ISSN: 0001-5113 AADRAY	ACTA ADRIAT., 53(3): 413 - 435, 2012	

Population structure and abundance of phytoplankton in three bays on the eastern Adriatic coast: Šibenik Bay, Kaštela Bay and Mali Ston Bay

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Present study describes the phytoplankton community structure and phytoplankton abundance in three bays on the eastern Adriatic coast (Šibenik Bay, Kaštela Bay and Mali Ston Bay) during 2005. The highest phytoplankton biomass (expressed as chlorophyll a) were recorded at one station in Šibenik Bay (4.73 mg m^{-3}), and in Kaštela Bay (2.79 mg m^{-3}), while at all other stations recorded values were generally below 1 mg m^{-3}. At the investigated area of Šibenik Bay a total of 114 phytoplankton taxa have been determined. The most diverse were diatoms with 61 and dinoflagellates with 37 taxa. Coccolithophorids contributed with 6, cryptophytes with 3, silicoflagellates, euglenophytes and chlorophytes with 2 taxa. In the area of Kaštela Bay 193 phytoplankton taxa have been recorded. Dinoflagellate group was the most diverse with 92 taxa, followed by diatoms (80), coccolithophorids (9), silicoflagellates and euglenophytes (4), cryptophytes (2) and chlorophyte (1). In the area of Mali Ston Bay a total of 88 phytoplankton taxa have been found, with 39 diatoms, 36 dinoflagellates, 2 silicoflagellates, 4 coccolithophorids, 2 euglenophytes, 1 chllorophyte and 3 chrisophyte taxa. Abundance of dinoflagellates was very low in this area. Coccolithophorids contributed more to the community composition in Mali Ston Bay, then in other areas of research. A diverse microflagellate group was present in the whole area of investigation with a high frequency of findings. During the investigated period a relatively small number of monospecific blooms in all areas have been recorded. The largest numbers of taxa were recorded at stations that are under an influence of freshwater input from rivers and strong anthropogenic influence.

Key words: phytoplankton, taxonomic composition, chlorophyll *a*, eastern Adriatic coast

INTRODUCTION

Environmental parameters as availability of light and nutrients, temperature and salinity mostly influence the development of phytoplankton community in the marine habitats. Phytoplankton abundance and volume proved to be useful for determination of trophic status of marine environment of Bays along the eastern Adriatic coast (VILIČIĆ, 1989). According to the same author Mali Ston Bay is characterized as oligotrophic area while Kaštela Bay and Šibenik Bay are eutrophic due to urban influence.

Šibenik Bay is a highly stratified estuary with small tidal amplitudes and permanently brackish surface water (SVENSEN *et. al.*, 2007). Phytoplankton community in the estuary is dependent on seasonal cycles of temperature and salinity (winter-spring and summer-autumn), and on the degree of eutrophication, which can be of natural or anthropogenic origin. To natural eutrophication and nutrients regeneration in the upper reaches of the estuary greatly contributes decomposition of freshwater phytoplankton and in the lower parts of estuary the eutrophication favoring anthropogenic sources (VILIČIĆ *et al.,* 1989; LEGOVIĆ *et al.,* 1994; SVENSEN e*t. al.*, 2007). Previous studies have shown a strong influence of freshwater inflow on winter-spring phytoplankton community. In the summer-autumn period estuary of river Krka is dominated by dinoflagellates, micro and nano fractions of phytoplankton community (CETINIĆ *et al.,* 2006). The maximum abundance of phytoplankton occurs in Šibenik harbor that has reduced exchange with the waters of the open sea and is under a direct anthropogenic influence (KUŠPILIĆ, 2005).

Anthropogenic eutrophication and nutrients inflow from the river Jadro were causing frequent summer algal blooms in Kaštela Bay, with development of the toxic dinoflagellates (MARASOVIĆ *et al.,* 1991). Previous studies have shown regularity in spring-autumn maximum abundances, but also that algal biomass and community structure had changed over time. An increase of abundance and phytoplankton biomass had been recorded in the period since mid-80’s to mid-90’s. Phytoplankton abundance shows a strong correlation with surface temperature. Diatoms show a negative and dinoflagellate a positive correlation with the surface temperature (NINČEVIĆ *et al.,* 2010). Previous studies confirm the regularity of layout in the size fractions, namely less pico and nano fractions contributed more to community composition in the outer, more open part of the bay, and larger micro fractions in the interior and more eutrophicated part of the Bay (MARASOVIĆ & NINČEVIĆ, 1997).

Principal regulator of the primary production conditions in Mali Ston Bay is specific, constant and strong exchange of water within the Bay and the open sea, strong impact of river Neretva and karstic submarine springs. Previous studies show that according to nutrients concentration, transparency of water column and quantity of phytoplankton, Mali Ston Bay may be qualified as a moderate natural eutrophicated system (VILIČIĆ, 1989). Phytoplankton community shows regularity in the occurrence of spring-autumn maximum. During low freshwater input from river Neretva, dense populations of phytoplankton develop in the surface layer and during stronger inflows phytoplankton community develops and accumulates in stable conditions below halokline. At the border of halokline a smaller fraction of phytoplankton accumulates (pico, nano) (VILIČIĆ *et al.,* 1998). Previous studies have shown that composition and diversity of the phytoplankton community reflects stable conditions throughout most of the year (VILIČIĆ, 1989).

The aim of this study is to describe the phytoplankton community structure in these three bays on the eastern Adriatic coast characterized with different hydrological conditions and trophic statuses.

