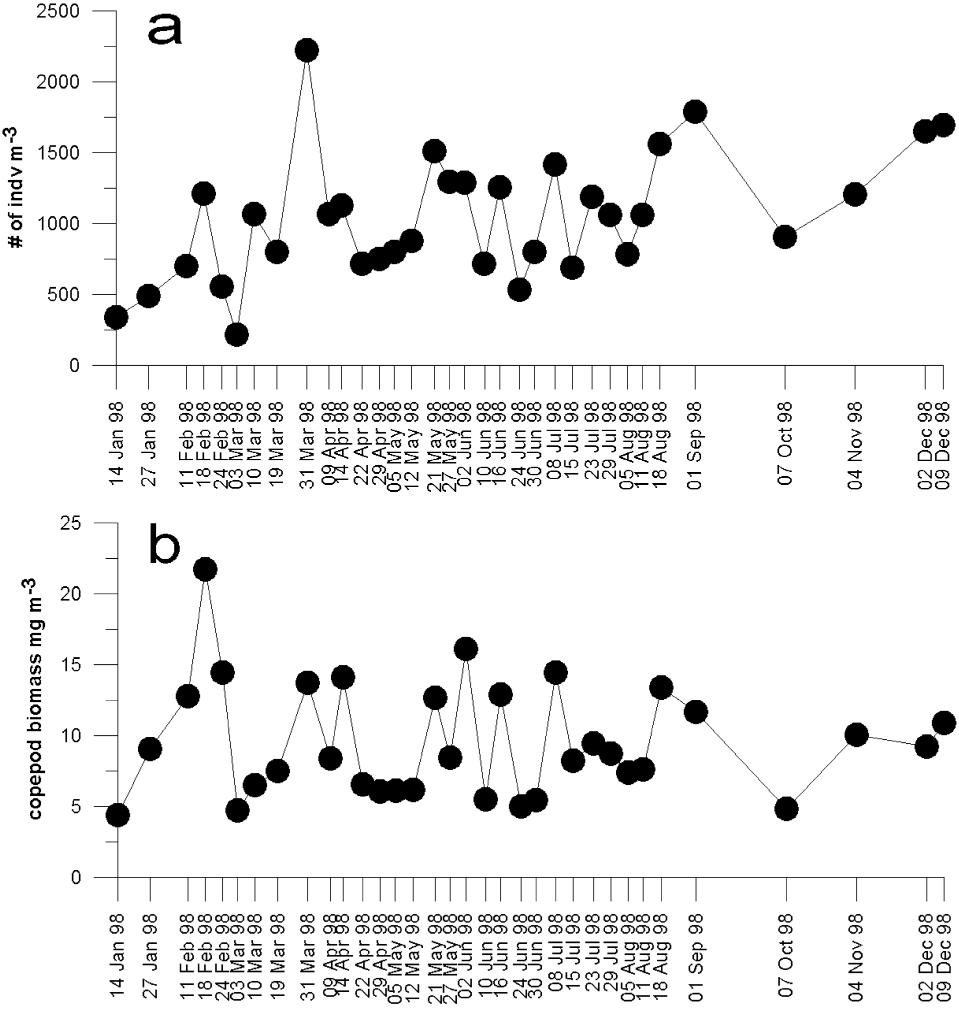

Fig. 3. Changes in: a, copepod abundance; and, b, biomass in time.

Among those 36 species reported for the first time only seven of them, including *Calanopia* sp., *Candacia* sp., *Eucalanus* sp., *Corycaeus* sp., *Spinocalanus* sp., *Scolecithricella* sp. and *Prodisco* sp., could not be identified to species level. We are confident that all these unidentified species belonging to different genera may be considered new to the region. The community consisted of 117 calanoid species with the remaining 76 species belonging to the Podoplea. With the addition of the new species, the total list of copepod species from the Levantine basin contains 233 species with several Indo-Pacific species included. This figure exceeds slightly the numbers reported earlier from the eastern Mediterranean (Lakkis, 1995b).

TABLE I

List of copepod species encountered in the northern Levantine basin shelf waters including those reported for the first time in the area (marked with *)

Calanoida	Podoplea
Acartia (*Acartiura*) *clausi* Giesbrecht, 1889	*Clytemnestra rostrata* (Brady, 1883)
Acartia (*Acartia*) *negligens* Dana, 1849	*C. scutellata* Dana, 1849
A. sp.	*Copilia mirabilis* Dana, 1852
Acrocalanus gibber Giesbrecht, 1888	*C. quadrata* Dana, 1849
A. longicornis Giesbrecht, 1888	*C.* sp.
A. sp.	Corycaeidae sp.
Aetideus giesbrechti Cleve, 1904	*Corycaeus clausi* F. Dahl, 1894
Arietellus sp.	*C. flaccus* Giesbrecht, 1891
*Calanopia americana** F. Dahl, 1894	*C. furcifer* Claus, 1863
C. elliptica (Dana, 1849)	*C. giesbrechti* F. Dahl, 1894
*C. levantina** Uysal & Shmeleva, 2004	*C. limbatus* Brady, 1883
*C. metu** Uysal & Shmeleva, 2004	*C.* sp.*
C. sp.*	*C. speciosus* Dana, 1849
Calocalanus adriaticus Shmeleva, 1965	*C. typicus* Krøyer, 1849
C. atlanticus Shmeleva, 1975	*Cymbasoma* sp.
C. contractus Farran, 1926	*Euterpina acutifrons* (Dana, 1847)
C. elegans Shmeleva, 1965	*E.* sp.
C. elongatus Shmeleva, 1968	*Farranula gracilis* (Dana, 1849)
C. gracilis Tanaka, 1956	*F. rostrata* (Claus, 1863)
*C. gresei** Shmeleva, 1973	*F.* sp.
*C. kristalli** Shmeleva, 1968	*Lubbockia aculeata* Giesbrecht, 1891
*C. lomonosovi** Shmeleva, 1975	*L.* sp.
*C. longisetosus** Shmeleva, 1965	*L. squillimana* Claus, 1863
*C. minor** Shmeleva, 1980	*Macrosetella gracilis* (Dana, 1847)
C. neptunus Shmeleva, 1965	*Microsetella norvegica** (Boeck, 1865)
C. ovalis Shmeleva, 1965	*M. rosea* (Dana, 1848)
C. pavo (Dana, 1852)	*Monothula subtilis* (Giesbrecht, 1893)
C. pavoninus Farran, 1936	*Oithona atlantica* Farran, 1908
*C. plumatus** Shmeleva, 1965	*O. attenuata** Farran, 1913
C. plumulosus (Claus, 1863)	*O. colcarva* Bowman, 1975
C. sp.	*O. decipiens* Farran, 1913
C. styliremis Giesbrecht, 1888	*O. fallax** Farran, 1913
*C. vivesei** Shmeleva, 1979	*O. hamata** Rosendorn, 1917
Candacia ethiopica (Dana, 1849)	*O. linearis* Giesbrecht, 1891
C. bispinosa (Claus, 1863)	*O. nana* Giesbrecht, 1893
C. longimana (Claus, 1863)	*O. plumifera* Baird, 1843
*C. parasimplex** Brodsky, 1962	*O. setigera* Dana, 1852
C. simplex (Giesbrecht, 1889)	*O. similis* Claus, 1866
C. sp.*	*O. simplex* Farran, 1913
C. truncata (Dana, 1849)	*O.* sp.
Centropages bradyi Wheeler, 1900	*O. tenuis* Rosendorn, 1917
*C. caribbeanensis** Park, 1970	*O. vivida* Farran, 1913
C. furcatus (Dana, 1849)	*Oncaea atlantica** Shmeleva, 1967
C. kroyeri Giesbrecht, 1893	*O. bathyalis* Shmeleva, 1968

TABLE I
(Continued)

