Tintinnids (Protozoa: Ciliophora) of the Büyükçekmece Bay in the Sea of Marmara*

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SUMMARY: This study on the species composition and distribution of tintinnids, which form one of the most abundant ciliate groups in the seas, was carried out in Büyükçekmece Bay in 1998-1999. Plankton samples were collected horizontally from the subsurface (0.5 m) with a 55 µm plankton net at five stations and a 3 l water sampler was used for their quantitative analysis. All tintinnid species were identified according to their lorica shape as the usual important criterion. A total of 14 species were identified. Primary hydrographic conditions such as salinity, temperature and dissolved oxygen were recorded on each sampling occasion. The genera *Favella* and *Eutintinnus* were dominant in terms of species and individual numbers. *Eutintinnus fraknoi* was the most abundant species, with a mean abundance of 0.4×10^3 ind. l^{-1}. The study shows that the species and individual numbers of tintinnids decreased in winter and early spring when phytoplankton increases. The abundance of tintinnids in Büyükçekmece Bay appears to be correlated with the decrease in abundance of total phytoplankton (r_s= -0.57, p= 0.05) and diatoms (r_s= -0.65, p<0.05) and the increase in temperature (r_s= 0.61, p<0.05). Furthermore, phytoplankton abundance was positively correlated to dissolved oxygen (r_s= 0.64, p<0.05). In particular, *Favella serrata* was more affected by temperature and *Eutintinnus lusus-undae* by salinity compared to other species.

Key words: tintinnids, abundance, phytoplankton, Büyükçekmece Bay, Sea of Marmara.

RESUMEN: TINTÍNNIDOS (PROTOZOA: CILIOPHORA) DE LA BAHÍA DE BUYUKCEKMECE EN EL MAR DE MÁRMARA. – El presente estudio sobre la composición y distribución de las especies de tintínnidos, que forman parte de uno de los grupos más abundantes de ciliados marinos, fue realizado en la Bahía de Buyukcekmece en 1998-1999. Las muestras de plancton se recogieron horizontalmente a 0.5 m de la superficie con una red de plancton de 55 µm en cinco estaciones y para el análisis cuantitativo se tomaban 3 litros de muestra. Todas las especies de tintínnidos eran identificadas de acuerdo a la forma de la lorica como principal criterio. Se identificó un total de 14 especies. Las condiciones hidrográficas como salinidad temperatura y oxigeno disuelto fueron determinadas en cada muestreo. El genero *Favella* y *Eutintinnus* dominaban en términos de abundancia. Eutintinnus frakmoi era la especie más abundante, con una media en abundancia de 0.4 x 10^3 ind l^{-1}. El estudio muestra que el número de especies y el número de individuos por especie decrecía en verano y al principio de la primavera cuando el fitoplancton incrementa. La abundancia de tintínnidos en la Bahía de Buyukcekmece parece estar correlacionada con la disminución de la abundancia del fitoplancton total (r_s = -0.57, p = 0.05) y diatomeas (r_s = -0.65, p < 0.05) y con el incremento de temperatura (r_s = 0.61, p<0.05). Además, la abundancia de fitoplancton estaba positivamente correlacionada con la concentración de oxígeno disuelto (r_s=0.64, p<0.05). Concretamente *Favella serrata* estaba mas afectada por la temperatura y *Eutintinnus lusus-undae* por la salinidad comparado con otras especies.

Palabras clave: tintínnidos, abundancia, fitoplancton, bahía de Buyukcekmece, Mar de Mármara.

INTRODUCTION

Ciliates frequently dominate the microzooplankton and have a key position in planktonic food webs as they can respond quickly to phytoplankton pulses composed chiefly of nanoplankton (Capriulo and Ninivaggi, 1982). Tintinnids constitute one major component of marine planktonic ciliates and many species have an apparent cosmopolitan distribution in the seas and oceans (Marshall, 1969).

*Received July 18, 2002. Accepted July 15, 2003.

The Büyükçekmece Bay is located in the northeast of the Sea of Marmara (Fig. 1). It remained connected to Büyükçekmece Lake until 1985, when the connection was blocked by a barrier (11.4 m in height) in order to meet the need for fresh water in Istanbul (Meriç, 1986, 1992). Since then, the Büyükçekmece Dam Lake has had no effect on the dynamics of the bay because of lack of a water current from the lake to the bay (Meriç, 1992). No previous published studies exist on the tintinnids in the Sea of Marmara, a two-layer water body in which the surface water has characteristics of the Black Sea whereas the deep water has those of the Mediterranean Sea. A study by Sorokin *et al.* (1995) involving zooplankton reported that tintinnids were rare in the Sea of Marmara and mentioned the abundance of ciliates. There are few data on phytoplankton and their ecological features in the Sea of Marmara (Aubert *et al.*, 1990; Uysal, 1996; Uysal and Ünsal, 1996; Balkıs, 2000, 2003). Of these, Balkıs (2003) presented data on seasonal variability and abundance of phytoplankton in Büyükçekmece Bay.

The aim of this study is to report on the biodiversity of tintinnids in surface waters in the Sea of Marmara and determine whether the occurrence of tintinnids is correlated to phytoplankton and selected hydrographical factors.

MATERIAL AND METHODS

This research was carried out in Büyükçekmece Bay. Tintinnids and phytoplankton samples for species identification were collected with horizontal tows from the subsurface (0.5 m) with a 55 µm plankton net at five stations (Fig. 1) at monthly intervals from April 1998 to March 1999 and fixed in a 4% neutral formaldehyde solution. The 55-µm net possibly underestimates the abundance of smaller tintinnids due to reduced retention. The species composition sampled with the plankton net should consequently be viewed as size-biased. Identification of smaller species was carried out using a 3 l water sampler at a depth of 0.5 m. Observations of the samples were made through the use of inverted phase contrast microscope equipped with a microphotosystem at a magnification of 400 X. For physical-chemical and quantitative analyses of tintinnid abundance, a 3 l water sampler with thermometer was used at the same depth. These samples were preserved in acidified Lugol's iodine fixative (Throndsen, 1978). Fifty ml subsamples from 3 l water sampler were concentrated by settling in special chambers for 24 h prior to analysis following the method of Utermöhl (Hasle, 1978) and counted. Also, the abundance of dominant phytoplankton