MATERIAL AND METHODS

Investigated bays with sampling stations are shown in Fig. 1. Station names, depths and geographical coordinates are given in Table 1. Šibenik Bay is located in Krka River estuary. In this area samples were taken at 2 stations SB103 and SB203 (Fig. 1). Kaštela Bay is the largest bay in the middle part of the eastern Adriatic coast. In this area samples were taken at 4 stations ST101, ST103, ST203B and CJ007 (Fig. 1). Mali Ston Bay is deeply cut between the mainland and the Pelješac Peninsula, and located at the end of the Neretva Channel. In

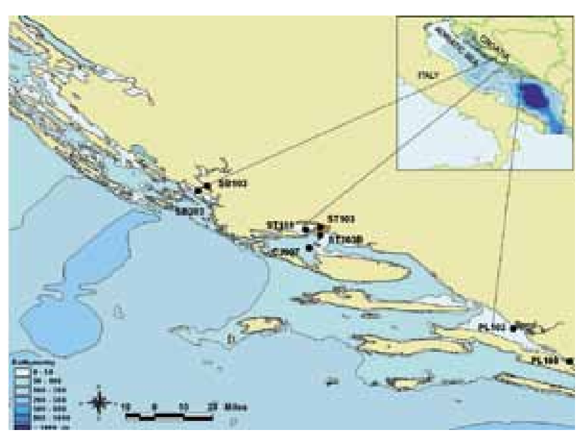

Fig. 1. Investigated areas with sampling stations

Table 1. Sampling station names, depths and geographical coordinates

INVESTIGATED AREA	STATION NAME	GEOGRAPHIC COORDINATES OF INVESTIGATED STATIONS		STATION DEPTH	SAMPLING DEPTHS (m)
Šibenik Bay	SB103	Φ 43º 44' 3''N	λ 15º 53' 31''E	35 m	0, 5, 10, 20, 35
	SB203	Φ 43º 42' 36''N	λ 15º 50' 48''E	25 m	0, 5, 10
Kaštela Bay	ST101	Φ 43º 31' 6''N	λ 16º 22' 54''E	37 m	0, 5, 10, 20, 35
	ST103	Φ 43º 31' 48''N	λ 16º 27' 12''E	12 m	0, 5, 10, 12
	ST203B	Φ 43º 29' 18''N	λ 16º 27' 12''E	35 m	0, 10, 20, 30, 35
	CJ007	Φ 43º 25' 36''N	λ 16º 23' 54''E	50 m	0-30, 50
Mali Ston Bay	PL102	Φ 43º 1' 30''N	λ 17º 24' 48''E	21 m	0, 10, 20
	PL105	Φ 42º 51' 48''N	λ 17º 41' 36''E	8 m	0, 6

this area samples were taken at 2 stations PL102 and PL105 (Fig. 1). Samplings were performed monthly in a period from January to December 2005. Measurements and samplings of seawater for determination of physical and chemical parameters as well as for phytoplankton community abundance were conducted using standard oceanographic methods. Temperature and salinity were measured with a Seabird-25 CTD probe. Nutrient concentrations were determined colorimetrically on AutoAnalyzeru III (Bran + Luebbe) by using modified method according to GRASSHOFF (1976). Chlorophyll *a* concentrations were measured by fluorometric method from 90% acetone extracts (STRICKLAND & PARSONS, 1972) and the results are expressed as mg chl *a* m^{-3}. Non parametric Spearman rank correlation has been used to determine the relation between phytoplankton biomass and environmental conditions since environmental data do not have normal distribution. Phytoplankton abundance and community composition have been determined according to the Utermöhl method (UTERMÖHL 1958). Water samples (250 mL) were collected with Nansen bottles and preserved with formaldehyde, to a final concentration of 2% formaldehyde-sea water solution. Subsamples of 25 mL were settled in counting chambers for at least 12 h. Counting was performed in one transect of the sedimentation chamber using an inverted microscope with magnifications of 100×, 200×, and 400× for different species, depending on their respective sizes. In the case of blooms or the high abundances of some species, counting was done in several randomly selected fields.

RESULTS AND DISCUSSION

Environmental parameters in the Šibenik Bay

Vertical profiles of temperature and salinity in the water column at the investigated stations in Šibenik Bay are shown in Fig. 2. Basic statistics of abiotic parameters (maximum, minimum, average and standard deviation) at the surface and bottom layers are given in Table 2. Temperature ranged from 7.3 to 23.5°C for entire water column in this area. Minimal values were recorded in January at the station SB103 in the surface layer, while temperature maximum was recorded in September in surface layer at the same station. Salinity values ranged from 4.42 to 38.74 at the SB103 station. The influence of freshwater input from river Krka is evident through temperature and salinity gradient at station SB103. Wide range of nitrate (0.01 - 53.86 mmol m^{-3}) and silicate (0.4 - 65.76 mmol m^{-3}) concentrations confirms the freshwater influence, especially the maximum nitrate and silicate concentrations in December at the surface layer that is typical for nutrient inflow with the river in the winter period (Table 3). Ranges of temperature and nutrient concentrations at the station SB203 were lower because it is further from the coast and less influenced by the land and freshwater inflow of the river Krka. Orthophosphate concentrations in the water column at

