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INTRODUCTION

Knowledge of the distribution and ecology of the planktonic Copepoda in the Eastern Mediterranean is very scanty compared to other areas such as the western basin and the Adriatic Sea. Data on the ecology of the inshore zooplankton community of the coastal waters of Lebanon with special reference to Copepoda have been reported by Lakkis (1971a, b, 1973). Other regions in the Eastern Mediterranean have been studied in more detail including the coast of Israel (Berdugo, 1968; Berdugo and Kimor, 1968) and that of Egypt (El-Maghraby, 1965; El-Maghraby and Halim, 1964; Dowidar and El-Maghraby, 1970). The purpose of this paper is to provide additional information on the distribution and seasonal variation in abundance of pelagic Copepoda in the surface and subsurface waters of Lebanon.

The Levant Basin is considered as warm temperature and subtropical sea. The surface water temperature off the coast of Lebanon has an annual average of 23°C with a maximum mean of 30°C in August and a minimum of 17°C in February (Table 1). The annual range of the temperature variation seems to be an important ecological factor. The salinity is very high relative to the other Mediterranean areas; the annual average of salinity at offshore stations being 39.15‰. Seasonal fluctuation in salinity values, however, is not as pronounced as that of temperature. On the other hand, fresh water discharge from several small rivers, precipitation and melting snow in winter and spring contribute to lowering the salinity especially in the inshore water. During summer, there is a slight increase in salinity due to the reduced river discharge and to the increase of evaporation. Prior to 1966, discharge from

Table 1. Seasonal values of hydrographic parameters at Stations C2 and F2.
Values are the monthly means from three consecutive years, 1970, 71 and 72.

Month	Station	J	F	M	A	M	J	J	A	S	O	N	D
Temperature (°C)	C2	18.00	17.50	18.50	19.50	22.30	24.70	27.00	28.80	29.40	28.00	23.10	20.60
	F2	16.50	17.00	15.80	18.00	22.00	25.60	27.00	28.40	29.30	26.50	23.00	19.00
Salinity (‰)	C2	38.60	38.65	38.60	39.05	39.10	39.15	39.20	39.60	39.50	39.45	39.00	39.05
	F2	37.90	37.85	37.40	37.50	37.75	38.20	38.70	39.00	39.00	38.50	38.20	38.00
Transparency	C2	9.00	8.50	10.50	13.50	18.00	20.00	22.00	25.00	23.00	24.00	23.00	14.00
(Secchi disc in m)	F2	6.00	5.50	8.00	5.40	5.00	18.00	18.00	20.00	20.00	19.00	19.00	12.00

the Nile River significantly affected the general hydrographic aspects of the Eastern Mediterranean waters as far as the coasts of Lebanon and Syria (Halim, Guergues and Saleh, 1967). The salinity decreased to 35‰ during the Nile flood off Beirut (Rouch, 1945). Following the completion of the Aswan High Dam, there has been a progressive increase in salinity of the Levant coastal waters (Oren and Hornung, 1972).

The general circulation pattern along the coast of Lebanon is a prevailing northward current during most of the year (December to September), with a maximum velocity of 0.50 m/sec in February and a minimum in summer of 0.15 m/sec (S.O.G.R.E.A.H., 1965). During the fall, the current is often reversed, depending on the wind system and is directed south close to the coastline, but with lower velocity. The water transparency is very high especially at offshore stations with a dark-blue color. During winter and storm periods, the inshore waters become highly turbid; this is due mainly to water movement, deep currents and to discharge of the Ibrahim and Beirut Rivers carrying a large amount of soil and organic material.

