PRELIMINARY OBSERVATIONS ON SEWAGE NUTRIENT ENRICHMENT AND PHYTOPLANKTON ECOLOGY IN THE THERMAIKOS GULF, THESSALONIKI, GREECE

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VIE ET MILIEU, 1984, 34 (1) : 35-39

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SELS NUTRITIFS
PHYTOPLANCTON
THERMAIKOS
GRÈCE

RÉSUMÉ. — L'abondance et la diversité taxonomique du phytoplancton ont été étudiées en rapport avec la pollution urbaine (à proximité d'un point de décharge) dans le Golfe Thermaikos en Grèce. Des échantillons d'eau de surface ont été pris sur un réseau de stations en septembre 1977. Des échantillons d'eau près d'un point de décharge d'égoûts montraient des teneurs très élevées en phosphore total, phosphate, ammonium et nitrite, ainsi qu'un nombre total de cellules phytoplanctoniques plus élevé et une plus petite diversité taxonomique que les échantillons plus éloignés des égoûts. Une variation considérable des espèces et de la dominance survenait en même temps que le changement du degré de pollution. Les Dinoflagellés dominaient dans les eaux plus propres, loin de la décharge des égoûts. Certaines espèces *(Gymnodinium* sp., *Prorocentrum micans, Peridinium* sp., et *Ceratium Pulchellum)* par leur dominance et leur distribution relative sur le gradient de pollution, se présentent comme indicatrices de pollution. Ces changements correspondent à une dégradation caractéristique d'une communauté complexe qui devient moins mûre en raison de l'apport d'eaux d'égoûts riches en sels nutritifs (eutrophisation) dans la Baie de Thessalonique.

NUTRIENT
PHYTOPLANKTON
THERMAIKOS
GREECE

ABSTRACT. — The abundance and taxonomic diversity of phytoplankton has been studied in relation to sewage pollution (proximity to outfalls) in the Thermaikos Gulf, Greece. Surface water samples were collected from a grid of stations in September 1977. Water samples from the vicinity of sewer outfalls showed very high concentrations of total phosphorus, PO_4^{-3}, NH_4^+, and NO_2^-, a greater total concentration of phytoplankton, and a lower taxonomic diversity than samples remote from outfalls. A considerable variation in the occurrence of species and dominance occurred along the pollution gradient. Dinoflagellates were dominant in pollution waters, while diatoms dominated in cleaner water away from sewage outflow. From the dominance and relative distribution of the species along the pollution gradient certain species *(Gymnodinium* sp., *Prorocentrum micans, Peridinium* sp., and *Ceratium pulchellum)* emerge as indicator species of pollution. These changes correspond to a typical degradation of a complex community to a less mature state by the inflow of nutrient-rich sewage (eutrophication) in the Thessaloniki Bay.

INTRODUCTION

It is most often the availability of nutrient such as nitrogen and phosphorus that controls the rate of organic production by marine phytoplankton (Thomas, 1966; Dugdale, 1967; Ignatiades, 1969; Ryther and Dunstan, 1971). In the Eastern Mediterranean Sea, the low influx of nutrients from land drainage and the characteristic circulation pattern normally result in a small phytoplankton crop and low rate of primary production (Becacos-Kontos, 1968). However continued increases in the influx of phytoplankton nutrients into coastal environments especially in enclosed seas such as the Mediterranean, can have harmful effects on marine communities. An increase in nutrients is often accompanied by an increase in phytoplankton standing-crop and a decrease in stability and taxonomic diversity, since species with the highest intrinsic rates of natural increase become dominant (Margalef, 1963, 1967). Species diversity indices, when correlated with physical and chemical parameters, provides one of the best ways to detect and evaluate the impact of pollution on aquatic communities (Williams, 1964; Margalef, 1967; Ignatiades, 1981).

As there was not any available literature on phytoplankton ecology and sewage nutrient enrichment in the Thermaikos Gulf, we studied the effects of untreated coastal sewage outfalls in this Gulf, on the relative abundance, species composition and taxonomic diversity of the marine phytoplankton community.