Calanoida	Podoplea
C. ponticus Karavaev, 1895	*O. media* Giesbrecht, 1891
C. sp.	*O. mediterranea* (Claus, 1863)
C. violaceus (Claus, 1863)	*O. minima* Shmeleva, 1968
Chiridius sp.	*O. minuta* Giesbrecht, 1893
Clausocalanus arcuicornis (Dana, 1849)	*O. obscura** Farran, 1908
C. furcatus (Brady, 1883)	*O. ornata* Giesbrecht, 1891
*C. jobei** Frost & Fleminger, 1968	*O. ovalis* Shmeleva, 1966
C. lividus Frost & Fleminger, 1968	*O. prendeli* Shmeleva, 1966
C. minor Sewell, 1929	*O.* sp.
C. paululus Farran, 1926	*O. tenella* G. O. Sars, 1916
*C. pergens** Farran, 1926	*O. tregoubovi* Shmeleva, 1968
C. sp.	*O. venusta* Philippi, 1843
*Ctenocalanus citer** Heron & Bowman, 1971	*O. venusta venella* Farran, 1929
C. sp.	*O. vodjanitskii* Shmeleva & Delalo, 1965
*Delibus nudus** (Sewell, 1929)	*O. zernovi* Shmeleva, 1966
Eucalanus sp.*	*Pachos punctatum* (Claus, 1863)
Euchaeta marina (Prestandrea, 1833)	*Paroithona parvula* Farran, 1908
E. sp.	*P.* sp.
Euchirella sp.	*Pontoeciella abyssicola* (T. Scott, 1893)
Haloptilus acutifrons (Giesbrecht, 1893)	*Sapphirina angusta* Dana, 1849
H. longicornis (Claus, 1863)	*S. gemma* Dana, 1852
H. sp.	*S. ovatolanceolata* Dana, 1849
Heterorhabdus papilliger (Claus, 1863)	*S.* sp.
H. sp.	*Spinoncaea ivlevi* (Shmeleva, 1966)
Lucicutia clausi (Giesbrecht, 1889)	*Triconia conifera* (Giesbrecht, 1891)
L. flavicornis (Claus, 1863)	*T. dentipes* (Giesbrecht, 1891)
*L. gaussae** Grice, 1963	*T. similis* G. O. Sars, 1918
L. gemina Farran, 1926	*Vettoria granulosa* (Giesbrecht, 1891)
L. longicornis (Giesbrecht, 1889)	*V. parva* (Farran, 1936)
L. ovalis (Giesbrecht, 1889)	*V.* sp.
L. sp.	Unidentified cyclopoid copepod
Mecynocera clausi Thompson I. C., 1888	Unidentified harpacticoid copepod
Mesocalanus tenuicornis (Dana, 1849)	
Nannocalanus minor (Claus, 1863)	
Neocalanus gracilis (Dana, 1852)	
Paracalanus aculeatus Giesbrecht, 1888	
*P. denudatus** Sewell, 1929	
P. dubia Sewell, 1912	
P. nanus Sars G. O., 1925	
P. parvus (Claus, 1863)	
P. sp.	
Paradisco gracilis K. T. Gordeeva, 1975	
*P. mediterraneus** (K. T. Gordeeva, 1974)	
P. sp.	
Paraeuchaeta acuta (Giesbrecht, 1893)	

TABLE I
(Continued)

Calanoida	Podoplea
P. hebes Giesbrecht, 1888	
Pareucalanus attenuatus (Dana, 1849)	
*P. sewelli** (Fleminger, 1973)	
Parvocalanus crassirostris (F. Dahl, 1894)	
*P. latus** Andronov, 1972	
P. sp.	
Phaenna sp.	
P. spinifera Claus, 1863	
Pleuromamma abdominalis (Lubbock, 1856)	
P. gracilis (Claus, 1863)	
P. sp.	
Pontellidae sp.	
Pontellina plumata (Dana, 1849)	
P. sp.	
Prodisco sp.*	
*Scaphocalanus emine** Uysal & Shmeleva, 2002	
Scolecithricella minor (Brady, 1883)	
S. sp.*	
Scolecithrix bradyi Giesbrecht, 1888	
S. sp.	
Scolecitrichidae sp.	
Spinocalanus sp.*	
*Subeucalanus crassus** (Giesbrecht, 1888)	
S. monachus (Giesbrecht, 1888)	
Temora stylifera (Dana, 1849)	
Unidentified calanoid copepod	
Unidentified copepod	

As illustrated in fig. 4a, the copepod fauna of the basin was found to be the most species rich on 4 November (Margalef's species richness index $d = 7.4$) and least on 10 March ($d = 3.3$). Lower index values were characteristic of the spring period. Based on seasonal averages, the fauna was found most species rich during the autumn period. In addition to the values of d, the Shannon-Wiener Index H', which incorporates both the species richness and equitability components, was calculated for each sampling event (fig. 4b). Based on H' values, diversity was found to be highest on 18 February ($H' = 2.9$) and lowest on 31 March ($H' = 1.6$). Higher index values were characteristic of the winter period. Proportional representation (Pielou's Evenness Index) of species among the population was well established during February, with the best situation occurring on 3 March and the most unbalanced representation at the end of March (fig. 4c).

Multivariate analyses (two-dimensional non-metric MDS) have shown formations of distinct seasonal copepod assemblages throughout the year. Fig. 5 displays

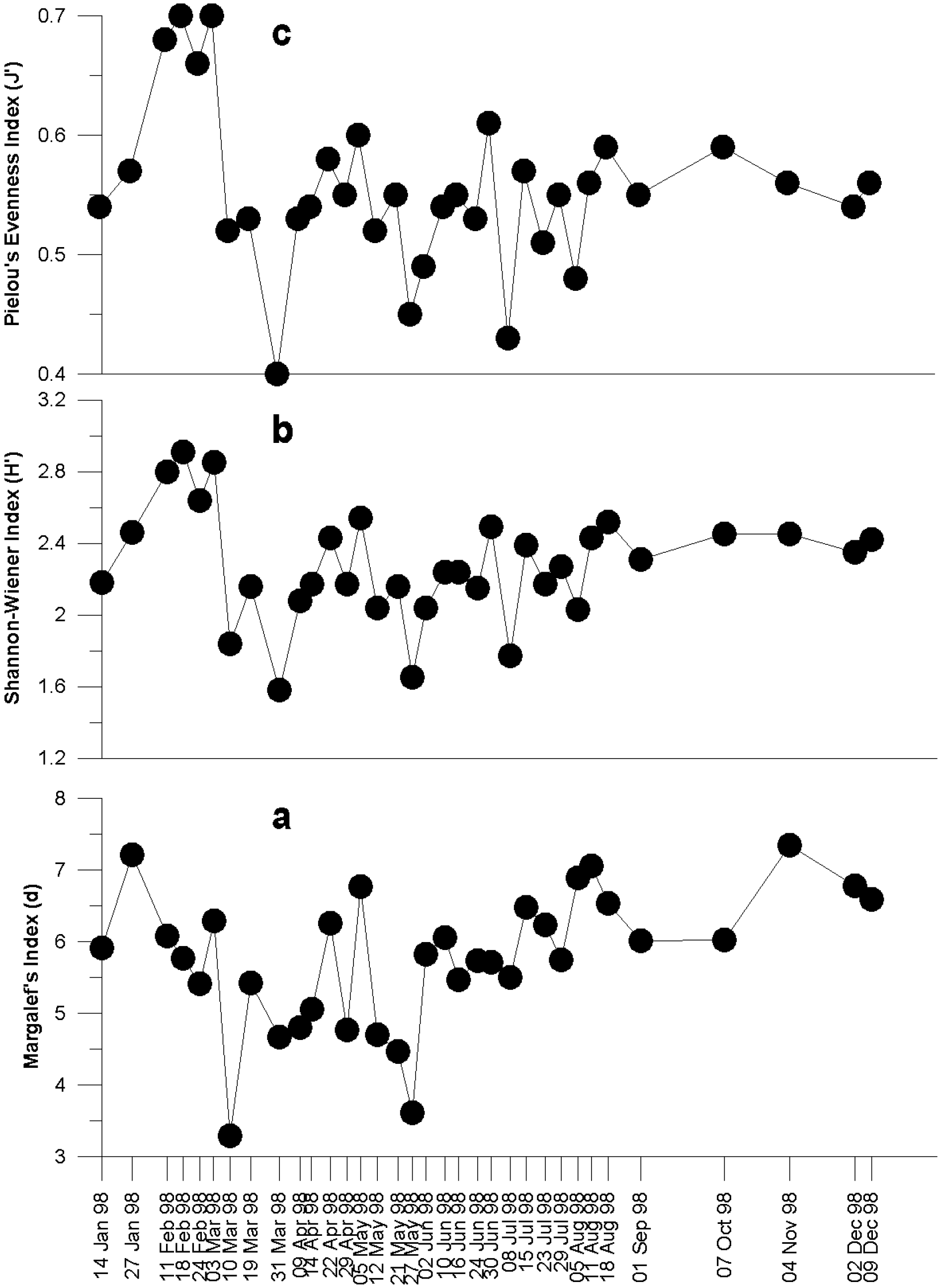

Fig. 4. Changes in levels of community diversity indices over time.

