Vol. 19: 25–32, 1984 | MARINE ECOLOGY – PROGRESS SERIES
Mar. Ecol. Prog. Ser. | Published August 30

Annual cycle of planktonic primary productivity off the Romanian Black Sea coast

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ABSTRACT: Data are presented on planktonic primary productivity (0, 5 and 10 m depth) collected in 1982 from a station 1.2 nautical miles off Constantza on the Romanian Black Sea coast. Primary productivity was measured using the ^{14}C technique under *in situ* conditions. Counting was done in a liquid scintillation spectrometer. Simultaneously, determinations of chlorophyll and microscopic enumeration of phytoplankton (density and biomass) were made. Mean values of primary productivity at 0, 5 and 10 m were 5.2, 1.4 and 1.0 mg C m^{-3} h^{-1} respectively; the water column value was 2.3 mg C m^{-2} h^{-1}.

INTRODUCTION

Some biological problems of the north-western shelf of the Black Sea have been discussed by Zaitsev (1979). Two problems considered are the influence of rivers and of industrial, agricultural and urban wastes on environmental biology. Both factors tend to increase phytoplankton biomass and primary productivity.

The study of planktonic primary productivity in Romanian coastal waters has been continued in the Constantza sector (Bologa et al., 1980, 1981; Bologa and Frangopol, 1982) during 1982. For the first time in this sector *in situ* determinations were performed both at depths of 0 m and at 5 and 10 m. The data obtained in the present study complement our knowledge on the bioproductive level of these marine coastal waters.

MATERIAL AND METHODS

Phytoplankton samples were collected every month from a station (data available since 1955) situated 1.2 nautical miles off the Constantza sector of the Romanian Black Sea Coast (44° 10′ N lat., 28° 41′ E long.). Samplings were obtained from 0, 5 and 10 m depths.

Light measurements were made by means of an Ogawa Seiki underwater illuminometer (Type OSK 3174); values (lx) were transformed in energetic units (W m^{-2}) by means of a nomogram (cf. Kubin, 1971, from Gaastra, 1959) (Table 1). Total inorganic carbon content of the sea water was determined by total carbonic alkalinity analysis (cf. Protecţia calităţii apelor, 1967).

The ^{14}C method (Steemann Nielsen, 1952) was used for determination of primary productivity. Three light and 1 dark bottle(s) containing phytoplankton were inoculated each with 25 µCi (925 kBq) aqueous $NaH^{14}CO_3$ solution and incubated *in situ* at the depths mentioned. All samples were exposed for 4 h (10.00 to 14.00 h) and fixed with formaline at the end of incubation.

Samples were filtered under vacuum, on Millipore membrane filters HA 04700 (pore size = 0.45 µm). Filters were washed with a 2 % HCl solution and sea water.

The filters, preserved in Packard-type vials (with previously determined background) were counted with an automatic Nuclear Enterprises spectrometer (Type 8310/1/2) at 5 °C, by liquid scintillation counting. The following mixture was used for measuring the ^{14}C activity: 3 ml dioxan (for filter solubilization) and 5 ml Unisolve Liquid Scintillator. Samples were measured with an efficiency of 83 %. Background and quenching corrections were applied to the results. Each sample was counted 3 times (1 min duration).

Computation of planktonic primary productivity was carried out by means of the formula of Vinberg et al. (1960). Results are expressed in mg C m^{-3} (or m^{-2}) h^{-1}. Values for dark (control) bottles were neither subtracted from photosynthetic assimilation values,

0171-8630/84/0019/0025/$ 02.50

nor calculated as percentage of the latter, but were considered as such (Sournia, 1973).

Chlorophyll from the 3 depths was spectrophotometrically measured with Beckman M 25 equipment (Richards and Thompson, 1952; Strickland and Parsons, 1965); chlorophyll *a* concentrations were calculated using the trichromatic equations (Unesco, 1966).

