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CONTRIBUTION OF PHYTOPLANKTON TO PARTICULATE ORGANIC CARBON IN THE GULF OF TRIESTE (NORTHERN ADRIATIC SEA)

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ABSTRACT

In the Gulf of Trieste (Northern Adriatic Sea) an investigation was carried out to determine the contribution of particulate phytoplankton carbon (PPC) to particulate organic carbon (POC) and their seasonal evolution. Water samples were collected monthly from March to October 1990 in three coastal stations at four depths. The suspended matter, temperature, salinity, chlorophyll a, phytoplankton composition and abundance were estimated and phytoplankton carbon content was calculated.

In the Gulf of Trieste, variations in the amounts and quality of total suspended matter (TSM) and its C/N ratio reflected river discharge changes and phytoplankton community succession. In 1990 high fresh water inputs were observed in spring and autumn, which corresponded to high TSM concentrations mostly due to inorganic fraction. In spring and autumn, even if phytoplankton blooms occurred, PPC was only a small part of the POC, because of the small dimensions of diatoms and the presence of high terrestrial contributions. The prevalence of nanoplankton and the very low PPC values observed in March and in April can also confirm this hypothesis. In summer, high PPC values, corresponded to large-sized diatom species although present at low concentrations.

Key words: Suspended matter, particulate organic carbon, particulate phytoplankton carbon, C/N ratio

INTRODUCTION

The bulk of suspended particles in marine waters (seston) consists of mineral and organic fractions (Posedel & Faganeli, 1991). In the coastal zone, the mineral part of seston, is carried out into the sea by means of land drainage, coastal erosion and atmospheric inputs, or it is stirred up from the bottom and, to a lesser extent, formed *in situ* (Fabiano *et al.*, 1986). The particulate organic matter, found in the open oceans, consists mainly of living organisms, like phyto- and zooplankton, bacteria and fungi (Faganeli, 1983; Honjo, 1980; Sreepada *et al.*, 1996). In coastal waters, such as the Gulf of Trieste, particulate organic matter is mostly derived from the terrigenous supply of rivers and resuspension of bottom sediments (Fonda Umani *et al.*, 1985; Airoldi *et al.*, 1995), except during phytoplankton blooms when living organic matter prevales.

The phytoplankton community in temperate areas is influenced by nutrient availability (Malone, 1980) and by environmental parameters: microphytoplankton blooms occur in spring and autumn, after high river inputs and in optimal chemical and physical conditions. In this situation, eukaryotic phytoplankton can constitute up to 80% of the POC (Hobson *et al.*, 1973; Laws *et al.*, 1988). On the other hand, nano- and picoplankton are abundant especially in summer months, but their contribution to POC is generally low due to their small size.

The aim of the present investigation is to estimate the contribution of particulate phytoplankton carbon (PPC) to particulate organic carbon (POC) and its seasonal evolution in a coastal area of a semi-enclosed Gulf.

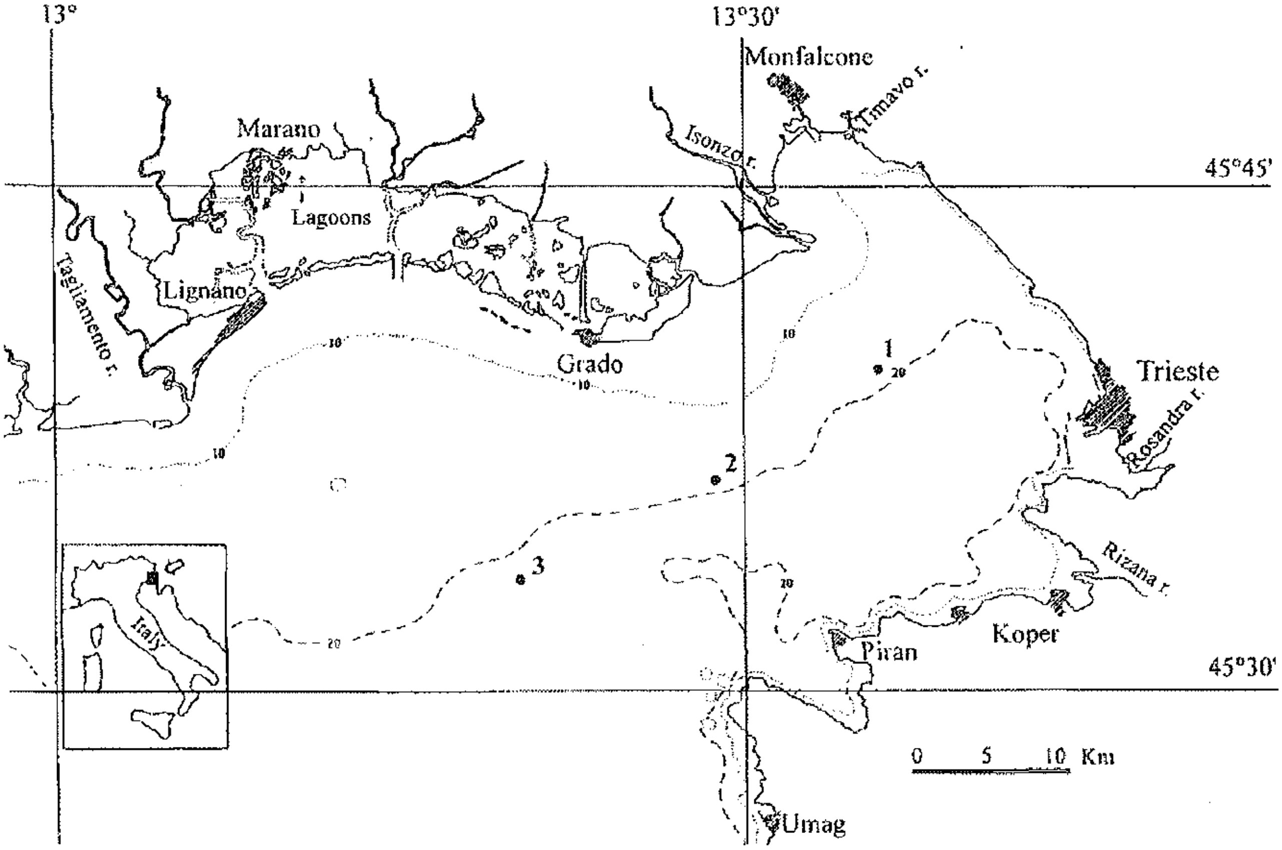


Fig. 1: Location map showing the sampling stations in the Gulf of Trieste.
Sl. 1: Položaj vzorčevalnih postaj v Tržaškem zalivu.

