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Annual cycle of the microzooplankton communities in the waters surrounding the Palm Island Nature Reserve (north Lebanon), with special attention to tintinnids.

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Abstract

The distribution, abundance and annual cycle of microzooplankton communities have been studied monthly at five sampling stations in the north Lebanon, covering both neritic and oceanic waters in the vicinity of small islands situated 5 km offshore.In general, the density of microprotozoans, except for ciliates, increased from the coastal towards the offshore area, with stations situated near the islands being similar to the offshore rather than to the coastal ones. The microprotozoan species showed their highest numbers in late autumn and early winter. Foraminifera abundance ranged from 20 to 3390 inds.m $^{-3}$ *(mean= 549) whereas Acantharia abundance was highest in spring and ranged from 0 to 2608 inds.m* $^{-3}$ *(mean 259). The Polycistina had their highest numbers in late winter, which ranged from 0 to 6024 inds.m* $^{-3}$ *(mean= 740). The Heliozoa were abundant in late autumn with numbers ranging from 0 to 5165 inds.m* $^{-3}$ *(mean= 555). The annual cycle of Tintinnids at all the stations was bimodal with a principal peak in October-November and another one in May, while minimum numbers were recorded in August-September. A succession of populations was observed all year round with a density ranging between 344 and 38986 inds.m* $^{-3}$ *(mean = 10878). Ninety different species of Tintinnids were recorded. The diversity index varied between 0.19 and 4.15. It was concluded that there was a large-scale gradient in seasonal diversity which could be related to the annual average sea surface temperature and to the development of the vertical thermic structure.*

Keywords: Eastern Mediterranean, Islands, Microzooplankton communities, Tintinnid diversity.

Introduction

In March 1992, a group of three islands off Tripoli in north Lebanon (Palm Island, Ramkine Island and Sanani Island) was declared a natural reserve. This park is probably the first marine park in the Levantine Sea (eastern Mediterranean). The plankton of the central part of the Lebanese coast has been studied since 1970 and a wealth of data exists on phytoplankton (TASLAKIAN & HARDY, 1976; ABBOUD-ABI SAAB,1985; 1986; ABBOUD-ABI SAAB & KASSAB, 1997). Furthermore, data on Tintinnids (ABBOUD-ABI SAAB, 1989), Actinopoda (ABBOUD-ABI SAAB, 1988a) &

Foraminifera (ABBOUD-ABI SAAB, 1993a) are also available. However, the northern coast has not been extensively studied; thus, a project was initiated in order to study the distribution of microzooplankton communities, which are of great importance in achieving a holistic understanding of marine ecosystems.

Ciliates, in planktonic food webs, constitute a major component of the microzooplankton in most marine environments as they play a functional role in marine food webs (BEERS *et al.,* 1982; CAPRIULO & NINIVAGGI, 1982; ALDER & BOLTOVSKOY, 1991; PIERCE & TURNER, 1992). Ciliates by virtue of their small size, form a link between trophic levels as they ingest the smallest food particles, unavailable to the larger organisms and are subsequently preyed on either by meso-, macro- or ichtyoplankton (CONOVER, 1982). Ciliates have the ability to rapidly increase in numbers (MONTAGNES *et al.,* 1988) and they have weight-specific metabolic rates and growth efficiencies higher than metazoan competitors (HEINBOKEL, 1978; 1982; CAPRIULO & NINIVAGGI, 1982; VERITY, 1985; ALDER, 1995). Many studies have quantified and underlined the significance of planktonic ciliates as grazers of nanoplankton and picoplancton (CAPRIULO & CARPENTER, 1983; VERITY, 1987; RASSOULZADEGAN *et al.*; 1988; CAPRIUOLO *et al.,* 1991). In oligotrophic systems, such as the eastern Mediterranean, pico- and nanoplankton are the dominant size fractions in terms of biomass and primary productivity (LI *et al.,* 1983; PLATT *et al.,* 1983; BERMAN *et al.,* 1984; LADRY *et al.,* 1996, ABBOUD-ABI SAAB, 1988a), Ciliates consumed 26% of primary production in the western Mediterranean Sea, 41% in the central and 70% in the eastern Basin and tintinnids ingested significantly more prey than aloricates by a factor of 5 (PITTA *et al.,* 2001). Accordingly, ciliates may also form a portion of the plankton on the Lebanese coast which is situated in the oligotrophic eastern Mediterranean basin.

Special attention has been paid to Tintinnids because their loricae, easy to preserve, facilitate their identification and classification. Loricate ciliates (Tintinnids) were studied in more detail because this group was found throughout the year. Short generation times, high abundances, and fast reproduction rates, coupled with high grazing impact, enhance the importance of Tintinnids as a key trophic link between the microbial and the metazoan compartments (LAVAL-PEUTO & BROWNLEE, 1986). Data allowing the calculation of Tintinnid diversity are in general rare in the eastern Mediterranean (DOLAN, 2000); we were interested in estimating the magnitude of Tintinnid diversity over a year's cycle.

While many reports exist which deal with ciliates, this might not be the case for the other groups of microzoa; these groups could play a particular role especially when present in high density. Hollande and Enjumet (1960) reported that Radiolaria constitute a very important nutritive source (Sphaerellaria are often found in the digestive tracts of Salps, Crustaceans and Pteropods). Acantharia consume a wide variety of prey; microscopic observations of feeding vacuoles showed remains of Tintinnids and other types of Ciliates, Diatoms, Dinoflagellates, copepod nauplii, copepodids and adults, pelagic Mollusks (CARON & SWANBERG, 1990). It should be stressed that as opposed to other microzooplanktonic groups, studies on the geographic distribution of Polycystina have been chiefly based on sedimentary- rather than on planktonic - materials.

The major objective of this work was to study the distribution patterns in time and space of the different microzooplankton communities in northern Lebanon, during a year's cycle. Furthermore, the particular features of the area, with inshore stations and offshore ones, offer an opportunity to examine the effects of intermingled neritic and oceanic conditions on microzooplankton group distribution and Tintinnid species diversity.

Materials and Methods

Site location and a brief description of the study area

A series of small islands are situated northwest of El Mina (near Tripoli) between 34° 27’ –34° 30’N and 35° 45’ -35° 49’E. The farthest three (Palm Island, Sanani Island & Ramkine Island) constitute the Palm Island Park. Some information about this park is published in TOHMÉ & TOHMÉ (1985) and HABER & HABER (1993). The park constitutes a unique and integrated natural marine basin in the eastern Mediterranean. Its surface area is about 5km^2. It lies 5.5 km northwest of the city of El-Mina, North Lebanon with Palm Island, Sanani Island and Ramkine Island having an area of 20, 4 and 1.6 hectares respectively. A bathymetric survey by EMERY *et al.,* (1966) showed the continental shelf to be very narrow. The 200m isobath is about 20km from the coast in north Lebanon and interesting geological data are given in SANLAVILLE (1977).

The average annual rainfall in the region is about 950mm with prevailing S - SW winds and a general current that flows from southwest to northeast along the entire Lebanese coast (Atlas Climatique du Liban, 1977).

