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PRIMARY PRODUCTION, BACTERIOPLANKTON AND PLANKTONIC PROTOZOA IN THE MARMARA SEA

MARMARA DENİZİNDE BİRİNCİL ÜRETİM, BAKTERİYOPLANKTON VE PLANKTONİK PROTOZOA

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Abstract

In this study, the number of bacteria, zooflagellates, cliates and biomass amount in the Marmara Sea are presented.

The total bacteria in surface waters of Marmara Sea is approximately $2x10^6$ cell ml^{-1}, the maximum number of bacteria was recorded at a station in the northern Marmara Sea as $4.96x10^6$ cell ml^{-1} and the lowest number of bacteria was recorded in the western part of Marmara Sea near the Dardanelles as 0.6010^6 cell ml^{-1}.

The average volume of planktonic bacteria in the surface waters of the Marmara Sea is 0.11 ^{3}, however this amount was recorded 2-3 times more in same stations where Ctenophora mucus density is high (in the second station 12 m. depth 0.3 ^{3}). The average of microbial biomass in the surface layer was recorded 232 mg m^{-3}, from pycnocline till 60 m. 26 mg m^{-3} and deeper than 60 m. 18 mg m^{-3}

The number of zooflagellates in the surface layers as $4x10^6$ cell L^{-1}, biomass as 50 mg m^{-3}, ciliates as $13x10^3$ cell L^{-1} and average biomass amount as 75 mg m^{-3} were calculated. The average microbial decomposition amount in the surface was calculated as 0.15 mg O_2L/day. It was seen that, there is too much pollution around the Bosphorus and the northern parts of the Marmara Sea has a eutrophic sea character because of the polluted waters of the Black Sea.

The microbiological production in the surface layers of the Marmara Sea shows similarity to the records of the mesotrophic waters of the Black Sea. In the deep waters of the Marmara waters there is a problem of oxygen deficiency because of the fast oxidation of H_2S.

The turnover time of labile organic matter in the surface layer was recorded as 40-60 days. Between summer and autumn in the surface water of the Marmara Sea there is 2-4 mg C m^{-3} labile organic matter and in the deep Mediterranean waters there is 1.2 mg C m^{-3} labile organic matter. Presently anoxia in deep waters is being prevented via aeration by the oxygenated Mediterranean waters entering through Dardanells.

Introduction

The Marmara sea is a deep transit basin situated between the Mediterranean and the Black Seas. In the surface layer the Black Sea waters with salinity 22-24 ‰ are passing from the Bosphorus to the Dardanelles Strait. Below 15-25 m. depth, through the Marmara sea in the Mediterranean waters with salinity 36-38 ‰ are passing in the reversed direction, from Dardanelles to Bosphorus. These waters originate from the surface waters of the Aegean sea These moving water masses are separated by a seep pinocline coinciding with the thermocline during the warm period of year. The vertical stability of the Mediterranean waters mass is very low. Under the influence of an intensive eastward horizontal movement of this water mass the water column below the picnocline can be readily mixed. This process is reflected in an even vertical distribution of t , S ‰ and O_2 down to a greater depths. The biological regime and ecological situation in the Marmara Sea basin which is extremely important economically largely depended upon the trophical level and degree of various contaminations in the Black Sea and the Aegean Sea areas, where the surface water, masses reciprocally passing through it, are forming. Because of general increase of eutrophication and pollution in both basins and especially in the shallow be expected also in the Marmara Sea. Another factor which could influenced in the same direction is the local anthropogenic impacts such as population growth, tansportation, industry and construction upon the Marmara Sea ecosystem. Now it is endangered by a drastic invasion of the Ctenophore intruder, *Mnemiopsis leidyi*. This predatory Ctenophore had travelled in to the Marmara Sea from the Black Sea, where it appeared in 1987, being brought with ballast waters by tankers from the western Atlantic coastal waters (Vinogradov *et al.*, 1989). It disasterously captured the Black Sea and then the Sea of Azov. During only a couple of years it completely altered transformed their pelagic communities (Shuskina and Vinogradov, 1991). Same invasion happened in the Marmara Sea during the autumn 1992, where the Ctenophore biomass reached over 10 Kgm^{-2} (Shiganova *et al.*, 1993).

All cumulative listed factors could gravely destabilize the Marmara Sea ecosystem even under conditions of a transit character of this basin and of an intensive dynamics of this water masses, which prevents stagnation. One of its most vulnerable points is the oxygen deficiency in the column of the saline Mediterranean waters down from the picnocline. The O_2 content below the picnocline is gradually decreasing down to 1.8 - 2.2 mg/L at depths of 100 -150 m. This present level of O_2deficiency in the Marmara Sea deep waters is defined by the equilibrium of two processes : by the annual debit of Mediterranean waters passing from the Aegean Sea via the Dardanelles in to the Marmara Sea, and by in situ rates of biological decomposition processes in its water column. Due to a relatively high temperature of deep waters of the Marmara Sea (14-15 C) the rate of microbial decomposition processes are controlled by the stock of labile organic matter arriving in Mediterranean waters, and upon by the transport of the organic matter into the water column from euphotic zone and from the shores. It seems quite obvious that an increase of eutrophication as well as destabilization of ecosystem by the intruder Ctenophore mentioned might result in a rapid rise of this flow, thus accelerating the O_2 consumption rate in deep column of Marmara Sea waters.

These developments obviously demand the organization of monitoring of the Marmara Sea ecosystem for the record of its present state, for the prediction of future phenomena and for the recommendation of necessary measures. Either during previous time of a minor anthropogenic impact at least from the side of the main seas, nor in the recent time a basic aspect of the Marmara Sea ecology remained unknown. Some sporadical measuremenets of nutrients and chlorophyll were done as well as the estimations of the number and taxonomic composition of diatoms (Ünsal and Uysal, 1988; Baştürk *et al.*, 1986). The data on heteotrophic microplankton composition, abundance and functioning rates, which are a main part of ecological monitoring were actually not available yet concerning the Marmara Sea. But especially (for this basin) now, these data are the most urgent in connection with the possible progres of anoxia in its deep layers, which could result in appearance hydrogen sulfide. A special interest the studies of heterotrophic microplankton should have due to the mass Ctenophore invasion is that when grazed by the intruder the filtering mesozooplankton could be replaced in the food web by the planktonic protozoa. Also it would be interesting to observe the influence of a masses of excerted by the Ctenophore mucus upon the bacterioplankton in water column especially under the picnocline. During the cruise on r/v "RIFT" in October 1992 we had the possibility to make necessary research of heteotrophic microplankton in the Marmara Sea. Within a group of three heterotrophic microplankton its main components were quantified : the bacterioplankton, planktonic nanoflagellates and ciliates. The production rate of bacterioplankton was also measured as well as the stock of labile organic matter and the time of its turnover via the microplankton metabolism.