DESCRIPTION OF THE STUDIED AREA

The Gulf of Trieste (Fig. 1) is a shallow semi-enclosed basin (max. depth of 25 m) in the north-eastern part of the Adriatic Sea. It receives conspicuous fresh water inflows driven by the Isonzo river, with a mean annual flow of 100 m^3s^{-1} (Olivotti *et al.*, 1986), by the Timavo river from the northern part of the Gulf and to, a lesser extent, by the Rosandra and Rižana rivers from eastern and southern parts. Urban sewages, industrial and agricultural effluents coming from the neighbouring area are discharged into the Gulf, generally through underwater pipelines.

The circulation system is typical of the northern Adriatic Sea characterized by two major currents: a deep one, anticlockwise, with an average vectorial velocity of about 2 cm sec^{-1} and a surface one, generally flowing clockwise (average velocity 5 cm sec^{-1}) which plays a fundamental role in the sediment distribution in shallow waters, particularly in association with strong winds and high river inputs (Stravisi, 1988).

The water column is characterized by a strong vertical temperature gradient (up to 8°C difference between surface and bottom water) during spring and summer and by vertical mixing, mostly produced by the Bora wind, during autumn and winter. Local winds in the Gulf are sea and land breezes, almost along the direction WNW-ESE respectively. South winds, from "Scirocco" (SE) to "Libeccio" (SW), are significant in the whole Adriatic basin (Stravisi, 1991).

MATERIALS AND METHODS

Sampling was carried out at monthly intervals from March to October 1990 at three stations (1, 2, 3) in the Gulf of Trieste. The stations were located along a NE-SW transect (Fig. 1). The water depth at these stations was 20, 17 and 19 m, respectively. Water sampling was performed using a Niskin bottle (5 l) at four different depths (surface, 5, 10 and 15m).

Total Suspended Matter (TSM) samples were pre-filtered through a 200 µm mesh net. One litre was filtered onto precombusted (3 hours at 450°C) and pre-weighed 47 mm Whatman GF/F glass-fibre filters (Fabiano & Povero, 1992). After filtration, the salt was removed by washing the filter with distilled water.

TSM was estimated by gravimetry and was separated into inorganic (ISM-Inorganic Suspended Matter) and

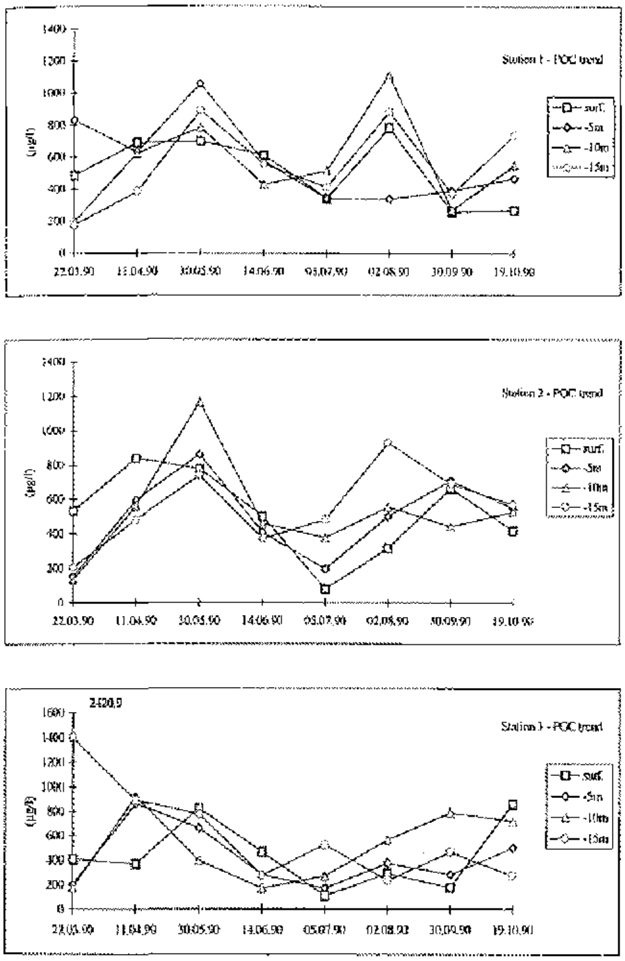


Fig. 2: Particulate Organic Carbon (POC) at the stations 1, 2 and 3.
Sl. 2: Partikulatni organski ogljik (POC) na postajah 1, 2 in 3.

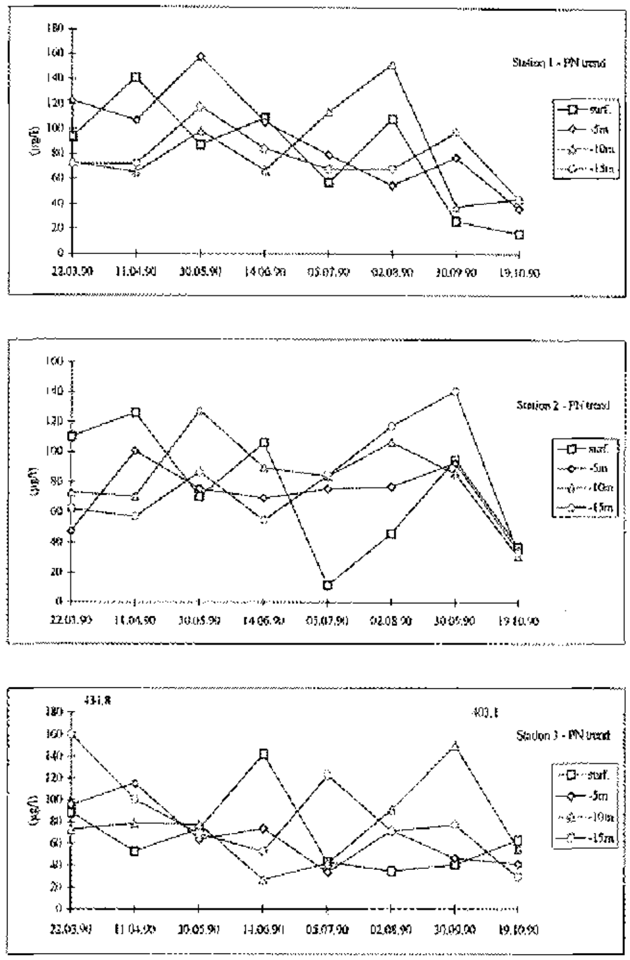


Fig. 3: Particulate Nitrogen (PN) at the stations 1, 2 and 3.
Sl. 3: Partikulatni dušik (PN) na postajah 1, 2 in 3.

organic (POM-Particulate Organic Matter) components, after removing carbonates with 1N HCl (Hedges & Stern, 1984) and measuring the organic residual by reweighting the filters (Smetacek *et al.*, 1978). Finally, the ISM lost during acidification was calculated according to the difference between TSM and POM. Analyses of Organic Carbon (POC) and Nitrogen (PN) in particulate matter were performed, on HCl treated filters, using a Perkin-Elmer 2400 CHN Elemental Analyzer for dry combustion (950°C).