METHODS AND MATERIAL

The data for this paper are based on 300 plankton samples collected monthly for three consecutive years: November 1969 to December 1972. Eight stations were selected and fixed along four transects; the nearest stations were at 400 to 500 m from the coastline; the furthest stations were up to 3 to 5 miles offshore depending to the transect. Three stations were chosen off Beirut, two off the Ibrahim River and the three remaining stations were located off Byblos (Figure 1). Surface as well as vertical hauls (50 to 0 m) were made using the recommended WP2 plankton net (UNESCO, 1968) having 200 mμ mesh size and a 57 cm diameter ring to which a flowmeter was fixed. Qualitative as well as quantitative analyses were carried out. Counts of Copepods were recorded as individuals per m^3 and quantified as follows: dominant species, more than 300 individuals/m^3; abundant species, between 51 and 300 individuals/m^3; common species, between 11 and 50 individuals/m^3; rare species, between 1 and 10 individuals/m^3. During the sampling, hydrographic measurements such as temperature, salinity and transparency were recorded. The hydrographic data for two stations, C2 and F2 (Figure 1), are given in Table 1.

RESULTS

A total of 82 species belonging to 39 genera were identified during the course of this study (Table 2). Several species have been added to a previous study by Lakkis (1973).

The seasonal distribution of the Copepoda from coastal waters of Lebanon has been determined. Table 3 gives the seasonal average abundance and the species index diversity (see below) for stations C2 and F2. Two annual peaks in the seasonal distribution have been determined, a major maximum in April-May with an average ranging between 6000 and 15,000 individuals/m^3