Materials and Method

The samples of water were taken with 2 L plastic (polycarbonate) bottles. The number and size of planktonic bacteria were estimated by epifluoresence

microscopy at black Nucleopore filters with the pore size 0.2 after Hobbie *et al.*, (1977). The water samples were fixed with 0.5 % glutaraldehyde solution (final concentration) and stained with the fluorochrome acridine orange. Data on number of microbial cells and on their average size were then used to calculate the microbial biomass. The zooflagellates were accounted by the same epifluoresence microscopical method after Caron (1983). The samples were fixed by addition of 0.4 ml 25 % glutaraldehyde solution per 10 ml. After 1-2 hours the fixed sample was stained by fluorochrome primuline for 5 min. and filtered at 0.04 pore size black Nucleopore filters in the funnel with 12 mm diameter of its "working" area. The filtration proceeded under a low vacuum of 5 mm Hg. The filters after filtration were mounted in the nonfluorescing oil preparation. The zooflagellates were counted and sized by magnification x 700. The ciliates were counted in freshly taken living water samples in special chamber 4 mm deep (Sorokin, 1980) under the microscope by magnification x 60, accounting 3 their size classes. A real size of ciliate cells was then estimated at preparations made for counts of zooflagellates, by epifluoresence microscope magnification x 200.

The microbial production was measured with the use of the dark uptake radiocarbon method as modified by Sorokin (1990). The respiration rate of bacterioplankton (M_b) was calculated using the data on microbial production (P_b) assiming the efficiency coefficient K_2 (use of assimilated food for growth) equal to 0.32 (Sorokin and Kogelshatz, 1980). Then,

$$M_b=P_b x(1-k_2)x2.67/K_2 \quad mg\ O_2L^{-1}\ day^{-1},$$

if P_b is microbial production in mg C m^{-1} day^{-1}. The respiration rates of protozoans (zooflagellates and ciliates) were calculated assuming their specific production coefficients 0.8 per day K_2-coefficients 0.35 and the carbon content in their cells - 8 %. The stock of labile (accessible to immediate microbial action) organic matter in water was estimated by measuring of the BOD - 30 day values. Then the stock of labile organic matter was calculated as values equal to 0.55 of BODY-30 (Sorokin *et al.*, 1982). The stock of acid soluble sulfides in bottom sediments was measured after our own methodology (Sorokin, 1992). The samples of sediments were taken from upper 0-3 cm layer of sediment sample taken by grab the sulfides in them were fixed with the $ZnSO_4$+Na_2CO_3 solution.

Results

For position of the stations (Fig 1). The main results of quantification of the number and biomass of main groups of heterotrophic microplankton : bacteria, zooflagellates and ciliates are shown in Table 1, in which the data are presented, obtained at several basic stations situated in different regions of the Marmara Sea. In Table 2, the generalyzed data are given on average values of their number and biomass and on limits of their variations at 18 stations done during the cruise. The total number of bacteria in surface waters of the Marmara Sea was at most of stabilisations over 2 x 10^6 cells ml^{-1}. The largest it was at station 4 : 4.96x10^6 cells m^{-1}. The lesser its values (0.6 - 0.7 x 10^6) ml^{-1}) were recorded at station 7, 8 and

11 in the western end of the sea near the Dardanelles entrance. An average value of total number of bacterioplankton in surface layer was 2.18 x 10^6 ml^{-1} and its shift limits at stations : 0.66-4.9^6 x 10 ml^{-1} (Table 2).On the vertical profiles the total number of planktonic bacteria usually rapidly decreased, while at some shallow stations, like st. 1, 2, 11 and 12 the maximal total number of bacteria were recorded in the thermocline-pinocline discontinuity layer at depths 10-25 m. At other stations the total number of bacteria in this layer varied within 0.3 to 1.6. 10^6ml^{-1}. Under the picnocline the total number of bacteria at most of stations was decreasing 5-10 times comparing with the surface layer (Table 1). Only at stations 14 it was increasing with the depth. At this station in water columnn starting from the thermocline layer down to 300 m depth the Ctenophore mucus presented in samples in a large quantities, so that the filter preparations were literally covered with the clouds of mucus shaining brownish red, as do any dead organic matter stained with the fluorochrome acridine-orange (Table 1). An average number of bacteria in the Mediterranean saline waters under the picnocline was about 0.4 x 10^6 ml^{-1} at depths interval 25-60 m and 0.26x10^6 at depths interval 60-400 m.

An average cell volumes of panktonic bacteria in upper water layers of the Marmara Sea varied within the limits of 0.06 to 0.12 μ^3 (average value 0.11μ^3, Table 2). But at some stations where the Ctenophore mucus presented in water samples, bacteria were larger 2-3 larger 2-3 times. Their average volume reached there 0.3μ^3 (station 2, 12 m depth). Below the depths of 50-100 m in column of Mediterranean waters the bacterial cells were extremely small, being dominated by coccoid forms of 0.4-0.5μ size and 0.05-0.06μ^3 of volume. The biomass of bacterioplankton in upper mixed of the sea was over 200 mg m^{-3} of wet weight (or over 40 mg C m^{-3}). Its highest level was recorded at upper boundary of thermocline at station 2, situated near the shore in the bay, influenced by discharges of industrial city of Silivri. It was there over 1.3 g m^{-3}. A very high microbial biomass was also recorded in samples taken at stations 1 and la close to Istanbul : 340-380 mg m^{-3}. The lowest its values in upper mixed layer was observed in the western end of the sea far from the populated coasts. An average value of microbial biomass in surface layer was 232 mg m^{-3} and the range was 50 to 380 mg m^{-3}. On vertical profiles the microbial biomass decreased. At most of stations also in the thermocline layer it was 204 mg m^{-3} of average value. In mediterranean waters below 25-30 m depth it varied between 15 to 30 mg m^{-3} (average values : down to 60 m depth -26 mg m^{-3} and below 60 m - 18 mg m^{-3}).