Phytoplankton samples (250 ml) were fixed with buffered formalin at 4% final concentration. 50-100 ml had been settled, counted according to Utermöhl (1958) using an inverted microscope (320x), and determined generally at the species level for microphytoplankton and at group level for nanoplankton. Particulate phytoplankton carbon (PPC) was obtained by calculating the cell volume (CV) for every species, where each one was expressed as a simple or composed solid geometric body. For the majority of the species, the cell volume is equal to plasma volume (CV=PV). Regarding the diatoms only 90% of the vacuolar volume (VV), which contains generally non nutritious cell sap, was subtracted from cell volume (Mullin *et al.*, 1966; Smayda, 1978; Edler, 1979). The carbon content of each species was calculated according to Strathmann (1967). The total PPC was obtained by summing individual values of species encountered in each sample.

Sea water samples for Chlorophyll *a* (Chl *a*) determination (2l) were filtered onto a 47 mm 0.45 µm Millipore HA filter. Chlorophyll a analyses were carried out using a Perkin-Elmer Lambda 2 spectrophotometer, according to Magazzù (1978).

Temperature and salinity were measured throughout the water column using a CTD probe (Hydronaut mod. 401).

		Station 1		Station 2		Station 3	
Months	Depth.	Temp. (°C)	Sal.	Temp. (°C)	Sal.	Temp. (°C)	Sal.
March 22.03.90	0m	14.22	35.28	13.29	35.90	12.79	37.78
	5m	11.26	38.31	10.72	38.07	11.20	38.27
	10m	10.91	38.28	10.29	38.07	10.91	38.29
	15m	10.66	38.25	10.32	38.09	10.87	38.27
April 11.04.90	0m	12.01	27.21	11.97	36.84	12.27	38.01
	5m	11.55	37.96	11.36	37.90	11.92	38.05
	10m	11.44	37.98	11.23	37.99	11.83	38.10
	15m	11.41	38.01	11.20	38.04	11.79	38.12
May 30.05.90	0m	19.02	35.79	19.22	35.58	18.51	37.52
	5m	17.81	36.37	18.65	36.44	17.79	37.52
	10m	16.48	37.44	17.96	36.93	17.50	37.73
	15m	14.07	37.97	13.79	38.01	14.97	38.12
June 14.06.90	0m	19.29	33.79	19.39	31.03	20.55	32.27
	5m	19.10	36.40	18.90	36.79	18.90	37.05
	10m	18.14	37.41	18.31	37.35	18.69	37.52
	15m	15.82	37.79	15.89	37.74	18.60	37.60
July 05.07.90	0m	21.38	37.13	24.32	37.01	23.04	37.46
	5m	20.83	37.43	22.53	36.89	22.52	37.46
	10m	19.98	37.82	20.16	37.49	20.65	37.86
	15m	18.50	37.77	18.41	37.74	18.46	37.89
August 02.08.90	0m	23.55	37.95	24.40	37.68	24.84	37.93
	5m	23.35	37.95	23.92	37.64	23.30	38.01
	10m	23.23	37.97	23.67	37.73	23.09	38.00
	15m	23.00	37.92	22.78	37.87	21.49	38.23
September 30.09.90	0m	23.53	36.20	24.63	36.78	24.89	37.78
	5m	23.25	37.75	23.25	37.71	24.07	37.77
	10m	22.76	37.80	22.94	37.77	23.29	37.81
	15m	22.11	38.05	22.30	37.90	21.91	38.07
October 19.10.90	0m	19.85	36.94	18.94	35.48	18.96	34.56
	5m	19.48	37.18	19.73	37.02	19.90	37.14
	10m	19.77	37.51	19.83	37.36	19.97	37.46
	15m	19.74	37.52	19.71	37.47	20.14	37.59

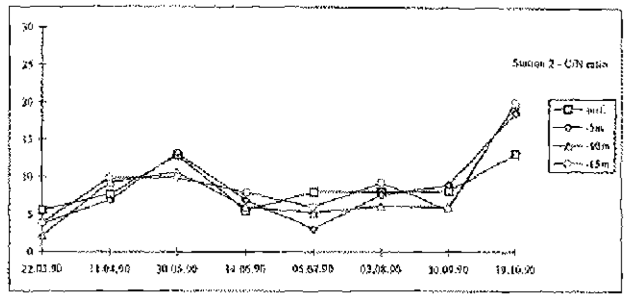
Tab. 1: Temperature and Salinity at the stations 1, 2 and 3.
Tab. 1: Temperatura in slanost morja na postajah 1, 2 in 3.

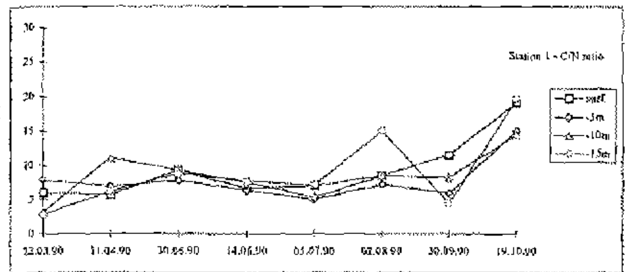
RESULTS

Hydrological features

In spring 1990 three water masses were recognized in the Gulf of Trieste, each characterized by different hydrological and nutrient regimes. Fresh water inputs were predominant in April, June and October and the intensity of each episode was weaker than in the previous and following years (Cardin & Celio, 1997).