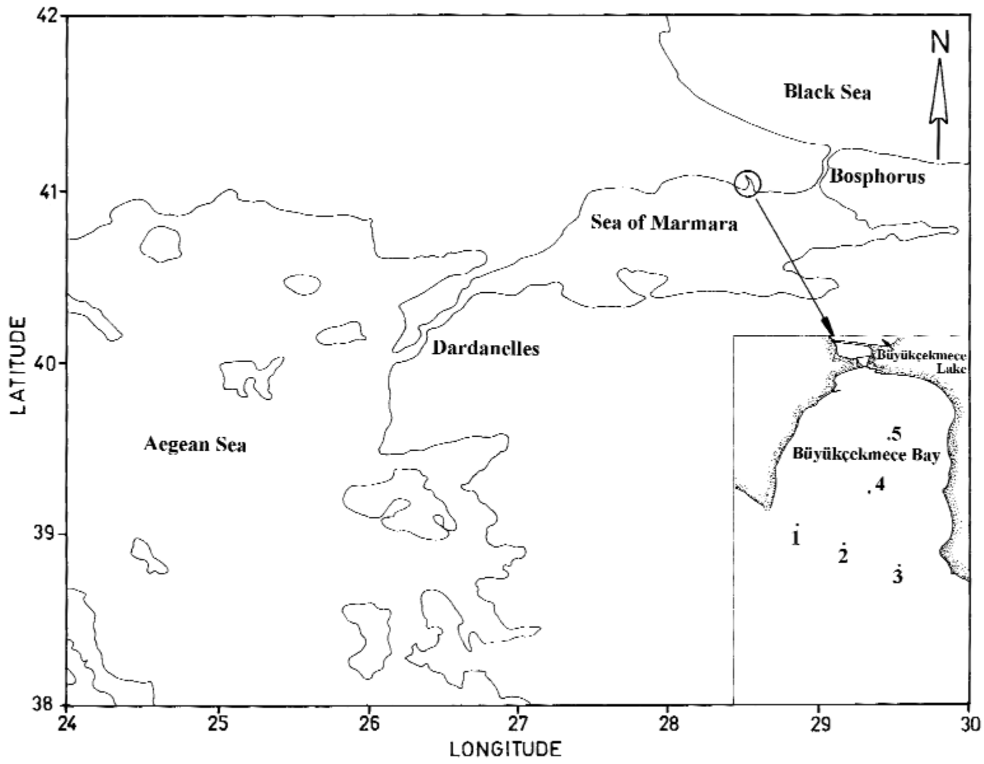

FIG. 1. – Research stations 1-5 in Büyükçekmece Bay.

species was recorded. Phytoplankton samples were counted in a Sedgwick-Rafter cell using an inverted phase contrast microscope. Small forms of doubtful taxonomic classification were not added to the list and not counted (Table 1).

References used to identify the tintinnids and phytoplankton species were Lebour (1930), Cupp (1943), Trégouboff and Rose (1957), Balech (1959), Hendey (1964), Sournia (1968), Steidinger and Williams (1970), Drebes (1974), Taylor (1976), Dodge (1982), Koray and Özel (1983), Ricard (1987), Balech (1988), Hasle and Syvertsen (1997), Steidinger and Tangen (1997) and Throndsen (1997).

At each sampling date measurements of salinity (psu), temperature (°C) and dissolved oxygen (mg l^{-1}) were performed (Table 2). The Mohr-Knudsen method (Ivanoff, 1972) was used to measure salinity values, and the Winkler method (Winkler, 1888) to measure dissolved oxygen (DO) values. The abundance of tintinnids and phytoplankton and physico-chemical parameters of the five stations, where the study was carried out, are similar to one another and only the means for all stations are reported. Since the coefficient of variance (V) calculated for five stations for each month was <10% for temperature (0%-5.8%) and salinity (0.3%-1.3%), standard deviations (SD) were not given in the tables and figures. However, V (3.7%-19%) calculated for dissolved oxygen was <10%, with the exception of October-December, so the standard deviation for DO is given in Figure 2.

Spearman rank order correlation was used to correlate abundance of tintinnids with abundance of other phytoplanktonic organisms and hydrographical parameters. Moreover, Nonmetric Multi-Dimensional Scaling (MDS) analysis was performed to estimate relationships between the tintinnid community and hydrographic data.

RESULTS

Abiotic parameters

The average surface water temperature in the study area was 14.9°C (from 6.8±0.26°C to 23.5±0.35°C). Salinity showed an average of 21.3 psu (from 19.7±0.25 psu to 23.3±0.49 psu), and the average dissolved oxygen was 9.53 mg l^{-1} (from 7.13±1.37 mg l^{-1} to 11.95±0.44 mg l^{-1}) (Fig. 2, Table 2). V calculated for DO was >10% in October-

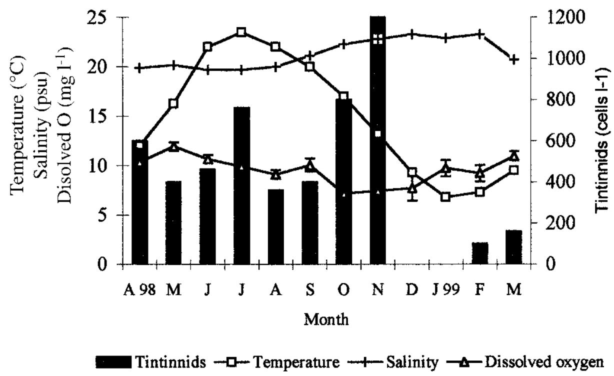

FIG. 2. – Monthly variations of abundance (cells l^{-1}) of total tintinnids, temperature (°C), salinity (psu) and dissolved oxygen (mg l^{-1}) in the surface water (0.5 m).

December only, the values being 19% (7.13±1.37 mg l^{-1}), 17% (7.42±1.28 mg l^{-1}) and 16% (7.73±1.27 mg l^{-1}) respectively.

Tintinnid composition

A total of 14 tintinnid species belonging to 9 genera and 5 families were identified (Table 1). Most of the tintinnids observed belong to the genera *Favella* and *Eutintinnus*. The latter was numerically the best represented genus. Total abundance of the tintinnid community varied greatly (Fig. 3). The maximum value for the period of this study was 1.2x10^3 ind. l^{-1} in November. The lowest densities were observed in February and March, 0.1x10^3 and 1.6x10^2 ind. l^{-1} respectively. In January and December no tintinnids were observed. *Eutintinnus fraknoi* was the most abundant species, with a mean abundance of 0.4x10^3 ind. l^{-1}.

Tintinnid species were observed for ten months within a period of one year. Especially in October and November, it was found that tintinnids increased while the phytoplankton decreased. The abundance of tintinnids was 8x10^2 ind. l^{-1} in October and 1.2x10^3 ind. l^{-1} in November. *A. amphora, E. apertus, E. fraknoi, E. lusus-undae, F. serrata, H. subulata, M. jörgensenii* and *S. steenstrupii* were the most abundant species. The highest species number was recorded in July (7 species) and November (6 species). The abundance of tintinnids was 7.6x10^2 ind. l^{-1} in July. The species found during the sampling of this month were *C. schabi, E. apertus, E. fraknoi, E. lusus-undae, F. campanula, F. ehrenbergi* and *T. radix*. In February and March only one tintinnid species (*F. ehrenbergi*) was found (Table 1).