Qualitative and quantitative phytoplankton determinations were made by employing the sedimentation method (Morozova-Vodyanitskaya, 1948, 1954) for establishing taxonomic composition and weight of the major groups of primary producers; both density (total cell number) and biomass (standard cell measurements multiplied by cell numbers; cf. Morozova-Vodyanitskaya, 1954, completed by Skolka, pers. comm.) analyses were carried out; these determinations exclude nanoplankton species.

Values of primary productivity, chlorophyll *a*, phytoplankton density and biomass were calculated for the water column according to the scheme generally adopted for the Black Sea (Morozova-Vodyanitskaya, 1954).

RESULTS AND DISCUSSION

Environmental factors such as light (irradiance), temperature, pH, salinity and total inorganic carbon were measured along with primary productivity (Table 1).

The results on primary productivity of the Constantza sector, nearshore, in 1982 (Table 2) list the highest value, 24.7 mg C m^{-3} h^{-1}, at 0 m in Jul. In both of the other 2 layers, lower values, ranging between 0.2 and 2.7 mg C m^{-3} h^{-1} (5 m) and between 0.1 and 3.0

Table 1. Hydrological data of the sea water in the Constantza sector, 1982

Month	Depth (m)	Irradiance (10.00 h) (W m^{-2})	Temperature (°C)	pH	S ‰	Total inorganic carbon (mg l^{-1})
Jan 26	0	> 11.7	1.0	8.2	14.33	39.09
	5	0.9	1.0	8.1	14.85	38.91
	10	0.2	1.0	8.1	14.85	38.33
Feb 16	0	> 15.6	1.5	8.1	13.95	40.45
	5	0.5	2.0	8.3	14.33	40.45
	10	0.02	2.0	8.3	14.07	39.24
Mar 26	0	> 24.1	3.0	8.3	13.82	41.04
	5	0.4	3.0	8.3	14.67	39.83
	10	0.01	3.0	8.1	15.37	38.02
Apr 26	0	> 29.7	9.5	8.2	11.17	38.02
	5	3.0	9.5	8.4	11.42	38.02
	10	0.7	9.0	8.4	12.45	38.02
May 06	0	> 30.6	7.5	8.1	18.22	41.05
	5	27.6	7.0	8.1	18.12	40.44
	10	7.4	7.0	8.1	18.31	40.44
Jun 16	0	> 32.8	13.5	8.2	12.32	41.49
	5	> 32.8	11.5	8.2	12.42	41.49
	10	22.9	9.5	8.3	12.76	41.49
Jul 26	0	> 31.1	24.0	8.8	13.77	30.12
	5	1.4	23.0	8.6	15.17	36.20
	10	0.2	21.0	8.4	16.20	38.02
Aug 13	0	> 28.3	25.0	8.4	14.15	33.78
	5	5.7	24.0	8.5	14.24	33.78
	10	0.6	24.0	8.7	14.33	34.38
Sep 24	0	> 24.1	22.0	8.5	13.30	37.42
	5	2.4	22.0	8.5	14.85	36.80
	10	0.5	22.0	8.4	15.26	35.01
Oct 21	0	> 18.8	16.0	8.2	16.92	38.01
	5	10.1	17.0	8.3	17.34	38.01
	10	2.3	17.0	8.2	17.12	38.01
Nov 22	0	> 13.7	12.0	8.4	15.56	39.23
	5	7.1	12.0	8.3	16.98	39.23
	10	2.2	12.5	8.4	16.73	39.23
Dec 06	0	> 11.7	7.5	8.3	13.77	34.00
	5	0.8	7.0	8.3	14.24	35.58
	10	0.2	7.0	8.4	14.42	36.80