The microbial production in the upper water layer was found to be very high. In the N.E. part of the sea (Stations 1-4) it was over 100 mg m^{-3} of wet biomass or over 20 mg C m^{-3} per day. At most other stations it was 40-100 mg m^{-3}. Average its value in the sea was in upper layer : 100 mg m^{-3} day^{-1} (Table 2). In the thermocline layer the microbial production decreased 1.5-3 times (20-70 mg m^{-3}). Below the thermocline it was gradually decreasing down to 6-15 mg m^{-3} (average values down to 60 m. depth 15 mg m^{-3} and below 60 m - 12 mg m^{-3} day^{-1}. The average values of specific growth coefficiens per day (P/B) were found to be in the surface layer 0.43 and in the deep waters around 0.6 (Table 2). The results of

number and biomass estimations of planktonic protozoa are given in same Tables 1, 2, 4 and 5. Within this group two its main components were accounted separately : the zooflegellates and the ciliates (see "Methods"). The planktonic phagotrophic zooflagellates class Zoomastighoporea were represented in the Marmara Sea by the genera of order Protomonadina and suborder Bodonina with the size of their round shaped cells 3 to 5 μ and with their volumes varied between 15 to 60 μ^3. They were numerous in the upper waters : $4x10^6$ cells L^{-1} and their biomass-over 50 mg m^{-3} (Table 1). Maximum their number (over $4x10^6$ cells L^{-1}) and the biomass over 120 mg m^{-3} were recorded at shallow station 3 in northern part of the sea. A high their density was recorded also in the western part of the Sea at stations 8-14. The number of zooflagellates in the layer of chemocline usually was comparable or even more than at the surface (stations 3, 4, 8, 11). An average their number in upper water layers was about 10^3 L^{-1} and their average biomass 22 mg m^{-3} (Table 2). In deep waters below the thermocline at most stations their number and biomass decreased 5-50 times. Average their number in deep waters below 60 m depth was only 0.5×10^{-6} L^{-1} and their biomass 1 mg m^{-3}.

The planktonic ciliates were represented in the sea mainly by average and small size Strombidium species and by Tontonia. Other ciliates including Tintinnides were rare. The small Strombidia have size 15 x 30 μ and cells volumes 2-3 x 10^3 μ^3 and average ones have 25 x 40 μ size and volumes of 9-12 x 10^3 μ^3. Same as zooflagellates, the ciliates have formed in the upper mixed waters a dense populations. Their numbers at many stations were over 30-50 x 10^3 L^{-1} and their biomass over 40-60 mg m^{-3}. A largest their density was observed at station 2 in area influenced by organic pollution from the Istanbul and the Bosphorus regions. In the surface layer their num ber was there 280 x 10^3 cells L^{-1} and biomass-over 120 mg m^{-3} (Table 1). An average number of ciliates in surface water layer was 13 x 10^3 L^{-1} and average their biomass 75 mgm^{-3}. About the same their density remained in the thermocline layer, while in deeper waters it rapidly recreased down to negligible values of 1-3 mg of biomass.

In Table 1, the calculated values are given of the respiration rates of total heterotrophic microplankton. These values are actually corresponding to the microbial decomposition rate. In the surface water layer it varied between 0.1-1 mg O_2 L^{-1} day^{-1} (average value for all stations done 0.15 mg O_2 L^{-1} day^{-1}). In the thermocline layer it decreased down to 0.10. In deep Mediterranean waters the rates of microbial decomposition remained quite significant : 10 to 70 μg O_2 L^{-1} day^{-1}. Average its values in samples taken down to 60 m depth was 26 μg O_2 L^{-1} and below 16 μg. The stock labile organic matter (LOM), accessible to the microbial decomposition, was measured by the BOD-30 method in water column down to a great depths at stations 14, 18 and 19 (Table 3). It varied in most samples between 1 to 2.3 mg C L^{-1}. Only at stations 8 at depth of 16 m was 4.16 mg (C m^{-3}. The stock of LOM did not largerly decreased with the depth. I remained same high in the Mediterranean deep waters as in the upper Black Sea water mass. Having estimated the microbial decomposition rates (Table 1). We have calculated also the turnover time of the stock of LOM (Table 3). It appeared

to be in upper water layer 46 to 69 days, increasing in deep waters up to 260-880 days at stations 18 and 19, while at station 14, where the deep waters were enriched with the Ctenophore mucus, it was even shorter at 280 m depth 45 days.

A definite role in the processes of deoxygenation of water column in the Marmara Sea especially in its coastal areas subjected to input terrestrial and anthropogenic organic matter, could play the processes of microbial production of hydrogen sulfide via sulfate reduction in bottom sediments. This process results in accumulation in sediments of the stock of sulfide sulfur. Under the influence of excess of CO_2 produced during the decomposition of organic matter, the acid soluble sulfides in bottom sediments could dissociate with formation of free mobile H_2S. Migrating into the water column it is quickly oxidized by dissolved oxygen, thus causing its deficiency in nearbottom water layers. Therefore the estimation of the stock of acid soluble sulfides is a necessary element in studies of oxygen depletion processes in water column. In according with there consideration we have measured also the stock of acid soluble sulfids and the rate of sulfate reduction in upper 0-3 cm layer of bottom sediments (Table 1). The results of estimations show, that in most sediment samples the stock of sulfide sulfur was low to medium : between 18 to 75 mg S L^{-1} of wet sediment. At stations 7 and 8 near the Dardanelles entrance, and at st. 17 in the mouth of Gemlik Bay it was over 100 mg S L^{-1}, and in the corner of this bay opposite the Gemlik port it was quite high-over 1000 mg L^{-1}. The sulfate reduction in this area could be stimulated by a stagnant conditions in the bay and by organic pollution arriving from the city. These data prove that even the upper layer of the Marmara Sea bottom sediments is occupied by reduced muds, containing acid soluble sulfides. Their stok in this layer is controlled by rate of microbial sulfate reduction from one side, by processes of their oxidation at the bottom-water interface and by the rate of sedimentation. Our data show that the rate of sulfate reduction in sediments of the bays like the Gemlik Bay could be very intensive up to 3.8 mg S L^{-1}. At stations 2-8, 17-18 it was also significant 1.7-2.7 mg S L^{-1} day^{-1}. This level of sulfate reduction rates in marine sediments is peculier to the mesotrophic marine coastal reduced sediments or to sediments of anoxic basins like the Black Sea (Sorokin, 1982a., Tchebotarev *et al.*, 1983). The lesser sulfate reduction rates were recorded in the western part of the sea less subjected to pollution influence. The turnover time at stations 2-5 along the northern coastal was only 21-44 days. At other stations it was 50-200 days and in the Gemlik Bay, where the a definite stagnation conditions existed, it was 268 days.