During the spring months (March, April and May) the water column was stratified with higher temperature at the surface and lower at the bottom related to residual winter water nuclei (Tab. 1). Minimum surface temperature was 11.97°C (St. 2, April) while maximum was 19.22°C (St. 2, May). On the contrary, minimum bottom value was 10.32°C (St. 2, March) while maximum was 14.97°C (St. 3, May). The difference between surface and bottom layers was on average 2.69°C in the three stations. Salinity was generally low at the surface because of the riverine inflows and it was higher at the bottom, owing to the presence of a high salinity nucleus with winter characteristics. Thermohaline stratification of the water column lasted also in June while during the warmest months the water column was more homogeneous. The highest surface temperature was observed in September (24.89°C, St. 3), whereas the lowest value was reported in June (19.29°C, St. 1). The highest bottom water temperature was observed in August (23.00°C, St. 1) whereas the lowest one was found in June (15.82°C, St. 1). Salinity values were generally homogeneous in July and August while in the other months the lowest values were found at the surface, especially in April (27.21) and in June (33.79). In October, a progressive mixing of the water column was evident (Tab. 1).





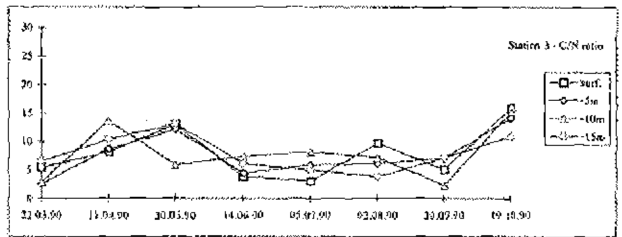


Fig. 4: C/N ratio at the investigated stations.

Sl. 4: Razmerje C/N na raziskovalnih postajah.

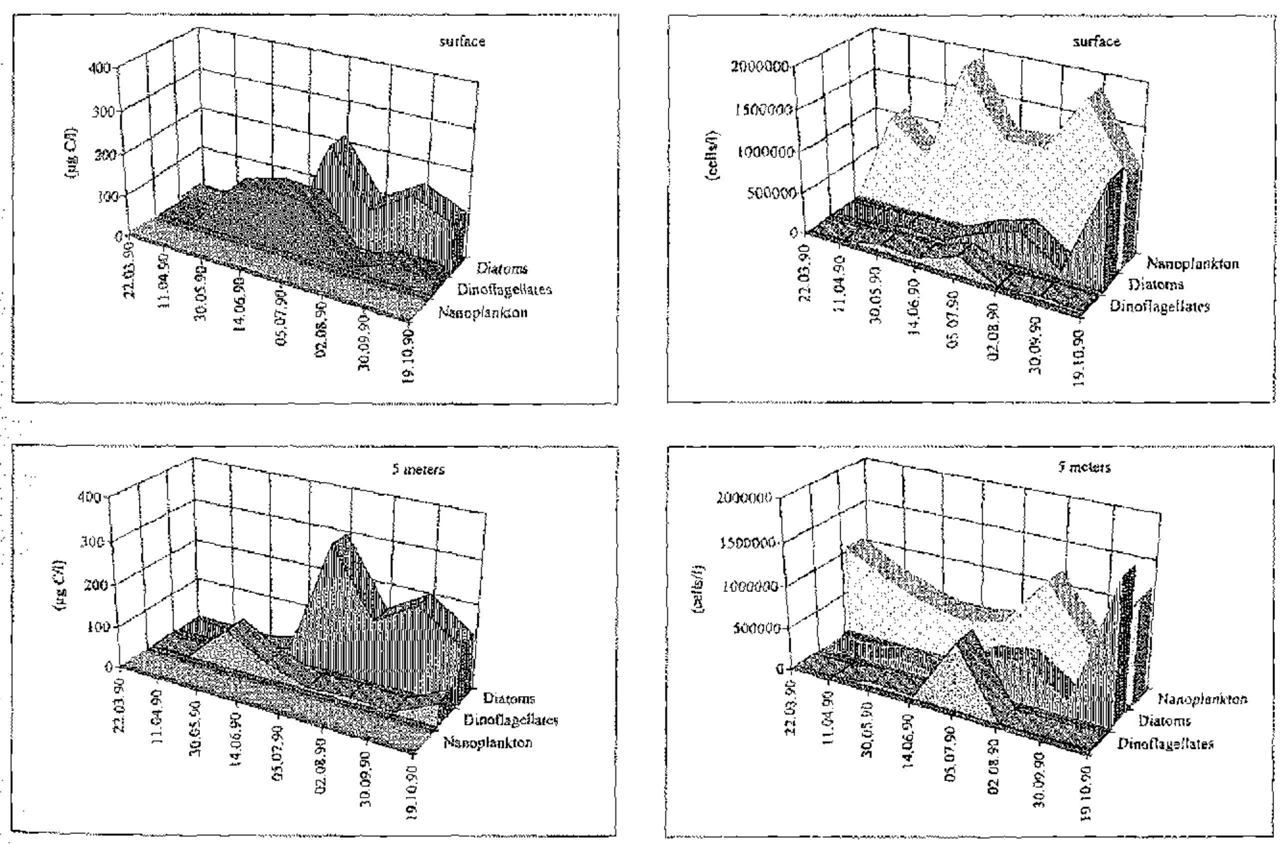


Fig. 5: Relationship between Particulate Phytoplankton Carbon (PPC - µgC/l) on the left and the abundance of phytoplankton cells (cells/l) on the right at the station 1 (surface and 5 meters).

Sl. 5: Razmerje med partikulatnim fitoplanktonskim ogljikom (PPC - µgC/l) na levi in relativna gostota fitoplanktonskih celic na desni strani na postaji 1 (na površju in v globini 5 m).