MATERIALS AND METHODS

The Bay of Thessaloniki is in the northern part of the Thermaikos Gulf. This Bay is a shallow semienclosed coastal basin heavily polluted by domestic and industrial waste (120 000-140 000 $m^3/24$ h), of the Major Thessaloniki area (Fig. 1). The annual mean discharge of the largest rivers Axios and Aliakmon is of the order of 200 m^3/sec. Water samples for the determination of the physico-chemical parameters and phytoplankton were obtained from the surface and sometimes at 20 m for phytoplankton with a Nansen water bottle of capacity 1.5 l/C.O.D. was measured by the SCAN-W (1966) method. The salinity samples were collected in 300 ml glass bottles and measured in the laboratory with an Autolab Mk III 601 inductive salinometer of precision ± 0.003 ‰. The water samples for nutrient analyses were collected in 100 ml plastic bottles to which one drop of 1 % $HgCl_2$ have been added for preservation and kept under deep freeze. The filtered samples were processed on a Technicon CSM_6 Autoanalyser following the method of Hager *et al.*, (1968) and Slawyk and MacIsaac (1972). Chlorophyll-*a*, filtered through Whatman GF/C filter, was measured by fluorescence after Holm-Hansen *et al.*, (1965). The phytoplankton species diversity D was estimated by the application of Margalef's (1967) formula :

$$D = \frac{1}{N} \cdot \log \frac{N!}{N_a!\, N_b! \ldots N_s!}$$

where Na, Nb,...Ns are numbers of individuals and N is the total number of individuals.

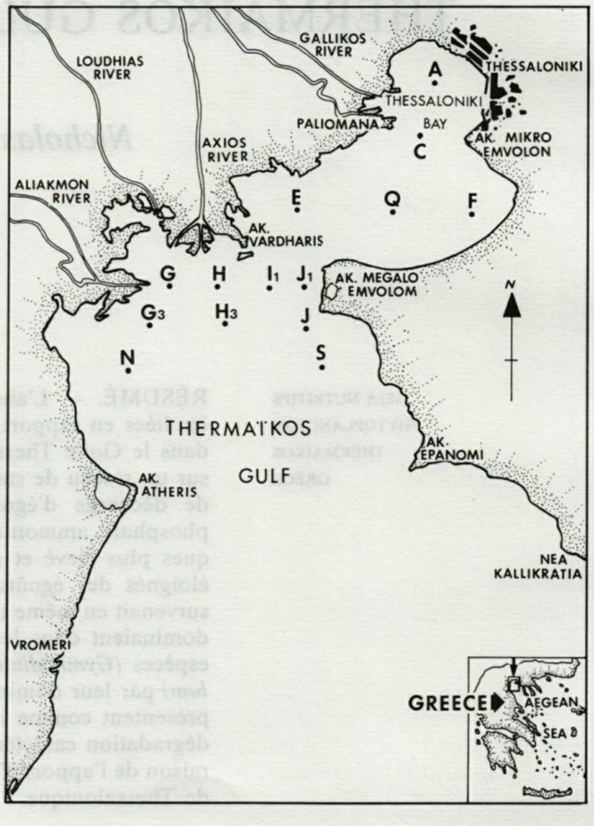

Fig. 1. — Location of the stations.

RESULTS

Physical and Chemical environment

The temperature ranged from 22.9-23.8 °C, while the salinity ranged from 35.4-36.4 ‰ with the lowest values in river estuaries (Table IA). The nutrient concentrations were ranged : $PO_4-P = 0.11.0.33$ µg-at/l, total phosphorus = 0.18-1.23 µg-at/l, $NH_3-N = 0.40\text{-}5.00$ µg-at/l, $NO_3-N = 0.06\text{-}0.31$ µg/l, $NO_3-N = 0.40\text{-}2.92$ µg-at/l and $SiO_4-Si = 1.29\text{-}3.27$ µg-at/l. The distribution of nutrients was not very clear; however total phosphorus, ammonia and silicate decreased with increasing distance from the sewer outfalls.