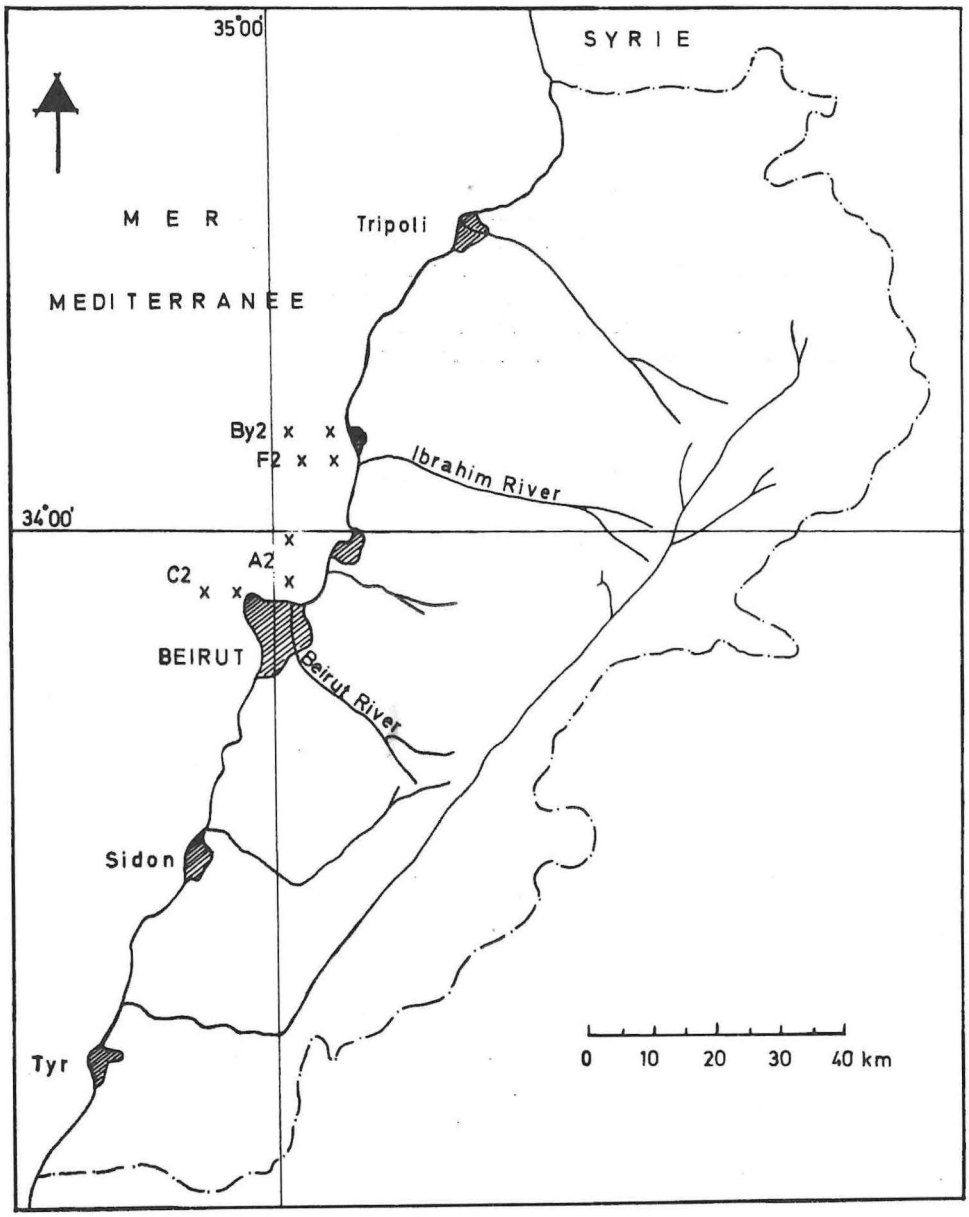

Fig. 1 — Location of plakton transects and stations along the coast of Lebanon.

Table 2. Combined seasonal distribution of copepod species recorded at Station F2 for three consecutive years, 1970, 71, 72.

D = dominant, A = abundant, C = common, R = rare, X = single specimen, — = absent.

SPECIES MONTHS	J	F	M	A	M	J	J	A	S	O	N	D
Acartia clausi	R	C	R	—	—	—	—	—	—	—	X	R
A. discaudata	C	D	A	R	—	—	—	X	X	C	A	A
A. fossae	R	X	—	—	—	—	—	—	X	R	R	R
A. latisetosa	R	R	R	X	—	—	—	—	—	R	R	R
A. longiremis	C	A	C	X	—	—	—	X	R	R	C	A
Anomalocera patersoni	—	X	X	X	X	—	—	—	—	—	—	X
Candacia armata	X	X	X	—	—	—	—	—	—	—	—	X
Calanus helgolandicus	C	C	C	C	C	—	—	—	X	R	R	C
C. longimana	R	X	X	—	—	—	—	—	—	—	—	X
C. minor	X	X	X	X	X	—	—	—	—	—	—	X
C. gracilis	—	—	—	—	—	—	—	—	X	C	A	R
C. bispinosa	—	—	—	—	—	—	—	R	R	X	—	—
C. media	R	X	X	—	—	—	—	—	—	—	X	R
C. tenuicornis	R	R	R	R	X	X	—	—	—	—	—	X
Calanopia elliptica	C	R	R	X	—	—	—	—	—	—	R	C
C. aethiopica	R	R	R	—	—	—	—	—	—	—	—	X
C. bipinnata	R	R	X	—	—	—	—	—	—	—	—	—
C. simplex	C	R	X	—	—	—	—	—	—	—	X	R
Centropages kröyeri	—	—	R	C	D	D	A	C	R	X	X	X
C. ponticus	—	—	—	—	R	R	R	R	R	R	X	—
C. violaceus	—	X	R	C	C	R	X	—	—	—	X	X
Clausocalanus arcuicornis	C	A	A	A	C	R	X	X	X	R	C	C
C. furcatus	C	C	C	C	C	R	X	X	X	C	C	C
C. lividus	R	R	R	X	—	—	—	—	—	—	X	R
C. mastigoforus	R	R	X	—	—	—	—	—	—	—	—	X
Calocalanus contractus	R	R	X	X	X	X	—	—	—	X	X	R
C. pavo	C	C	R	R	R	X	—	—	—	C	C	C
C. styliremis	R	R	X	X	X	X	—	—	—	R	R	R
Clytemnestra rostrata	X	X	—	—	—	—	—	—	—	—	—	X
Copilia mediterranea	X	X	X	—	—	—	—	—	—	X	X	X
Corycaeus clausi	R	C	C	C	C	R	X	X	X	R	R	R
C. (Agetus) flaccus	A	A	A	A	C	C	X	—	—	X	R	C
C. (Onychocorycaeus) latus	R	R	X	X	X	X	—	—	—	X	R	R
C. (Agetus) limbatus	R	C	R	X	X	X	—	—	—	—	X	R
C. (Corycella) rostratus	C	C	C	A	A	C	R	X	X	R	R	R
C. speciosus	R	R	R	C	X	—	—	—	—	—	X	X
C. (Agetus) typicus	R	R	R	X	X	X	—	—	—	—	X	X
Ctenocalanus vanus	X	X	R	R	R	X	—	—	—	—	X	X
Cymbasoma rigidum	X	X	X	X	—	—	—	—	—	—	—	X
C. longispinosum	X	X	X	—	—	—	—	—	—	—	—	—
Euaetideus giesbrechti	X	X	X	X	X	X	—	—	—	—	—	—
Eucalanus attenuatus	X	X	X	—	—	—	—	—	—	—	X	X
E. elongatus	X	X	X	—	X	X	—	—	—	—	—	—
E. monachus	R	R	X	X	X	X	—	—	—	—	—	—
Euchaeta marina	R	R	R	X	R	X	—	—	—	—	X	X
Euchirella rostrata	X	X	X	—	—	—	—	—	—	—	—	—
Euterpina acutifrons	R	C	A	A	A	C	R	R	R	R	C	C
Haloptilus longicornis	X	X	X	—	—	—	—	—	—	X	X	X
Heterorhabdus papilliger	X	X	X	X	X	—	—	—	—	—	X	X
Isias clavipes	X	R	C	C	C	R	—	—	—	—	X	X
Labidocera brunescens	—	—	—	R	R	R	R	X	X	X	R	—
L. madurae	—	—	—	—	—	—	—	—	X	X	R	X