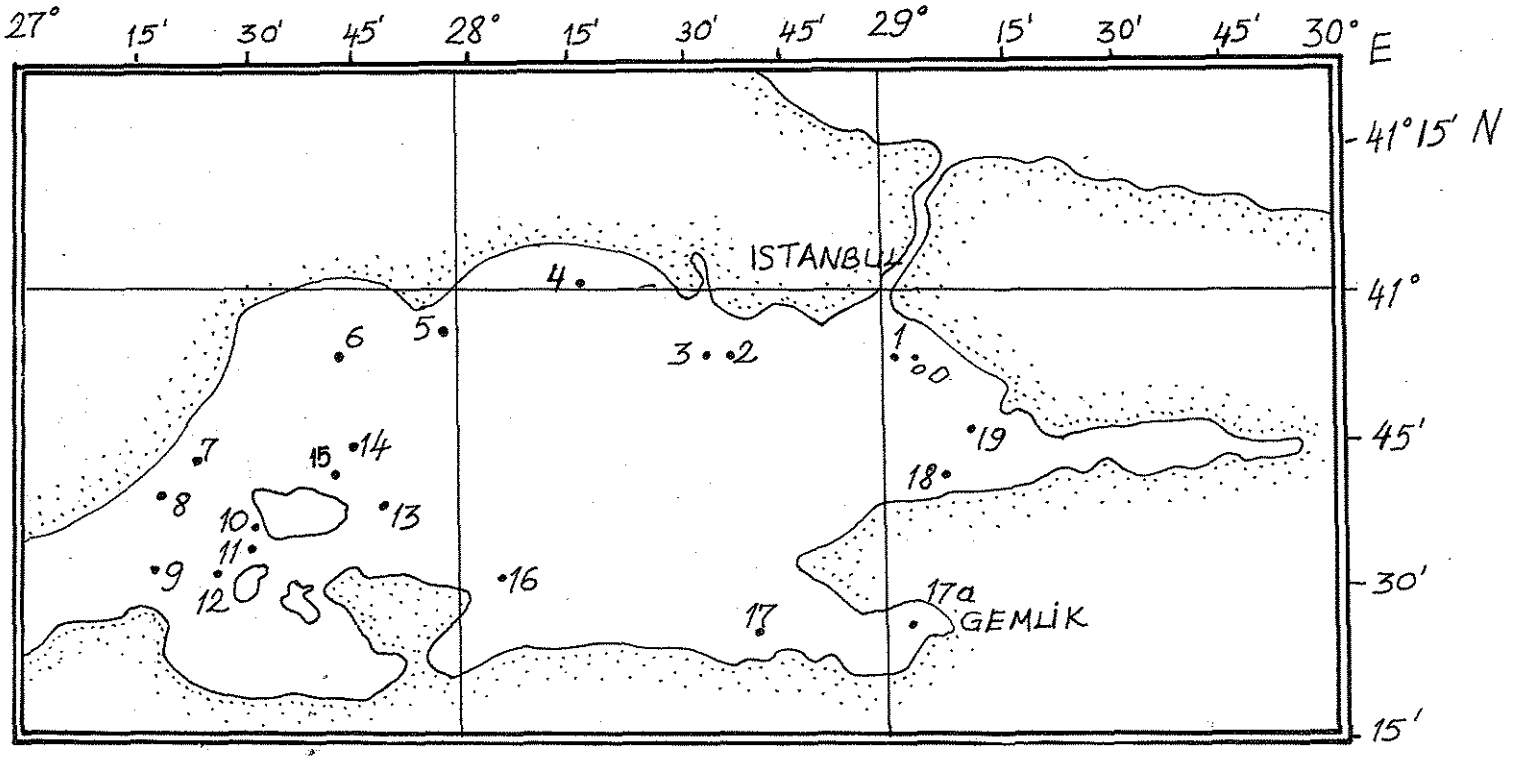

Fig:1. Scheme of positions of stations in the Marmara Sea

ABLE 1. QUANTITATIVE CHARACTERISTICS OF HETEROTROPHIC MICROPLANKTON IN THE MARMARA SEA ; DESIGNATIONS : N-NUMBER OF CELLS B-BIOMASS (WET WEIGHT), $mg\,m^{-3}$, P-PRODUCTION PER DAY, M- CALCULATED RESPIRATION OF MICROHETEROTROPHS PER DAY.

NO:OF STATIONS	DEPTH	BACTERIOPLANKTON			ZOOFLAGELLATE		CILIATES		M	
	(m)	N $10^8 l t^{-1}$	B	P	N $10^8 l t^{-1}$	B	N $10^8 l t^{-1}$	B	mg O2 l t-1	mg C l t-1
1	0	2.35	380	89	158	8	54	52	0.12	48
	10	3.41	510	64	83	4	58	51	0.09	35
	25	0.76	113	16	74	3	4	2	0.02	8
3	0	2.53	253	115	4060	14	55	46	0.20	76
	15	1.54	154	106	3040	76	65	57	0.17	62
	25	0.45	27	11	760	19	21	18	0.03	12
	40	0.39	23	3	389	8	6	4	0.007	2.8
	60	0.18	11	4	0	0	3	1	0.005	2
4	-	0	496	297	145	78	3	22	14	-
	0	4.96	297	145	78	3	22	14	18	68
	14	0.63	32	23	260	12	33	40	0.05	19
	30	0.27	14	8	74	2	6	1	0.09	19
6	0	2.64	292	105	340	10	10.5	93	0.16	59
	18	0.88	220	71	98	4	4.5	40	0.10	38
	40	0.51	51	22	35	1	0.2	2	0.03	12
11	0	0.67	80	60	300	9	8.8	70	0.01	37
	24	1.63	340	73	590	24	3.2	32	0.11	40
	50	0.29	29	13	37	1	0.1	1	0.02	6
14	0	2.08	166	47	430	8	8.8	66	0.08	31
	22	0.68	54	44	37	1	2.2	8	0.06	22
	50	0.38	57	8	64	2	0.2	<1	0.009	4
	100	0.59	106	30	20	-	-	-	0.04	15
	280	1.19	119	55	20	-	-	-	0.07	26
18	0	2.94	238	83	180	7	4.4	53	0.12	46
	16	0.63	50	23	83	3	1.6	10	0.04	14
	50	0.20	19	17	18	<1	0.2	<1	0.02	9
	150	0.35	28	18	10	<1	-	-	0.03	10
	350	0.43	34	22	10	<1	-	-	0.03	11