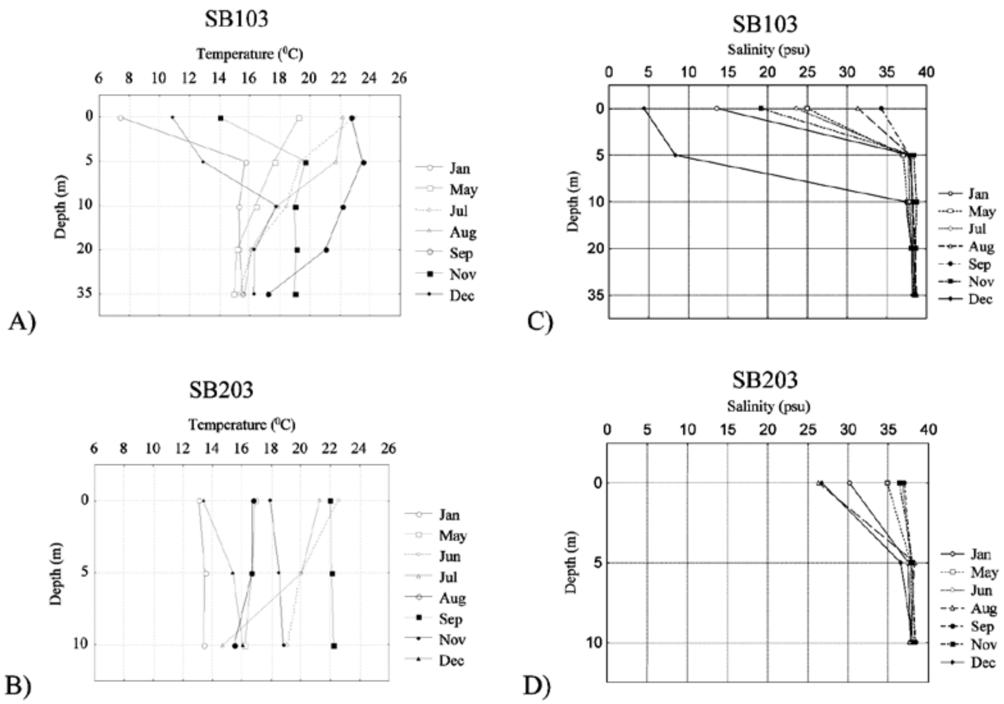

Fig. 2. Vertical profiles of temperature (A, B) and salinity (C, D) at the investigated stations in Šibenik Bay

Table 2. Abiotic parameters of surface and bottom layers at investigated stations in Šibenik Bay

		SB103				SB203			
		max	min	avg	st.dev	max	min	avg	st.dev
NO_3^- (mmol m^{-3})	S	53.862	0.071	11.514	18.667	16.119	0.149	1.849	3.907
	B	2.680	0.014	0.961	0.980	1.750	0.088	0.643	0.602
NO_2^- (mmol m^{-3})	S	0.610	0.006	0.171	0.169	0.317	0.010	0.100	0.093
	B	0.600	0.010	0.237	0.242	0.231	0.016	0.116	0.087
NH_4^+ (mmol m^{-3})	S	18.280	0.301	2.316	4.353	1.452	0.411	0.786	0.360
	B	27.170	0.296	4.256	9.271	1.343	0.416	0.913	0.316
TIN (mmol m^{-3})	S	57.928	0.679	13.992	19.334	17.852	0.726	2.736	4.193
	B	30.450	0.824	5.454	10.157	3.131	0.696	1.674	0.933
PO_4^{3-} (mmol m^{-3})	S	0.086	0.003	0.046	0.027	0.094	0.002	0.049	0.026
	B	0.115	0.005	0.054	0.032	0.093	0.007	0.043	0.027
SiO_4^{4-} (mmol m^{-3})	S	65.761	0.400	16.587	20.928	23.340	0.155	4.128	6.063
	B	9.410	1.444	4.210	2.419	4.220	0.210	1.689	1.247

* S – surface layer (0-5m); B – bottom layer (last sampling depth)

Šibenik Bay area ranged between 0.002 to 0.12 mmol m^{-3}.

Environmental parameters in the Kaštela Bay

Vertical profiles of temperature and salinity in the water column at the investigated stations in Kaštela Bay are shown in Fig. 3, while basic statistics of abiotic parameters (maximum, minimum, average and standard deviation) at the surface and bottom layers are given in Table 3. Temperature ranged from 9.45 to 26.93^{0}C for entire water column in this area. The maximum value was measured in July at the ST103 station