Sampling protocol

Samples were collected in surface waters, at monthly intervals between March 1991 and February 1992, along a transect of 5 stations from El-Mina to Palm Island (Fig.1). The characteristics of these stations are: T1 is near the coastal area and outside the breakwater limit, T2 is situated north of El Bellan Island, T3 is midway between T2 & T4 and directly exposed to the general SW-NE current. T4 is situated SW of Palm Island and T5 NE of the same island. All stations have a rocky bottom except T5, which has a sandy one. The depth of stations is between 4-5m except at T3, where

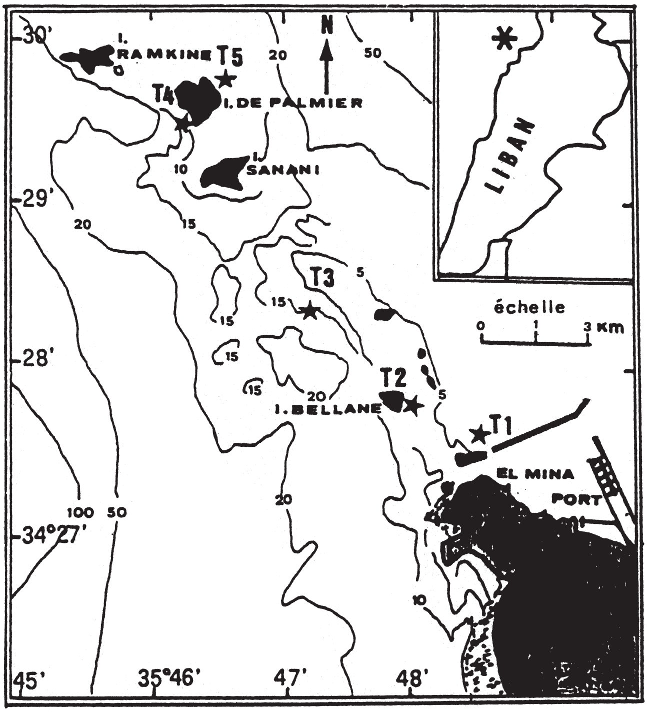

Fig 1: Map of the study area with the position of sampling station.

the depth is 15m. Temperature was measured directly by a thermometer (+ 0.01). Salinity was determined using a salinometer Beckman (model R57-C). Horizontal haul sampling for qualitative and quantitative analyses were performed using plankton net gauze (55 μm mesh size). In spite of the finer mesh used for microplankton sampling, no evidence of clogging was observed. The samples were preserved on board with buffered formalin (4%). The net volume of the filtered water was computed by taking into consideration the record of the digital flowmeter attached to the mouth of the net, the time of hauling, the boat speed, the distance dragged, the area of the net opening and the filtering coefficient of the net. Counts of specimens were made using Utermohl's method (1958) and an inverted microscope Wild M40. After homogenization, a sub sample of 2ml was taken and analyzed. Numerical abundance was determined for all the taxa, except non-loricates ciliates, in the entire sub sample. Density was expressed as number of organisms per m^{-3}. Non-loricate ciliates, due to their fragility and small size of the cells, were directly sampled using a water sampler, preserved by adding lugol and later concentrated by settling (ib.id.). Part of these samples was used to determine the density of nano.-and phytoplankton populations in relation to protozoan populations, data presented in detail in ABBOUD-ABI SAAB & KASSAB (1997).

Sixty net samples and sixty water samples from the different months and stations over a complete year were processed and analyzed in the course of the present investigation. Samples were collected at each station between 07.30 and 10.00 hours. The taxonomic groups studied under microzooplankton were as follows: Foraminifera, Actinopoda, Ciliophora (Loricates and Non-Loricates Ciliates).

Data analysis

In order to establish spatial and temporal relationships between the environmental variables and plankton populations in the area, bivariate correlation analysis was applied to the data using the Microstat program. The diversity index of the tintinnids was determined using Shannon's formula (1948) and was applied to each sample. Taxonomic diversity was also estimated by number of species. Variations among the 12 sampling series and among the five stations were evaluated by ANOVA followed by the Student t-test to identify differences among stations.

Results

Hydrography

The study of hydrological parameters at the surface layer showed that August was the warmest month, with surface temperature of 28˚C and the coldest period was in January-March, with surface temperatures of 15.5-16˚C. Salinity in general was higher than 39 psu and fluctuated within a narrow range (38.67 to 39.59 psu) in the coastal station. It rarely dropped below this value in winter. Table 1 shows the monthly mean values of temperature and salinity.

Biological Variables

For all examined populations, densities differed in coastal and offshore waters. Descriptive statistics of microzooplankton are presented in Table 2. Details on the different groups are presented as follows.

Table 1
Monthly mean surface temperature and salinity.

	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
T˚C	17.1	19.28	21.12	25.16	26.5	27.9	26.74	25.18	22.96	19.22	15.55	16.06
Spsu	39.49	39.46	39.00	39.575	39.48	39.14	39.26	39.55	39.59	39.20	38.67	39.115

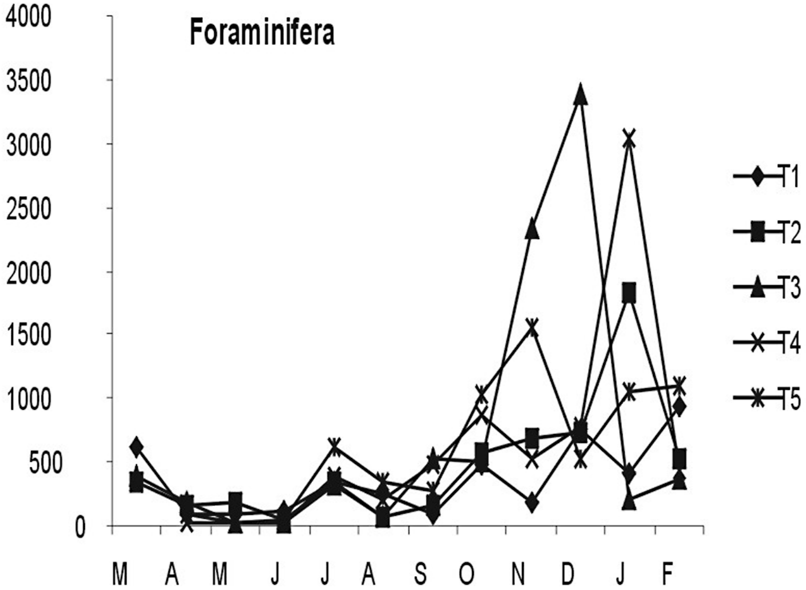

Fig.2: Monthly abundance of Foraminifera populations (Inds. m^{-3}) along the northern Lebanese coast during an annual cycle between March 1991 and February 1992.

Table 2
Descriptive statistics of nano-, microphyto-., microzooplankton in the north Lebanese coastal area (inds.m $^{-3}$).

Variable	**Mean**	**S.E.Mean**	**Std.Dev.**	**Range**	**Minimum**	**Maximum**
T˚C	21.91	.55	4.26	12.90	15	27.9
S psu	39.30	.04	.32	1.80	37.93	39.37
Nanoplank.X10^3	586989	54570	408369	2311765	102920	2414685
Microphyto.X10^3	48693	10967	82803	537244	920	538164
N.L.CiliatesX10^3	851	169	1285	5992	20	6012
Foraminifera	549	89	681	3370	20	3390
Acantharia	260	69	522	2608	0	2608
Polycystina	740	150	1145	6024	0	6024
Heliozoa	555.5	112	850	5165	0	5165
Tintinnids	10878	1282	9836	38961	344	38986

Foraminifera

Density of Foraminifera varied between 20 and 3390 inds.m $^{-3}$ (mean= 549 ± SE 89). They were present all through the year with a maximum between November and January, depending on the station. The highest densities were noted at the offshore station (T3) and the stations situated near the islands (Fig.2). At the first station (T1), which is in a shallow coastal area, density was relatively low and the maximum was only 765 inds.m $^{-3}$. From the point of view of the qualitative study, it should be noted that because of the presence of juvenile forms of Foraminifera, which complicates identification, all forms, juveniles and adults, were counted together; 2 species of particular abundance, *Globigerinoides rubber* and *Orbulina universa* and two other less abundant *Globigerina bulloides* and *Pulleniatina obliquiloculata* were present. All these species are warmwater species with their maximum density in late autumn and were noted from October to December.