Generally, there was a negative correlation between the abundances of tintinnids and the record-

TABLE 1. – The abundance (cells l^{-1}, average from 5 stations, see Fig. 1) and frequency (f) of each identified species from the subsurface (0.5 m) in Büyükçekmece Bay from April 1998 to March 1999. (Abbreviations used: V=very abundant, 81-100%; A=abundant, 61-80%; C= common, 41-60%; R=rare, 21-40%; X=present sporadically, 1-20%).

	A 1998	M	J	J	A	S	O	N	D	J 1999	F	M	f
Tintinnids													
Amphorides amphora (Clap.and Lach.) Strand, 1926	-	-	-	-	-	60	-	160	-	-	-	-	X
Codonellopsis orthoceras (Haeckel) Jörgensen, 1924	140	200	-	-	-	-	-	-	-	-	-	-	X
C. schabi (Brandt) Kofoid and Campbell, 1929	-	-	100	100	-	-	-	-	-	-	-	-	X
Coxliella annulata (Daday) Brandt, 1907	-	-	220	-	-	-	-	-	-	-	-	-	X
Eutintinnus apertus Kofoid and Campbell, 1939	-	-	-	60	40	-	-	180	-	-	-	-	R
E. fraknoi (Daday) Kofoid and Campbell, 1939	-	-	-	100	100	-	-	400	-	-	-	-	R
E. lusus-undae (Entz) Kofoid and Campbell, 1939	360	-	-	40	100	160	160	-	-	-	-	-	C
Favella campanula (Schmidt) Jörgensen, 1924	-	-	-	200	80	60	-	-	-	-	-	-	R
F. ehrenbergi (Clap.and Lach.) Jörgensen, 1924	100	-	140	100	-	-	-	-	-	-	100	160	C
F.serrata (Mobius) Jörgensen, 1924	-	200	-	-	-	100	300	-	-	-	-	-	R
Helicostomella subulata (Ehren.) Jörgensen, 1924	-	-	-	-	-	-	100	160	-	-	-	-	X
Metacylis jörgensenii (Cleve) Kof. and Camp., 1929	-	-	-	-	-	20	140	220	-	-	-	-	R
Steenstrupiella steenstrupii (Clap. and Lach.) Kof. and Camp., 1929	-	-	-	-	-	-	100	80	-	-	-	-	X
Tintinnopsis radix (Imhof) Brandt, 1907	-	-	-	160	40	-	-	-	-	-	-	-	X
Dinoflagellates	-	-	-	-	-	-	-	-	-	-	-	-	
Ceratium furca (Ehrenberg) Clap. and Lach., 1859	-	990	290	600	200	140	140	430	110	40	70	60	V
C. fusus (Ehrenberg) Dujardin, 1841	-	170	140	870	1300	1100	1400	1500	30	90	210	590	V
C. minutum Jörgensen, 1920	-	20	-	-	-	-	-	-	-	-	-	-	X
C. trichoceros (Ehrenberg) Kofoid, 1908	-	-	-	-	-	130	130	-	-	-	-	-	X
C. tripos (O.F.Müller) Nitzsch, 1817	980	860	340	260	140	-	-	-	-	-	-	170	C
Dinophysis acuta Ehrenberg, 1839	-	-	10	-	-	-	-	-	-	-	-	-	X
D. caudata Saville-Kent, 1881	-	-	-	-	-	-	-	90	30	-	-	-	X
D. hastata Stein, 1883	190	-	10	-	-	-	-	-	-	-	-	-	X
Diplopsalis lenticula Bergh, 1881	7300	590	20	-	190	220	-	-	-	3000	1500	2900	A
Gonyaulax grindleyi Reinecke, 1967	-	200	40	-	-	-	-	-	-	-	-	-	X
G. monacantha Pavillard, 1916	-	-	-	-	-	70	-	-	-	-	-	-	X
Gymnodinium sanguineum Hirasaka, 1922	550	1340	440	290	100	-	30	-	50	570	60	-	A
G. simplex (Lohmann) Kofoid and Swezy, 1921	730	480	-	-	-	-	-	-	-	-	-	-	X
Heterocapsa triquetra (Ehrenberg) Stein, 1883	-	320	-	-	-	-	-	-	-	-	520	-	X
Kofoidinium velleloides Pavillard, 1928	-	-	40	-	-	-	-	-	-	-	-	-	X
Lingulodinium polyedrum (Stein) Dodge, 1989	-	650	-	-	140	-	-	-	-	-	-	-	X
Noctiluca scintillans (Macart.) Kof.and Swezy, 1921	190	210	-	-	30	20	30	-	30	-	-	-	C
Oxytoxum scolopax Stein, 1883	-	-	-	-	-	-	50	-	30	-	-	-	X
Phalacroma rotundatum (Clap.and Lach.) Kof. and Mich., 1911	-	-	-	20	120	60	60	40	160	80	80	60	A
Prorocentrum compressum (Bailey)Abe *ex* Dod., 1975	100	-	770	2500	4700	-	530	360	720	570	-	-	A
P. cordatum (Ostenfeld) Dodge, 1975	-	-	-	-	-	530	-	-	-	-	-	-	X
P. micans Ehrenberg, 1833	2100	18400	1200	3600	2800	6100	1500	1400	1900	620	1200	780	V
P. scutellum Schröder, 1900	730	32800	60	120	60	290	290	100	4900	3600	12100	1600	V
P. triestinum Schiller, 1918	250	-	-	690	3700	6700	980	-	560	-	-	-	C
Protoperidinium bipes (Paulsen) Balech, 1974	1200	2100	-	-	-	-	-	-	-	490	-	60	R
P. brochi (Kofoid and Swezy) Balech, 1974	-	-	-	-	-	-	50	-	-	-	-	-	X
P. claudicans (Paulsen) Balech, 1974	-	-	-	-	30	-	-	-	-	-	-	-	X
P. crassipes (Kofoid) Balech, 1974	-	-	10	160	-	-	-	-	-	-	-	-	X
P. depressum (Bailey) Balech, 1974	1400	250	30	30	30	-	-	-	-	840	760	500	A
P. divergens (Ehrenberg) Balech, 1974	250	800	290	360	90	150	270	-	-	-	-	170	A
P. leonis (Pavillard) Balech, 1974	-	-	-	-	110	150	-	-	-	210	260	-	R
P. paulseni Pavillard, 1905	-	-	-	-	210	-	-	-	-	-	-	-	X
P. pellucidum Bergh, 1881	3600	270	-	-	-	-	-	-	-	-	500	810	R
P. pentagonum (Gran) Balech, 1974	-	60	-	-	-	-	-	-	-	-	-	-	X
P. pyriforme (Paulsen) Balech, 1974	-	40	-	-	880	210	-	-	-	-	60	-	R
P. steinii (Jörgensen) Balech, 1974	230	210	140	180	180	30	-	-	-	-	-	-	C
P. subinerme (Paulsen) Loeblich III, 1970	-	-	-	-	-	60	-	-	-	-	-	-	X
Protoperidinium spp.	1400	-	-	170	380	-	-	-	-	-	-	-	R
Pyrophacus horologium Stein, 1883	-	-	-	-	-	30	100	-	-	-	-	-	X
Scrippsiella trochoidea (Stein) Loeblich III, 1976	1800	3100	650	830	840	870	40	-	60	4000	140	240	V
Diatoms	-	-	-	-	-	-	-	-	-	-	-	-	
Achnanthes brevipes Agardh, 1824	-	-	-	-	-	-	-	-	-	-	-	60	X
Cerataulina pelagica (Cleve) Hendey, 1937	-	-	2700	740	3800	-	-	60	50	-	-	-	C
Chaetoceros spp.	360	180	-	5100	2900	2000	180	1200	900	9500	2900	8400	V
Climacosphenia spp.	-	-	-	130	30	-	60	-	-	-	-	-	R
Coscinodiscus spp.	470	510	260	30	710	50	-	110	150	170	150	240	V
Cylindrotheca closterium (Ehr.)Rei. and Lew., 1964	120	20	-	2700	150	-	50	330	360	5700	2400	23100	V
Dactyliosolen fragilissimus (Bergon) Hasle, 1996	-	-	-	-	-	1100	-	-	2100	-	-	-	X
Ditylum brightwellii (West)Grun. *in* V.Heurck, 1883	-	-	-	-	-	-	40	410	290	100	130	-	C
Guinardia flaccida (Castracane) Peragallo, 1892	-	-	-	-	-	270	-	-	-	280	-	-	X
Hemiaulus hauckii Grunow *in* Van Heurck, 1880-85	-	-	-	-	-	3900	170	80	-	-	-	-	R
Leptocylindrus danicus Cleve, 1889	-	-	120	-	1900	15100	-	-	-	1500	-	-	R
Navicula spp.	130	220	-	-	-	-	-	-	-	-	70	120	R