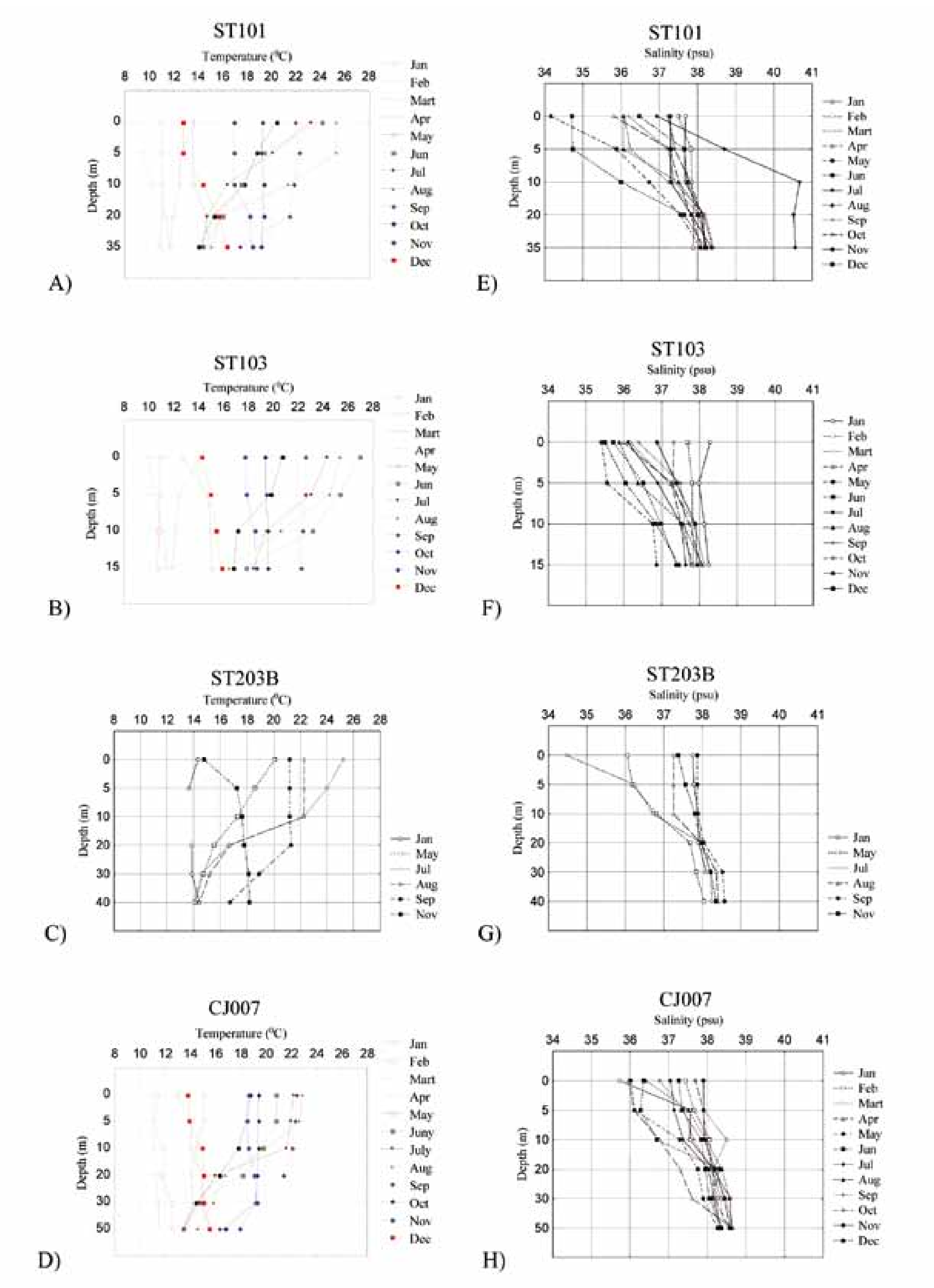

Fig. 3. Vertical profiles of temperature (A, B, C, D) and salinity (E, F, G, H) at the investigated stations in Kaštela Bay

Table 3. Abiotic parameters of surface and bottom layers at investigated stations in Kaštela Bay

		ST101				ST103				ST203B				CJ007			
		max	min	avg	st.dev	max	min	avg	st.dev	max	min	avg	st.dev	max	min	avg	st.dev
NO_3^- (mmol m^{-3})	S	5.212	0.018	1.152	1.354	12.170	0.002	1.957	3.044	2.650	0.085	0.944	0.952	2.539	0.026	0.859	0.873
	B	2.460	0.007	0.972	0.729	2.785	0.046	1.020	0.845	3.460	0.028	0.806	1.316	2.853	0.090	1.110	0.777
NO_2^- (mmol m^{-3})	S	0.476	0.022	0.146	0.114	1.045	0.012	0.166	0.222	0.378	0.013	0.105	0.111	0.340	0.001	0.122	0.100
	B	0.542	0.020	0.197	0.171	1.008	0.011	0.242	0.294	0.596	0.009	0.174	0.214	0.446	0.018	0.217	0.132
NH_4^+ (mmol m^{-3})	S	3.046	0.353	1.105	0.590	15.400	0.325	1.966	3.703	2.574	0.104	0.875	0.670	1.479	0.299	0.891	0.288
	B	1.887	0.395	0.843	0.424	1.660	0.265	0.788	0.446	27.300	0.173	5.010	10.927	1.957	0.381	0.880	0.451
TIN (mmol m^{-3})	S	8.546	0.690	2.396	1.729	24.902	0.478	4.089	6.122	4.772	0.547	1.924	1.511	3.916	0.467	1.867	1.039
	B	3.696	0.772	2.013	1.024	3.667	0.705	2.050	0.980	27.445	0.357	5.990	10.663	3.642	1.176	2.207	0.785
PO_4^{3-} (mmol m^{-3})	S	0.128	0.012	0.058	0.024	1.500	0.026	0.123	0.294	0.075	0.013	0.045	0.022	0.105	0.004	0.051	0.029
	B	0.094	0.019	0.060	0.024	0.126	0.038	0.071	0.028	0.077	0.034	0.060	0.019	0.089	0.002	0.044	0.025
SiO_4^{4-} (mmol m^{-3})	S	5.810	0.137	1.647	1.867	12.319	0.178	2.615	3.266	5.520	0.113	1.873	1.697	4.380	0.008	1.525	1.260
	B	5.132	0.890	3.275	1.465	8.750	0.490	3.706	2.261	5.610	1.801	3.287	1.420	4.716	1.070	2.912	1.029

* S – surface layer (0-5m); B – bottom layer (last sampling depth)

and minimum was recorded in March at station ST101, both in the surface layer. In this area salinity gradient was fairly uniform throughout the year and ranged from 34.16 to 38.71. Nutrients concentrations showed higher range at the ST103 station that is directly influenced by the freshwater input of the river Jadro. At this station maximum values of silicate (12.32 mmol m^{-3}) and nitrate (12.17 mmol m^{-3}) concentrations were measured in December at the surface layer. Orthophosphate concentrations in Kaštela Bay area were in highest range than at all investigated areas, from 0.002 mmol m^{-3} at CJ007 station that is under the lowest influence of the land to 1.5 mmol m^{-3} at ST103 station that is under a direct influence of the land and freshwater input of the river Jadro.