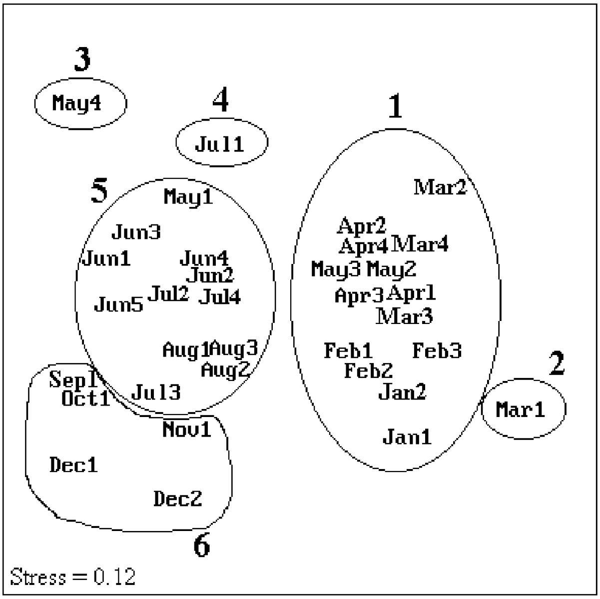

Fig. 5. Two-dimensional non-metric Multi-Dimensional Scaling (MDS) ordination of 34 zooplankton samples.

two-dimensional non-metric MDS plots of copepod assemblages forming six distinct clusters at an arbitrary similarity level (based on Bray-Curtis similarity) of 60% (fig. 6). The largest group (group 1) represents mainly the winter and spring populations and the second largest group (group 5) contains mainly the summer population. Group 6 represents the autumn and early winter populations. Temperature other than salinity was the main factor determining seasonality in copepod assemblages (fig. 7a, b).

Species clustering or ordination is generally less informative than methods which highlight species that contribute to patterns of sample clustering or ordination. Discriminating species for the samplings and within the groups responsible for such patchy distribution are given in tables II and III. Six groups as displayed in fig. 5 are found to determine the major discriminating species of such clusters.

Higher species contribution (S_i) and ratio $\{S_i/\mathrm{SD}(S_i)\}$ highlight species consistently prominent in a given group. Table II indicates that unidentified calanoid copepod, unidentified copepod and *Oithona* sp., with higher ratios, contributed much to the similarity in group 1. Similarly, two of these species, unidentified calanoid and unidentified copepod, also contributed much to the central group 6. In group 5 unidentified copepod, *Calocalanus* sp. and *Oncaea* sp. were consistently prominent.

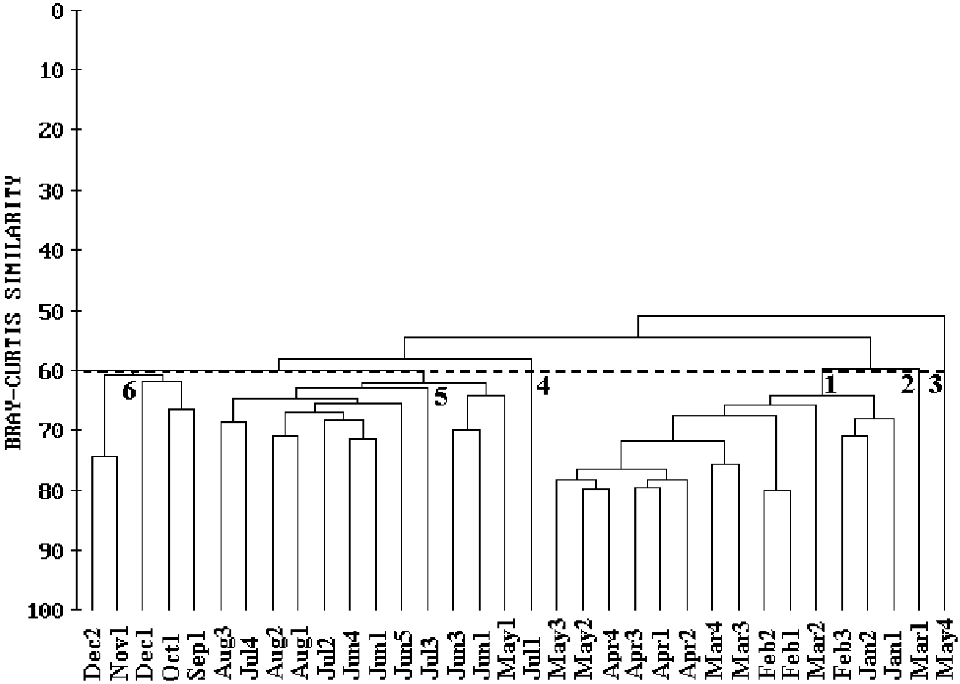

Fig. 6. Dendogram showing classification of 34 samples with six major groups distinguished at an arbitrary similarity level of 60%.

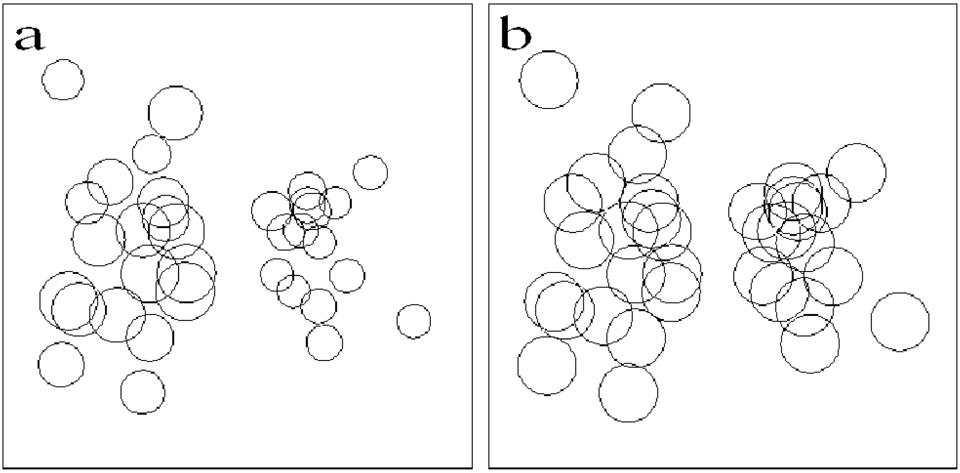

Fig. 7. MDS of 34 samples with values of: a, surface temperature ranging from a minimum of 16°C in March to a maximum of 29.9°C in late August; b, surface salinity ranging between minimum 38.5 in May and maximum 39.4 in September superimposed for each sampling event.

TABLE II

Species contributions ($\overline{S}_i$) to average similarities ($\overline{S}$) within groups

Group	Species	$\overline{S}_i$	SD(S_i)	$\overline{S}_i$/SD(S_i)	$\sum \overline{S}_i\%$
68.5*	Calanoid copepod	5.3	0.6	9.5	7.7
	Unidentified copepod	3.5	1.8	2.0	12.9
1	*Oithona* sp.	3.5	1.6	2.2	18.0
	Oncaea sp.	3.4	0.7	4.8	22.9
	Oncaea media	2.6	0.4	6.4	26.7
64.2*	Unidentified copepod	4.8	0.4	13.4	7.5
	Calocalanus sp.	3.4	0.7	5.1	12.8
5	*Oncaea* sp.	3.3	1.0	3.3	17.9
	Oithona nana	2.3	2.0	1.1	21.5
	Clausocalanus furcatus	2.2	0.6	3.9	24.9
62.9*	Unidentified copepod	4.5	0.3	13.0	13.4
	Calanoid copepod	3.9	0.3	13.9	12.8
6	*Oncaea* sp.	3.8	0.2	20.6	19.4
	Calocalanus sp.	3.7	0.4	8.2	25.3
	Oithona nana	2.6	1.1	2.4	29.4

* Average similarity ($\overline{S}$) within the group.