Actinopoda

Based on the taxonomy proposed by RIEDEL (1967) and the cytological data of CACHON-ENJUMET (1961), super-class Actinopoda comprises 4 classes: Acantharia, Polycystina (Order Spumellarida - S.O. Sphaerocollina and S.O. Sphaerellarina and O. Nassellarida), Phaeodaria and Heliozoa. Based on a previous study, the maximum density was different between classes of the Actinopoda, (ABBOUD-ABI SAAB, 1988a) thus, the classes were considered separately and only the most abundant species were identified at species level.

The abundance of Acantharia ranged from 0 to 2608 inds.m $^{-3}$ (mean 260 ± SE 69) with a major peak in January and August at T5 and in May- June at the four other stations. In general, Acantharia were more abundant during spring at all stations and absent for most of the year, particularly at the first coastal station (Fig. 3). Two species were of particular abundance: *Amphilonche elongata* and *Diploconus fasces followed* by *Acanthometra pellucida.*

Class Polycystina abundance ranged from 0 to 6024 inds.m $^{-3}$ (mean= 740 ± SE 150) and were present in general from October to March, with maximum values in December-January. An exception was station T4 where the maximum values were recorded in April. A minor presence was also noted at all stations in July (Fig. 4). Maximal values were due to Sub-order Sphaerocollina (presented as a mass of hundreds of cells), which had their maximum density in late winter and spring, while S.order Sphaerellarina were abundant in late autumn with a high number of species. The abundance of species of the order Nassellaria was comparable to Sphaerellarina, with maximum numbers of species in December. More precisely the following species were recorded: in April *Collozome inerme*, *Sphaerozom punctatum* and *Sphearozom neopolitanum* (order Radiolaria Nasselaria) at T3; in June, Acantharia *Diploconus* sp. at T1, T2 and T4,

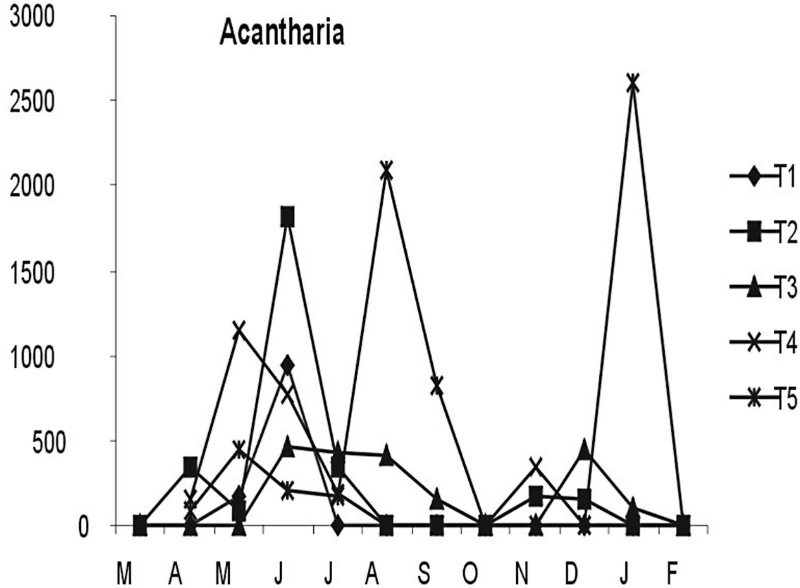

Fig.3: Monthly abundance of Acantharia populations (Inds. m^{-3}) along the northern Lebanese coast during an annual cycle between March 1991 and February 1992.

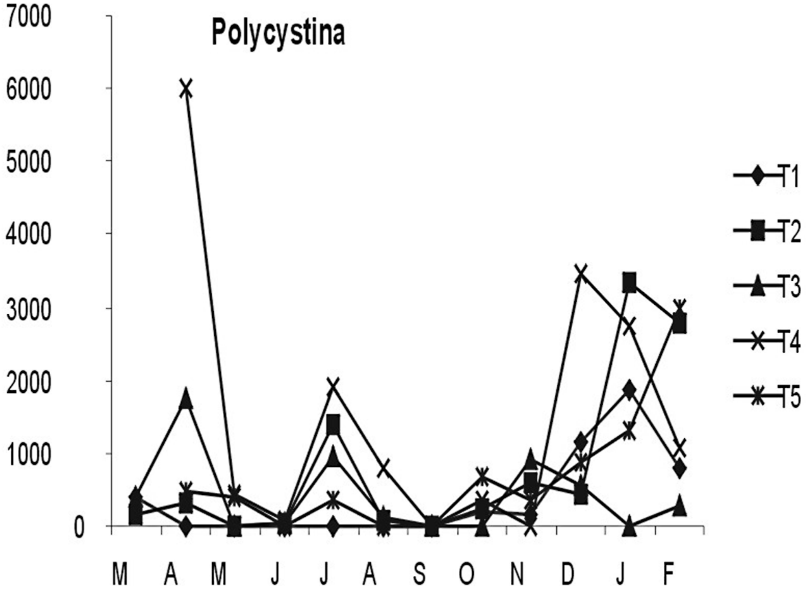

Fig.4: Monthly abundance of Polycystina populations (Inds. m^{-3}) along the northern Lebanese coast during an annual cycle between March 1991 and February 1992.

and *Myxosphaera coerula* (S-order Sphaerocollina) at T2, Heliozoa *Diploconus* atT4 and *Raphidiophrys pallida* atT2; in July, among Radiolaria Nasselaria, the species *Pseudocubis obelscus* and different other Radiolaria Nasselaria at all stations, except at T1 where Heliozoa *R. pallida* was found. In August, September, October, November and December, a variety of Radiolaria Nasselaria mainly *Pseudocubus obeliscus* and Heliozoa (*Sticholanche zanclea*) were noted. In January and February, different species of Spumellarida Spharellarina mainly *Thalassophysa spiculos* and different species of Nasselaria and Heliozoa *S. zanclea* were also found.

The class Phaeodaria, which constitute the most homogenous group and the most differentiated Actinopoda, live in general in deeper water. This group was only recorded once in January.

Heliozoa abundance ranged from 0 to 5165 inds.m $^{-3}$ (mean = 555 ± SE 112) with a maximum in late autumn (December T1, T3, T4 and November T5). T2 did not show a net maximum, but Heliozoa populations were present from June to December (Fig. 5). These populations were present for most of the year at the three offshore stations. *Sticholanche zanclea*, the most abundant species was particularly abundant during late autumn and during January and February.

Ciliophora

Non-loricate ciliates, of all size-classes, ranged from 20 to 6012 x 10^3 inds.m^{-3} (mean = 851 x 10^3 ± SE 169). Maximum densities occurred during August at T1, T2 and in February at T3, T4 with a minor peak in February-March at all stations (Fig. 6). During the sampling period, the total abundance of loricate ciliates (tintinnids) ranged from 344 to 38961 inds.m $^{-3}$ (mean=10878 inds.m $^{-3}$ ± SE 1282). The annual cycle was bimodal, but the appearance of peaks, and their importance, were irregular (Fig.7). A principal peak was noted in May at all stations and another one in October-December, while minimum levels were recorded in August-September.