TABLE 1 (Cont.). – The abundance (cells l^{-1}, average from 5 stations, see Fig. 1) and frequency (f) of each identified species from the subsurface (0.5 m) in Büyükçekmece Bay from April 1998 to March 1999. (Abbreviations used: V=very abundant, 81-100%; A=abundant, 61-80%; C= common, 41-60%; R=rare, 21-40%; X=present sporadically, 1-20%).

	A 1998	M	J	J	A	S	O	N	D	J 1999	F	M	f
Pleurosigma normanii Ralf *in* Pritchard, 1861	-	-	40	-	-	20	-	-	-	-	-	-	X
Proboscia alata (Brightwell) Sundsrôm, 1986	-	20	-	-	30	840	-	-	-	-	-	-	R
Pseudonitzschia spp.	-	-	-	-	1100	1100	100	60	420	90	-	120	C
Pseudosolenia calcar-avis (Schult.) Sundsrôm, 1986	-	-	40	1600	1100	40	-	1100	-	-	-	-	C
Rhizosolenia setigera Brightwell, 1858	-	-	-	-	-	-	-	-	60	12300	10100	1800	R
Skeletonema costatum (Greville) Cleve, 1878	1900	-	90	2000	2900	350	-	230	-	1700	3700	250000	A
Striatella unipunctata (Lyngbye) Agardh, 1832	-	-	20	-	-	-	-	-	-	-	-	-	X
Thalassionema nitzschioides (Grunow)Meresh., 1902	-	-	-	50	1400	-	-	-	-	-	130	-	R
Thalassiosira anguste-lineata (Sch.) Fry.and Hasle, 1977	-	-	-	-	-	-	-	-	-	1300	5700	400	R
T. rotula Meunier, 1910	-	-	-	-	-	-	-	-	1100	-	1900	-	X
Silicoflagellates	-	-	-	-	-	-	-	-	-	-	-	-	
Dictyocha fibula Ehrenberg, 1839	-	-	-	50	130	30	-	-	530	130	-	-	C
D. speculum Ehrenberg, 1839	-	-	20	-	-	-	-	-	-	-	-	60	X
Octactis octonaria (Ehrenberg) Hovasse, 1946	-	-	20	-	-	-	-	-	-	-	-	-	X
Euglenophycean	-	-	-	-	-	-	-	-	-	-	-	-	
Eutreptiella spp.	-	-	-	-	-	59400	-	-	-	-	-	-	X
Prasinophycean	-	-	-	-	-	-	-	-	-	-	-	-	
Halosphaera viridis Schmitz, 1878	-	-	-	-	-	-	50	-	1000	-	-	-	X
Tintinnids	600	400	460	760	360	400	800	1200	-	-	**100**	**160**	
Dinoflagellates	23000	63860	4480	10680	16230	16860	5600	3920	8580	14110	17460	7940	
Diatoms	2980	950	3270	12350	16020	24770	600	3580	5430	32640	27180	284240	
Silicoflagellates	-	-	40	50	130	30	-	-	530	130	-	60	
Euglenophycean	-	-	-	-	-	59400	-	-	-	-	-	-	
Prasinophycean	-	-	-	-	-	-	50	-	1000	-	-	-	
Total Phytoplankton	25980	64810	7790	23080	32380	101060	6250	7500	15540	46880	44640	292240	

ed phytoplankton (Fig. 3). Spring phytoplankton blooms generally developed and presumably persist because of low grazing pressure from zooplankton. Throughout the year, total phytoplankton reached its maximum values at a depth of 0.5 m ($292x10^3$ ind. l^{-1}) in March. Diatoms in particular increased ($284 x10^3$ ind. l^{-1}) and only the tintinnid *F. ehrenbergi* ($1.6x10^2$ ind. l^{-1}) was observed. *S. costatum* was the species with the most significant increase ($250x10^3$ ind. l^{-1}), followed by *C. closterium* ($23.1x10^3$ ind. l^{-1}) and *Chaetoceros* spp. ($8.4x10^3$ ind. l^{-1}) in that order. Only low numbers of dinoflagellates were recorded in this month, with the exception of *Diplopsalis lenticula* ($2.9x10^3$ ind. l^{-1}) and *P. scutellum* ($1.6x10^3$ ind. l^{-1}). In April when the dinoflagellates were numerically dominant ($23x10^3$ ind. l^{-1}), the number of tintinnids was $6x10^2$ ind. l^{-1}. During this month only 3 tintinnid species were observed (*C. orthoceras, E. lusus-undae, F. ehrenbergi*). Among dinoflagellates and diatoms, the most copious were *D. lenticula* ($7.3x10^3$ ind. l^{-1}), *P. pellucidum* ($3.6x10^3$ ind. l^{-1}), *P. micans* ($2.1x10^3$ ind. l^{-1}) and *S. costatum* ($1.9x10^3$ ind. l^{-1}). May was another important month in which total phytoplankton increased. *P. scutellum* ($33x10^3$ ind. l^{-1}) and *P. micans* ($18x10^3$ ind. l^{-1}) were present in large amounts at that depth. The species found during the sampling of this month were *C. orthoceras* ($2x10^2$ ind. l^{-1}) and *F. serrata* ($2x10^2$ ind. l^{-1}).