TABLE 2. GENERALIZED DATA ON NUMBER (N), BIOMASS (B, mg m^{-3}), PRODUCTION (P, mg m^{-3} day^{-1} WET WEIGHT) OF MAIN GROUPS OF HETEROTROPHIC MICROPLANKTON AND ITS TOTAL RESPIRATION (M_t, μgO_2 lt^{-1} day^{-1}): DESIGNATIONS: Av-AVERAGE VALUES FOR 16 STATIONS, Lim-LIMITS OF VALUES, V-AVERAGE VOLUME OF CELLS, μ^n.

LAYER	BACTERIOPLANKTON							ZOOFLAGELLATES			CILIATES			
	N	V	B		P		P/B	N	B		N	B		
	$10^6 ml^{-1}$ (Av)	μ^n	Av	Lim	Av	Lim		$10^4 l^{-1}$ (Av)	Av	Lim	$10^3 l^{-1}$ (Av)	Av	Lim	M_t (Av)
Upper mixed layer (0-7m)	2.18	0.11	232	52-380	100	45-158	0.43	600	22	3-121	130	75	12-200	150
Thermocline layer (10-24m)	1.45	0.14	204	22-138	59	18-106	0.29	600	20	1-63	44	31	4-105	94
Mediterranean deep waters (25-60m)	0.36	0.07	26	6-113	15	4-29	0.58	120	3	1-19	4	3	0-11	26
Same (over 60m)	0.26	0.07	18	9-119	12	4-22	0.66	17	0.5	0-1	<1	<1	0-1	16

TABLE 3. Stock of labile organic matter (S) as calculated with the use of BOD-30 data in samples of water taken on vertical profiles; designations: M-Calculated respiration of microheterotrops (Destruction rate) and T-turnover time.

NN of Station	Depth (m)	BOD-30 $mgO_2 lt^{-1}$	S $mgC lt^{-1}$	M per day		T days
				$mgO_2 lt^{-1}$	$\mu gC lt^{-1}$	
14	0	3.57-0.14	1.96	0.08	31	63
	100	1.83-0.12	1.01	0.04	15	67
	280	2.14-0.15	1.17	0.07	26	45
18	0	3.82-0.12	2.10	0.12	46	46
	16	7.51-0.10	4.13	0.04	14	290
	50	3.70-0.13	2.04	0.02	8	230
	150	3.68-0.10	2.02	0.03	10	200
	350	2.04-0.15	1.12	0.03	11	102
19	0	4.36-0.11	2.34	0.09	34	69
	100	3.71-0.08	2.04	0.02	7	290
	200	3.35-0.06	1.84	0.02	7	260
	400	3.06-0.13	1.68	0.005	1.9	880

TABLE 4. Contents of acid soluble sulfides (K_s ,mgSlt^{-1} of wet sediment) and the rate of sulfate reduction (S_r ,mgSlt^{-1} of wet sediment per day); T-turnover time of the stock of Sulfides in sediments (K_s / S_r), days.

NN of Station	Ks	Sr	T	NN of station	Ks	Sr	T
2	58	2.77	21	12	40	0.21	190
3	82	2.03	40	13	55	0.27	200
4	75	1.72	44	14	23	0.44	52
5	22	0.73	30	16	28	0.72	39
7	188	1.88	100	17	102	1.95	52
8	165	1.86	89	17a	1030	3.85	268
9	44	0.62	71	18	18	1.57	11

TABLE 5. RESULTS OF PRIMARY PRODUCTION MEASUREMENTS AND MICROPLANKTON GROUP'S NUMBER AND BIOMASS ESTIMATIONS IN THE MARMARA SEA ; DESIGNATIONS : N- NUMBER OF CELLS, B AND P- BIOMASS AND PRODUCTION PER DAY (mgm^{-3} OF WET WEIGHT), M- TOTAL RESPIRATION OF MICROHETEROTROPHS PER DAY (ug C lt^{-1} day^{-1}), CALCULATED ASSIMING CARBON CONTENT IN MICROBIAL BIOMASS 20 % AND IN PROTOZOANS- 10 %, THE EFFICIENCY COEFFICIENT K2 (USE OF ASSIMILATED FOOD FOR GROWTH) IN BACTERIA 0.32 AND IN PROTOZOA 0.35 AND THE SPECIFIC PRODUCTION RATE IN PROTOZOA (P/B)—0.8 PER DAY.