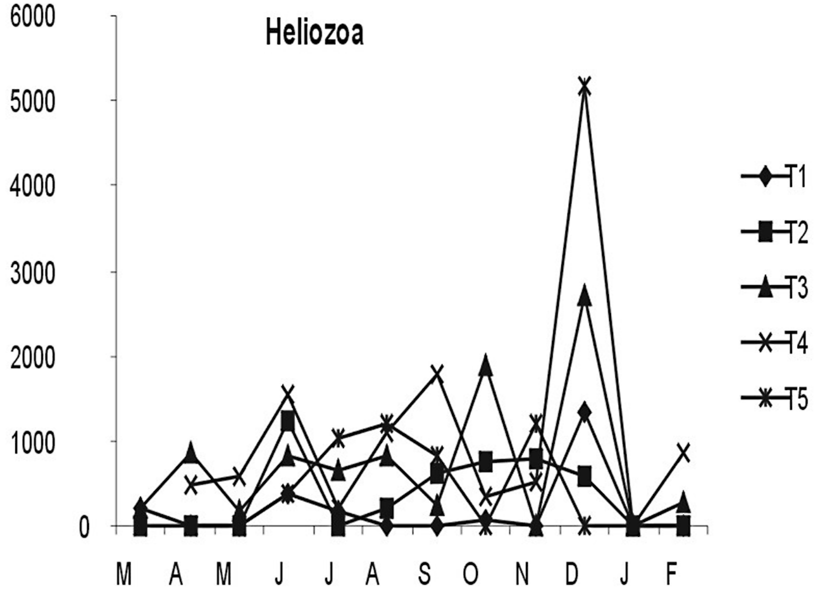

Fig.5: Monthly abundance of Heliozoa populations (Inds. m^{-3}) along the northern Lebanese coast during an annual cycle between March 1991 and February 1992.

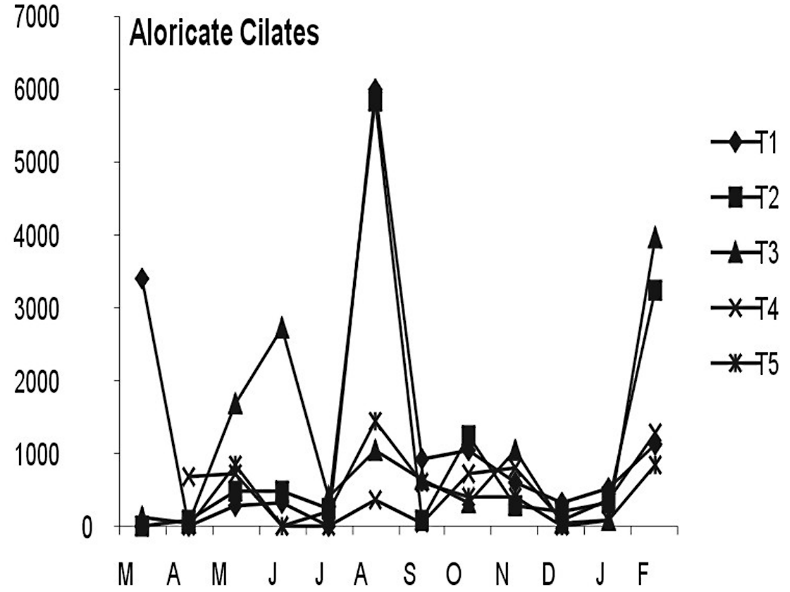

Fig.6: Monthly abundance of Aloricate Ciliates populations (Inds. m^{-3}x 10^{3}) along the northern Lebanese coast during an annual cycle between March 1991 and February 1992.

Descriptive statistics of the 5 stations during a one-year cycle are presented in Table 3. Ranges of variation were less accentuated in stations situated near Palm Island (T4 and T5) with a minimum of more than 1000 inds.m $^{-3}$.

The list of all Tintinnids species identified during the study is given in Table 4. Notifications of common species, between the east Mediterranean and the Red Sea, between east and west Mediterranean and thermal affinities of species were also indicated, according to HALIM (1969), PAULMIER (1997), PITTA *et al.,* (2001) and DOLAN (2000). A total of 90 species was recognized in this study comprising 29 genera. Eight genera constituted 54% of the total species with 13 species of *Tintinnopsis*, 9 species of *Eutintinnus*, 6 species of *Xystonella* and 5 species of *Epiplocylis, Favella, Rabdonella, Salpingella* and *Undella.* Eleven new species were recorded for Lebanese waters (Table 4) which were rare species, except *Favella campanula* and *Tintinnopsis radix*, which were more abundant. However, according to regional geographic distribution, 52 species are common within the Red Sea and 65 within the eastern Mediterranean sea. These numbers are only indicative; they could be higher, depending on progress of research into the problems of lessepsian migration for the former, and on more studies for the second.

The most abundant species, with their density and their percentage of the total number of Tintinnids, at each station are listed

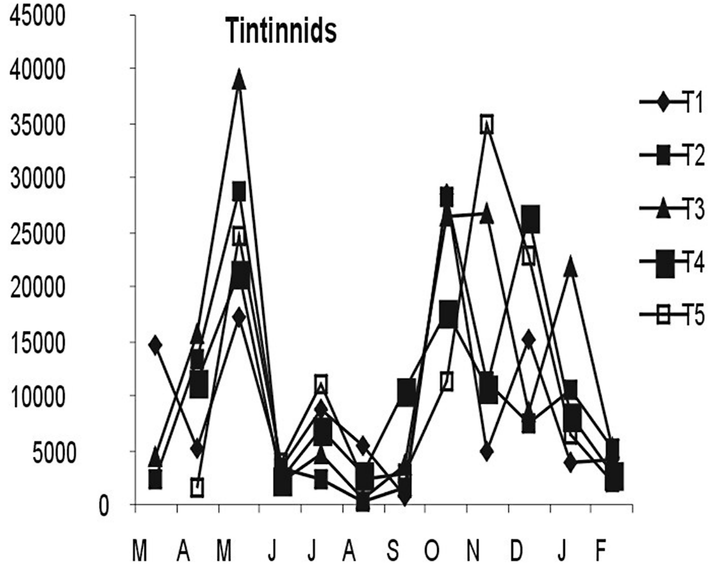

Fig.7: Monthly abundance of Tintinnid populations (Inds. m^{-3}) along the northern Lebanese coast over an annual cycle, between March 1991 and February 1992.

Table 3
Descriptive statistics of Tintinnids at 5 stations during a year's cycle (March 1991- Feb.1992).

	STATIONS					
	Total	**T1**	**T2**	**T3**	**T4**	**T5**
Mean (inds.m $^{-3}$)	10878	9344	9613	13175	11045	11253
Std Dev.	9836	8036	9811	12493	7937	11330
Minimum	344	826	344	628	2202	1922
Maximum	38986	28574	28871	38986	26604	34954

Table 4
Recorded Tintinnids along the northern Lebanese coast between El Mina and Palm Island Park from March 1991 to February 1992.

(R = common species between the Red Sea and the east Mediterranean; N= new records from Lebanese waters; C= common species between east and west Mediterranean); thermic distribution (T= tropical and subtropical, t =subtropical).