Table 2. Planktonic primary productivity values in the Constantza sector in 1982

Month	mg C m^{-3} h^{-1}			mg C m^{-2} h^{-1}
	0 m	5 m	10 m	
Jan	6.0	0.2	0.2	1.7
Feb	5.1	1.4	1.4	2.3
Mar	4.8	1.9	1.5	2.5
Apr	0.6	0.5	0.3	0.5
May	1.8	2.7	3.0	2.6
Jun	0.4	0.7	0.6	0.6
Jul	24.7	2.4	1.9	7.9
Aug	6.7	1.0	1.6	2.6
Sep	5.2	0.9	0.2	1.8
Oct	3.8	1.9	0.4	2.0
Nov	1.1	1.0	0.1	0.8
Dec	2.5	2.4	0.7	2.0
Annual mean	5.2	1.4	1.0	2.3

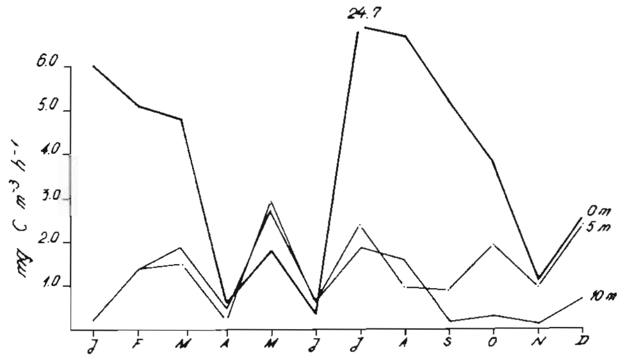

Fig. 1. Annual cycle of planktonic primary productivity at 0, 5 and 10 m in the Constantza nearshore sector

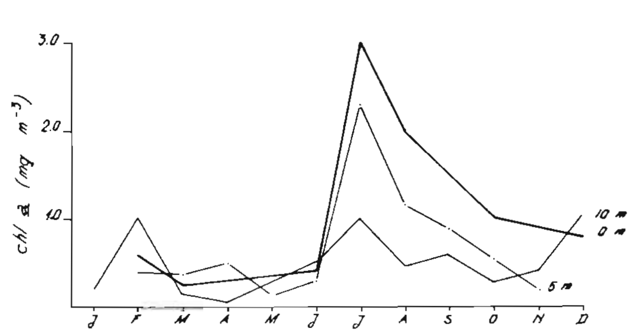

Fig. 2. Annual cycle of chlorophyll *a* concentrations at 0, 5 and 10 m in the Constantza nearshore sector

(10 m), were recorded. Maximum productive rates occurred in late spring and summer. These results no longer confirm the usual higher values of primary productivity off the Romanian Black Sea Coast during spring and autumn, as before (e.g. in 1979; Bologa et al., 1981).

The highest m^{-2} values were 7.9 mg C h^{-1} (Jul) and 2.6 (May, Aug). The maximum primary productivity level in Jul is correlated also with the highest chlorophyll *a* concentrations and with the highest density and biomass values of phytoplankton in 1982.

The lower value of primary productivity in May, compared to previous years (e.g. Bologa et al., 1981), correlated with low chlorophyll *a* concentrations and with low phytoplankton biomasses, may be explained by the drifting of phytoplankton populations due to upwelling (Table 1). However, also comparatively, it is obvious that not only the lower value in May, but even the maximum value over the whole year, are much lower as compared to the primary productivity level of 1,530 mg C m^{-3} d^{-1}, determined in the Romanian predanubian sector during an extremely intense bloom of *Skeletonema costatum* also in May 1982 (Bologa et al., 1983).

The vertical distribution of primary productivity showed higher values at 0 m, except in May (5 and 10 m). The maximum annual mean value occurred also at 0 m (5.2 mg C m^{-2} h^{-1}). The higher value of primary productivity in the surface layers (Fig. 1) agrees with earlier data from the same sector, down to 50 m depth, in 1980 (Bologa and Frangopol, 1982).

Chlorophyll *a* concentration values at 0 m ranged between 0.1 (May) and 3.1 mg m^{-3} (Jul), at 5 m between 0.3 (Mar) and 2.3 (Jul) and at 10 m between 0.1 (Apr) and 1.8 (Jul) in 1982 (Fig. 2). Generally, the values ranged between known limits, e.g. between 0.5 and 1.4 mg m^{-3} in 1976 (Bologa, 1977) or between 0.3 and 3.6 in 1977 (Bologa, 1978).