NN OF STATION	DEPTH	PRIMARY PRODUCTION		PHYTOPLANKTON							MICROHETEROTROPHS								
		PER DAY		PLANCTONIC CYANOBACTERIA		SMALL PHYTOFLAGELLATES		LARGER ARGAL		TOTAL BIOMASES OF ALGAE	BACTERIA			ZOOFLAGELLATES		CILIATES		M PER DAY	
	(m)	AT THE SURFACE $mgCm^{-3}$	IN WATER COLUMN gCm^{-2}	N $10^{6}lt^{-1}$	B	N $10^{3}lt^{-1}$	B	N $10^{3}lt^{-1}$	B	gm^{-3}	N $10^{6}lt^{-1}$	B	P	N $10^{3}lt^{-1}$	B	N $10^{2}lt^{-1}$	B	mgO_2lt^{-1}	$ugCl^{-1}$
1a	0	82	0.43	38	661	410	33	105	307	401	2.42	343	143	405	19	90	28	0.18	68
	0	55	0.30	33	53	148	32	97	298	383	2.53	380	89	158	8	54	52	0.12	48
	10	-	-	16	26	112	7	8	21	54	3.41	510	64	83	4	58	51	0.09	35
	25	-	-	6	9	60	3	0	0	12	0.76	113	16	74	3	4	2	0.02	8
2	0	58	0.30	28	44	176	14	124	352	410	2.75	165	111	167	8	280	126	0.18	66
	12	-	-	55	88	330	20	10	17	125	4.62	1380	138	195	8	187	105	0.20	74
	30	-	-	7	11	55	4	0.6	2	17	0.45	7	29	18	1	13	11	0.04	15
3	0	56	0.30	92	148	1630	10	54	326	484	2.53	253	115	4060	14	55	46	0.20	76
	15	-	-	83	133	500	25	113	178	336	1.54	154	106	3040	76	65	57	0.17	62
	25	-	-	17	28	334	17	0	0	45	0.45	27	11	760	19	21	18	0.03	12
	40	-	-	4	7	46	2	0	0	9	0.39	23	3	389	8	6	4	0.007	2.8
	60	-	-	0	0	0	-	0	0	0	0.18	11	4	0	0	3	1	0.005	2
4	0	60	0.43	102	163	700	86	75	237	486	4.96	237	145	78	3	22	14	0.18	68
	14	-	-	56	88	415	38	54	181	307	0.63	32	23	260	12	33	40	0.05	19
	30	-	-	1	2	74	4	0	0	6	0.27	14	8	74	2	6	1	0.09	4
5	0	57	0.31	48	77	90	17	60	292	386	1.98	118	81	296	9	41	49	0.11	43
	16	-	-	4	6	110	7	10	36	49	2.42	145	90	74	3	35	21	0.11	44
	40	-	-	2	3	60	4	0.6	2	9	0.24	12	9	55	2	4	1	0.013	5
	200	-	-	1	2	20	1	0	0	3	0.18	9	6	28	1	0	0	0.006	3
6	0	56	0.31	35	56	540	43	76	239	338	2.64	292	105	340	10	105	93	0.16	59
	18	-	-	5	7	182	9	16	37	60	0.88	220	71	98	4	45	40	0.10	38
	40	-	-	2	4	63	2	0	0	4	0.51	51	22	35	1	2	2	0.03	12

7	0	67	0.48	94	150	1010	61	92	236	447	0.66	32	45	440	15	77	30	0.11	7
	25	-	-	4	7	810	51	6	15	72	0.30	36	48	520	21	11	10	0.07	26
	60	-	-	1	1	110	6	0	0	8	0.13	10	8	300	12	2	1	0.02	6
8	0	73	0.50	96	154	417	38	45	144	336	0.72	108	61	519	20	555	205	0.15	55
	24	-	-	111	177	305	40	21	60	227	0.70	46	31	2790	84	165	21	0.09	33
	60	-	-	6	9	20	3	0	0	12	0.18	6	17	12	1	3	2	0.009	3
11	0	75	0.46	120	192	960	120	55	200	512	0.67	80	60	300	9	88	70	0.01	37
	24	-	-	20	32	880	160	39	125	317	1.63	340	73	590	24	32	32	0.11	40
	50	-	-	17	18	20	1	0	0	29	0.29	29	13	37	1	1	1	0.02	6
12	0	29	0.18	121	193	1650	100	24	76	330	2.31	346	151	1950	78	8	12	0.21	77
	25	-	-	28	44	760	61	8	14	119	2.90	174	65	288	11	2	2	0.09	32
	50	-	-	5	7	33	2	0	0	9	0.16	8	12	18	1	0	0	0.02	6
13	0	36	0.23	32	51	770	62	44	119	239	2.02	162	84	482	19	264	74	0.15	51
	22	-	-	12	18	300	15	14	43	75	1.58	94	55	695	63	3	4	0.09	33
	45	-	-	0	0	20	1	0	0	1	0.26	40	7	110	3	0	0	0.08	2.9
14	0	42	0.27	65	103	1230	98	31	117	318	2.08	116	47	430	8	88	66	0.08	31
	22	-	-	15	23	130	10	16	25	58	0.68	54	44	37	1	22	8	0.06	22
	50	-	-	7	12	30	2	0	0	14	0.39	57	8	64	2	2	1	0.009	4
	100	-	-	2	4	0	0	0	0	4	0.59	106	30	20	-	-	-	0.04	15
	280	-	-	0	0	0	0	0	0	0	1.19	119	55	20	-	-	-	0.07	26
16	0	75	0.48	51	81	1440	86	82	358	525	3.06	367	91	350	10	55	45	0.13	49
	17	-	-	9	14	410	20	20	8	42	0.51	92	62	653	26	110	65	0.11	40
	40	-	-	3	5	10	0.5	0	0	6	0.28	23	13	18	1	1	1	0.02	6
17	0	76	0.42	35	57	560	56	44	338	451	1.85	224	136	360	14	2971	220	0.24	89
17a	0	91	0.76	60	96	820	91	122	400	582	1.67	200	158	77	3	132	59	0.21	76
	14	-	-	7	11	250	33	13	47	91	0.63	63	53	166	8	44	26	0.08	28
	25	-	-	4	6	20	1	3	8	15	0.29	25	16	56	3	5	3	0.02	8
18	0	55	0.34	8	8	440	35	86	317	190	2.94	238	83	180	7	44	53	0.12	46
	16	-	-	6	10	140	7	31	84	101	0.63	50	23	83	3	16	10	0.04	14
	50	-	-	2	3	10	1	12	31	35	0.20	19	17	18	1	2	1	0.02	9
	150	-	-	0	0	0	0	0	0	0	0.35	28	18	10	1	-	-	0.02	10
	350	-	-	0	0	0	0	0	0	0	0.43	34	22	10	1	-	-	0.03	11
19	0	92	0.52	6	10	30	33	174	645	688	1.61	242	51	260	8	81	62	0.09	34
	7	-	-	98	150	230	11	53	134	295	0.64	64	47	230	9	105	68	0.09	33
	16	-	-	18	44	5	1	14	62	107	0.28	22	18	70	3	64	28	0.04	14
	100	-	-	0	0	0	0	0	0	0	0.22	18	14	27	1	-	-	0.02	7
	200	-	-	0	0	0	0	0	0	0	0.32	19	14	10	1	-	-	0.02	7
	400	-	-	0	0	0	0	0	0	0	0.18	14	4	10	1	-	-	0.005	2