Environmental parameters in the Mali Ston Bay

Vertical profiles of temperature and salinity in the water column at the investigated stations in Mali Ston Bay are shown in Fig. 4, while basic statistics of abiotic parameters (maximum, minimum, average and standard deviation) at the surface and bottom layers are given in Table 4. Temperature ranged from 10.54 to 23.65°C for entire water column in this area. The maximum value was measured on the surface in August at the station PL102, and the minimum temperature was recorded in January at the station PL105 in the surface layer. Salinity in this area ranged between 26.47 and 38.62. Both values were recorded at the station PL102, which is strongly influenced by the land, submarine springs and inflow of the river Neretva. High variability of nutrient concentrations (silicates 0.37 - 21.93 mmol m^{-3}, nitrate 0.05 - 17.67 mmol m^{-3}, TIN 0.34 - 38.85 mmol m^{-3}) characterizes this area. Maximum values of silicates and nitrate occur at PL102 station in December at the surface layer, indicating the strong freshwater inflow at this station during the winter period. Orthophosphate concentrations ranged between 0.01 mmol m^{-3} and 0.11 mmol m^{-3}.

Since nitrate and silicate indicate the freshwater influence, while phosphate mostly indicates the urban influence, it is evident that Šibenik Bay is under the strong freshwater influence while the urban influence is highest in the Kaštela Bay particularly in its eastern part.

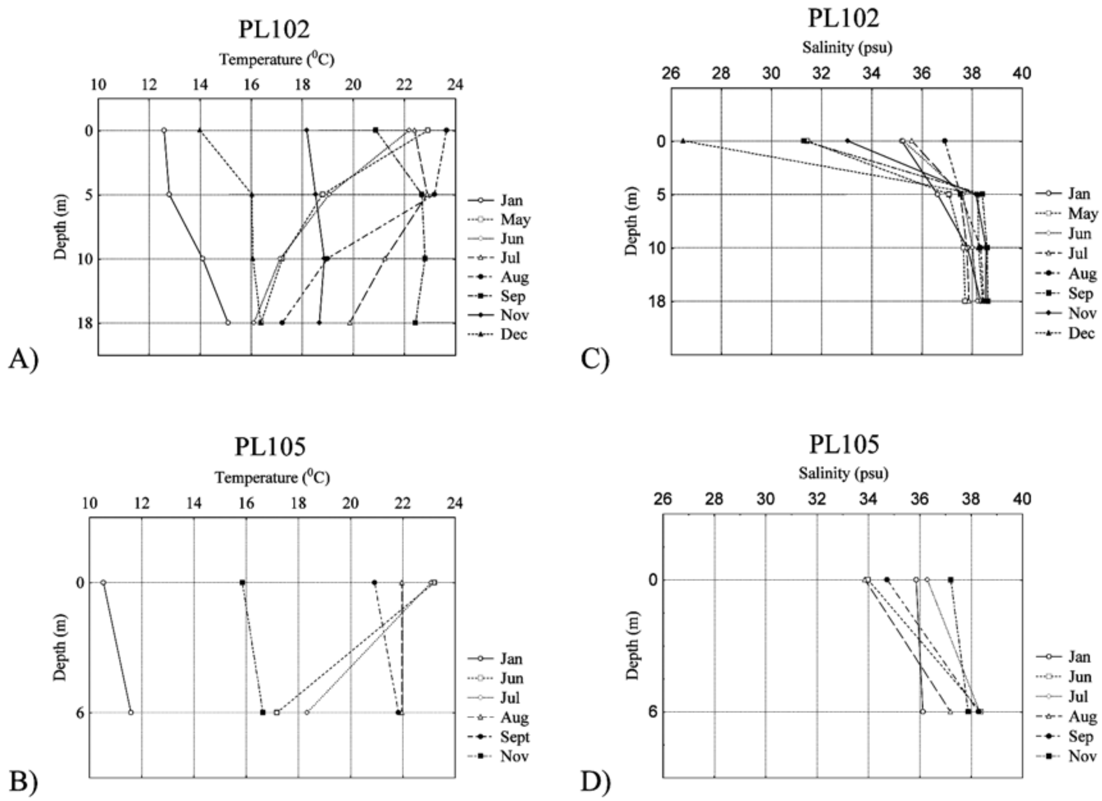

Fig. 4. Vertical profiles of temperature (A, B) and salinity (C, D) at the investigated stations in Mali Ston Bay

Table 4. Abiotic parameters of surface and bottom layers column at investigated stations in Mali Ston Bay

		PL102				PL105			
		max	min	avg	st.dev	max	min	avg	st.dev
NO_3^- (mmol m^{-3})	S	17.667	0.060	2.514	4.414	3.790	0.087	1.335	1.450
	B	2.726	0.046	1.053	0.921	4.300	0.059	0.861	1.686
NO_2^- (mmol m^{-3})	S	0.282	0.015	0.091	0.084	0.564	0.038	0.166	0.225
	B	0.330	0.034	0.110	0.101	0.721	0.018	0.161	0.277
NH_4^+ (mmol m^{-3})	S	37.390	0.196	3.138	9.168	1.849	0.405	1.139	0.573
	B	3.410	0.128	1.041	1.083	3.520	0.565	1.482	1.155
TIN (mmol m^{-3})	S	38.850	0.589	5.743	9.939	5.674	0.530	2.641	1.871
	B	4.780	0.505	2.204	1.523	7.171	0.806	2.502	2.551
PO_4^{3-} (mmol m^{-3})	S	0.101	0.011	0.053	0.026	0.101	0.012	0.045	0.037
	B	0.094	0.010	0.053	0.028	0.109	0.008	0.046	0.036
SiO_4^{4-} (mmol m^{-3})	S	21.927	0.365	6.304	6.560	18.279	2.914	7.302	6.597
	B	6.390	0.625	3.254	1.965	15.790	1.595	8.123	5.190

* S – surface layer (0-5m); B – bottom layer (last sampling depth)

Phytoplankton biomass, abundance and community composition

List of recorded phytoplankton species on all investigated areas, their presence and frequency of findings (F %) at sampling stations are shown in Table 5.