The vertical distribution of chlorophyll *a* shows higher values at 0 m. During intense blooms, a vertical stratification of chlorophyll *a* concentration, as well as phytoplankton abundance, were observed. The high values of chlorophyll *a* in Jul and Aug, due to summer blooms, are closely correlated with the high level of primary productivity and with the phytoplankton biomass during this period of the year.

Specific composition and quantitative dynamics of planktonic primary producers were noticed. During this study a total number of 64 species were identified (Table 3).

The annual cycle of phytoplankton density and biomass differs, depending on taxonomic position (Table 4) and water depth (Table 5). The lowest quantities of phytoplankton (20 to 25.10^{3} cells l^{-1} and 140 to 240 mg m^{-3}) were found during Jan, May and Nov which are transitional months. This dominant bloom forming phytoplankton species showed distinct qualitative variations. Thus, in Feb and Mar, the winter species, viz. *Thalassiosira subsalina*, followed by *Skeletonema costatum* and *Chaetoceros socialis*, were dominant. A remarkable dominant population of *Gonyaulax polygramma* among dinoflagellates was noticed in Apr as had been observed in the previous

Table 3. Taxonomic composition of planktonic primary producers in the Constantza sector in 1982

No.	Species	EG*	Months**											
			J	F	M	A	M	J	J	A	S	O	N	D
	BACILLARIOPHYTA													
1	*Melosira sulcata* (Ehr.) Kütz.	M			o									
2	*Hyalodiscus scoticus* (Kütz.) Grun.	M	o											
3	*Skeletonema costatum* (Grev.) Cl.	M	=	=	×	o					o	=	o	=
4	*Thalassiosira excentrica* (Ehr.) Cl.	M	o	o									o	+
5	*T. nordenskiöldii* Cl.	M		o										
6	*T. parva* Pr.-Lavr.	M	o	=	o				o		o	o	o	=
7	*T. subsalina* Pr.-Lavr.	M		=	=	o						o	o	
8	*Cyclotella caspia* Grun.	M	o					o		o	o			
9	*Coscinodiscus concinnus* W. Sm.	M						o	o	o				
10	*C. granii* Gough.	M		o										
11	*Detonula confervacea* (Cl.) Gran	M										+	o	
12	*Rhizosolenia calcar-avis* M. Schultze	M						o		o		o	o	
13	*R. fragilissima* Bergon	M						o					o	=
14	*Chaetoceros curvisetus* Ostf.	M	o					o				o	o	
15	*C. muelleri* Lemm.	M												+
16	*C. rigidum* Ostf.	M												=
17	*C. simile* Cl.	M	o	o										
18	*C. socialis* Laud.	M										=		+
19	*C. subtile* Cl.	M	o	×								=		=
20	*Ditylum brightwelli* (West) Grun.	M	o	o	o			o	o	o			o	=
21	*Cerataulina bergonii* Perag.	M		o		o		o	o	+	+	o	o	
22	*Thalassionema nitzschioides* Grun.	M									o	=	o	o
23	*Diatoma elongatum* (Lyngb.) Ag.	F	o	o	o	o	o							
24	*Navicula pennata* A. S.	M		o		o	=							
25	*Nitzschia closterium* (Ehr.) W. Sm.	M	o		o			o		=		o	o	o
26	*N. seriata* Cl.	M		o	o	o		o	o	o		+	o	=
	PYRROPHYTA													
27	*Exuviaella cordata* Ostf.	M	o	=	o	o	o	×	×	×	o	o	=	=
28	*E. compressa* Ostf.	M		o		o						o	o	
29	*Prorocentrum micans* Ehr.	M						o		o		o	o	o
30	*P. scutellum* Schröder	M						o						o
31	*Phalacroma rotundatum* Kof. et Mich.	M											o	
32	*Dinophysis fortii* Pav.	M												o
33	*D. sacculus*	M				o								
34	*Gymnodinium rhomboides* Scütt.	M		o	o							=	o	o
35	*G. splendens* Lebour	M				o								
36	*Gyrodinium fusiforme* Kof. et Sw.	M					o	=	o			o	o	o
37	*G. lachryma* Kof. et Sw.	M		o		o	o	o						
38	*Glenodinium apiculatum* Zach.	M		o					o	o				
39	*G. lenticula* Bergh	M								o	o		o	
40	*Peridinium brevipes* Paulsen	M		o	o	o	o					o	o	o
41	*P. crassipes* Kof.	M				o		o						
42	*P. depressum* Bailey	M							o					
43	*P. minusculum* Pav.	M											o	
44	*P. pentagonum* Gran	M		o										
45	*P. steinii* Jörg	M	o	o					=					o
46	*Gonyaulax polygramma* Stein	M	o	o	o	=	o	o						=
47	*Ceratium furca* Ehr.	M								o		o	o	=
48	*C. fusus* (Ehr.) Duj.								o	o				o
49	*C. tripos* (O. F. Müller) Nitzsch	M							o	o			o	o
50	*Protoceratium reticulatum* Bütschli	M											o	o
51	*Hypnodinium sphaericum* Klebs	M				o		=	o					
	Pyrrophyta kysts?	M	o						=			o		
	CHLOROPHYTA													
52	*Ankistrodesmus falcatus* (Corda) Ralfs	F										o	o	o
53	*Crucigenia tetrapedia* West et G. S. West	F												o
54	*Lagerheimia* sp.	F		o										
55	*Pterosperma cristatum* Schiller	M		o				o				o	o	