Station **Name of species**	**N**	**R**	**C**	Thermic distribution	**T1**	**T2**	**T3**	**T4**	**T5**
Acanthostomella sp.	N				0	0	0	0	16
Amphorides amphora (Cl.& Lach.) Strand		R	C	Tt	380	537	414	458	228
A. quadrilineata (Cl.& Lach.) Strand		R	C	Tt	48	27	219	194	86
Amphorides sp.1					0	15	60	32	48
Amplectella collaria (Brandt,) K.&C.				T	13	0	0	0	0
Ascampbelliella acuta (K.& C.)Cor. (ph.)	N	R	C	t	0	0	0	29	0
Bursaopsis punctatostriata Daday					5	0	0	0	9
Climacocylis scalaria (Brandt) Jörg.		R	C	Tt	1320	592	1435	537	219
C. elongata K & C.	N	R	C	t	0	14	0	0	0
Codonella amphorella Biedermann.			C	Tt	0	15	8	0	0
C. galea Haeck.		R	C	, T	78	0	10	9	30
Codonella sp.					0	0	0	14	0
Codonellopsis schabi (Brandt) K. & C.		R	C	Tt	1230	2247	2991	1937	3120
C. orthoceras (Haeck.)Jörg.		R	C	Tt	0	0	12	0	7
Coxliella annulata (Daday) Brandt		R	C	t	0	28	0	46	0
Coxliella decipiens (Jörg.) K. & C. (ph.)		R		t	15	15	0	16	0
C. laciniosa (Brandt) Brandt		R	C	t	0	0	30	7	16
Cyttarocylis sp.1					6	0	0	32	0
Dadayiella ganymedes (Entz, Sr.) K.& C.		R	C	Tt	232	155	126	220	450
Dictyocysta lepida Ehr. (ph.)			C	Tt	68	0	23	0	48
D. mitra Haeck.			C	Tt	48	21	0	213	87
D. nidulus K.& C.		R			0	12	0	0	0
Epiplocylis acuminata (Daday) Jörg.		R	C	t	42	0	0	14	0
E. blanda Jörg.		R	C	t	127	239	103	194	463
E. constricta K.& C.	N	R	C	t	0	0	4	9	119
E. undella (Ost.& Sch.) Jörg.		R	C	Tt	0	14	15	37	0
Epiplocylis sp1	N				46	15	15	0	7
Eutintinnus apertus K .& C.		R	C	Tt	0	61	130	118	70
E. fraknoi (Daday) K.& C.		R	C	Tt	30	56	70	122	88
E. latus (Jörg.) K.& C.		R	C	t	52	15	0	32	32
E. lusus-undae (Entz) K.& C.		R	C	Tt	715	2250	3139	1502	2262
E. macilentus (Jörg.) K.& C. (m.ph.)		R	C	t	78	70	170	160	93
E. medius K.& C.		R		T t	0	29	9	26	41
E. tubulosus (Ost.) K. & C. (m.ph.)			C		0	5	0	16	0
Eutintinnus sp1Balech					5	15	306	41	16
Eutintinnus sp2					0	0	0	9	0
Favella azorica (Cleve) Jörg. (m.ph.)		R	C	t	615	6	6	0	0
F. Campanula (Schmidt) Jörg.	N	R	C	t	130	345	168	319	24
F. ehrenbergi (Cl.& Lach.) Jörg.			C		72	0	0	71	0
F. macilentus			C		0	0	58	0	0
Favella sp.1	N				33	0	0	0	0
Helicostomella subulata (Ehr.)Jörg.		R	C	Tt	404	58	0	0	0
Metacylis sp					0	0	0	0	24

Table 4 (continued)

Metacylis jörgensenii Cleve (ph.)			C	t	0	0	0	0	7
Parundella lohmanni			C		0	0	0	0	16
Parundella longa Jörg.	N	R			0	14	30	0	0
Petalotricha ampulla (Fol.) Kent		R	C	Tt	0	69	40	0	0
Proplectella. acuta?	N		C		0	0	8	0	0
Proplectella angustior		R	C	t	0	0	0	0	35
P. claparedei (Entz sen.) K.& C.		R	C	t	128	58	248	273	346
P. pentagona Jörg.					51	153	0	14	0
Proplectella sp.	N				275	620	0	0	16
Protorhabdonella simplex (Cleve) K.& C. (ph.)		R	C	T,t	51	0	880	876	892
P. curta	N	R	C	t	0	27	0	0	16
Rahbdonella amor (Cleve) K.& C. (ph.)		R	C	T	77	14	58	202	285
R. brandti K.& C.		R			78	12	7	28	158
R. elegans Jörg.		R	C	t	0	131	229	191	224
R. lohmanni K.& C.					478	9	8	0	0
R. spiralis (Fol.) Brandt		R	C	Tt	461	480	510	520	144
Salpingella acuminata (Cl.& Lach.)Jörg. (ph.) C,Tt		R	C	Tt	35	29	48	0	70
S. elegans Jörg. (ph.)					0	0	17	0	0
S. glockentögeri (Brandt) K.& C. (ph.)			C		0	0	0	75	38
S. gracilis K.& C.			C		0	0	15	0	0
Salpingella sp.1					0	0	0	0	8
Salpingacantha ampla K.& C.		R	C	t	0	0	15	0	0
Stenstrupiella intumescens Jörg.		R	C	t	0	0	9	43	0
S. steenstrupii (Cl.& Lach.) K.& C.		R	C	Tt	90	178	61	114	142
Stenosemella nivalis (Meunier) K.& C. (ph.) C,			C	C	30	29	0	92	142
S. ventricosa (Cl.& Lach.)Jörg.			C	C	450	36	0	380	63
Tintinnopsis beroidea Stein		R	C	t	172	95	123	190	150
T. brandti Nordqvist					17	49	28	128	16
T. bütschlii Daday		R	C	,t	0	0	66	0	0
T. campanula (Ehr.) Daday		R	C	t	806	367	310	104	27
T. compressa (Daday) Laackmann			C	t	0	7	163	147	237
T. fimbriata Meunier		R		t	12	0	0	0	0
Tintinnopsis levigata		R	C	t	0	0	9	0	0
T. mortensenii Schmidt		R		t	0	12	0	171	126
T. minuta Lohmann (ph.)		R	C	t	29	0	0	0	0
T. nana Lohmann			C		0	0	0	21	32
T. radix Imhof		R	C	T	39	315	130	75	16
T. sp. aff. *cylindrica*		R	C		577	164	293	478	237
Tintinnopsis sp.1					23	0	43	28	0
Tintinnus inquilinus (O.F.Muller) Schrank			C		26	15	0	89	16
Undella clevei Jörg. (ph.)			C		0	0	0	0	16
Xystonella longicauda (Brandt) Laack.		R	C	Tt	32	40	47	0	63
X. longicauda var. clavata Jörg.		R	C	t	0	14	0	0	0
X. lohmanni (Brandt) Brandt			C	C	0	7	10	71	0
X. treforti (Daday) Laack.		***R***	C	Tt	0	12	0	0	0
Xystetonellopsis cymatica (Brandt) K.& C. (ph.)				T	0	7	0	0	7
X. paradoxa (Cleve) Jörg.			C	T	0	15	0	0	0

monthly in Table 5. Many species succeeded each other during the one-year cycle, depending on water conditions and food availability. The percentage of dominant species varied from 16 to 88% and T4 and T5 were more related to each other as compared with the other stations. During maximum density (May, September and January), dominant species were the same in all stations, but with different percentages. However, during the other months, dominant species changed among stations (April, October and December). It should be mentioned that except for some abundant species which were present during most of the year, such as *Amphorella amphora, Codonellopsis schabi, Epiplocylis blanda, E. lusus-undae, Protorhabdonella simplex* and *Tintinnopsis beroidea*, the majority of the species were sporadically present, such as *Climacocylis scalaria* which had an outburst in October with very high densities especially in T1 and T3 (15846 and 17215 inds.m $^{-3}$, respectively). Annual density of each species at each station could determine the geographic distribution of species as some avoid neritic waters and prefer oceanic waters, whereas others are cosmopolite.

Some genera, characteristic of tropical and subtropical waters, such as *Rhabdonella, Xystonella, Xystonellopsis, Epiplocylis, Climacocylis, Dadayiella, Petalotricha,* are present on our list. These genera are present in both neritic and oceanic waters. Coastal genera such as *Tintinnopsis, Codonellopsis, Codonella , Stenosemella* are also present, as well as cold water genera such as *Acanthostomella* and *Steenstrupiella.*

Dominant species of tintinnids

Species are listed according to their density:

Codonellopsis schabi: (annual mean = 2305 inds.m $^{-3}$). It was noted especially in autumn and was absent from April to July. It was also present at all stations with an annual mean between 3120 (T5) and 1230 inds.m $^{-3}$ (T1). A principal peak was recorded in October-November successively (8626, 15861, 18260, 7826 & 16522 inds.m $^{-3}$) at all stations and a minor one in January, except in T3 where the result was reversed.