Species discriminating groups are given in table III. Group 1 separated from the nearby group 5 by lacking copepod species *Euterpina acutifrons*, *Calocalanus* sp. and the unidentified calanoid copepod.

DISCUSSION

A total of 192 copepod species belonging to 61 genera were identified during the course of this study. In a similar study prior to this one (November 1984 to November 1985), a total of 55 copepod species belonging to 34 genera were reported from the same area (Gucu et al., 1991). Even fewer species, from as few as 40 taxa, have been reported from the entire eastern Mediterranean during the summer of 1965 (Kimor & Wood, 1975). Calanoid copepods, the majority of which comprise open sea forms, have been observed to dominate the copepod fauna during this period. The results presented here from 1998 yield a total of 116 calanoid species (belonging to 40 genera) and 76 podopleid species (belonging to 21 genera). Among these, 36 species are reported for the first time from this region including three new species. With the addition of these three new species, namely *Scaphocalanus emine* Uysal & Shmeleva, 2002, *Calanopia metu* Uysal & Shmeleva, 2004 and *C. levantina* Uysal & Shmeleva, 2004, at present the total list of copepod species from the Levantine basin contains 233 species with several Indo-Pacific forms included (Berdugo, 1968; Casanova, 1973; Lakkis,

TABLE III

Species contribution ($\overline{\delta}_i$) to total average dissimilarity ($\overline{\delta} = \sum \overline{\delta}_i$) between groups

Group	Species	$\overline{\delta}_i$	SD(δ_i)	$\overline{\delta}_i$/SD(δ_i)	$\sum \overline{\delta}_i$%
40.2*	Calanoid copepod	3.0	0.4	7.9	7.4
	Unidentified copepod	2.5	1.1	2.3	13.5
1 and 2	*Calocalanus elegans*	1.3	0.3	4.3	16.8
	Oncaea zernovi	1.3	0.6	2.0	20.1
	Corycaeus sp.	1.1	0.7	1.7	22.9
52.4*	Calanoid copepod	3.1	0.4	7.7	6.0
	Oncaea media	1.6	0.3	6.1	9.1
1 and 3	*Discoidea* sp.	1.6	0.1	11.9	12.1
	Unidentified copepod	1.5	1.0	1.6	15.0
	Oncaea ivlevi	1.4	0.1	11.9	17.8
45.5*	*Euterpina acutifrons*	1.5	0.8	1.8	3.2
	Unidentified copepod	1.5	0.8	1.8	6.4
1 and 4	*Parvocalanus latus*	1.4	0.1	14.7	9.4
	Oithona nana	1.3	0.4	3.4	12.4
	Oncaea ivlevi	1.2	0.1	14.7	15.0
43.5*	*Euterpina acutifrons*	1.3	0.8	1.6	2.9
	Calocalanus sp.	1.2	0.7	1.8	5.8
1 and 5	Calanoid copepod	1.2	0.8	1.5	8.7
	Oithona nana	1.0	0.5	2.0	11.1
	Oncaea ivlevi	1.0	0.4	2.8	13.5
51.3*	Unidentified copepod	2.8	0.3	10.9	5.5
	Calocalanus sp.	2.1	0.4	5.6	9.7
2 and 5	Calanoid copepod	1.5	0.8	1.9	12.5
	Oithona nana	1.2	0.5	2.5	15.0
	Calocalanus elegans	1.2	0.2	5.0	17.3
43.4*	Calanoid copepod	1.5	0.8	1.9	3.6
	Clausocalanus furcatus	1.5	0.4	4.2	7.1
3 and 5	*Triconia dentipes*	1.2	0.2	6.8	10.0
	Clausocalanus paululus	1.2	0.4	3.3	12.8
	Oncaea media	1.1	0.5	1.9	15.2
40.0*	*Oithona nana*	1.6	1.0	1.6	4.1
	Parvocalanus latus	1.1	0.3	3.6	6.9
4 and 5	*Oncaea tregoubovi*	1.1	0.1	21.7	9.7
	Clausocalanus sp.	1.0	0.4	2.6	12.3
	Unidentified copepod	1.0	0.2	4.6	14.7
47.9*	*Calocalanus* sp.	1.5	0.6	2.4	3.1
	Euterpina acutifrons	1.3	0.7	1.7	5.8
1 and 6	*Oithona* sp.	1.0	0.7	1.5	7.9
	Parvocalanus sp.	1.0	0.5	1.7	9.9
	Oncaea zernovi	0.9	0.6	1.6	11.9

TABLE III
(Continued)

Group	Species	$\bar{\delta}_i$	SD(δ_i)	$\bar{\delta}_i$/SD(δ_i)	$\sum\bar{\delta}_i$%
55.2*	Unidentified copepod	2.8	0.2	14.2	5.1
	Calanoid copepod	2.5	0.3	7.1	9.6
2 and 6	*Calocalanus* sp.	2.3	0.3	8.0	13.8
	Calocalanus elegans	1.1	0.1	19.8	15.9
	Calocalanus pavoninus	1.1	0.1	8.7	17.8
51.3*	Calanoid copepod	2.6	0.4	7.0	5.1
	Clausocalanus furcatus	1.5	0.6	2.4	8.1
3 and 6	*Parvocalanus* sp.	1.4	0.5	2.7	10.9
	Clausocalanus paululus	1.4	0.2	8.4	13.6
	Oncaea media	1.1	0.3	4.8	15.8
46.3*	*Oithona nana*	1.7	0.7	2.6	3.7
	Parvocalanus sp.	1.2	0.4	2.7	6.3
4 and 6	*Oncaea zernovi*	1.1	0.5	2.0	8.7
	Parvocalanus latus	1.0	0.4	2.6	11.0
	Oncaea tregoubovi	1.0	0.1	20.4	13.2
40.0*	Calanoid copepod	1.0	0.7	1.4	2.5
	Oncaea zernovi	0.9	0.7	1.2	4.7
5 and 6	*Oithona nana*	0.9	0.7	1.3	6.9
	Oithona sp.	0.9	0.6	1.3	9.0
	Microsetella rosea	0.8	0.5	1.7	11.0

* Average dissimilarity ($\bar{\delta}$) between the groups.

1973, 1976a, b, 1990a, 1995a; Shmeleva, 1973; Kovalev & Shmeleva, 1982). These figures exceed slightly those reported from the neighbouring Lebanese waters. Prior to this study, 173 copepod species, 109 of which were calanoids, have been reported from the Lebanese waters during the period 1970-1988 (Lakkis, 1990a). The copepod fauna in Lebanese waters included 55 tropical forms as well as 15 Lessepsian immigrants (Lakkis et al., 2002). The neritic subsuperficial Mediterranean species have been found to dominate the population along the coast of Lebanon during this period. The invasion of the basin waters with species of Indo-Pacific origin is a common observation from all of the above-mentioned studies. Invasion of the basin waters with Indo-Pacific species confirms by biological data the fact that the Red Sea waters may occasionally extend outmost to the northeastern parts of the Mediterranean. Sharing the same species of Indo-Pacific origin gives the copepod fauna of the Levantine basin a subtropical affinity.