SPECIES MONTHS	J	F	M	A	M	J	J	A	S	O	N	D
L. detruncata	—	—	—	—	—	—	—	—	—	R	R	—
Lubbockia squillimana	X	R	R	X	X	—	—	—	X	X	X	X
Lucicutia flavicornis	C	C	C	R	R	—	—	—	—	—	R	C
Macrosetella gracilis	X	X	X	R	R	X	—	—	—	—	—	X
Microsetella rosea	R	R	R	R	R	X	—	—	—	—	X	X
Mecynocera clausi	R	C	C	R	R	—	—	—	—	—	R	R
Oithona helgolandica	X	R	R	R	X	X	—	—	—	X	X	X
O. nana	R	R	C	C	C	C	C	R	R	R	R	R
O. plumifera	R	R	R	C	C	A	A	C	C	C	R	R
Oncaea conifera	R	R	R	R	X	X	—	—	X	X	R	R
O. mediterranea	C	C	C	C	C	C	X	X	X	X	X	R
O. venusta	R	R	R	R	R	X	—	—	—	X	X	X
Paracalanus parvus	C	A	D	D	D	D	C	C	R	R	A	A
P. crassirostris	R	R	R	R	R	R	C	A	C	C	R	R
Parapontella brevicornis	R	R	X	—	—	—	—	—	—	—	—	X
Phaenna spinifera	X	X	X	—	—	—	—	—	—	—	X	R
Pleuromamma abdominalis	R	R	R	—	—	—	—	—	—	—	R	R
P. gracilis	X	X	X	—	—	—	—	—	—	—	X	X
Pontella mediterranea	—	—	—	R	R	C	X	X	X	X	R	R
Pontellina plumata	X	X	X	X	—	—	—	—	—	—	X	X
Sapphirina angusta	X	X	X	X	X	—	—	—	—	—	—	X
S. metallina	X	X	X	X	R	X	—	—	—	—	—	—
S. nigromaculata	X	X	X	X	X	X	X	—	—	—	X	X
S. ovatolanceolata	X	X	X	X	X	—	—	—	—	—	X	X
S. opalina	X	X	X	X	—	—	—	—	—	—	—	—
S. iris	X	X	X	X	X	X	—	—	—	—	X	X
S. gemma	X	X	X	X	X	X	—	—	—	X	X	X
Scolecithricella minor	X	X	X	—	—	—	—	—	—	—	X	X
Scolecithrix bradyi	X	X	X	—	—	—	—	—	—	—	X	X
Temora stylifera	R	C	A	A	A	A	C	R	R	R	R	R