		Station 1			Station 2			Station 3		
Months	Depth.	TSM (mg/l)	ISM (mg/l)	POM (mg/l)	TSM (mg/l)	ISM (mg/l)	POM (mg/l)	TSM (mg/l)	ISM (mg/l)	POM (mg/l)
March 22.03.90	0m	13.27	8.35	4.92	11.55	7.16	4.39	4.90	0.36	4.54
	5m	22.38	11.30	11.08	8.11	6.09	2.12	8.09	1.50	6.59
	10m	16.57	9.11	7.46	8.09	4.67	3.42	7.45	2.02	5.43
	15m	11.38	8.15	3.23	7.46	3.90	4.06	10.92	0.17	10.75
April 11.04.90	0m	12.69	9.67	3.02	30.69	26.40	4.29	7.70	2.20	2.50
	5m	13.59	10.84	2.75	4.05	1.77	2.28	12.31	10.17	2.14
	10m	12.47	8.54	3.93	5.35	2.99	2.36	9.50	6.42	3.08
	15m	9.98	0.11	9.87	6.86	4.68	2.18	6.27	4.04	2.23
May 30.05.90	0m	5.62	3.42	2.20	10.29	7.65	2.64	7.59	5.65	1.94
	5m	6.45	2.86	3.59	14.25	11.00	3.25	5.81	4.02	1.79
	10m	12.13	9.07	3.06	11.24	10.34	0.90	26.11	20.48	5.63
	15m	11.91	8.64	3.27	4.80	2.57	2.23	4.92	2.41	1.91
June 14.06.90	0m	30.22	28.01	2.21	18.86	16.68	2.18	50.64	36.15	14.49
	5m	42.43	31.35	11.08	14.72	8.25	6.47	50.67	41.16	9.51
	10m	25.26	20.03	5.23	50.09	37.90	12.19	24.00	16.54	7.46
	15m	7.40	3.88	3.52	41.59	31.64	9.95	22.14	18.40	3.74
July 05.07.90	0m	7.84	5.86	1.98	17.85	16.88	1.97	4.77	4.14	0.63
	5m	49.82	31.50	18.32	13.19	11.04	2.15	7.89	6.87	1.02
	10m	9.95	7.76	2.28	15.56	12.56	3.00	27.58	17.57	9.01
	15m	7.75	6.01	1.74	8.75	6.81	1.94	14.00	11.51	2.49
August 02.08.90	0m	5.27	3.05	2.22	3.24	2.30	0.94	4.28	3.13	1.15
	5m	2.63	1.28	1.35	2.75	0.89	1.86	4.38	3.05	1.33
	10m	5.60	2.60	3.00	3.37	1.52	1.85	3.94	2.21	1.73
	15m	4.33	0.28	4.05	8.74	3.06	5.68	6.95	5.63	1.32
September 30.09.90	0m	4.90	4.66	0.24	22.79	21.58	1.21	10.09	9.93	0.16
	5m	16.07	5.99	10.08	14.72	11.32	3.40	4.61	3.11	1.50
	10m	7.54	6.86	0.68	19.66	18.84	0.82	24.12	21.92	2.20
	15m	7.33	6.36	0.97	14.49	12.11	2.38	21.83	20.52	1.31
October 19.10.90	0m	8.62	7.56	1.06	16.26	14.63	1.63	14.02	11.54	2.48
	5m	12.93	11.63	1.30	9.27	4.45	4.82	32.97	28.44	4.53
	10m	11.61	9.41	2.20	26.14	25.47	0.67	5.74	1.96	3.78
	15m	11.28	6.72	4.56	12.64	11.01	1.63	13.74	8.68	5.06

Tab. 2: Concentrations of Total Suspended Matter (TSM), Inorganic Suspended Matter (ISM) and Particulate Organic Matter (POM).
Tab. 2: Koncentracije skupnih suspendiranih snovi (TSM), anorganskih suspendiranih snovi (ISM) in partikulatnih organskih snovi (POM).

SEASON	POC (µg/l)		
	St. 1	St. 2	St. 3
SPRING	621±268	587±313	743±594
SUMMER	575±242	432±208	312±145
AUTUMN	415±167	571±109	507±257
	PN (µg/l)		
SPRING	101±29	84±27	110±104
SUMMER	89±29	77±29	67±36
AUTUMN	48±27	69±41	95±126

Tab. 3: Average values of POC and PN concentrations in spring (March, April and May), in summer (June, July and August) and in autumn (September and October).
Tab. 3: Povprečne vrednosti koncentracij POC in PN spomladi (marec, april, maj), poleti (junij, julij, avgust) in jeseni (september, oktober).

		Station 1			Station 2			Station 3		
Months	Depth.	Diatoms cells/l	Dinofl. cells/l	Nanopl. cells/l	Diatoms cells/l	Dinofl. cells/l	Nanopl. cells/l	Diatoms cells/l	Dinofl. cells/l	Nanopl. cells/l
March 22.03.90	0m	2008	2008	1506415	0	6025	666840	0	8034	950715
	5m	0	4017	1060516	0	2008	441882	0	2008	448577
	10m	0	0	468663	0	4017	441882	0	0	449916
	15m	0	2008	578463	0	8034	482053	4016	4016	578463
April 11.04.90	0m	8034	12050	1116756	12051	0	606583	2008	4017	425813
	5m	0	6024	795387	6026	2008	241026	6025	2008	514190
	10m	0	2033	554361	2008	0	224958	10043	2008	449916
	15m	2008	12051	1060517	2008	4016	241026	2008	8033	482053
May 30.05.9	0m	78333	88376	763250	62265	88375	626669	5213	14337	414520
	5m	11487	68291	614617	86367	48204	574446	5213	7821	250274
	10m	148632	76324	716384	62265	30127	401711	8471	3259	332395
	15m	72306	92391	776641	88354	52217	637715	0	14336	310236
June 14.06.90	0m	40171	68290	2350008	10043	48203	711602	96410	54228	763250
	5m	52222	44188	506156	16066	54221	580249	52221	20083	346475
	10m	74315	18077	940003	26110	22094	355360	24101	20085	351497
	15m	34144	24101	508834	26112	64272	368235	82350	20084	568134
July 05.07.90	0m	275107	234943	1189064	12050	92370	194160	36154	38162	417779
	5m	407635	8033	618635	48203	12051	278835	42179	12049	570429
	10m	295213	2008	739148	192774	14060	373355	126539	14059	1312255
	15m	516062	38159	747182	132534	60243	500313	243015	38157	708011
August 02.08.90	0m	424349	13400	763829	502518	6700	506156	178672	20100	465295
	5m	493584	8933	699804	833065	42435	385643	435514	11166	504752
	10m	469016	0	571755	681192	24568	345471	51368	8934	405737
	15m	252376	22333	746600	58069	31266	610600	154105	4466	635283
September 30.09.90	0m	96037	51359	1876071	558335	98269	1045239	4466	20100	565799
	5m	149638	8933	567288	73702	31267	848699	8934	11167	499473
	10m	312676	4466	990148	151871	33501	1241780	15634	6700	540081
	15m	321611	17866	841254	33500	17866	1268581	22332	17866	585652
October 19.10.90	0m	1266347	31267	1101819	138471	6700	558354	498051	69236	938035
	5m	1683996	20100	1228380	1168820	20100	1012483	406481	2233	1124153
	10m	134005	4466	796586	1634862	11167	1197112	29034	4466	731444
	15m	1652728	11166	1429387	1485221	4466	1188178	46901	2233	658858

Tab. 4: Phytoplankton distribution at the three studied stations.
Tab. 4: Razširjenost fitoplanktona na treh raziskovalnih postajah.