Discussion

The level of Bacterioplankton abundance in the Marmara Sea recorded during present study, corresponds to that in an eutrophic marine basin, especially in the northern shallow its part, where the main stream of the Black Sea waters carries the polluting effluents from the densely populated areas of Bosphorus and large Istanbul. The biomass of bacteria in the Black Sea waters, travelling through the Marmara Sea in its upper layer, reached 380 mg m^{-3}. At station 2 at 12 m depth it was even 1380 mg m^{-3}. Comparing with western shallow part of the Black Sea itself, from where the surface waters are going to the Marmara Sea, the bacterioplankton biomass in Autumn 1990 was 1.5-2 less (120-150 mg m^{-3}, Sorokin unpubl. data). So this increase of microbial biomass in seems to be a sequence of local anthropogenic eutrophication in the Marmara Sea. More clear from thus point are waters in the western part of the Sea near the Marmara (stations 7-11) where the level of microbial biomass corresponded more to the mesotrophic level : 50-100 mg m^{-3} (Table 1). The microbial repoduction in the Marmara Sea in upper layer corresponded to its level, recorded in the mesotrophic waters of the Black Sea (Sorokin and Avdeev, 1991).

In the Mediterranean deeper waters microbial biomass and production decreased by about an order of values at most stations. Such a decrease is unusual for an inland sea with warm deep Marmara Sea waters. It could be explaned by the origin of deep Marmara Sea waters from the oligotrophic surface waters of Mediterranean and Aegean Seas. At present the explosive intrusion of stranger Ctenophore *Mnemiopsis leidyi* in the Marmara Sea surely influences upon all aspects of its biology including the composition and density of its bacterioplankton and other microplankton. But we can not now clearly define this impact because of complete absence of corresponding data on previous state of the Marmara Sea ecosystem and its microplankton. The interesting from this point observations were done at station 14, where all the water column down to 280 meter depth was filled with the Ctenophore mucus (Table 1). The mucus, accumulated at the picnocline at 22 m depth was scarcely populated by bacteria. The water at this depth contained also wery poor protozoan population comparing with adjacent stations. The observations seem to be proving that the fresh Ctenophore mucus could be definitely toxic for microplankton. This observation surely needs further experimental approval. The mucus which was accumulating in the density gradient layer at 20-25 m depth at this station, absorbed the mineral particles, thus increasing its specific weigth. Then it settled down, spreading through all water column down to about 300 m. When settling it obviously loosed its toxic capacity becoming more populated by bacteria. So th bacterioplankton biomass at this station instead of decreasing increased with the depth. At 280 m. depth it was about twice more than in the picnocline.

The biomass of bacterioplankton of 200-300 mg m^{-3} recorded in the Marmara Sea should be sufficient as a basic food source even for Dicopleuractude planktonic filter feeders like *Paracalamus, Eucalamus* to say nothing about *Cladocerans* or *Oicepleura.* But the intruder *Ctenophore* had managed to exterminate the mesozooplankton. By this situation the microbial biomass could be grazed the decomposed only by phagotrophic planktonic protozoa. Thus a replacement of larger filtering grazers by protozoa we have actually observed. In

fact the density of both main groups of panktonic protozoa was high in upper mixed layer and also in the layer of picnocline during ours study (Table 1). The joint biomass of planktonic protozoa was there 50 mg m^{-3} at most stations. At some of them it reached 100-160 mg m^{-3}. Accounting that the specific growth rate of planktonic protozoa at water temperature 18-20 C is roughly an order more than in Crustacean mesozooplankton (1-1.5 opposite 0.05-0.15 per day, Zaika, 1972), the grazing activity (food rations) in those populations of equal to that by mesozooplanktonic population with biomass of 500-1500 mg m^{-3}. An abundant protozoan populations in the Marmara Sea, recorded during the present study, were a main agent of the nutrients regeneration, thus providing a high level of primary production and high biomass of panktonic algae (Sorokin, 1992). These data definitely demonstrate an importance of protozoans quantification during the ecological studies in such a stressed basins, like the Marmara Sea. Just the protozoans, in conditions of microzooplankton extermination by Ctenophore, are forming a completede food wem, which is necessary for normal proceeding of the self-purification processes in water column.

An abundant heterotrophic microplankton with its woint biomass of 200-400 mg m^{-3} in upper mixed layer was in the Marmara Sea a main agent of organic matter decomposition and selfpurication. This its function became extremely important especially during the Ctenophore invasion. The Ctenophore as any Coelenterates produce a large quantity of mucus, which has a function of cleanning their bodies surfaces and preventing their fouling with bacteria. They spend for the mucus production 10-30 % of total energy, acquired with food. So the population of Ctenophores of 3-6 kg m^{-2} should produce daily roughly about 50 g of raw mucus, thus causing an additional self-pollution of also stessed antropogenically Marmara Sea ecosystem. Our observations proved, that the fresh mucus could be toxic even for Bacteria. But being an aged and settling down it looses its toxicity and finally is populated by bacteria and gradually decomposed.