Table 5. List of recorded phytoplankton species in all investigated areas, their presence (+/-) and frequency of findings (F %) at all investigated stations

Group	Taxon	Šibenik Bay	Kaštela Bay	Mali Ston Bay	F (%) SB103 N=38	SB203 N=20	ST101 N=60	ST103 N=44	ST203B N=38	CJ007 N=24	PL102 N=24	PL105 N=12
DIA	*Achnantes longipes* Agardh	+	+	-	0	10	2	0	0	0	0	0
DIA	*Achnanthes* spp.	-	+	-	0	0	0	2	0	4	0	0
DIA	*Amphiprora* spp.	-	+	+	0	0	0	2	0	0	8	0
DIA	*Amphiprora sulcata* O'Meara	+	+	-	3	0	3	0	0	0	0	0
DIA	*Asterolampra hookeri* (Ehrenberg) Greville	-	+	-	0	0	2	0	0	0	0	0
DIA	*Asterolampra marylandica* Ehrenberg	+	-	-	3	5	0	0	0	0	0	0
DIA	*Asteromphalus* spp.	-	+	-	0	0	0	0	0	4	0	0
DIA	*Asterionella formosa* Hassall	+	+	-	8	5	2	2	5	4	0	0
DIA	*Asterionellopsis glacialis* (Castracane) Round	-	+	-	0	0	7	14	3	0	0	0
DIA	*Auricula insceta* (Grunow) Cleve	-	+	-	0	0	2	0	0	0	0	0
DIA	*Bacteriastrum hyalinum* Lauder	-	+	+	0	0	3	0	0	0	4	0
DIA	*Odontella mobiliensis* (Bailey) Grunow	-	+	-	0	0	5	9	0	0	0	0
DIA	*Cerataulina pelagica* (Cleve) Hendey	+	+	+	16	20	25	36	36	30	4	0
DIA	*Chaetoceros affinis* Lauder	+	+	+	5	15	22	23	13	21	8	17
DIA	*Chaetoceros anastomosans* Grunow	-	+	-	0	0	0	2	0	0	0	0
DIA	*Chaetoceros atlanticus* Cleve	+	-	-	0	5	0	0	0	0	0	0
DIA	*Chaetoceros brevis* Schütt	+	+	-	3	0	7	5	0	4	0	0
DIA	*Chaetoceros compressus* Lauder	+	+	+	11	40	2	9	13	8	8	0
DIA	*Chaetoceros costatus* Pavillard	-	+	-	0	0	0	0	0	4	0	0
DIA	*Chaetoceros curvisetus* Cleve	+	+	+	5	20	18	16	24	17	4	17
DIA	*Chaetoceros danicus* Cleve	-	+	-	0	0	0	0	0	4	0	0
DIA	*Chaetoceros decipiens* Cleve	-	+	-	0	0	2	5	0	0	0	0
DIA	*Chaetoceros didymus* Ehrenberg	+	+	-	3	0	5	9	3	4	0	0
DIA	*Chaetoceros diversus* Cleve	+	+	-	0	5	3	0	3	0	0	0
DIA	*Chaetoceros gracilis* Schütt	+	+	+	8	10	13	14	3	8	0	8

DIA	*Chaetoceros holsaticus* Schütt	-	+	-	0	0	0	0	0	4	0	0
DIA	*Chaetoceros peruvainus* Brightwell	+	+	-	3	0	20	9	11	0	0	0
DIA	*Chaetoceros rostratus* Lauder	-	+	-	0	0	0	0	0	4	0	0
DIA	*Chaetoceros similis* Cleve	+	+	-	3	0	2	0	0	0	0	0
DIA	*Chaetoceros simplex* Ostenfeld	+	-	-	3	0	0	0	0	0	0	0
DIA	*Chaetoceros socialis* Lauder	+	+	-	0	10	15	9	3	4	0	0
DIA	*Chaetoceros* spp.	+	+	+	63	75	72	73	42	63	46	25
DIA	*Chaetoceros diadema* (Ehrenberg) Gran	-	+	-	0	0	0	0	5	0	0	0
DIA	*Chaetoceros teres* Cleve	-	+	-	0	0	0	0	3	0	0	0
DIA	*Chaetoceros tortissimus* Gran	-	+	-	0	0	0	0	3	0	0	0
DIA	*Climacospahenia moniligera* Ehrenberg	+	+	+	3	0	0	0	3	0	13	0
DIA	*Corethron hystrix* Cleve	+	-	-	3	0	0	0	0	0	0	0
DIA	*Cyclotella choctawhatcheeana* Prasad	+	+	-	8	10	3	0	3	0	0	0
DIA	*Cyclotella* spp.	+	+	+	11	10	10	0	3	8	8	0
DIA	*Cylindrotheca closterium* Reimann et Lewin	+	+	+	53	50	40	64	45	54	21	58
DIA	*Dactyliosolen mediterraneus* (Peragallo) Hasle	+	+	+	5	5	7	2	5	4	4	0
DIA	*Dactyliosolen* spp.	-	-	+	0	0	0	0	0	0	8	0
DIA	*Diploneis* spp.	+	+	+	13	5	17	18	11	21	17	8
DIA	*Eucampia cornuta* (Cleve) Grunow	+	+	-	5	0	17	18	8	0	0	0
DIA	*Eucampia zoodiacus* Ehrenberg	-	+	-	0	0	0	2	0	0	0	0
DIA	*Grammatophora marina* (Lyngbey) Kützing	+	-	-	5	5	0	0	0	0	0	0
DIA	*Grammatophora oceanica* Ehrenberg	+	-	-	3	0	0	0	0	0	0	0
DIA	*Guinardia flaccida* (Castracane) Peragallo	+	+	+	8	30	25	9	16	25	17	8
DIA	*Hemiaulus hauckii* Grunow	+	+	+	11	25	33	25	26	29	33	17
DIA	*Hemiaulus sinensis* Greville	-	+	+	0	0	3	2	0	0	0	8
DIA	*Leptocylindrus adriaticus* Schroder	+	+	+	13	0	7	25	16	8	4	0
DIA	*Leptocylindrus danicus* Cleve	+	+	+	11	65	43	32	34	17	17	0
DIA	*Leptocylindrus minimus* Gran	+	+	+	26	45	37	41	18	13	17	0
DIA	*Licmophora flabelata* (Carmichael) Agardh	+	-	-	3	0	0	0	0	0	0	0
DIA	*Licmophora paradoxa* (Lyngbey) Agardh	+	-	-	3	0	0	0	0	0	0	0
DIA	*Licmophora reichardtii* Grunow	-	-	+	0	0	0	0	0	0	4	0
DIA	*Licmophora* spp.	+	+	+	5	5	2	2	0	0	0	8