In the summer, total phytoplankton reached its maximum values in July ($23x10^3$ ind. l^{-1}) and August ($32.4x10^3$ ind. l^{-1}). The most significant diatom species in July were *Chaetoceros* spp. ($5.1x10^3$ ind. l^{-1}), *Cylindrotheca closterium* ($2.7x10^3$ ind. l^{-1}), *Skeletonema costatum* ($2x10^3$ ind. l^{-1}) and *Pseudosolenia calcar-avis* ($1.6x10^3$ ind. l^{-1}) and the dinoflagellates *P. micans* ($3.6x10^3$ ind. l^{-1}) and *Prorocentrum compressum* ($2.5x10^3$ ind. l^{-1}). The high-

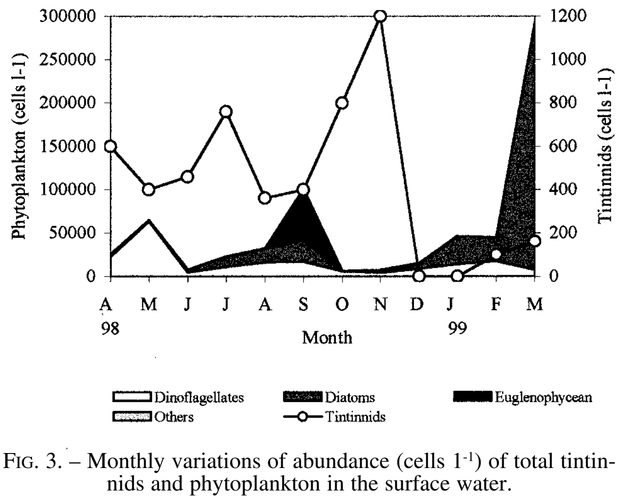

FIG. 3. – Monthly variations of abundance (cells l^{-1}) of total tintinnids and phytoplankton in the surface water.

TABLE 2. – Tintinnid species obtained in Büyükçekmece Bay and some hydrographical parameters. Temperature: °C; salinity: psu; dissolved oxygen: mg l^{-1}.

Tintinnid species	°C (min-max)	psu (min-max)	mg l^{-1} (min-max)	Months
Amphorides amphora	13.2-20	21.1-22.8	7.42-10.06	9,11
Codonellopsis orthoceras	12-16.3	19.9-20.2	10.38-11.95	4,5
Codonellopsis schabi	22-23.5	19.7	9.93-10.66	6,7
Coxliella annulata	22	19.7	10.66	6
Eutintinnus apertus	13.2-23.5	19.7-22.8	7.42-9.93	7,8,11
Eutintinnus fraknoi	13.2-23.5	19.7-22.8	7.42-9.93	7,8,11
Eutintinnus lusus-undae	12-23.5	19.7-22.3	7.13-10.38	4,7,8,9,10
Favella campanula	20-23.5	19.7-21.1	9.10-10.06	7,8,9
Favella ehrenbergi	7.3-23.5	19.7-23.3	9.22-10.98	2,3,4,6,7
Favella serrata	16.3-20	20.2-22.3	7.13-11.95	5,9,10
Helicostomella subulata	13.2-17	22.3-22.8	7.13-7.42	10,11
Metacylis jörgensenii	13.2-20	21.1-22.8	7.13-10.06	9,10,11
Steenstrupiella steenstrupii	13.2-17	22.3-22.8	7.13-7.42	10,11
Tintinnopsis radix	22-23.5	19.7-20	9.10-9.93	7,8

est tintinnid species number was recorded in this month (7 species). In August, the dinoflagellates *P. compressum* (4.7x10^3 ind. l^{-1}), *P. triestinum* (3.7x10^3 ind. l^{-1}), *P. micans* (2.8x10^3 ind. l^{-1}) and *C. fusus* (1.3x10^3 ind. l^{-1}), and the diatoms *C. pelagica* (3.8x10^3 ind. l^{-1}), *Chaetoceros* spp. (2.9x10^3 ind. l^{-1}), *S. costatum* (2.9x10^3 ind. l^{-1}), *L. danicus* (1.9x10^3 ind. l^{-1}) and *T. nitzschioides* (1.4x10^3 ind. l^{-1}) dominated.

In autumn, another phytoplankton peak was detected in September (101x10^3 ind. l^{-1}), dominated by the Euglenophycean *Eutreptiella* spp. (59.4x10^3 ind. l^{-1}) and the diatom *L. danicus* (15.1x10^3 ind. l^{-1}). During this month five tintinnid species were observed (*A. amphora, E. lusus-undae, F. campanula, F. serrata, M. jörgensenii*). In October and November the dinoflagellates, *Ceratium fusus* and *Prorocentrum micans*, were dominant. The maximum cell number of *C. fusus* was 1.4x10^3 ind. l^{-1} in October and 1.5x10^3 ind. l^{-1} in November, whereas that of *P. micans* was 1.5x10^3 ind. l^{-1} in October and 1.4x10^3 ind. l^{-1} in November.