Table 3. Continued

No.	Species	EG*	Months** J	F	M	A	M	J	J	A	S	O	N	D
	CHLOROPHYTA													
56	*Raciborskiella salina* Wislouch	M	o			o								o
57	*Scenedesmus quadricauda* (Turp.) Breb.	F	o	o										
58	*Tetracoccus botryoides* West	F	=	o		o								
	EUGLENOPHYTA													
59	*Euglena pisciformis* Klebs.	F											o	
60	*Eutreptia lanowii* Steuer	M	o	o	o	o						o	o	o
	SILICOFLAGELLATA													
61	*Dictyocha speculum* Ehr.	M	o	o										o
62	*Ebria tripartita* (Schum.) Lemm.	M				=		o						
	COCCOLITHOPHORIDA													
63	*Coccolithus fragilis* Lohm.	M			o		o		o	o				
	CYANOPHYTA													
64	*Anabaena spiroides* Kleb.	F												=
	Total Bacillariophyta		11	13	8	6	2	9	5	7	5	12	13	11
	Total Pyrrophyta		4	9	4	9	5	8	9	7	2	8	12	13
	Total other groups		4	6	2	4	1	2	1	1	0	3	4	7

* Ecological group: M, marine and brackish-marine species; F, fresh and brackish-freshwater species
** o, fewer than 10^4 cells l^{-1}; =, 10^4 to 10^5 cells l^{-1}; +, 10^5 to 10^6 cells l^{-1}, ×, more than 10^6 cells l^{-1}

Table 4. Density and biomass dynamics of planktonic primary producers as a function of taxanomic position in the Constantza sector in 1982