Eutintinnus lusus-undae: (annual mean = 1976 inds.m $^{-3}$). It was present during most of the year at all stations. The annual mean varied between 715 (T1) and 3140 inds.$^{-3}$ (T3). It had a distinct peak in May at all stations reaching 32622 inds.m $^{-3}$ at T3, which represented more than 60% of the total tintinnids, except at the very coastal station (table 3).

Protorhabdonella simplex: (annual mean = 540 inds.m $^{-3}$). Present at all stations in February, April and November-December with maximum of 1913 inds.m $^{-3}$ at T1. It was more frequent in spring and in autumn at T2, absent in summer and reached a maximum in November (4996 inds.m $^{-3}$) and 7702 inds.m^{-3} at T3.

Rhabdonella spiralis: (annual mean = 423 inds.m $^{-3}$). Present at all stations from December to May with a maximum of 2390 inds.m $^{-3}$ at T3 in January. It avoided high temperatures.

Amphorides amphora: (annual mean = 403 inds.m $^{-3}$). Present at all stations for most of the year; reached a maximum in May at all stations and had the highest density at T2 (4348 inds.m^{-3}).

Tintinnopsis cylindrica: (annual mean = 350 inds.m $^{-3}$). Absent in summer, with a maximum in December at T1 (4974 inds.m^{-3}) and T2 (1480 inds.m^{-3}) and in January at the other stations.

Tintinnopsis campanula: (annual mean = 323 inds.m^{-3}). Like other species of Tintinnopsis, it is neritic. The annual mean varied between 806 inds.m^{-3} (T1) and 310 inds.m^{-3}. It was present particularly in spring (February-May) with a maximum in March at T1 (7930 inds.m^{-3}) and in April at T2 (3880 inds.m^{-3}) and in May at T4 and T5 (1140 and 296 inds.m^{-3}, respectively).

Table 5
Monthly abundant species, their density and their percentage of the total Tintinnids in 5 stations along the northern Lebanese coast from March 1991 to February 1992.

Stations	T1			T2			T3			T4			T5		
	Species	**density cells/m^3**	**%**	**Species**	**density**	**%**	**Species**	**density**	**%**	**Species**	**density**	**%**	**Species**	**density**	**%**
March	*T.campanula*	7930	54	*P. simplex*	2262	15	*T.campanula*	1784	41						
April	*T. campanula*	1565	31	*F. campanulla*	4048	30	*R spiralis*	15654	37	*F.campanulla*	3443	30	*F.campanulla*	261	16
	R. spiralis	1217	24	*T.campanula*	3880	29				*R. spiralis*	2348	21	*R.spiralis*	261	16
				R. spiralis	2193	16									
May	*E. lusus-undae*	5217	30	*E. lusus-undae*	22261	77	*E.lusus-undae*	32622	83	*E lusus-undae*	12835	60	*E.lusus-undae*	21878	88
	H. subulata	4695	27												
	A. amphora	3652	21												
June	*R. spiralis*	1217	35	*R. spiralis*	1865	54	*R. spiralis*	1096	51	*R. elegans*	670	30	*R.elegans*	1304	34
	E. lusus-undae	730	21										*E.constricta*	1304	34
	R. elegans	548	16												
July	*F.azorica*	6956	80	*E. lusus-undae*	695	31	*E. lusus-undae*	1195	26	*S. ventricosa*	1722	25	*C. schabi*	7130	65
	E.apertus	869	19												
August	*S.ventricosa*	5217	98	*A.amphora*	275	80	*C. schabi*	209	33	*C. schabi*	1500	51	*C. schabi*	1740	77
September	*C. schabi*	330	40	*C. schabi*	391	24	*C. schabi*	1330	37	*C. schabi*	5895	56	*C. schabi*	1095	38
							A. amphora	887	25	*S.ventricosa*	2456	23			
October	*C. scalaria*	15846	55				*C. scalaria*	15846	65	*C. schabi*	7826	44	*C. schabi*	4476	40
	C. schabi	8626	30	*C. scalaria*	7104	25	*C. schabi*	8626	21	*C. scalaria*	5913	34	*C. scalaria*	2410	22
November	*P. simplex*	1217	25	*P. simplex*	4696	41	*C. schabi*	8060	30	*C. schabi*	2608	24	*C. schabi*	16522	47
	C. schabi	870	18	*C. schabi*	1565	14	*P simplex*	1922	23						
	T. cylindrica	696	14	*P. pentagona*	1565	14									
	E. blanda	696	14												
December	*T cylindrica*	4974	33	*P.simplex*	1480	20	*T. cylindrica*	2035	24	*P. simplex*	7200	27	*P.simplex*	4869	21
	D. ganymedes	2296	15	*T. cylindrica*	1480	20	*P. simplex*	1922	23				*D.ganymedes*	4000	18
	P. simplex	1913	13				*C. schabi*	1017	12						
January	*C. schabi*	2087	53	*C.schabi*	7304	69	*C. schabi*	18260	84	*C. schabi*	2739	33	*C. schabi*	2348	36
February	*R.spiralis*	1408	33	*T. radix*	1565	30	*R.spiralis*	1004	20	*P. claparedei*		23	*C. schabi*	395	20
	C. schabi	626	15				*E.lusus-undae*	1095	22				*E. lusus-undae*	316	16
	E. macilentus	626	15												

Data analysis

A one-way analysis of variance indicated that there were significant differences among the means of the five stations for the different groups of Actinopoda (Probability value 0.5%). However, differences were not significantly different for Tintinnids and Foraminifera.

Coefficient of correlation (Table 6) showed that temperature was correlated with Tintinnids (.289*). Also, Polycystina, Heliozoa and *A. amphora* were correlated with temperature (r= .403**, .326* and .392**); Polycystina were correlated with Tintinnids (r=. 335*); Polycystina and *C. schabi* were correlated (r= .773**) as well as *A. amphora* and *C. schabi* (r=. 262*) with total phytoplankton populations ($p<0.05$).

Diversity index, which is an indicator of organization of populations, was applied to Tintinnids. It varied between 0.19 and 4.15. A minimum was noted in August (T1, T2, T5) and another one in May (T3, T4, T5) and a maximum in December (T1, T3 and T5) and in April (T2, T4 and T5). High values were also recorded during autumn (Fig.8).

Taxonomic diversity was also estimated by the number of species. It varied between 2 (August) and 27 (December) at T5. The number of species started to decrease with the increase in temperature until it reached the lowest value at all stations in August; then it started to increase with the decrease in temperature and the phenomena of water convection to reach a maximum in November-December (Fig. 9).