As it was mentioned above one of the most vulnerable points of the Marmara Sea ecology is the oxygen deficiency in its deep layers, thus endangered by probable developing of anoxia under the influence of progressing eutrophication of this basin and of its mother seas. From this point the first data on the stock labile organic matter its water column and on it decomposition rates and turnover time giv a start for experimental investigation of this problem. The evaluation of respiration rates of micropplankton gave its values in upper mixed layer of 0.1-0.2 mg O_2 or 30-40 μg L^{-1} day^{-1}. These values are typical to the mesotrophic-eutrophic coastal marine waters (Sorokin, 1978). The heterotrophic microplankton respiration rates of planktonic heterotrophs in normal basiness (Sorokin, 1981). In the Marmara Sea, where the planktonic community has been recently injured and transformed by the Ctenophore, rough calculations show that this share should be even more-over 90 % calculated integral destruction by heterotrophic mikroplankton per day 700 mg C m^{-2} the respiration of the remains of mesozooplankton respiration of Ctenophore 15 mg C m^{-2} day^{-2}. Therefore the calculated rates of heterotrophic microplankton respiration could be used for the evaluation of O_2 consumption rates in water column of the Marmara Sea down to a large depth. In accordance to its rates an approximate in situ O_2 consumption (decomposition) should be around 5 to 15 μg L^{-1} day^{-1}. It means that the age of the

Mediterranean waters in the Marmara Sea at depth 100-400 m. could be evaluated within 2 years : 8-2 / 0.1 = 600 days, if: 8 and 2 O_2 contents mgO_2^{-1} correspondingly in the surface Mediterranean waters, entering the Marmara Sea via Dardanelles and in the same water mass in the Marmara Sea at depth 40-1000 m. The experimental estimations of turnover time of labile organic matter stock gave the values of same order of several hundreds days (200-800 days)_ (Table 3). A more exact estimations of this value and especially attempts to get some mean its ranges for the whole basin become at present hardly accomplishable, again because of the Ctenophore invasion. In the place of its most massive accumulations with an intensive production of mucus the composition of microplankton communities and rates of organic matter in water column also change. It could be seen at station 14 (Table 1), where an accumulation of Ctenophore mucus occured (see above). The turnover time of organic matter at this station was 3-10 times less than at other 2 stations and decreased with the depth instead of increasing . Same, the respiration rates were at st. 14 in deep waters about the same as at the surface, while at other stations they were several times less (Table 3).

In the surface layer the turnover time of labile organic matter was found to be 40 to 60 days (Table 3). It is 2-3 times longer than in other marine productive waters by same t of 17-19 C (Sorokin and Mamaeva, 1980; Tchebotarev and Sorokin, 1983). Most probably that a relatively slow turnover of labile organic matter in upper water water layer in the Marmara Sea is a result of destruction of normal food web by Ctenophore, which has about exterminated the mesozooplankton. Concerning the size of LOM stock in waters of the Marmara Sea of 2-4 mg C m^{-3} in the Mediterranean deep waters (Table 3), it was some 2-3 times more than in the coastal waters of the Black Sea by summer autumn period (Tchebotarev and Sorokin, 1983). This stock in the dep waters of Marmara sea is now sufficient for complete consumption of oxygen by its biological oxydation. So the anoxia in the Marmara sea is preventing now only buy its aeration with passing through it for the oxygenated Mediterranean waters, arriving via Dardanelles.

Above data on stock of LOM, on its turnover rates and on the rates of plankton respiration surely are very provisional They should be respected as a first attempt to approach the problem. Future more expended experiments are needed with a direct experimental estimations of insitu oxygen consumption rates.

A high rates of hydrogen sulfide production in sediments of the Marmara Sea sediments, caused by the microbial sulfate reduction, in most cases did not result in accumulation of a large stock of sulfides (Table 4). It means that the H_2S produced is rather rapidly oxidized, migrating up to the water column. So this process in fact could be one of important factors causing the oxygen deficiency in its deep waters. Therefore the process of sulfide production in sediments, being one of undesirable sequences of pollution in marine environments (Sorokin, 1982a; Tchebotarev *et al.,* 1983) needs further attention, especially in places of organic pollution, aqua culture sites, etc. Besides with the stock of acid soluble sulfides the redox-potential in column of sediments should be measured.

Özet

Bu çalışmada Marmara denizindeki bakteri zooflagellat ve siliatların miktarı ve biyomas değerleri verilmiştir.

Marmara Denizinin yüzey sularındaki toplam bakteri sayısı ortalama $2x10^6$ hücre ml $^{-1}$; en yüksek 4. istasyonda $4.96x10^6$ hücre ml^{-1}; en düşüğü $0.6x10^6$ hücre ml^{-1}. Çanakkale Boğazı yakınlarında Marmara Denizinin batı ucundaki 7, 8, ve 11'nci istasyonlarda kaydedilmiştir. Marmara denizinin üst sularındaki planktonik bakterilerin ortalama hacimleri 0.11 μ^3'olup, Ctenophora mukusunun yoğun olduğu bazı istasyonlardan alınan su örneklerinde ise bu değer 2-3 kat daha fazla bulunmuştur (2'nci istasyonda 12 m derinlikte $0.3 \mu^3$).

Mikrobiyal biomasın ortalama değeri yüzey tabakasında 232 mg m^{-3}, 60 m'ye kadar 26 mg m^{-3} ve 60 m'den daha derinlerde ise 18 mg m^{-3} olarak bulunmuştur.

Marmara Denizindeki zooflagellatların üst tabakalardaki sayısı $4x10^6$ hücre L^{-1} ve bioması 50 mg m^{-3} Ciliatların ortalama miktarı $13x10^3$ L^{-1} ve ortalama biomasları 75 mg m^{-3} olarak hesaplandı. Yüzeydeki mikrobiyolojik bozunma değerleri ortalama 0.15 mg O_2 L/gün olarak ölçüldü. İstanbul ve Boğaz çevresinin yoğun olarak kirletildiği ve Karadenizin kirli sularının etkisinin görüldüü Marmaranın kuzey bölgelerinin ötrofik deniz özeliğine sahip olduğu anlaşılmıştır. Marmara denizinde üst tabakadaki mikrobiyal üretim de Karadenizin mesotrofik sularında kayıtlara uygundur.

Marmara Denizinin dip kısımlarında üretilen H_2S'in oldukça hızlı okside olması ve suya geçmesiyle dip sularında oksijensizlik problemi yaşanmaktadır.

Yüzey tabakasındaki çözünebilir organik maddenin yenilenme süresi 40-60 gün bulundu. Yaz-sonbahar peryodunda Marmara denizinin üst suları 2-4 mg C m^{-3} ve dipteki Akdeniz suyu 1-2 mg Cm^{-3} çözünebilir organik madde içermektedir. Bugün, Marmara denizindeki oksijensizlik (özellikle dip kısımlarda) Çanakkale Boğazı yoluyla Marmaraya geçen oksijeni yüksek Akdeniz suyunun Marmara suyunu havalandırmasıyla önlenmektedir.

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