Tabl. I. — A, Physico-chemical parameters, abundance and diversity of the phytoplankton in the sampling stations; B, cell percentage of the most abundance phytoplankton species in surface samples at the sampling stations.

STATIONS		A	C	Q	F	E	I_1	H	G	G_3	H_3	J_1	J_4	N	S
A Parameters															
T,	°C	23.0	23.2	23.1	22.9	23.0	23.0	22.9	23.8	23.4	23.1	23.0	23.1	23.1	23.0
S,	‰	36.0	36.0	36.2	35.8	35.7	35.8	35.6	35.8	35.6	35.4	36.4	36.2	35.7	36.1
NH_4-N,	µg-at/l	1.19	1.27	1.27	1.03	2.14	0.64	0.71	0.64	0.71	1.03	5.00	1.59	0.40	–
NO_2-N,	µg-at/l	0.17	0.31	0.15	0.12	0.10	0.07	0.07	0.06	0.13	0.17	0.09	0.24	0.07	–
NO_3-N,	µg-at/l	2.29	1.42	1.56	1.14	2.29	0.57	0.40	0.97	0.64	2.40	2.92	1.34	0.28	–
SiO_4-Si,	µg-at/l	3.27	2.91	2.19	1.74	2.01	1.47	1.29	3.27	4.35	2.70	1.59	1.96	1.71	–
PO_4-P,	µg-at/l	0.24	0.17	0.20	0.13	0.17	0.33	0.11	0.13	0.13	0.13	0.31	0.24	0.13	–
T.P,	µg-at/l	0.65	0.68	0.63	0.25	0.27	0.40	0.18	0.21	1.23	0.18	0.32	0.30	0.18	–
COD,	mg/l	0.80	0.32	1.44	1.28	0.80	–	0.48	1.44	0.64	0.48	1.92	1.28	0.13	–
Chl *a*,	mg/m^3	2.60	–	2.40	0.68	0.63	0.70	0.35	0.65	0.80	0.19	0.33	0.16	0.31	0.10
Abundance,	cells/l x 10^3	112	64	27	81	27	41	58	72	66.0	27	50	16	69	7
Diversity,	bits/individu	3.2	3.4	3.5	3.5	3.3	3.7	3.6	3.9	3.9	3.7	3.9	3.4	3.6	3.4
B Species															
Diatoms															
Chaetoceros affinis															18
Chaetoceros danicus						7				25					
Leptocylindrus danicus					29							19	32		
Nitzschia closterium				11											
Rhizosolenia styliformis							17	22	13		17		20	22	26
Schroederia delicatula		16	19	29	48	43	43	42	33	26	26	33		35	
Dinoflagellates															
Exuviaella compressa		21													
Prorocentrum micans		24	25												

Abundance, Diversity and Dominance

What are the effects of the sewage nutrient-enrichment described above on phytoplankton abundance, taxonomic diversity and dominance? A dense phytoplankton population was recorded in the water near the sewer outfalls (Table IA) where the density reached 112 cells. ml^{-1}. In contrast, the density was much lower at station S away from the outfalls (7 cells.ml^{-1}). The distribution of chlorophyll-a (Table IA) showed higher values at the point of discharge of the effluents, smaller at small distance and much smaller even further. The distribution of COD was not clear (Table IA).

Taxonomic diversity decreased with decreasing distance from the sewer outfalls (Table IA). The diversity was minimum at stations A(3.2) (Fig. 1). At stations A to N, taxonomic diversity generally increased with decreasing nutrient concentrations. In general diversity was inversely related to abundance. No correlation was found between the chemical parameters and the phytoplankton abundance and diversity, except in the case of total phosphorus and diversity (r-0.45). The greatest degree of dominance (the ratio of the concentration of the two most abundance species to the total cell concentration in a sample) occurred near the sewer outfalls and decreased as the distance from the sewer increased. Thus stations A and C had the highest dominance values concerning Dinoflagellates (Table IB). Of the four major phytoplankton groups identified, Dinoflagellates dominated polluted waters and their abundance decreased with increasing distance from the sewer. On the other hand, Diatoms were dominant in relatively clean waters (Fig. 2).