and a minor maximum recorded in November with an average of 1000 to 2000/m^3. In both peaks, *Paracalanus parvus* was the numerically dominant species.

The general pattern in the seasonal distribution of the copepods was as follows.

Winter Group. — This group was present during the winter season (December—March). The seawater temperature was between 17°C and 20°C and the salinity around 38.60‰ at offshore stations; there was a strong surface current and high turbidity. The species of winter group was as follows (Table 2):

a) Dominant: *Paracalanus parvus, Acartia discaudata, A. longiremis.*

b) Abundant: *Clausocalanus arcuicornis, C. furcatus, Corycaeus flaccus, C. limbatus, Euterpina acutifrons, Corycaeus rostratus.*

c) Common: *Acartia clausi, Euchaeta marina, Candacia bipinnata, C. bispinosa, C. cimplex, Calanus minor, Calocalanus pavo, C. styliremis, Lucicutia flavicornis, Mecynocera clausi.*

d) Rade: *Candacia longimana, C. armata, C. aethiopica, Clausocalanus mastigoforus, C. lividus.*

Table 3. Seasonal average abundance of total Copepoda and the Index Diversity of species for the three consecutive years combined (1970, 71, 72) at stations C2 and F2.

Month	Station	J	F	M	A	M	J	J	A	S	O	N	D
Total Copepoda	C2	600	1500	7500	5000	4500	2000	200	50	250	950	1700	1600
(ind./m^3)	F2	900	2500	7500	11,600	9800	3000	750	600	1500	2000	2500	2300
Index	C2	4.7	4.8	4.7	3.6	2.9	2.1	1.0	1.2	1.8	2.2	3.5	4.5
Diversity	F2	4.3	4.9	4.8	3.1	2.8	2.1	1.5	1.0	1.7	3.0	3.4	4.7

During winter, the species diversity index calculated usind the Margalef formula which is $Id = \frac{S-1}{\log_n N}$ (S is the number of species, $\log_n N$ being the natural log of the total number of individuals in a given sample), was the highest (Table 3).

Spring Group. — This group was present during March—June. The seawater temperature increased to 23°C and the salinity was relatively low (38.35‰) especially at the inshore stations and the currents were moderate. These conditions favored a maximum phytoplankton bloom, followed immediately by large numbers of zooplankton larvae and other zooplankters. The copepods showed a high species diversity index (Table 3), some times higher than in winter. The abundance of copepod populations was higher than in winter. The spring group was characterized as follows:

a) Dominant: *Paracalanus parvus* forming more than 95 percent of the total zooplankton.

b) Adundant: *Temora stylifera, Clausocalanus arcuicornis, C. furcatus, Centropages kröyeri.*

c) Common: *Oithona plumifera, Oncaea* spp., *Pontella mediterranea, Microsetella rosea, Lucicutia flavicornis, Calocalanus pavo, Candacia* spp., *Centropages violaceus.*

d) Rare: *Sapphirina* spp., *Labidocera brunescens, Centropages ponticus, Isias clavipes, Calocalanus styliremis.*