Total Suspended Matter (TSM)

TSM concentration (Tab. 2), showed maximum and minimum levels of 50.1 mg/l (St. 2, -10 m) in June and 2.6 mg/l (St. 1, -5m) in August, respectively.

The most abundant component of TSM was the inorganic fraction (average 67.5 ± 23.8% in St.1, 71.3 ± 18.1% in St. 2 and 66.8 ± 25.2% in St. 3). The organic fraction (POM) was relatively low (32.7 ± 23.8% St. 1, 28.7 ± 18.1% St. 2 and 33.2 ± 25.2% St. 3). Only in March (ISM = 39.9 ± 22.8% and POM = 60.1 ± 22.8% in St. 1) and in August (ISM = 13.6 ± 11.4% and POM = 86.4 ±11.4%) the concentrations of POM were higher.

The highest values of POC (2420.9 µg/l) and PN (434.8 µg/l) were found in March at station 3 at 15m depth (Figs. 2 and 3). The lowest values were measured in August for POC (80.2 µg/l St. 2, surface) and in July for PN (11.7 µg/l St. 2, surface).

The C/N atomic ratio was especially low in March, June and July. The mean C/N values were 8.1 ± 4.3 in station 1, 9.0 ± 4.4 in station 2 and 7.6 ± 3. 7 in station 3 (Fig. 4).

Phytoplankton and Particulate Phytoplankton Carbon (PPC)

In March and April, the phytoplankton community was characterized by low abundances with the prevalence of the nanoplankton (< 10 µm) fraction. In May, diatoms increased and reached a maximum of $1.5*10^5$

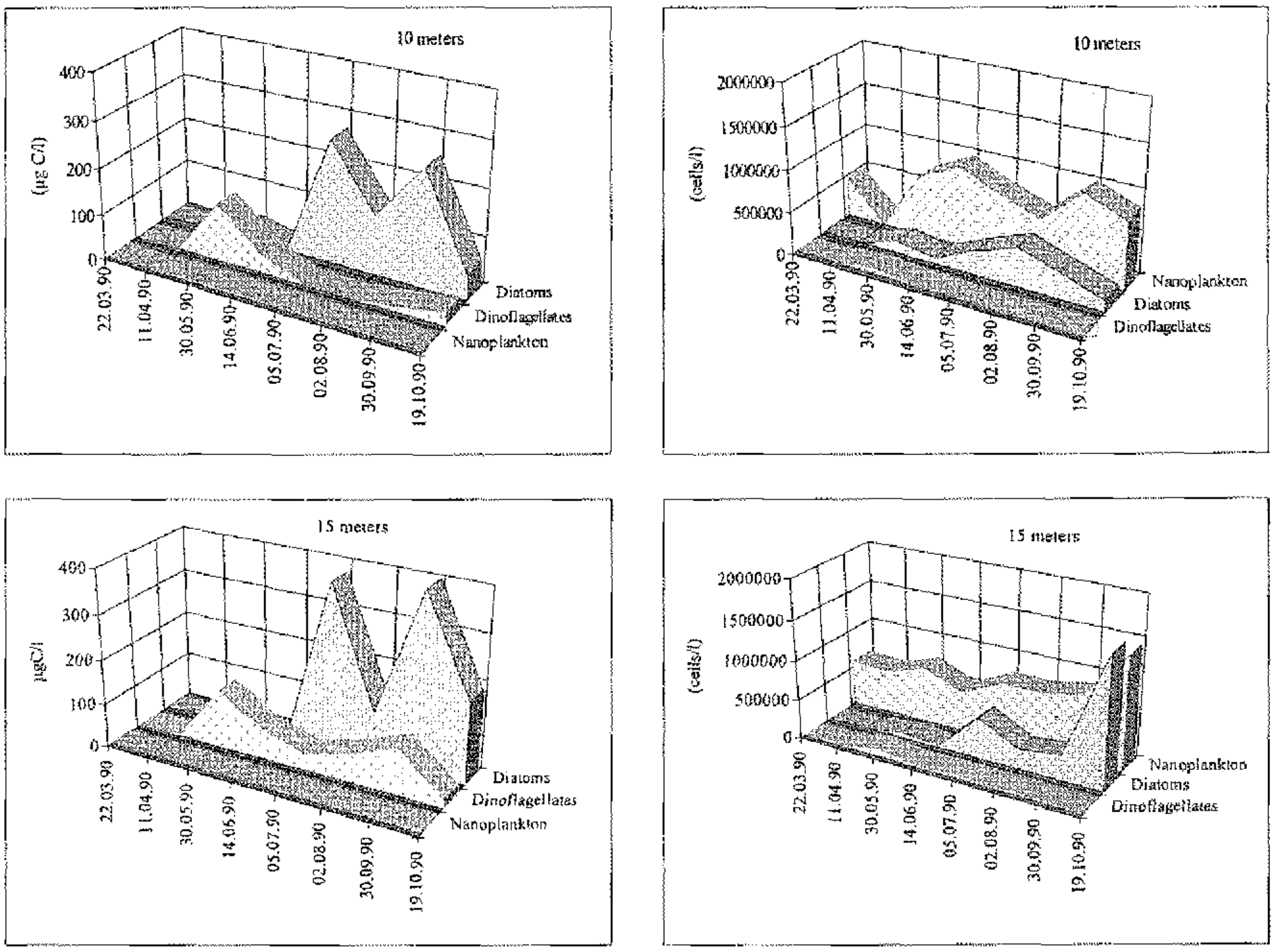


Fig. 6: Relationship between Particulate Phytoplankton Carbon (PPC - µgC/l) on the left and the abundance of phytoplankton cells (cells/l) on the right at the station 1 (10 and 15 meters).

Sl. 6: Razmerje med partikulatnim fitoplanktonskim ogljikom (PPC - µgC/l) na levi in relativna gostota fitoplanktonskih celic na desni strani na postaji 1 (v globini 10 in 15 m).

cells/l at station 1 (Figs. 5 and 6). *Cyclotella glomerata* (average of 76.5% of total diatoms), *Pseudonitzschia delicatissima* (average of 16.4%) and *P. seriata* (average of 2.5%) were the dominant species.