In winter, the number of diatoms increased more than it did in the other seasons. In January, the predominant species of diatoms were *R. setigera* (12.3x10^3 ind. l^{-1}), *Chaetoceros* spp. (9.5x10^3 ind. l^{-1}) and *C. closterium* (5.7x10^3 ind. l^{-1}). The tintinnid *F. ehrenbergi* was only observed in February in this season. In February, the dinoflagellate *P. scutellum* (12.1x10^3 ind. l^{-1}) and the diatoms *R. setigera*

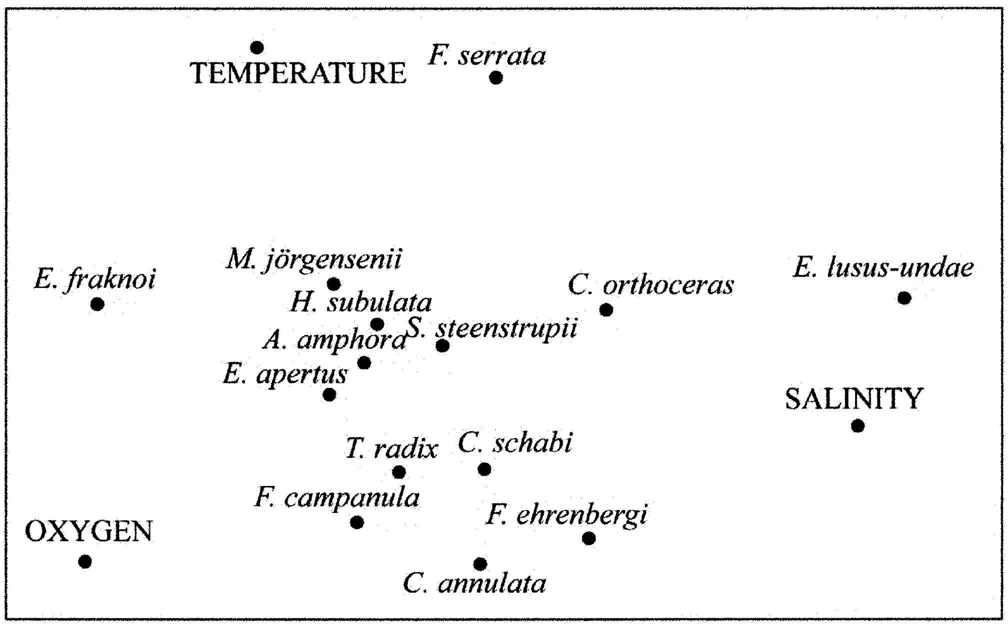

FIG. 4. – Multi-Dimensional Scaling (MDS) plot in two dimensions for the tintinnid community in Büyükçekmece Bay with relation to temperature, salinity and oxygen.

($10.1x10^3$ ind. l^{-1}), *T. anguste-lineata* ($5.7x10^3$ ind. l^{-1}) and *S. costatum* ($3.7x10^3$ ind. l^{-1}) dominated.

The generalist species that were found throughout the whole year were the dinoflagellates *Prorocentrum micans* (f=100%), *P. scutellum* (f=100%), *Ceratium furca* (f=92%), *C. fusus* (f=92%), *Scrippsiella trochoidea* (f=92%), *Gymnodinium sanguineum* (f=75%) and *Phalacroma rotundatum* (f=75%), and the diatoms *Chaetoceros* spp. (f=92%), *Coscinodiscus* spp. (f=92%), *Cylindrotheca closterium* (f=83%) and *Skeletonema costatum* (f=75%) (Table 1).

The abundance of tintinnids in Büyükçekmece Bay appears to be negatively correlated to the abundance of total phytoplankton (r_s= -0.57, p= 0.05) and diatoms (r_s= -0.65, $p<0.05$) and positively correlated to temperature (r_s= 0.61, $p<0.05$). Furthermore, phytoplankton abundance is positively correlated to dissolved oxygen (r_s= 0.64, $p<0.05$). The other parameters did not appear to play any role in the dynamics of the plankton community of Büyükçekmece Bay. In particular, *F. serrata* was more affected by temperature and *E. lusus-undae* by salinity compared to other species (Fig. 4).

DISCUSSION

There are 90 ciliate species known to exist in all the seas of Turkey (Koray *et al*., 1999). Öztürk (1999) reported 17 whereas Türkoğlu and Koray (2000) reported 18 tintinnid species found in the Turkish territorial waters of the Black Sea. Off the coasts of Ukraine, Romania, Bulgaria and Georgia 27, 15, 23 and 9 tintinnid species were found respectively (Petranu, 1997; Zaitsev and Alexandrov, 1998; Konsulov, 1998; Komakhidze and Mazmanidi, 1998). This study reports on 14 tintinnid species found in the Sea of Marmara. All the species found in Büyükçekmece Bay are known to occur in the Aegean and the Mediterranean Seas, while only *Coxliella annulata, Favella campanula, F. ehrenbergi, F. serrata, Helicostomella subulata* and *Tintinnopsis radix* are present in the Black Sea. If the sampling had been carried out using a smaller mesh size, more tintinnid species might have been detected.

In this study of the surface waters of the Büyükçekmece Bay the highest numbers of tintinnid species were found in July and November and the lowest number in February and March. In January and December no tintinnids were observed. A negative correlation was observed between tintinnids and the recorded phytoplankton species. In particular, tintinnids increased in both individual number and in species during October and November, when there was a decrease in phytoplankton. In March, in contrast to the increases in diatom abundance, the tintinnid abundance decreased. This may be explained by the general inability of ciliates to feed on colonial diatoms and large dinoflagellates (Hansen, 1991a). Ciliates mainly feed on nanosized prey, preferably nanoflagellates (Burkill *et al*., 1987; Dolan and Coats, 1990; Paranjape, 1990; Sherr and Sherr, 1994). It is possible that the nanoflagellates were abundant when the large dinoflagellates and diatoms were not, which would explain the negative correlation between tintinnids and the recorded phytoplankton species. Since nanoflagellate abundance was not measured in this study, the role of nanoflagellates remains unknown. However, Aubert *et al.* (1990) found that nanoflagellates were common in the Sea of Marmara in July ($1.3x10^6$ ind. l^{-1}). This value is concordant with the peak shown by tintinnids in the summer period. Nevertheless, Aubert *et al*. (1990) did not mention nanoflagellate abundance in November, when tintinnids appear to reach a maximum in this study.

Apart from nanoflagellates, there are several other causes for the negative correlations between tintinnid abundance and phytoplankton abundance. Also, heterotrophic and mixotrophic dinoflagellates are often numerous in marine plankton and are considered important consumers of both phytoplankton and bacteria (Hansen, 1991a; Bockstahler and Coats, 1993a), and they can consume ciliates (Bockstahler and Coats, 1993b). Mixotrophy appears to be widespread among prymnesiophytes and many dinoflagellates (Hansen and Nielsen, 1997; Hansen, 1998). *G. sanguineum* is one of several species of large mixotrophic dinoflagellates and a predator of ciliates (Bockstahler and Coats, 1993b). In this study, the highest cell number of *G. sanguineum* was found in May ($1.3x10^3$ ind. l^{-1}). Also, *Dinophysis hastata* and *Phalacroma rotundatum* can ingest ciliates (Hansen, 1991b), but these species did not reach great numbers during the sampling period. Other mixotrophic dinoflagellates such as *Ceratium* and *Dinophysis,* and heterotrophic ones such as *Diplopsalis, Gymnodinium, Noctiluca* and *Protoperidinium* were found throughout the year. However, the abundance was generally low and it is thus not likely that there was any major grazing pressure from dinoflagellates on ciliates. It is more likely that other preda-