Summer Group. — The summer group was present during June—September. During this period the average seawater temperature (29°C) as well as salinity (39.50‰) reached a maximum value in August. The water movement and currents were reduced. Plankton was poor, in species diversity and in abundance (Table 2). During this season, the characteristic copepods were as follows:

a) Dominant: *Centropages kröyeri*

b) Abundant: *Paracalanus parvus, Oithona plumifera, O. nana, Corycella rostrata*

c) Common: *Paracalanus crassirostris, Temora stylifera, Centropages kröyeri*

d) Rare: *Clausocalanus furcatus, C. arcuicornis, Euterpina acutifrons, Pontella mediterranea, Labidocera brunescens*

Autumn Group. — During the autumn, hydrographic conditions became more favorable for plankton development. The temperature dropped to 21 to 22°C; salinity remained the same as in summer with a slight decrease (average 39.10‰). The index of species diversity increased progressively because of the big variety of species occurring during this season. On the other hand, the abundance of copepod populations increased and reached a density of 2000 to 3000 individuals per m^3 (Table 2). The autumn copepod community included:

a) Dominant: *Paracalanus parvus, P. crassirostris, Acartia discaudata.*

b) Abundant: *Calanopia elliptica, Acartia longiremis, Temora stylifera, Labidocera brunescens, Clausocalanus arcuicornis, C. furcatus, Corycaeus flaccus*

c) Common: *Isias clavipes, Centropages violaceus, Corycella rostrata, Oithona helgolandica, O. plumifera, Calocalanus styliremis, Pontella mediterranea.*

d) Rare: *Labidocera madurae, L. detruncata, Euchaeta marina, Calanus minor, Pleuromamma abdominalis, Mecynocera clausi, Phaenna spinifera, Oithona nana, O. plumifera.*

CONCLUSIONS

Most of the recorded species in the Lebanese coastal waters belong to the temperate and subtropical forms and they are considered as Mediterranean--Atlantic fauna. On the other hand, several species have a wide geographical distribution. Most of them have been reported from the Western Mediterranean by many authors (Sars, 1925; Gaudy, 1962; Rose, 1929; Giron, 1963; Furnestin, 1966; Mazza, 1962) and from the Adriatic Sea (Hure and Scotto di Carlo, 1968). These species are also reported from different areas of the Atlantic (Vervoort, 1965; Binet and Dessier, 1971) and the Indian Ocean (Brady, 1883; Scott, 1909; Gaudy, 1967; Sewell, 1948). In the Eastern Mediterranean, the major proportion of these species was recorded along the coast of Israel (Berdugo and Kimor, 1968; Berdugo, 1968) and Egypt (Dowidar and El-Maghraby, 1970). The majority of the species is epipelagic, few are mesopelagic or bathypelagic forms including *Calanus tenuicornis, Eucalanus attenuatus, E. elongatus, Euaetideus giesbrechti, Scolecithricella bradyi, Euchirella rostrata, Phaenna spinifera, Pleuromamma abdominalis, P. gracilis, Arietellus aculeatus, Heterorhabdus papilliger* and *Haloptilus longicornis.* Several species recorded in this area are considered by different authors as Atlantic epiplanktonic forms including *Centropages violaceus, Anomalocera patersoni, Parapontella brevicornis, Isias clavipes, Mecynocera clausi, Lucicutia flavicornis, Calocalanus pavo* and *Ctenocalanus vanus* (Rose, 1929; Sars, 1925; Furnestin, 1966; Gaudy, 1962; Giron, 1963). The latter six species have been reported by the same authors as indicators of Atlantic water current flowing into the Mediterranean. It is important to mention that all these species are found in the Levant waters at different seasons and in more or less high numbers. Thus they may have established themselves in the Eastern Mediterranean.