Among the copepod species (except those not identified at genus level) *Oncaea* sp., *Oithona* sp., *Oithona nana*, *Calocalanus* sp., *Euterpina acutifrons*, *Oncaea zernovi*, *Temora stylifera*, *Clausocalanus furcatus*, *Oncaea media* and *Clau-*

socalanus paululus were found most numerous. Similarly, *Euterpina acutifrons* and *Clausocalanus furcatus* have been found most numerous during the 1984-1985 period (Gucu et al., 1991). The dominant copepod species observed during late winter and spring were *Oithona nana*, *Oithona* sp., *Oncaea media*, *Oncaea* sp., *Calocalanus elegans*, *Euterpina acutifrons* and *Oncaea zernovi*, respectively. *Calocalanus* sp., *C. elegans*, *Triconia dentipes*, *Oncaea* sp., *Oithona nana*, *Clausocalanus furcatus*, and *Temora stylifera* were the dominant species during summer and *Oncaea* sp., *Calocalanus* sp., *Oithona nana*, *Clausocalanus paululus*, *C. furcatus*, *Parvocalanus* sp., and *Calocalanus elegans* dominated the autumn and early winter populations. Although samples were collected from epipelagic surface layers, some of the species captured were characteristic for mesopelagic zones. Mesopelagic species, namely *Chiridius* sp., *Paraeuchaeta acuta*, *Euchirella* sp., *Neocalanus gracilis*, *Pleuromamma abdominalis*, *P. gracilis* and *Subeucalanus monachus*, were observed in samples collected during the winter months when the water column was subject to convective mixing.

Among the total of 19 species of Acartiidae present in the Ponto-Mediterranean province (Belmonte & Potenza, 2001) only three of these were identified during this study. The presence of *Acartia clausi* and *Acartia danae* was reported earlier from this region (Gucu et al., 1991). *Acartia clausi* has been reported from the Indian, Atlantic and Pacific oceans (Carli & Crisafi, 1983) as well as from the eastern Mediterranean (El Maghraby & Halim, 1965; Lakkis, 1976b; Pasteur et al., 1976). *Acartia negligens* has been reported both from the Lebanese coast (Lakkis, 1994) and the Iskenderun Bay (Toklu, 2006). In the area between Fethiye Bay and Iskenderun Bay five more species of Acartiidae were also recorded (Uysal et al., 2002). Among these, *Acartia discaudata*, present in the western Mediterranean, was also cited from the shallow coastal waters of Lebanon (Lakkis, 1990a). *Acartia italica* was recorded earlier from various regions of the Ponto-Mediterranean Province (Brian, 1927; Potemkina, 1940; Alcaraz et al., 1988) including the Lebanese coast (Lakkis & Zeidane, 1990). *Acartia tonsa* has been reported earlier from the northern area of the Ponto-Mediterranean Province (Belmonte et al., 1994) from the south at Cagliari (Zagami & Guglielmo, 1990) and also from the Sea of Marmara (Hajderi, 1995). This species has been reported from the Ponto-Mediterranean Province only recently (Gaudy & Vinas, 1985). *Paracartia latisetosa* is common in the entire Ponto-Mediterranean Province (Belmonte & Potenza, 2001) and regarded as strictly coastal. Finally, the fifth Acartiidae species, *Pteriacartia josephinae*, has been recorded in the western Mediterranean around the Italian coasts and along the Lebanese coasts (Lakkis & Zeidane, 1990).

Acrocalanus gibber has been cited to exist in the Alboran Sea, Balearic Islands and the Black Sea (Razouls et al., 2005-2010). Although the presence of *Acrocalanus longicornis* in the Mediterranean was questioned by Razouls et al. (2005-2010), its presence in the Red Sea was confirmed by El-Serehy & Abdel-Rahman (2004). Five species of the genus *Calanopia*, which consists predominantly of Indo-Pacific species (Bowman, 1957), were recorded during this study. Among these *Calanopia metu* and *C. levantina* are new, both to science and to the world oceans (Uysal & Shmeleva, 2004). *Calanopia metu* was abundant in the samples and the presence of all developmental stages, from nauplii to adult, of individuals of the genus *Calanopia* indicates their suitability for the Levantine basin shelf waters. *Calanopia metu* was also observed in the Marmara (Unal et al., 2000) and Aegean seas but remains absent from the Indian Ocean, as recently confirmed by Shmeleva (unpubl. data). In addition, Indo-Pacific individuals such as *Parvocalanus latus*, *P. elegans* and *Centropages furcatus* were also recorded from the Sea of Marmara (Unal et al., 2000). The observed high abundance of *C. furcatus* and *Calanopia* species which are common in the plankton of the Indian Ocean (Fleminger & Hulsemann, 1973) is interesting from a faunistic view, because these species of the Indo-Pacific group are recorded for the first time in the Levantine basin along the Turkish coast. These species are numerous and reproduce in the Levantine waters. *Centropages furcatus* was recorded in Levantine coastal waters on a yearly basis, with peak numbers occurring in the autumn (70 individuals m^{-2}) and a reduced abundance in winter (50 individuals m^{-2}). Near the Lebanese coast this species was found from April until December where it was numerous only in the warmer months (Lakkis 1990a, 1995b).

Calanopia elliptica, which is of Indo-Pacific origin, is present in the Levantine basin (Lakkis, 1973, 1976b), but lacks from the western part of the Mediterranean and the Atlantic ocean. The presence of *Calanopia americana* in the samples raises questions about their introduction to the basin whilst it is absent from rest of the areas in the Mediterranean, as well as from the Black Sea and the Red Sea. Shipment via tankers' ballast waters may be one of the transport mechanisms for this species. The species distribution of *Calanopia* along the Turkish Mediterranean coast shows them to be coastal species. Berdugo (1968) and Lakkis (1976b) also mentioned the presence of *Calanopia media* and *C. elliptica* along the coastal waters near Port Said and Haifa.

Although not observed during this study, several species of Indo-Pacific origin were recorded also in the area between the Fethiye and Iskenderun bays. Such species include *Calanopia biloba*, *C. media*, *C. minor*, *Euchaeta concinna*, *Eucalanus crassus*, *E. subcrassus*, and *Parvocalanus elegans* (cf. Uysal et al., 2002). Among these species *Parvocalanus latus*, *P. elegans*, *Calanopia biloba* and *C. minor* have not previously been obtained from the entire Mediterranean basin. *Parvocalanus crassirostris* was numerous, both in the Levantine basin and in the Red Sea (Delalo, 1966), while *P. latus* and *P. elegans* were recorded in small numbers from the Levantine waters. Some individuals belonging to the genus *Scolecithricella* were not identified on a species level, but in our view they should also belong to the Indo-Pacific group.

Most of the total of 20 *Calocalanus* species observed in the study area were also cited from different regions of the Mediterranean. Some species, such as *Calocalanus atlanticus*, *C. elongatus*, *C. gracilis*, *C. kristalli*, *C. lomonosovi*, *C. longisetosus*, *C. minor*, *C. ovalis* and *C. vivesei*, were present only in a few basins (Razouls et al., 2005-2010). In addition to this study *C. neptunus* was also cited from Izmir Bay (Turkish Aegean coast) by Ozel & Aker (2001). Among the *Candacia* species observed during this study (6 species) *C. truncata* was recorded only from the southeast and Malta regions of the Mediterranean. Additionally, *C. parasimplex* was recorded for the first time from the Levantine Basin (this study) as well as from Izmir Bay (Ozel & Aker, 2001).

Ctenocalanus citer is common in Antarctic epiplankton and it reaches a density of about 2400 individuals m^{-2} in the spring (Kaczmaruk, 1983; Zmijeiwcka, 1983; Hopkins, 1987; Tucker & Burton, 1990; Schnack-Schiel & Mizdalski, 1994). *Ctenocalanus citer*, originally described by Heron & Bowman (1971) from the Antarctic waters, was not previously reported to exist in the Mediterranean (Lakkis, 1976b; Kovalev & Shmeleva, 1982) but is common here as well. For example, lately *C. citer* has been found in samples collected on board R/V "Prof. Vodyanitskiy" during November-December 1987 from the Iberian and Ionian Seas, and recently in the eastern part of the Sea of Marmara (Unal et al., 2000). Perhaps, this species was confused with very similar species, such as *Ctenocalanus vanus*, which was not found by Shmeleva in the western and central regions of the Mediterranean. The present records from the Mediterranean and Antarctic waters demonstrate that the geographical range of *C. citer* extends from the colder Antarctic region to the much warmer Mediterranean (Uysal et al., 2002).