Discussion

This study was conducted at the surface layer exposed to high annual fluctuations, mainly of temperature (15-28°C) and of other environmental parameters. Similarly, meteorological parameters have an effect, as some coastal stations were directly influenced by land input. Water depth was not very high, so mixing of waters and ascension of suspended matter from the bottom were produced,

Table 6

Correlation Coefficient Matrix (Bravais-Pearson) between parametrs along the northern Lebanese coast

(A. amphora = Amphoriades amphora; C. schabi = Codonellopsis schabi; E. lususundae = Eutintinnus lusus undae)

Parameters														
Temp	1	1.000												
Salinity	2	-.194	1.000											
Tintinnids	3	.289*	.123	1.000										
Nano.	4	-.114	.114	.013	1.000									
Phyto	5	.181	-.094	.011	-.126	1.000								
N.L.Ciliates	6	-.221	-.043	-.033	-.104	-.084	1.000							
Foraminifera	7	.011	.047	.019	-.081	.284*	-.118	1.000						
Acantharia	8	.187	-.083	-.206	-.173	.167	.091	.124	1.000					
Polycystina	9	.403**	.001	335*	-.038	-.242	.069	-.202	-.135	1.000				
Heliozoa	10	.326*	-.196	-.051	.016	.063	-.085	-.080	.030	-.028	1.000			
A. amphora	11	.392**	.044	.603**	.026	-.193	.016	-.141	-.141	.773**	-.051	1.000		
C. schabi	12	.108	.099	.250	.028	-.251	.174	.122	-.172	.352**	-.092	.262*	1.000	
E.Lususundae	13	.165	.077	-.055	-.043	.037	-.167	-.031	-.038	-.142	.085	-.072	-.240	1.00
		1	2	3	4	5	6	7	8	9	10	11	12	13

Number of variable: 13

Number of case: 60

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

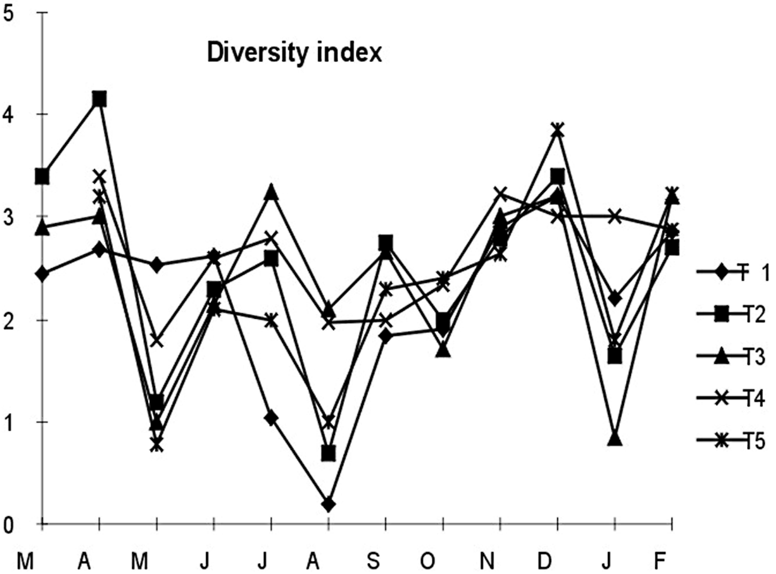

Fig.8: Diversity index (bits/individual) of tintinnids (calculated by Shannon's formula) along the northern Lebanese coast over an annual cycle, between March 1991 and February 1992.

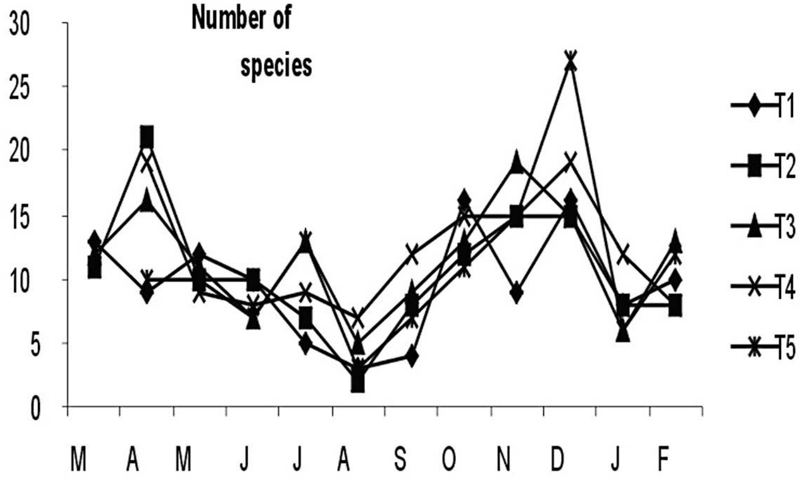

Fig.9: Number of tintinnid species along the northern Lebanese coast over an annual cycle, between March 1991 and February 1992.

resulting in changes of the phytoplankton population (ABBOUD-ABI SAAB, & KASSAB, 1997) and probably followed by changes in the microzooplankton communities.

The hydrological parameters were similar to those observed on the Lebanese coast (ABBOUD-ABI SAAB, 1993b), but values of salinity were generally high at the coastal station and during winter salinity rarely dropped below 38 psu because of the absence of fresh water sources nearby. However, this parameter apparently did not constitute a meaningful factor in the distribution patterns of the microzooplankton communities and no significant correlation was found between salinity and any population of these groups. In comparison with the central coastal waters of Lebanon, the studied area showed relatively higher salinity and lower temperatures.

Biological parameters revealed that data on Foraminifera were in accordance with a previous study, carried out in the central part of the Lebanese coastal waters, where 12 species, essentially tropical and subtropical, were observed with densities showing a distinct peak in November-January and a minor one during May-June (ABBOUD-ABI SAAB, 1993a). Furthermore, Foraminifera seemed to avoid shallow waters and were more abundant in offshore water. In general, the planktonic Foraminifera are scarce in shelf areas and confined marine basins like the Red Sea; species occurrence is mainly controlled by climatic belts (mostly temperature-dependent), current systems and by food availability; all three boundary conditions normally vary seasonally. Densities also depend greatly on food availability and hydrographic characteristics (CARON & SWANGERG, 1990). CIFELLI (1974) and BLANC *et al.,* (1975; 1976) reported that thermal control was instrumental in controlling population distribution; local water properties may also be of major importance (UFKES *et al.,* 1998).

The Actinopoda, were particularly abundant and diversified during autumn and winter. According to KRSINIC (1998) they avoid the very coastal area and are more frequently present in offshore waters, as this group is more abundant in deeper waters. Due to the heterogeneity of the superclass Actinopoda, results were different from one class to another; For this reason, it is hard to specify precisely the distribution patterns of these taxa from this study of restricted area and depth, but we can conclude that Actinopoda were present in shallow and neritic waters and some species reached a relatively high density; to have more useful ecological results, it is recommended to take each order or sub- order separately.

The Acantharia, which are strictly marine protozoa, are frequently present in plankton and their abundance can change with zones, depth, seasons and also in relation to various chemical-physical factors (BOTTAZZI & ANDREOLLI, 1982). However, they are common in surface waters of tropical and subtropical oceans, in temperate and polar seas they occur in much lower numbers. In nearshore environments they are usually scarce and they are restricted to the illuminated upper layer of the sea. This affinity is probably related to the photosynthetic physiology of their symbiotic algae. Species of polycystina were present at coastal and offshore stations, with higher density and diversity at the latter. Spring bloom was usually due to the proliferation of one or two species while the late autumn bloom was due to a high number of species. The polycystines are typically open ocean organisms occurring throughout the worldwide ocean. However, distinct coastal associations are uncommon or absent in areas with an extended shelf (BOLTOVSKOY, 1980). Vertical profiles of total radiolarian abundance in tropical and subtropical waters indicate that the bulk of their populations is usually located in the upper 50-100m (BOLTOVSKOY, 1995) while Phaeodaria inhabit all oceans at all water depths.

In a previous study (ABBOUD-ABI SAAB, 1988a), concerning the super class of Actinopoda in the central part of the Lebanese coast, based on vertical and horizontal hauls in nearshore and offshore waters, 66 species were identified and the maximum density occurred between February and June for Acantharia and Polycystina and between December-January for Heliozoa and some orders and suborders of Polycystina (O. Nassellarida and S.O. Sphaerellarina); the maximum annual mean density of all the classes was observed in offshore horizontal hauls, except for Heliozoa which showed maximal densities in the vertical hauls.