The copepod species which are confined to the Eastern Mediterranean include *Calanopia elliptica, C. media, Arietellus aculeatus, Centropages ponticus, Labidocera madurae, L. detruncata* and *Acartia fossae.* These species have been reported either from the Pacific and Indian Oceans or the Red Sea and Suez Canal (Brady, 1883; Scott, 1909; Sewell, 1948; Gurney, 1927; Halim, 1969). All these species but *Calanopia elliptica* and *C. media* are found for the first time in the Mediterranean. The latter two species have been recorded in small numbers off Haifa (Berdugo, 1968). They have been found in high numbers in the Lebanese coastal waters, but only in August—September for *Calanopia media* (10 individuals/m^3) and in October—November for *C. elliptica* (50 to 100 individuals/m^3). All these species are of Indo-Pacific origin and are restricted to the Eastern Mediterranean. It thus appears that they have been subjected to transport from the Red Sea into the Mediterranean through the Suez Canal.

Fifteen out of 82 species form the main bulk of the Lebanese copepod fauna. These are the most abundant and are considered as neritic and epiplanktonic forms belonging to the Mediterranean and Atlantic fauna. They include *Paracalanus parvus, P. crassirostris, Acartia longiremis, A. discaudata, Temora stylifera, Centropages kröyeri, Clausocalanus arcuicornis, C. furcatus, Oithona nana, O. plumifera, Euterpina acutifrons, Corycaeus flaccus, Lucicutia flavicornis, Calanopis elliptica* and *Candacia* spp. It should be emphasized that this is based on occurrences at the surface and to a depth of 50 m. A more precise picture of the occurrence, distribution and abundance must include more extensive sampling from various depths, different areas and seasons.

SUMMARY

The neritic copepod fauna of the Lebanese coastal waters has been described from both vertical and horizontal subsurface hauls at different stations for three consecutive years (November 1969 to December 1972). The seasonal variation has been outlined in relation to hydrographic conditions. A total of 82 species belonging to 39 genera have been recorded, most of them are neritic, temperate and subtropical forms. The greater bulk of the copepod population comprised 15 common species. Several species reported as Atlantic and bathypelagic were found in lower numbers. The copepods have been divided into four groups based on the seasonal variations in abundance. Six out of 82 species are recorded only in the Eastern Mediterranean, 4 are new records for the Mediterranean. The 6 species have an Indo-Pacific origin and have migrated through the Suez Canal. Some other species, reported as Atlantic have been recorded in this area and their role as hydrologic indicators of the current flowing into the Mediterranean reaching the Levant waters is suggested.

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PRILOG POZNAVANJU RASPODJELE PELAGIJSKIH KOPEPODA ISTOČNOG MEDITERANA U OBALNIM VODAMA LIBANONA

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KRATAK SADRŽAJ

U radu je opisana kopepodna fauna obalnih voda Libanona. Materijal je sakupljen vertikalnim i horizantalnim potezima mrežom. Istraživanja su vršena na više postaja tokom tri uzastopne godine (od studenog 1969. do prosinca 1972).

Iznose se rezultati studija sezonskih varijacija kopepoda u odnosu na hidrografske faktore.

Ukupno su zabilježne 82 vrste iz 39 rodova među kojima prevladavaju neritski oblici temperiranih i subtropskih voda. Glavninu kopepodne populacije predstavlja 15 uobičajenih vrsta. Atlantske batipelagijske vrste su nađene u manjem broju. Kopepodi su podijeljeni na 4 skupine s obzirom na sezonske varijacije njihove abundancije. Od zastupljenih vrsta, 6 vrsta je nađeno samo u istočnom Mediteranu, a 4 vrste predstavljaju nove nalaze za Mediteran. Ovih 6 vrsta je indopacifičkog porijekla, a u Mediteran su došle migracijom kroz Sueski kanal. Pretpostavlja se da bi atlantske vrste kopepoda, zabilježene u tom području, mogle biti indikatori struja koje ulaze u Mediteran i dopiru do Levanta.