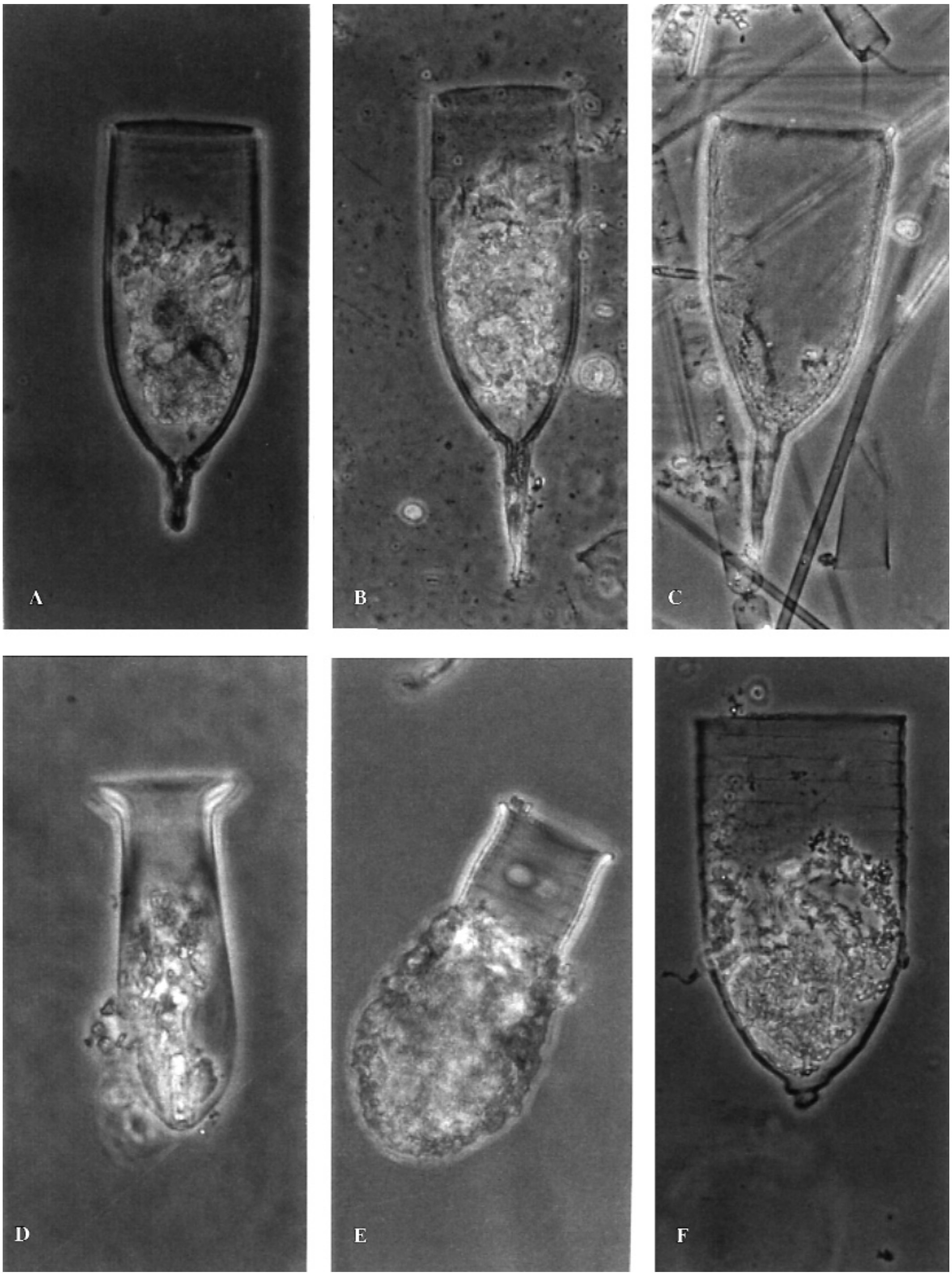

FIG. 5. – A, *Favella campanula* (x 200); B, *F. ehrenbergi* (x 200); C, *F. serrata* (x 200; D, *Amphorides amphora* (x 400); E, *Codonellopsis schabi* (x 400); F, *Coxliella annulata* (x 200).

tors, i.e. mesozooplankton, were more important consumers of the tintinnids (Turner and Anderson, 1983; Turner *et al*., 1998; Coats and Revalente, 1999; Levinsen and Nielsen, 2002). Since, mesozooplankton was not measured in this study, we do not know the extent of this predation, but it would be interesting to study it in the future since it could explain some of the seasonal patterns of the tintinnids that were found. Only Uysal (1996) reported individuals of different zooplankton groups formed by copepods, siphonophores, chaetognaths, polychaete larvae, cladocerans and appendicularians in the Sea of Marmara. The percentage distribution of zooplankton groups revealed that the predominance