DISCUSSION

The annual range of air temperature is 7-27 °C, the lowest, 7 °C, during February and the highest 27 °C, in August. Surface sea water temperature in the Gulf fluctuated between 10 and 23 °C and surface salinity between 34 and 38 ‰, with the lowest salinity at the surface in the river estuaries (Friligos, 1977). Tides in this region are not very remarkable and normally the currents are influenced by winds prevailing in the Gulf. Ganoulis *et al.*, (1980) and Balopoulos (1982) reported the prediction of the water movement in Thessaloniki Bay using mathematical models. The nutrients values shown in Table IA do not differ significantly from those found in the same area during August 1975 (Friligos and Satsmadjis, 1977).

Phytoplankton abundance was maximum at the sewer outfalls and lowest at relatively clean stations (Table IA). At the unpolluted reference stations (S), the abundance (7 cells. ml^{-1}) was slighly higher than that of a station in the lower Saronikos Bay (0.1 cells. ml^{-1}; Ignatiades, 1969). However the maximum abundance (112 cells. ml^{-1}) at station A was lower than that of a station near the sewage outfall in the upper Saronikos Gulf (1 000 cells. ml^{-1}; Ignatiades, 1981).

Increased nutrient concentrations, brought to the sea by sewage, increase the average level of phytoplankton abundance, and result in a population dominated by a few species. A few "opportunistic" fastgrowing species increase at a much faster rate than others. Consequently the diversity index based on the distribution of individuals, into species decreases. At stations near the sewer the abundance of phytoplankton was high, the number of taxa low, and consequently the taxonomic diversity low compared to the other stations (Table IA). Also in the same study of zooplankton, it was observed that the biomass decreased and the diversity increased gradually from the north to the south (Paradimitriou, 1979). Moreover, it was observed from measurements of nutrients and zooplankton in the Thermaikos Gulf during August 1975, that the nutrients decreased from north to south (Friligos and Satsmatjis, 1977), while the distribution of zooplankton had not a clear patter (Yannopoulos, 1979).

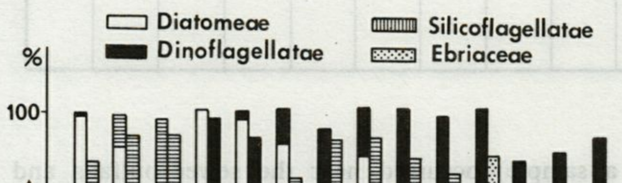

Fig. 2. — The degree of dominance of the two most important groups in surface (1) and water column (2) samples.

Phytoplankton abundance and taxonomic diversity depend upon the supply of nutrients in natural waters. This in Table IA shows that the abundance increases and diversity falls as the nutrient concentrations go-up. Total phosphorus seems to play the most important role in controlling taxonomic diversity.

The occurrence and dominance of species changed along a pollution gradient (Table IB). Compared to reference station S, the greatest degree of dominance in Dinoflagellate species composition occurred at the sewer outfalls and decreased with increasing distance from the sewer. This relative dominance and the distribution of taxa (Fig. 2) along the pollution gradient points to "indicator species" of pollution. The best indicator of sewage pollution are the Dinoflagellates (mainly *Gymnodinium* sp., *Prorocentrum micans, Peridinium* ssp., and *Ceratium pulchellum*). Almost the same species are also recorded along the central coast of Lebanon (Taslakian and Hardy, 1976).

Thus, the natural coastal phytoplankton community appears disturbed by the increased level of nutrients from untreated sewage effluents. Increased total phosphorus and probably some trace metals increase abundance, decrease diversity and radically change the species composition within an extensive coastal area in the Thessaloniki Gulf.

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