Starting in June, the abundance of these species slowly decreased whereas, particularly in July and August, some typical summer species appeared (*e.g. Chaetoceros* spp - average of 73.4%; *Proboscia alata* - average of 5.6% of total diatoms). The autumn bloom was again characterized by diatoms (up to $1.6*10^6$ cells/l) of the *Pseudonitzschia* genus and particularly by the species *P. seriata* (average of 91.6% of total diatoms). Dinoflagellates strongly increased in July ($2.3*10^5$ cells/l) in the surface layer at station 1. The most important species were: *Gymnodinium corii* (average of 26.4% of total dinoflagellates), *Gymnodinium* spp. (average of 21%) and several species of *Prorocentrum* (average of 21.7%) such as *P. micans, P. minimium* and *P. nanum*.

Nanoflagellates, abundant throughout the whole period, had a mean value, for the three stations, of 2.24 ± 0.58µgC/l (Figs 5 and 6), representing only 2.38% of total carbon. This was due to their small cell volume, equivalent only to 30 μm^3. Also for the diatoms, that reached $1.5*10^5$ cells/l in May, the PPC content was not particularly high (142.02 µg/l, St. 1, surface) because the most abundant species (*e.g. Cyclotella glomerata* and *Pseudonitzschia delicatissima*) were characterized by small sizes (182 and 413 μm^3, respectively). In summer, PPC content presented the highest values (509.2 µg/l, St. 1, surface), although total cell abundance was low, due to the presence of *Proboscia alata* (Cell Volume = 52 mm^3), a large diatom species. In autumn, during the seasonal blooming period, the PPC content never reached the high summer values (228.5 µg/l - St. 1, 15 m) although it was higher than in spring.

The contribution of PPC content to POC (Tab. 3) ranged from an average of 3.4% in March and April, when the lowest cell abundances were observed, to a maximum of 50% in summer, when species with the highest cell volumes were prevalent. In May, the average percentage was 9.4% whereas in October it was 37%: the difference between the two bloom periods was due to the presence of large species in the autumn samples.

From March until the end of May, PPC contributed from 3.6 to 6.2% to the suspended POC. During the remaining months PPC comprised on average 32 to 54% of the suspended POC.

On five occasions, calculated PPC exceeded POC values. These situations corresponded almost exclusively to surface samples in July and they were due to high percentages of unidentified dinoflagellate species, probably because the average volume values assigned to them, had been overestimated or empty thecae were considered in computation.

Chlorophyll a and POC/Chl a ratio

Chlorophyll *a* concentrations ranged from a minimum of 0.2 µg/l on many occasions during the studied period to a maximum of 3.0 µg/l (St. 2 bottom, July). The mean value for the three stations was 0.63 ± 0.14 µg/l. Values higher than 1 µg/l were observed (Tab. 3) only for certain months and at certain depths.

Generally, the POC/Chl a ratio was high (Tab. 3), ranging from 143 (St. 1, surface, July) to more than 5000 (5560, St. 1, -10 m, August). The lowest values correspond to the highest percentage of PPC to POC and to the lowest values of the C/N ratio.

DISCUSSION AND CONCLUSIONS

In 1990, freshwater input, particularly from the Isonzo and Tagliamento rivers, was evident, expecially in spring and autumn. This was reflected by the low salinity surface values and by the high TSM concentrations along the whole water column, with the dominance of the inorganic fraction in almost all studied stations.

In spring (March and April), the phytoplankton community was characterized by low abundances and by the presence of nanoplankton as confirmed by the low C/N ratios in the subsurface and bottom layers (generally around 3).

As stated by Parsons *et al.* (1977), Lee & Fuhrman (1987), Calvo *et al.*, (1991), and Eppley *et al.*, (1992), nanoplankton leads to a C/N ratio lower than 4 because of its high protein content. Also the low contribution of PPC to POC confirmed that the living fraction was mainly composed of very small-sized cells.

In May, C/N ratios > 10 and low PPC values were observed, indicating the prevalence of the detritic fraction over the living one (Calvo *et al.*, 1991; Fabiano & Povero, 1992). This hypothesis was also supported by the high POC/Chl *a* ratio, which underlines the prevalence of the detrital material, as previously stated by Fabiano *et al.*, (1993) and by Galois *et al.*, (1996). Similar situations were also observed by Faganeli & Malej (1981) and Faganeli (1983) in the Gulf of Trieste.

On the other hand, the contribution of PPC to POC was higher in autumn than in spring, due to the presence of large phytoplankton species. Simultaneously C/N ratio was high in all stations because of the continuous terrigenous supply of riverine origin.

In summer, especially in August, there were the lowest TSM observed throughout the whole period, and the general prevalence of the organic fraction (expecially in St. 1 and 2). The low C/N ratios observed in summer (June-September) supported the idea of a strong dominance of the living fraction over the detritic one as well as the high PPC values. In particular, in September the highest values of PPC, corresponding to low C/N ratio, were found at the bottom layer, confirming that primary production was higher below the pycnocline. High primary production in the deepest layers, due to both higher nutrient availability and reduced photolimitation, is usually observed in the North Adriatic Sea (Cabrini *et al.*, 1989) at the end of summer.

The seasonal distribution of the phytoplankton community confirmed previous observations on the same area (Milani *et al.*, 1989; Cabrini *et al.*, 1989; Fonda Umani, 1992; Fonda Umani *et al.*, 1992; Malej *et al.*, 1995): a prevalence throughout the whole period of nanoplankton and diatoms and an increase of dinoflagellates in summer. In particular diatoms show a late spring and autumn bloom and they are, with the dinoflagellates, the main component of PPC.

In general the temporal pattern of PPC followed both the quantitative and qualitative fluctuation of phytoplankton, even if it appeared to be more related to cell volume of the phytoplankton species than to cell abundance, as previously observed by Viličić (1985). Consequently it was strongly coupled with phytoplankton succession because each species was characterized by different PPC contents. During the studied period, a seasonal variability of PPC values was observed; lower in early spring (with the lowest percentage on POC) and higher in summer.

Andersson & Rudehäll (1993) also observed a marked seasonal variability in the components of the POC pool. The percentages of PPC, similar to those observed in our case, can vary from 3.4% in March and April to a maximum of 50% in summer (Zeitzschel, 1970; Sarma & Nageswara, 1989) when species with large cell volume prevail. The same situation was also reported by Eppley *et al.* (1992) (PPC range = 25-50%).