Month	Bacillariophyta	Pyrrophyta	Other groups	Total
		Density (cells l^{-1})		
Jan	11,725	5,500	7,875	25,100
Feb	177,250	11,500	7,000	195,750
Mar	327,125	3,375	375	330,875
Apr	13,125	74,000	42,250	129,375
May	11,625	9,125	125	20,875
Jun	12,375	7,038,875	375	7,051,625
Jul	3,000	35,752,500	125	35,755,625
Aug	68,625	1,871,250	625	1,940,500
Sep	188,625	1,875	0	190,500
Oct	272,250	18,875	3,500	294,625
Nov	9,750	12,625	875	23,250
Dec	483,125	72,375	16,375	571,875
Annual mean	131,550	3,739,323	6,625	3,877,498
		Biomass (mg m^{-3})		
Jan	79.96	54.57	4.75	139.29
Feb	2,566.54	108.76	20.45	2,695.77
Mar	1,698.33	70.48	1.94	1,770.75
Apr	329.84	820.79	95.34	1,245.97
May	22.50	129.01	1.76	153.28
Jun	582.28	7,672.50	0.49	8,255.49
Jul	117.05	28,444.57	0.87	28,562.50
Aug	871.74	1,571.30	4.37	2,447.42
Sep	4,113.20	8.77	0	4,121.97
Oct	371.08	289.73	3.07	663.89
Nov	96.83	141.11	0.94	238.88
Dec	1,129.49	984.94	12.00	2,126.43
Annual mean	998.24	3,358.03	12.16	4,368.47

Table 5. Density and biomass dynamics of planktonic primary producers depending on the depth in the Constantza sector in 1982

Month	0 m	5 m	10 m	Mean
		Density (cells l^{-1})		
Jan	44,500	9,200	37,500	25,100
Feb	65,000	298,500	121,000	195,750
Mar	1,222,500	40,500	20,000	330,875
Apr	99,500	177,500	63,000	129,375
May	19,500	28,000	8,000	20,875
Jun	26,420,500	482,000	822,000	7,051,625
Jul	54,722,000	31,287,000	25,726,500	35,755,625
Aug	2,034,000	1,787,000	2,154,000	1,940,500
Sep	361,500	195,000	10,500	190,500
Oct	556,000	219,500	183,500	294,625
Nov	23,500	8,500	52,500	23,250
Dec	484,500	568,000	667,000	571,875
Annual mean	7,171.083	2,925,058	2,488,792	3,877,498
		Biomass (mg m^{-3})		
Jan	194.90	87.58	187.09	139.29
Feb	594.37	3,229.22	3,491.35	2,586.16
Mar	2,378.82	1,959.52	785.14	1,770.75
Apr	749.94	1,519.75	1,194.45	1,245.97
May	264.62	151.56	45.38	153.28
Jun	21,677.96	3,444.85	4,454.32	8,255.49
Jul	42,764.60	24,895.40	21,694.60	28,562.50
Aug	2,441.97	1,779.90	3,817.90	2,447.42
Sep	7,888.78	4,189.36	220.39	4,121.97
Oct	898.28	600.20	556.88	663.89
Nov	391.77	75.70	412.38	238.88
Dec	1,447.90	2,020.42	3,016.98	2,126.43
Annual mean	6,805.32	3,672.56	3,323.07	4,368.47

years. The weight of the diatoms also decreased during this period.

In May the quantities of these species decreased considerably. A bloom of *Exuviaella cordata* commenced in Jun, and continued until it decreased in Aug. During Aug a rich population of *Cerataulina bergonii* started; it attained a maximum concentration in Sep.

A small number of species (fewer than 20) was recorded round the year except in Feb (28 species); their number had particularly declined in May (8 species) when the phytoplankton was poor and in Sep (7 species) when *Cerataulina bergonii* probably inhibited the development of other species, as had been observed for other diatom species (Aubert et al., 1981).

Since Oct the phytoplankton diversity increased continuously, owing to the appearance of autumn and winter species, besides the summer species.

Towards end of Oct *Detonula confervacea, Thalassionema nitzschioides, Nitzschia seriata* and *Skeletonema costatum* appeared in the plankton in high quantities. However, the abundance of all the above-named species was less in Nov. In Dec, *S. costatum, Thalassiosira excentrica, Chaetoceros socialis* and *C. muelleri* became dominant among the diatoms, and *Exuviaella cordata* and *Gonyaulax polygramma* among the dinoflagellates.

In our samples, species belonging to 7 phyla were found, among which diatoms (41.0 %) and dinoflagellates (39.0 %) were dominant; the other 5 phyla represented only 20 % of the total number of species (Table 6).