Individuals of the genus *Oithona* (15 species) and *Oncaea* (17 species) recorded during this study contained highly diverse species. Among these species *Oithona attenuata*, *O. fallax*, *O. hamata*, *Oncaea atlantica*, and *O. obscura* were recorded for the first time from the study area.

Overall, the copepod species currently inhabiting the region are interesting in their faunal composition as well as in their distribution, which may be regulated via several mechanisms. On a wider scale, transport of both Atlantic and Indo-Pacific originating species to the Mediterranean is assured via two passages, namely Gibraltar in the western and the Suez Canal located in the southeastern corner of the Mediterranean. Indo-Pacific species were able to penetrate into the eastern Mediterranean waters only after the opening of the Suez Canal in 1869. Following the opening of the canal, there existed a remarkable water exchange through the Suez Canal between the Red Sea and the Mediterranean. Previous investigations

(Bogdanova, 1982) have shown that through the Suez Canal the flow of the Red Sea water mass towards the Mediterranean is two-fold greater than in the opposite direction. Indo-Pacific species had to encounter temperature and salinity extremes on their way to the eastern Mediterranean through the Red Sea and the Suez Canal. For example, surface temperature and salinity ranged between 16-29.9°C and 38.5-39.4, respectively, in the sampling area. However, the surface temperature for the Red Sea varies in a narrower range, between a minimum of 20.3°C in March and a maximum of 29°C in August (data obtained from NOAA sea surface temperature data averaged over the years 1992-1996 for Eilat, Red Sea). The surface temperature ranges from 17.1°C in February to 26.2°C in August at the Red Sea exit of the Suez Canal. In the central region of the canal it may reach 29°C on the surface in September. Maximum salinity ranging from 45 to 54 was observed in the central part of the canal, located in the lakes. Then, salinity sharply decreases to 28-30. The flow, which gathers a large proportion of high salinity waters, drains into the eastern Mediterranean. The denser water mass moves along the bottom layer of the shelf while sinking in the slope until it reaches the middle high salinity layer (Bogdanova, 1982). Invasion of the Levantine basin with species of Indo-Pacific origin confirms by biological data the fact that the Red Sea waters may penetrate farther north towards the Turkish coast. The distribution of these species highlights the possible boundaries of such penetration. The differences are even more striking when the coldest and less saline waters of the Antarctic are compared with the much warmer and saline waters of the eastern Mediterranean. The presence of *C. citer* in the Levantine basin denotes how tolerant a species may be. Moreover, major rivers, namely Asi, Ceyhan, Seyhan and Goksu (see fig. 1), draining efficiently to the basin's shelf waters, provide a suitable shelter in their drainage areas for copepod species that are tolerant to relatively colder and less saline waters. Another transport mechanism for species could be shipment via tankers ballast waters which visit Mersin and Iskenderun harbours intensively.

Fig. 5 displays two dimensional non-metric MDS plots of all sampling events having six distinct groups at an arbitrary similarity level of 60% (fig. 6). Groups 2, 3 and 4 are composed of single sampling events. The largest group (group 1) represents both the winter and spring populations and the second largest group (group 5) contains mainly the summer population. The remaining larger group (group 6) contains both the autumn and early winter populations. The most abundant 5 species consistently prominent in the larger groups 1, 5 and 6 are listed in table II. Group 2 (indicated as Mar1 on the MDS, corresponding to the sampling event on 3 March) is separated from the larger group 1 having least abundance and biomass (see fig. 3a, b), as well as lacking species *Calocalanus elegans*, *C. styliremis*, *Oncaea zernovi*, unidentified copepod and unidentified calanoid copepod which were highly abundant in group 1 (see table III). Similarly, group 4 (indicated as Jul1 on MDS, corresponding to the sampling event on 8 July) is separated from larger group 5 having maximal abundance and biomass, as well as having dominating species *Parvocalanus latus*, *Oncaea tregoubovi* and *Clausocalanus* sp., which were least detected in group 5 (see fig. 3a, b and table III). *Oithona nana*, which was abundant in group 5, was not observed in group 4. Group 3 differs from group 1 in lacking *Oncaea media*, *O. dentipes* and unidentified calanoid copepod, which were abundant in group 1. The copepod community structure showed significant anomalies during May. The first sampling in May was included in the summer group 5, the second and third sampling events were included in group 1 and finally the fourth sampling event was classed as a separate group. A slight increase in the temperature of near-surface waters coupled with a slight decrease in salinity due to increasing runoff from rivers was observed during April and May. Except samplings in May, both the solitary groups 2 and 4 are positioned nearby the larger groups 1 and 5, as desired. Among the ambient physical parameters, temperature but not salinity, seemed to display major role in determining seasonality in copepod assemblages (fig. 7a, b). In the area, surface temperature ranged between 16.0 and 29.9°C over the year, being coldest in March and warmest in late August (fig. 2). In contrast, surface salinity varied in a much narrower range (between 38.5 and 39.4 over the year), being least saline in May due to excess river input, and most saline in September as a result of evaporation during summer.

CONCLUSION

Pronounced seasonality in the water column temperature is a permanent feature of the basin. Surface temperature ranged between 16.0 and 29.9°C over the year, being coldest in March and warmest in late August. Analysis of the copepod community over a year in the Levantine basin shelf waters has revealed the presence of approximately 192 copepod species of which 36 are reported for the first time in the region. The community includes species of both Atlantic and Indo-Pacific origin. Invasion of the basin waters with Indo-Pacific species confirms by biological data the fact that the Red Sea waters may occasionally extend, sometimes reaching the northeastern parts of the Mediterranean. The distribution of these species may indicate possible boundaries of this penetration. Sharing similar species of Indo-Pacific origin gives the copepod fauna of the Levantine basin a subtropical affinity. The presence of non-native species in the study area points out that their invasion and adaptation in the basin waters is intensive at present. Lastly, the prevailing wide range of changes in temperature over the course of the year shape the copepod community structure in the Levantine basin shelf waters.

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REFERENCES

ANON., 1992. Report of the FAO/IOC/UNEP training workshop on the statistical treatment and interpretation of marine community data. In cooperation with IOC/UNEP. Athens, February 1992: 1-212.

AKYUZ, E. F., 1957. Observations on the Iskenderun Red Mullet (*Mullus barbatus*) and its environment. Proc. Gen. Conc. Med., **4**: 305-326.

ALCARAZ, M., E. SAIZ, C. MARRASE & D. VAGUE, 1988. Effects of turbulence on the development of phytoplankton biomass and copepod populations in marine microcosms. Mar. Ecol. Prog. Ser., **49**: 117-125.

BARANOVIC, A., M. SOLIC, T. VUCETIC & N. KRSTULOVIC, 1993. Temporal fluctuations of zooplankton and bacteria in the middle Adriatic Sea. Mar. Ecol. Prog. Ser., **92**: 65-75.

BELMONTE, G., M. G. MAZZOCCHI, I. Y. PRUSOVA & N. V. SHADRIN, 1994. *Acartia tonsa*: a species new for the Black Sea fauna. Hydrobiologia, **292-293**: 9-15.

BELMONTE, G. & D. POTENZA, 2001. Biogeography of the family Acartiidae (Calanoida) in the Ponto-Mediterranean Province. Hydrobiologia, **453-454**: 171-176.

BERDUGO, V., 1968. Sur la presence dans la Mediterranee orientale de deux especes du genre *Calanopia* (Copepoda, Calanoida). Rapp. Comm. Int. Mer Medit., **19**: 445-446.

BOGDANOVA, G. K., 1982. The main features of hydrology and water exchange of the Suez Channel. Biological investigation in the Red and Arabian seas. Biol. Morya, **21**: 3-41. [In Russian.]

BOWMAN, T. E., 1957. A new species of *Calanopia* (Copepoda, *Calanopia*) from the Caribbean Sea. Proc. US Natl. Mus., **107**(3382): 39-45.

BRIAN, A., 1927. Descrizione del maschio di *Hypoacartia adriatica* Steuer, copepodo pelagico rinvenuto in abbondanza nell'Egeo. Boll. Mus. Zool. Anat. Comp., **2**: 1-4.