DIA	*Lithodesmium undulatum* Ehrenberg	+	-	-	3	0	0	0	0	0	0	0
DIA	*Melosira italica* (Ehrenberg) Kützing	-	+	-	0	0	0	2	0	0	0	0
DIA	*Melosira nummuloides* Agardh	-	+	-	0	0	0	0	0	4	0	0
DIA	*Melosira* spp.	-	+	-	0	0	0	0	3	0	0	0
DIA	*Paralia sulcata* (Ehrenberg) Cleve	+	+	-	3	0	0	0	3	0	0	0
DIA	*Navicula bicapitata* Ehrenberg	+	+	+	3	0	0	2	0	0	8	0
DIA	*Navicula* spp.	+	+	+	16	10	8	20	3	13	21	17
DIA	*Nitzschia longissima* (Brébisson) Ralfs	+	+	+	8	15	18	30	34	13	38	25
DIA	*Nitzschia paradoxa* Gmelin	+	+	-	3	0	0	0	0	4	0	0
DIA	*Pennatae indeterm*	+	+	+	84	100	75	75	66	75	83	100
DIA	*Pleurosigma angulatum* (Quekett) Smith	-	+	-	0	0	0	0	3	0	0	0
DIA	*Pleurosigma* spp.	+	+	+	3	10	27	23	8	38	17	25
DIA	*Proboscia alata* (Brightwell) Sundström	+	+	+	32	50	37	34	39	25	38	33
DIA	*Pseudo-nitzschia* spp. Peragallo	+	+	+	71	100	87	100	76	79	63	75
DIA	*Rhabdonema adriaticum* Kützing	-	-	+	0	0	0	0	0	0	4	0
DIA	*Proboscia indica* (H.Peragallo) Hernández-Becerril	+	+	-	0	5	5	2	5	8	0	0
DIA	*Pseudosolenia calcar avis* (Schultze) Sundström	-	+	-	0	0	2	2	3	4	0	0
DIA	*Guinardia delicatula* (Cleve) Hasle	+	+	+	0	10	0	2	8	0	4	8
DIA	*Dactyliosolen fragilissimus* (Bergon) Hasle	+	+	+	47	40	45	43	21	33	8	0
DIA	*Rhizosolenia imbricata* Brightwell	+	+	-	3	10	5	2	0	4	0	0
DIA	*Rhizosolenia setigera* Brightwell	-	+	-	0	0	2	0	0	0	0	0
DIA	*Rhizosolenia* spp.	+	+	+	5	0	2	0	16	8	4	0
DIA	*Guinardia striata* (Stolterfoth) Hasle	+	+	+	18	40	62	39	26	46	4	17
DIA	*Rhizosolenia styliformis* Brightwell	+	+	+	13	30	10	7	8	8	29	8
DIA	*Rhizosolenia styliformis f. longispina* Hustedt	-	+	-	0	0	0	5	0	0	0	0
DIA	*Detonula pumila* (Castracane) Gran	+	+	-	5	0	20	25	3	4	0	0
DIA	*Skeletonema cf. costatum* (Greville) Cleve	+	+	-	34	40	23	27	8	8	0	0
DIA	*Synedra capitata* Ehrenberg	-	+	-	0	0	0	2	0	0	0	0
DIA	*Synedra* spp.	-	+	+	0	0	0	2	0	0	8	0
DIA	*Thalasiothrix frauenfeldii* (Grunow) Hallegraeff	+	+	+	29	30	28	34	8	21	17	8