Primary producers were analysed also from the ecological point of view. Because of the large variation in salinity conditions in the Constantza sector, the brackish-freshwater species represented 12.5 %, and the brackish-marine species 87.5 % (Table 7). These values are similar to those reported earlier, viz. 15.5 and 84.5 %, respectively for 1979 (Bologa et al., 1981).

The values of primary productivity reported here are lower than those reported for 55 samples from 0 m in 1979 (Bologa et al., 1981) and for 130 samples from 0, 10, 25 and 50 m in 1980 (Bologa and Frangopol, 1982). The lower values could be due – in spite of the high nutrient concentrations (P-PO_4) which still occur – to the decreasing tendency of eutrophication beginning in 1975 and continuing until 1982: 10.2 mg m^{-3} in 1959 to 1970, 302.6 in 1975, 173.9 in 1971 to 1982, and 158.4

Table 6. Number and percentage of phytoplankton species belonging to different taxonomic groups

Taxonomic group	Species number	%
Bacillariophyta	26	41.00
Pyrrophyta	25	39.00
Chlorophyta	7	10.80
Euglenophyta	2	3.12
Silicoflagellata	2	3.12
Coccolithophorida	1	1.56
Cyanophyta	1	1.56
Total	64	100.00

Table 7. Distribution of ecological groups of the planktonic primary producers in the Constantza sector in 1982

Ecological group	Species number	%
Marine and brackish-marine species	56	87.5
Fresh and brackish-freshwater species	8	12.5
Total	64	100.0

in 1982 (Cociaşu and Popa, 1980; Voinescu et al. 1981; Cociaşu et al., pers. comm.). Nevertheless, the same sequence of microalgal populations which have dominated the phytoplankton of Romanian coastal waters since 1974 has been observed. Two maxima of phytoplankton development could be delimited quite distinctly until then in these waters: a stronger one in spring and a weaker one in autumn. These maxima were strongly linked to the 2 high floods of the Danube (Skolka and Bodeanu, 1978). Beginning with the eutrophication of the sea, the spring bloom caused by the diatom complex *Skeletonema–Thalassiosira* was replaced by the dinoflagellate *Gonyaulax polygramma;* this, in turn, was gradually replaced by the very intense *Exuviaella cordata* bloom, which lasted until Aug. Under such circumstances the summer minimum can either be blurred or even replaced by the annual maximum of phytoplankton development (Bodeanu and Roban, 1975; Bodeanu and Uşurelu, 1979). Hence, there is only one winter phytoplankton minimum during one annual cycle, due to diminution of light energy. However, this winter minimum can also become shorter, or may even occur at the outset of a winter-spring bloom (during a cloudless sky and high temperatures) as was the case in Dec 1982.

CONCLUSIONS

(1) Planktonic primary productivity in the Constantza sector, nearshore, amounts to 5.2, 1.4 and 1.0 mg C m^{-3} h^{-1} at 0, 5 and 10 m, respectively; the water-column value was 2.3 mg C m^{-2} h^{-1} in 1982.

(2) Quantitatively, primary productivity was correlated with chlorophyll *a* concentrations and phytoplankton biomass, especially in terms of increased production levels.

(3) The maximum primary productivity value in Jul 1982 was due to the intense bloom of the dinoflagellate *Exuviaella cordata*.

(4) *Exuviaella cordata* has produced blooms of different intensities every year since 1974. Accordingly, the original seasonal occurrence of phytoplankton at the Romanian Black Sea Coast, with spring and autumn maxima and with winter and summer minima, became blurred or even disappeared completely.

(5) Maximum primary productivity values occurred, with few exceptions, at 0 m, not at 5 or 10 m.

Acknowledgements. We sincerely thank Mr. N. Mustafa for technical assistance during sampling and exposure of samples under *in situ* conditions.

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This paper was submitted to the editor; it was accepted for printing on April 30, 1984