CARLI, A. & P. CRISAFI, 1983. Copepodi lagunari. Consi. Nazio. Del. Ricer. Genova, 1-126.

CASANOVA, J. P., 1973. Pénétration du Copépode *Euchaeta concinna* Dana en Méditerranée orientale par le canal de Suez. Rapp. Comm. Int. Mer Medit., **21**: 513-515.

CHRISTOU, E. D., 1998. Interannual variability of copepods in a Mediterranean coastal area (Saronikos Gulf, Aegean Sea). J. Mar. Syst., **15**: 523-532.

CINAR, M. E., 2006. Serpulid species (Polychaeta: Serpulidae) from the Levantine coast of Turkey (eastern Mediterranean), with special emphasis on alien species. Aquat. Invasions, **1**: 223-240.

— —, 2009. Alien polychaete species (Annelida: Polychaeta) on the southern coast of Turkey (Levantine Sea, eastern Mediterranean), with 13 new records for the Mediterranean Sea. J. Nat. Hist., **43**: 2283-2328.

CINAR, M. E. & C. A. ALTUN, 2007. Preliminary study on population characteristics of the Lessepsian species, *Pseudonereis anomala* (Polychaeta: Nereididae), in Iskenderun Bay (Levantine Sea, eastern Mediterranean). Turk. J. Zool., **31**: 403-410.

CINAR, M. E., M. BILECENOGLU, B. OZTURK & A. CAN, 2006. New records of alien species on the Levantine coast of Turkey. Aquat. Invasions, **1**: 84-90.

DELALO, E. P., 1966. Zooplankton of the eastern part of the Mediterranean. In: Investigations of plankton of the southern seas, **7**: 62-81. (Moscow). [In Russian.]

EL MAGHRABY, A. M., 1965. The seasonal variations in length of some marine planktonic copepods from the eastern Mediterranean at Alexandria. Crustaceana, **8**: 37-47.

EL MAGHRABY, A. M. & Y. HALIM, 1965. A quantitative and qualitative study of the plankton of Alexandria waters. Hydrobiologia, **25**: 221-238.

EL-SEREHY, H. A. & N. S. ABDEL-RAHMAN, 2004. Distribution patterns of planktonic Copepod crustaceans in the coral reef and sandy areas along the gulf of Aqaba, Red Sea, Egypt. Egypt. J. Biol., **6**: 126-135.

FERNÁNDEZ DE PUELLES, M. L., F. ALEMANY & J. JANSA, 2007. Zooplankton time-series in the Balearic Sea (western Mediterranean): variability during the decade 1994-2003. Prog. Oceanogr., **74**: 329-345.

FERNÁNDEZ DE PUELLES, M. L., A. MORILLAS, A. LOPEZ-URRUTIA & J. C. MOLINERO, 2009. Seasonal and interannual variability of copepod abundance in the Balearic region (western Mediterranean) as indicator of basin scale hydrological changes. Hydrobiologia, **617**: 3-16.

FERNÁNDEZ DE PUELLES, M. L., J. VALENCIA & L. VICENTE, 2004. Zooplankton variability and climatic anomalies from 1994 to 2001 in the Balearic Sea (western Mediterranean). ICES J. Mar. Sci., **61**: 492-500.

FLEMINGER, A. & K. HULSEMANN, 1973. Ecological studies. In: B. ZEITZSCHEL (ed.), Analysis and synthesis: 339-349. (Springer, New York, NY).

FURNESTIN, M. L., 1979. Aspects of the zoogeography of the Mediterranean plankton. In: S. VAN DER SPOEL & A. C. PIERROT-BULTS (eds.), Zoogeography and diversity of plankton: 191-253. (Bunge, Utrecht).

GAUDY, R. & M. D. VINAS, 1985. Premiere signalisation en Mediterranee du Copepode pelagique *Acartia tonsa*. Rapp. Comm. Int. Mer Medit., **29**: 227-229.

GOKALP, N., 1972. Comparative investigation of the state of plankton assemblages of Edremit, Bodrum and Iskenderun bays. Publ. Hydrobiol. Res. Inst., **3**: 1-71. [In Turkish.]

GREZE, V. N., 1963. Zooplankton of the Ionian Sea. Okeanol. Issled. Mezhd. Geofiz. God., **9**: 42-59. [In Russian.]

GRUZOV, L. N. & L. G. ALEKSEEVA, 1970. Weight characteristics of copepods from the equatorial Atlantic ocean. Okeanologiya, **10**: 1076-1085. [In Russian with English summary.]

GUCU, A. C. & F. BINGEL, 1995. Trawlable species assemblages on the continental shelf of the northeastern Levant Sea (Mediterranean) with an emphasis on Lesseptian migration. Acta Adriat., **35**: 83-100.

— — & — —, 2011. Hake, *Merluccius merluccius* L., in the northeastern Mediterranean Sea: a case of disappearance. J. Appl. Ichthyol., **27**: 1001-1012.

GUCU, A. C., F. BINGEL, D. AVSAR & N. UYSAL, 1994. Distribution and occurrence of Red Sea fish at the Turkish Mediterranean coast — northern Cilician basin. Acta Adriat., **34**: 103-113.

GUCU, A. C., F. BINGEL & M. UNSAL, 1991. Zooplankton populations and its time series in the northern Cilician Basin-Turkish coast. Doga, Turk. J. Zool., **15**: 202-210.

HAJDERI, E., 1995. Osservazioni sui copepodi del Mare di Marmara. Biol. Mar. Medit., **2**: 541-542.

HALIM, Y., S. GUERGUES & H. H. SALEH, 1967. Hydrographic conditions and plankton in the southeast Mediterranean during the last normal Nile flood. Int. Revue Ges. Hydrobiol., **52**: 401-425.

— —, — — & — —, 1976. Marine biological studies in Egyptian waters. A review. Acta Adriat., **18**: 31-38.

HERON, G. A. & T. E. BOWMAN, 1971. Postnaupliar developmental stages of the copepod crustaceans *Clausocalanus laticeps*, *C. brevipes* and *Ctenocalanus citer* (Calanoida: Pseudocalanidae). Biology of the Antarctic seas. Antarctic Res. Ser., **17**: 141-165.

HOPKINS, T. L., 1987. Midwater food web in McMurdo Sound, Ross Sea, Antarctica. Mar. Biol., **96**: 93-106.

KACZMARUK, B. Z., 1983. Occurence and distribution of the Antarctic copepods along the ice shelves in the Weddell sea in summer 1979/80. Meeresforschung, **30**: 25-41.

KIDEYS, A. E. & A. C. GUCU, 1995. *Rhopilema nomadica*: a poisonous Indo-Pacific Scyphomedusan new to the Mediterranean coast of Turkey. Isr. J. Zool., **41**: 615-617.

KIMOR, B. & V. BERDUGO, 1967. Cruise to the eastern Mediterranean, Cyprus 03. Plankton Reports. Sea Fish. Res. St. Halif. Bull., Israel, **45**: 5-31.

KIMOR, B. & E. J. F. WOOD, 1975. A plankton study in the eastern Mediterranean Sea. Mar. Biol., **29**: 321-333.

KOUWENBERG, J. & C. RAZOULS, 1990. The incidence of environmental factors on the evolution of copepod populations in the 'Golfe du Lion' during the period 1986-88 in comparison with the period 1957-64. Bull. Soc. Zool. Fr., **115**: 23-36.

KOVALEV, A. V. & A. A. SHMELEVA, 1982. Fauna of Copepoda in the Mediterranean. Ehkol. Morya: 82-87. (Naukova Dumka, Kiev). [In Russian.]

LAKKIS, S., 1973. Note préliminaire sur la présence et la répartition des Copépodes dans les eaux superficielles Libanaises. Rapp. Comm. Int. Mer Medit., **21**: 459-464.

— —, 1976a. Considerations on the distribution of pelagic copepods in the eastern Mediterranean off the coast of Lebanon. Acta Adriat., **18**: 41-52.

— —, 1976b. Sur la présence dans les eaux Libanaises de quelques Copépodes d'origine indopacifique. Rapp. Commun. Int. Mer. Medit., **23**: 83-85.