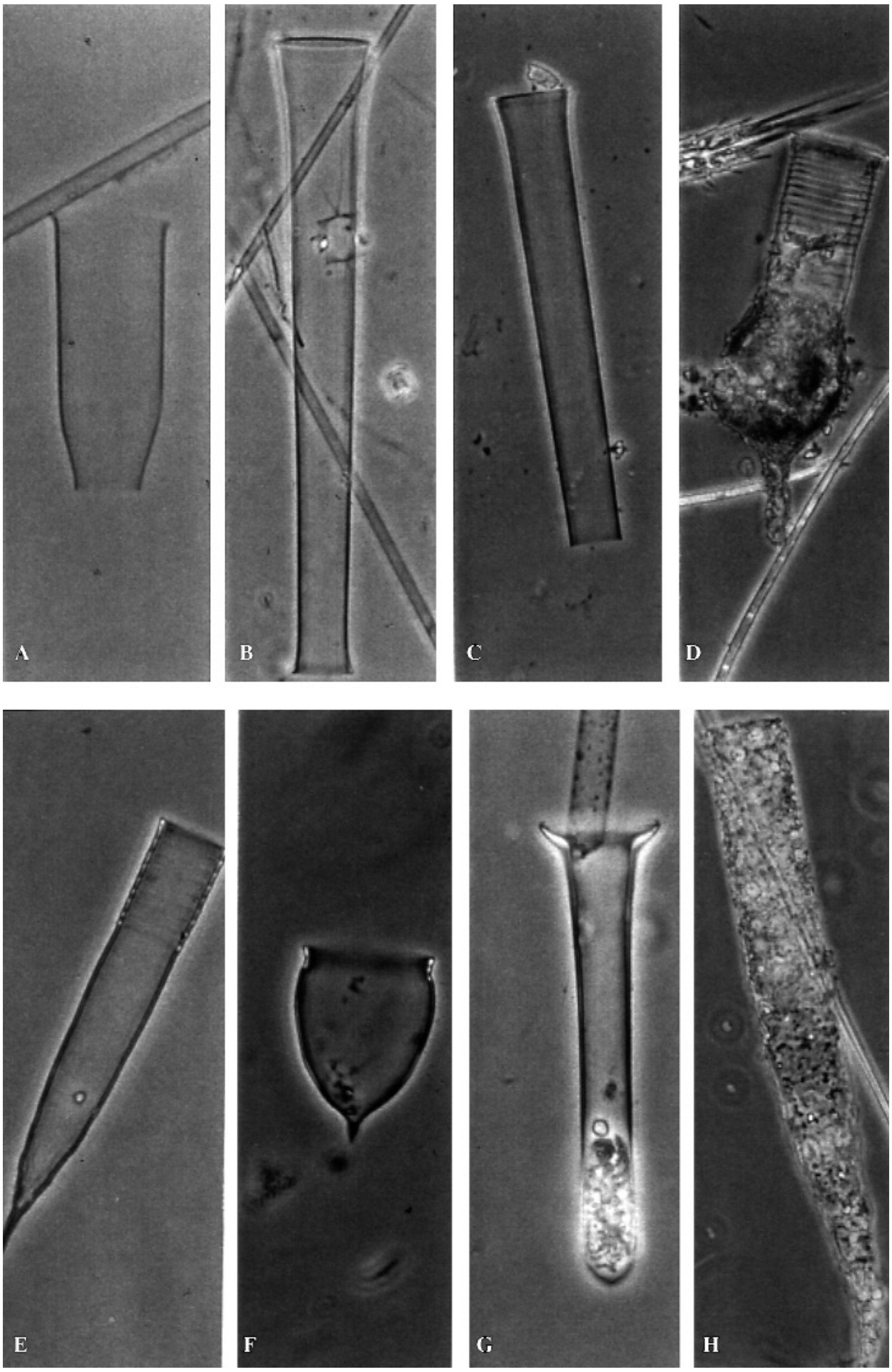

FIG. 6. – A, *Eutintinnus apertus* (x 400); B, *E. fraknoi* (x 200); C, *E. lusus-undae* (x 200); D, *Codonellopsis orthoceras* (x 200); E, *Helicostomella subulata* (x 400); F, *Metacylis jörgensenii* (x 400); G, *Steenstrupiella steenstrupii* (x 400); H, *Tintinnopsis radix* (x 200).

of copepods persists throughout the year in the region, and the highest recorded zooplankton level for the upper layer was 125400 ind./m^3 in September 1985, and the lowest was 3980 ind./m^3.

Other factors that can cause the negative correlation between phytoplankton and ciliates include the possibility that some phytoplankton may produce chemical defence compounds. The best-known are toxin-producing dinoflagellates, which may have a negative impact on tintinnids (Hansen *et al.,* 1992). A number of marine dinoflagellates have been known to produce nonprotein toxins, and these dinoflagellates are capable of forming red tides that inhibit zooplankton grazing (Hansen, 1989). During late spring/summer, peaks for phytoplankton abundances and production have been recorded in many Mediterranean coastal regions. Red tides are also more frequent at these times of the year (Zingone *et al*., 1990). In this study, none of the phytoplanktonic species exceeded one million cells per litre of surface water. At no time during this study was any colouring of the surface water detected. Despite the presence of certain dinoflagellate species (*Ceratium furca, Dinophysis acuta, Heterocapsa triquetra, Lingulodinium polyedrum, Noctiluca scintillans, Phalacroma rotundatum, Prorocentrum micans, P. triestinum, Scrippsiella trochoidea*) responsible for red tides and other noxious algal blooms in other geographic areas (Koray *et al*., 1992; Hallegraeff, 1993; Smalley and Coats, 2002), red tides were not recorded during the sampling period of this study.

Throughout the year, the tintinnid species were found in the range of 7.3-23.5°C, 19.7-23.3 psu and 7.13-11.95 mg l^{-1}. These values are characteristic for this area (Ünlüata *et al*., 1990; Beşiktepe *et al*., 1995) and the chemical oceanography of the Sea of Marmara is significantly influenced by the biochemistry of the Black Sea and the Aegean Sea. It connects to the Black Sea through the Bosphorus in the NE and to the Aegean Sea via the Dardanelles in the SW. The basin is occupied by two distinctly different water masses throughout the year: the brackish waters (22-26 psu) of the Black Sea origin, forming a relatively thin surface layer (10-15 m thick) with a mean residence time of about 4-5 months, and the subhalocline waters of Mediterranean origin (38.5-38.6 psu) separated from the former by a sharp interface (pycnocline) about 10-20 m thick. Because of the large volume of water inflow from the adjacent Black Sea (about 600 km^3) into the relatively small upper layer volume (about 225 km^3) of the Sea of Marmara, the upper layer ecosystem of the latter has been influenced to a large extent. (Ünlüata *et al*., 1990; Tuğrul and Polat, 1995). In particular, at depths of 0.5-20 m, the Sea of Marmara is known to be affected by the brackish water coming from the Black Sea via the Bosphorus (Yüce and Türker, 1991). The abundance of tintinnids has been effected by different water masses in the area. It was observed that the maximum abundance of tintinnids was found when salinity was high and temperature low. It is known that there are limited vertical exchanges between water masses due to thermocline and halocline layers, particularly during spring and summer, and the water on the surface does not usually sink down to the bottom. In autumn and winter, winds cause the water to become rough, the stratification is broken up, and the water from the bottom comes up to the surface (Balkıs, 2003). Such a phenomenon is important for the transport of tintinnids to the upper strata and may explain the maximum abundance of tintinnids in autumn. Moreover, on the surface, the water is usually over-saturated due to the exchanges with the atmosphere. Mixed water during the period of October to December may be the reason for the differences between the stations, especially in the O_2 values (V>10%).

This study is the first to report on the composition and abundance of tintinnid species in the Büyükçekmece Bay, and the photographs of species have been illustrated (Figs. 5, 6). The abundance of tintinnids was negatively correlated with that of large phytoplankton species, which is probably due to their inability to consume these large prey. It is more likely that the tintinnids prey on nanoflagellates, but these were not included in this study and need to be explored in the future.

ACKNOWLEDGMENTS

The author is grateful to Assoc. Prof. Dr. Serhat Albayrak, Istanbul University, and Assoc. Prof. Dr. M. Ertan Çınar, Ege University, for their help with the statistical methods.

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Scient. ed.: P. Jonsson