In our case, as observed also by Andersson & Rudehäll (1993), POC can be used as an index of phytoplankton biomass only in summer months, when large phytoplankton species occur. In early spring and autumn POC appears to be more related both to riverine inputs and probably to nanoplankton and to small-sized microalgae. Consequently it can give limited information on phytoplankton biomass.

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		Station 1				Station 2				Station 3			
Months	Prof.	POC (µg/l)	PPC (µg/l)	Chl. a (µg/l)	POC/Chl. a ratio	POC (µg/l)	PPC (µg/l)	Chl. a (µg/l)	POC/Chl. a ratio	POC (µg/l)	PPC (µg/l)	Chl. a (µg/l)	POC/Chl. a ratio
March 22.03.90	0m	487	13.78	1.80	270	533	5.45	0.80	666	410	19.90	0.80	512
	5m	831	12.69	0.40	2075	155	2.54	0.40	387	204	9.26	0.20	1016
	10m	199	1.54	0.80	248	137	3.89	0.60	228	177	1.48	0.20	886
	15m	176	1.98	0.60	293	207	7.76	1.40	147	2421	11.08	0.40	6045
April 11.04.90	0m	690	9.71	0.71	967	838	2.37	1.00	837	371	3.61	0.00	/
	5m	632	6.25	0.45	1417	596	1.92	0.80	742	863	11.90	0.40	2155
	10m	625	/	1.00	624	560	1.28	1.20	466	921	8.76	0.60	1533
	15m	386	5.29	0.45	864	482	2.60	1.00	481	891	9.00	0.40	2224
May 30.05.9	0m	700	142.02	0.40	1747	777	148.02	0.60	1293	823	19.78	0.60	1370
	5m	1055	99.47	0.80	1317	861	116.00	1.00	859	664	8.84	0.80	829
	10m	784	152.90	0.20	3912	1165	101.74	0.40	2909	396	10.20	0.60	659
	15m	889	138.87	0.40	2220	739	73.37	0.40	1846	775	54.76	0.80	968
June 14.06.90	0m	613	150.73	1.80	340	502	71.39	0.40	1253	468	106.14	1.20	390
	5m	573	70.55	0.40	1430	408	46.78	0.40	1019	281	56.72	0.60	468
	10m	429	48.71	0.20	2143	461	51.04	0.80	576	172	38.40	0.20	859
	15m	557	74.07	0.60	926	372	91.63	0.80	464	276	64.03	0.60	460
July 05.07.90	0m	343	374.06	2.40	143	80	87.62	0.20	401	110	162.24	0.40	275
	5m	341	311.58	0.60	568	198	49.31	0.20	990	172	46.88	0.20	857
	10m	514	273.31	0.60	856	378	252.60	1.00	377	269	177.18	0.20	1345
	15m	412	415.78	0.80	514	484	99.57	3.00	161	527	180.54	1.20	439
August 02.08.90	0m	785	133.24	0.40	1959	318	136.94	0.80	397	291	34.79	0.27	1089
	5m	340	186.24	0.80	424	501	235.64	0.20	2501	376	103.18	0.27	1404
	10m	1114	166.18	0.20	5560	557	187.23	0.60	927	567	203.33	0.20	2833
	15m	882	189.89	0.60	1468	929	122.09	1.20	773	231	31.91	0.20	1154
September 30.09.90	0m	260	218.34	0.60	433	663	214.59	0.20	3314	177	99.61	0.80	221
	5m	392	216.86	0.20	1955	708	281.51	0.20	3535	282	202.95	0.20	1409
	10m	270	266.87	0.40	675	442	440.78	0.40	1104	787	88.41	0.20	3928
	15m	372	539.41	0.80	465	689	183.81	0.60	1147	467	78.95	0.40	1166
October 19.10.90	0m	270	181.92	0.80	336	418	75.97	0.60	696	858	37.91	0.60	1428
	5m	469	238.61	0.60	780	549	249.43	0.20	2742	499	35.68	0.40	1246
	10m	552	96.22	0.80	689	528	186.03	0.60	879	719	60.64	0.71	1006
	15m	738	224.56	1.00	737	571	244.85	1.00	571	271	52.81	0.20	1355

Tab. 5: Concentrations of Particulate Organic Carbon (POC), Particulate Phytoplankton Carbon (PPC), Chlorophyll a (Chl. a) and POC/Chl. a rations.
Tab. 5: Koncentracije partikulatnega organskega ogljika (POC), partikulatnega fitoplanktonskega ogljika (PPC), klorofila a (Chl a) in razmerja POC/Chl a.

SEZONSKI DELEŽ FITOPLANKTONA V PARTIKULATNEM ORGANSKEM OGLJIKU V VODAH TRŽAŠKEGA ZALIVA

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POVZETEK

Avtorice pričujočega članka so v Tržaškem zalivu s temeljito raziskavo ugotavljale delež partikulatnega fitoplanktonskega ogljika (PPC) v partikulatnem organskem ogljiku (POC) in njuno sezonsko spreminjanje. Vsak mesec od marca do oktobra 1990 so na treh postajah v obrežnih vodah Tržaškega zaliva jemale vzorce morske vode na štirih različnih globinah. Izmerjene so bile količine suspendiranih snovi, temperatura, slanost, klorofil a, sestava fitoplanktona in njegova relativna gostota ter vsebnost ogljika.

V Tržaškem zalivu so razlike v količinah in kvaliteti skupnih suspendiranih snovi (TSM) in njihovo razmerje C/N odsevale spremembe v rečnih odplakah in sukcesijo fitoplanktonske združbe. Spomladi in jeseni leta 1990 so bile ugotovljene velike količine sladke vode, kar se je ujemalo z visokimi koncentracijami TSM zlasti zaradi anorganske frakcije. Spomladi in jeseni je količina PPC, tudi v primeru cvetenja fitoplanktona, dosegala le manjši del POC, predvsem zaradi majhnih dimenzij diatomej in večjih količin zemeljskih snovi. To hipotezo je mogoče potrditi tudi s prevladujočim nanoplanktonom in z zelo nizkimi vrednostmi PPC, opaženimi v marcu in aprilu. Poleti so se visoke vrednosti PPC ujemale z majhnimi količinami padavin in z nizkimi koncentracijami mikroalg, vendar so prevladovale vrste večjih dimenzij.

Ključne besede: suspendirane snovi, partikulatni organski ogljik, partikulatni fitoplanktonski ogljik, razmerje C/N

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