— —, 1990a. Composition, diversité et successions des copépodes planctoniques des eaux Libanaises (Méditerranée Orientale). Oceanol. Acta, **13**: 489-501.

— —, 1990b. Vingt ans d'observation sur le plancton des eaux libanaises; structure et fluctuations interannuelles. Bull. Inst. Oceanogr. Spec., **7**: 51-66.

— —, 1994. Coexistence and competition within *Acartia* (Copepoda, Calanoida) congeners from Lebanese coastal water: niche overlap measurements. Hydrobiologia, **292-293**: 481-490.

— —, 1995a. Cycle annuel du plancton côtier du Liban, succession et variation saisonnières des peuplements. Rapp. Comm. Int. Mer Medit., **34**: 212.

— —, 1995b. Biogeography of the plankton from Lebanese water (eastern Mediterranean): the Levantine basin and species of Indo-Pacific origin. Pelagic Biogeography ICOPB II, Proceeding of the 2nd International Conference, 9-14 July, 1995. UNESCO, 233-238.

LAKKIS, S., A. E. KIDEYS, A. A. SHMELEVA, A. V. KOVALEV, E. UNAL & R. ZEIDANE, 2002. Comparison of zooplankton biodiversity between Levantine Basin and Black Sea with reference to the alien species. Second International Conference on "Oceanography of the Eastern Mediterranean and Black Sea: Similarities and Differences of Two Interconnected Basins": 821-827. (Tubitak Publishers, Ankara, Turkey).

LAKKIS, S. & R. ZEIDANE, 1990. Associations congeneriques d'*Acartia* (Copepoda Calanoida) dans les eaux cotieres Libanaises: calcul des indices d' 'Overlap' et de 'Niche hypervolume'. Rapp. Comm. Int. Mer Medit., **32**: 222-223.

MAZZOCCHI, M. G., E. D. CHRISTOU, N. FRAGOPOULU & I. SIOKOU-FRANGOU, 1997. Mesozooplankton distribution from Sicily to Cyprus (eastern Mediterranean): I. General aspects. Oceanol. Acta, **20**: 521-535.

MAZZOCCHI, M. G. & M. RIBERA D'ALCALA, 1995. Recurrent patterns in zooplankton structure and succession in a variable coastal environment. ICES J. Mar. Sci., **52**: 679-691.

MORAITOU-APOSTOLOPOULOU, M., 1972. Occurrence and fluctuation of the pelagic copepods of the Aegean Sea with some notes on their ecology. Hell. Oceanogr. Limnol., **11**: 325-402.

OZEL, I. & V. AKER, 2001. Seasonal changes in zooplankton of the Izmir bay. XI. Symposium on National Water Products, Hatay, Turkey. Ser. Publ. Mustafa Kemal Univ., **8**: 155-162.

PANCUCCI-PAPADOPOULOU, M. A., I. SIOKOU-FRANGOU, A. THEOCHARIS & D. GEORGOPOULOS, 1992. Zooplankton vertical distribution in relation to the hydrology in the NW Levantine and the SE Aegean seas (spring 1986). Oceanol. Acta, **15**: 365-381.

PASTEUR, R., V. BERDUGO & B. KIMOR, 1976. The abundance, composition and seasonal distribution of epizooplankton in coastal and offshore waters of the eastern Mediterranean. Acta Adriat., **18**: 53-80.

PAVLOVA, E., 1966. Composition and distribution of zooplankton in the Aegean Sea. In: M. SCIENCE (ed.), Investigation of Plankton in the South Seas (7^{th} ed.): 38-61. (Moscow). [In Russian.]

POTEMKINA, D. A., 1940. The age stages of some Black Sea Copepoda. Zool. Zh., **19**: 119-125. [In Russian.]

RAZOULS, C., F. DE BOVÉE, J. KOUWENBERG & N. DESREUMAUX, 2005-2010. Diversity and geographic distribution of marine planktonic copepods. Available online at: http://copepodes.obs-banyuls.fr/en

REGNER, D., 1985. Seasonal and multiannual dynamics of copepods in the Middle Adriatic. Acta Adriat., **26**: 11-99.

SCHNACK-SCHIEL, S. B. & E. MIZDALSKI, 1994. Seasonal variation in distribution and population structure of *Microcalanus pygmaeus* and *Ctenocalanus citer* (Copepoda, Calanoida) in the eastern Weddell Sea, Antarctica. Mar. Biol., **119**: 357-366.

SHMELEVA, A. A., 1973. New data on planktonic fauna from the east of the Mediterranean Sea. Rapp. Comm. Int. Mer Medit., **21**(8): 537-539.

SIOKOU-FRANGOU, I., E. D. CHRISTOU, N. FRAGOPOULU & M. G. MAZZOCCHI, 1997. Mesozooplankton distribution from Sicily to Cyprus (Eastern Mediterranean): II. Copepod assemblages. Oceanol. Acta, **20**: 537-548.

SIOKOU-FRANGOU, I. & M. A. PANCUCCI-PAPADOPOULOU, 1990. Observations sur le zooplancton de la mer de Rhodos (nw mer du Levant et se mer Egee). Thalassographica, **13**: 25-28.

TOKLU, B., 2006. Seasonal changes and distribution of zooplankton in the Iskenderun bay (Yumurtalik-Kokar Cape): 1-107. (Ph.D. Thesis. Cukurova University, Adana). [In Turkish.]

TUCKER, M. J. & H. R. BURTON, 1990. Seasonal and spatial variations in the zooplankton community of an eastern Antarctic coastal location. Polar Biol., **10**: 571-579.

UNAL, E., A. A. SHMELEVA, J. ZAGORODNYAYA & A. E. KIDEYS, 2000. Zooplankton structure and copepod species of the Sea of Marmara in spring 1998. In: B. OZTURK, M. KADIOGLU & H. OZTURK (eds.), Proceedings of Symposium on Marmara Sea 2000, Tudav, Istanbul, **5**: 450-460.

UYSAL, Z., M. IWATAKI & T. KORAY, 2003. On the presence of *Heterocapsa pygmaea* Loeblich III, Schmidt & Sherley 1981 (*Peridiniales* Haeckel 1894b, *Dinophyceae* Pascher 1914) in the northern Levantine basin (eastern Mediterranean). Turk. J. Bot., **27**: 149-152.

UYSAL, Z., A. E. KIDEYS, A. A. SHMELEVA, J. A. ZAGORODNYAYA & A. D. GOUBANOVA, 2002. Checklist of copepods (Calanoida and Podoplea) from the northern Levantine basin shelf waters. Hydrobiologia, **482**: 15-21.

UYSAL, Z. & E. MUTLU, 1993. Preliminary note on the occurrence and biometry of Ctenophoran *Mnemiopsis leidyi* finally invaded Mersin Bay. Doga, Turk. J. Zool., **12**: 229-236.

UYSAL, Z. & A. A. SHMELEVA, 2002. New species of the genus *Scaphocalanus* (Calanoida: Scolecithricidae) from the Iskenderun Bay — northeastern Levantine basin. Hydrobiologia, **470**: 45-48.

— — & — —, 2004. Two new species of the genus *Calanopia* (Copepoda: Calanoida, Pontellidae) from the northern Levantine basin (Mediterranean Sea). Vestn. Zool., **38**: 9-13.

VIVES, F., 1978. Sobre la distribución de *Calanus helgolandicus*, Claus (Copepoda, Calanoida) en el Mediterráneo occidental. Res. Exp. Cient. B/O Cornide, **7**: 83-92.

ZAGAMI, G. & L. GUGLIELMO, 1990. Prima segnalazione nel Mar Tirreno del copepode pelagico *Acartia tonsa* Dana. Mem. Biol. Mar. Oceanogr., **18**: 71-74.

ZMIJEIWCKA, M. I., 1983. Copepoda (Calanoida) from the Prydz Bay (Antarctica, Indian Ocean sector). Pol. Polar Res., Warsaw, **4**: 33-47.

ZORGANI, M., 1984. Distribution of copepods in the Gulf of Gabes. Bulletin of the Marine Research Centre, Tripoli, **5**: 37-68.

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