Similarly in a well- studied Mediterranean region, the Tyrrhenian Sea, the Acantharia were always present at high levels (BOTTAZI-MASSERA & ANDREOLI, 1972) and 44 species have been recorded (BOTTAZZI *et al.,* 1965). The Adriatic plankton is usually devoid of them or Acantharia are only present during short periods of the year and in very low percentages, while a clear difference in abundance is noted between the northern and southern Adriatic Sea. BOTTAZZI & ANDREOLI (1978) found that in the Ligurian and Tyrrhenian seas, the highest density for Acantharia has been found in the July-August September period whereas for Radiolaria the highest mean value coincided with the spring; from the quantitative point of view, they found that Acantharia showed a mean value considerably higher than that of Radiolaria. KIMOR (1971), from a study in the eastern Mediterranean, noted that most Acantharia species were recorded in the offshore waters with the Spumellaria and Nassellaria species being recorded at stations closer to the main land. Regarding seasonal changes of Acantharia in the Atlantic Ocean, spring was found to be the period of greatest abundance while the lowest percentage was observed during summer (MASSERA BOTTAZZI & ANDREOLI, 1982).

Ciliate abundance throughout the year revealed that density was not homogeneous, either along the sampling area or within time, in agreement with an earlier study in the central part of Lebanon (ABBOUD-ABI SAAB & KASSAB, 1988). Densities of non-loricate ciliates decreased from coastal regions towards the offshore area. However, this was not the case for loricate ciliates which had higher mean values in the last three stations. Aloricate ciliates showed a mean concentration about 78 times higher than loricate ciliates. This estimation could be criticised because we did not use the same method to study the two different communities. Aloricate ciliates were studied using water samples sedimented directly, while in the case of Tintinnids the net explored much more volume and all cells under 50μm could pass through the mesh of the filtering area. The comparison was made only to give us a rough idea concerning the magnitude of abundance of the two groups. In a previous study (ABBOUD & KASSAB, 1988) using only a water sampler, aloricate ciliates were also more abundant but the magnitude of difference was less. The oceanic station T3 had the highest annual mean density of loricate ciliates and also the highest maximum, followed by the stations T5 and T4, situated near the Park (Table 3). The dominant species in T4, T5, situated near the islands, were more similar most of the time to the oceanic station T3 than to the coastal stations T1 and T2. Qualitatively, it seems that most species avoided high temperatures and that is why August, the warmest month, showed the lowest numbers.

The Diversity index revealed that the first minimum value (August) corresponded to the minimum of density and low number of species while the second one (May) corresponded to maximum density. In the first time period, it is a sign of poverty and in the second time period it is a sign of high density of dominant species; It is perhaps necessary to put together the diversity index and the number of species in each sample. Diversity appears unrelated to trophic specialization, at least as indicated by varieties in lorica diameter and also was unrelated to Tintinnid abundance (CARIOU *et al.,* 1999). Thus, in spring or during a coastal bloom, it could be related in part to the nutrition level, but also in summer and autumn it could be related to water temperature and hydrodynamic changes.

Densities of aloricate ciliates decreased from coastal regions towards the offshore area. The maximum densities were noted at the first stations (T1 and T2) where food seemed to be available and decreased towards the open sea stations. Peak numbers and biomass generally occur in bays and estuaries but high densities are also found in nutrient-rich upwelling areas and divergences in the open ocean (LAYBOURN-PARRY, 1992). The results suggest that ciliate distributions depend more on factors like food supply than on geographic latitude or ocean topography. Due to the fact that aloricate ciliates regroup as small and large species and each size class shows maximum abundance at a particular time of the year, small ciliates reached their maximum at the end of summer while the largest ciliates were most abundant at the beginning of the summer (IBANEZ & RASSOULZADEGAN, 1977), it is known that the efficiency of particle ingestion by these protozoans is related to the ratio prey dimensions/cytopharynx diameter of the ciliates. According to the variation of density of phytoplankton and the succession of populations, ciliates can profit from all sizes of nano. and micropankton.

The absence of significant correlation between nano.- microphyto and ciliates could be due to the fact that all of the non-loricate ciliates were taken together at all stations. Food relationships could be different from one zone to another, from one season to another and among different size classes. Aloricate ciliates were more abundant in the water samples and a maximum was noted in August, the period of minimum Tintinnids.

In a previous study in the central part of Lebanon (ABBOUD-ABI SAAB, 1989), we noted a major peak of Tintinnids in May-June and a minor one in November-December, but the density and the maximum values were much higher. The bimodal annual cycle of Tintinnids was comparable to those observed in similar Mediterranean localities (VITIELLO, 1964; TRAVERS & TRAVERS, 1971; RASSOULZADEGAN, 1979; ABBOUD-ABI SAAB, 1989; PAULMIER, 1997)

WALSH (1988) noted that each coastal zone has a peculiar ecological physiognomy, which implies that general predictive schemes cannot be applied to these systems. The timing of the principal phytoplankton bloom, which constitutes the principal element, could change and other phytoplankton blooms may be observed throughout the year outside the usual time (IGNATIADES, 1984), which in turn could affect the Tintinnid populations. However, the phytoplankton populations showed the principal maximum at some stations during January and not in early spring, as in the other Lebanese coastal areas (ABBOUD-ABI SAAB & KASSAB, 1997). Spring maximum of Tintinnids (May) corresponded to the maximum of phyto and nanoplankton in May; while the minimum density of Tintinnid corresponded to the period of highest temperatures (July to September) and the period of the lowest temperatures (February-March).

From a qualitative point of view, the analysis of Loricate ciliates (Tintinnids) resulted in a total of 90 species that were recognized, comprising 29 genera, while 131 species were previously recorded in Lebanese waters (ABBOUD-ABI SAAB, 1989). The leading species, *Tintinnopsis beroidea* was the most abundant species while in northern Lebanon *Codonellopsis shabi* was the most abundant, followed by *Eutintinnus lusus -undae* in both areas. Abundant species in both studies and their percentage of total Tintinnids were sometimes different. Results showed that the Lebanese coastal waters are rich in plankton species of Tintinnids but only a few reach bloom conditions. These results are in agreement with the geographic and ecologic distribution listed by PIERCE & TURNER (1993), which recorded a high ciliate diversity in intertropical waters. Thermal affinity data showed that most of the species present in our waters were found in tropical or inter-tropical waters, which may mean that our waters are temperate-warm. The eastern Mediterranean Sea has been shown to possess strong tropical affinities (OREN, 1957), which account for the great variability in plankton species that are affected by seasonal variations, particularly of temperature rather than by geographical distribution.

The number of species of Tintinnids, Foraminifera, and some groups of Actinopoda present in autumn as compared to the total number is comparatively high. Similar results have been shown for some Dinoflagellates, such as *Ceratium* and *Dinophysis.* The higher diversity during this period of the year is a trait of similarity between these groups of microzooplankton and these groups of Dinoflagellates. These are phenomena noted by Jörgensen in 1920 and 1923. Many of the winter epipelagic species of the groups cited above sink to deeper levels during the summer months; a phenomena apparently governed by temperature and light intensity factors (KIMOR, 1983). The autumn period corresponds to the start of the water-cooling period and the destruction of thermocline by convection movement, which results in the ascension of meso. and epipelgic species together, before the installation of winter homothermic conditions in the upper 100m. Similarly, significant correlations were noted between temperature and Tintinnids, Polycystina and Heliozoa

Thermal affinity and diversity in species could mean that our waters were more comparable to warm waters than temperate waters, especially when there is a warm surface layer and a thermocline which are very pronounced for half of the year.

Conclusions

From the preceding results, the following could be concluded:

i- In general, density of microprotozoans, except for aloricate ciliates, increased from the coastal towards the offshore and stations situated near the islands are more similar to offshore stations than to the coastal ones for all groups.

ii- The observed species were typical for the surface layer and were epipelagic species. Late autumn and early winter showed the highest number of microprotozoans. The large-scale gradient in seasonal diversity was either directly or indirectly related to the seasonal pattern of mixing and stratification of sea temperature.

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