DIA	*Thalasiothrix mediterranea* Pavillard	+	+	-	3	0	2	7	0	0	0	0
DIA	*Thalassionema nitzschoides* (Grunow) Mereschkowsky	+	+	+	24	20	17	20	21	25	4	17
DIA	*Thalassiosira rotula* Meunier	+	+	-	3	5	12	20	0	13	0	0
DIA	*Thalassiosira* spp.	+	+	+	18	0	10	18	11	8	0	17
DIN	*Amphidinium acutissimum* Schiller	+	+	+	13	10	12	14	24	25	17	0
DIN	*Amphidinium curvatum* Schiller	-	+	-	0	0	2	0	0	0	0	0
DIN	*Amphidinium extensum* Wülff	-	-	+	0	0	0	0	0	0	4	0
DIN	*Amphidinium globosum* Schröder	-	+	-	0	0	0	0	0	4	0	0
DIN	*Amphidinium glaucum* Conrad	-	+	-	0	0	0	2	0	0	0	0
DIN	*Amphidinium klebsi* Carter	-	+	-	0	0	0	0	3	0	0	0
DIN	*Amphidinium longum* Lohmann	-	+	-	0	0	0	0	3	0	0	0
DIN	*Amphidinium* sp.	-	+	+	0	0	0	0	0	4	8	0
DIN	*Amphidinium sphenoides* Wülff	-	+	-	0	0	0	2	0	0	0	0
DIN	*Amphidinium stigmatum* Schiller	-	+	-	0	0	0	0	0	4	0	0
DIN	*Akashiwo sanguinea* Hansen et Moestrup	+	-	+	3	5	0	0	0	0	4	17
DIN	*Amphidinium lacustre* Stein	-	-	+	0	0	0	0	0	0	0	8
DIN	*Amphidinium longum* Lohmann	-	+	-	0	0	0	0	3	0	0	0
DIN	*Amphidoma acuminata* Stein	-	+	-	0	0	0	2	0	0	0	0
DIN	*Amylax triacantha* (Jorgensen) Sournia	-	+	-	0	0	0	7	0	0	0	0
DIN	*Alexandrium minutum* Halim	-	+	-	0	0	0	2	0	0	0	0
DIN	*Alexandrium tamarense* (Lebour) Balech	-	+	-	0	0	0	2	0	0	0	0
DIN	*Centrodinium maximum* Pavillard	-	+	-	0	0	0	5	0	0	0	0
DIN	*Ceratium biconicum* Murray et Whitting	+	-	-	3	0	0	0	0	0	0	0
DIN	*Ceratium furca* (Efrenb.) Claparéde et Lachmann	+	+	+	0	10	0	2	0	0	0	8
DIN	*Ceratium fusus* (Ehrenberg) Dujardin	-	+	-	0	0	3	5	0	0	0	0
DIN	*Ceratium hexachantum* Gourret	-	+	-	0	0	2	0	0	0	0	0
DIN	*Ceratium* spp.	-	+	-	0	0	2	0	0	0	0	0
DIN	*Ceratium trichoceros* (Ehrenberg) Kofoid	-	+	-	0	0	3	5	0	0	0	0
DIN	*Ceratium tripos* (Müller) Nitzsch	-	+	+	0	0	2	0	0	0	0	8
DIN	*Ceratocorys armata* (Schütt) Kofoid	-	+	-	0	0	0	5	0	4	0	0
DIN	*Cochlodinium achromaticum* Lebour	-	+	-	0	0	0	2	0	0	0	0

DIN	*Cochlodinium archimedes* (Pouchet) Lemmermann	+	-	-	3	0	0	0	0	0	0	0
DIN	*Cochlodinium pupa* Lebour	-	-	+	0	0	0	0	0	0	0	8
DIN	*Cochlodinium* spp.	-	+	+	0	0	0	5	0	4	8	0
DIN	*Dinoflagella* spp. < *20µ*	+	+	+	5	0	0	2	11	4	0	17
DIN	*Dinophysis acuminata* Claparéde et Lachmann	-	+	+	0	0	2	2	0	0	0	8
DIN	*Dinophysis caudata* Seville-Kent	-	+	-	0	0	2	0	0	0	0	0
DIN	*Dinophysis fortii* Pavillard	-	+	-	0	0	2	0	0	0	0	0
DIN	*Dinophysis sacculus* Stein	-	+	-	0	0	0	18	3	4	0	0
DIN	*Dinophysis tripos* Gourret	+	-	-	3	0	0	0	0	0	0	0
DIN	*Diplosalis lenticula* Bergh	-	+	-	0	0	0	5	0	0	0	0
DIN	*Glenodinium apiculatum* Penard	-	-	+	0	0	0	0	0	0	0	8
DIN	*Glenodinium lenticulata Bergh*	+	-	-	3	0	0	0	0	0	0	0
DIN	*Glenodinium rotundatum* Skvortzov	-	+	-	0	0	0	2	0	0	0	0
DIN	*Glenodinium* spp.	-	+	-	0	0	0	0	3	0	0	0
DIN	*Gonyaulax fragilis* (Schütt) Kofoid	+	-	-	5	0	0	0	0	0	0	0
DIN	*Gonyaulax polygramma* Stein	-	+	+	0	0	7	0	5	4	4	0
DIN	*Gonyaulax spinifera* Diesing	+	+	-	5	0	0	7	0	0	0	0
DIN	*Gonyaulax* spp.	-	-	+	0	0	0	0	0	0	0	8
DIN	*Gonyaulax rostratum* Dangeard	-	+	-	0	0	0	2	0	0	0	0
DIN	*Gymnodinium biconicum* Schiller	+	+	-	8	0	0	2	0	0	0	0
DIN	*Gymnodinium caput* Schiller	-	+	-	0	0	0	2	0	0	0	0
DIN	*Gymnodinium flavum* Kofoid et Swezy	-	+	-	0	0	0	2	0	0	0	0
DIN	*Gymnodinium lebouriae* Pavillard	-	-	+	0	0	0	0	0	0	4	0
DIN	*Gymnodinium opressum* Conrad	+	+	-	3	0	0	2	0	0	0	0
DIN	*Gymnodinium ostenfeldii* Schiller	-	+	-	0	0	0	0	3	0	0	0
DIN	*Gymnodinium* spp.	+	+	+	89	100	100	95	82	92	100	100
DIN	*Gymnodinium uberimum* (Allman) Kofoid et Swezy	+	+	+	0	10	0	14	0	4	0	8
DIN	*Gyrodinium estuariale* Hulbert	-	+	-	0	0	0	2	0	0	0	0
DIN	*Gyrodinium fuscum* (Ehrenberg) Stein	-	+	-	0	0	0	2	0	0	0	0
DIN	*Gyrodinium fusiforme* Kofoid et Swezy	+	+	+	21	10	10	32	21	21	8	25
DIN	*Gyrodinium hyalinum* (Schilling) Kofoid et Swezy	-	+	-	0	0	0	2	0	0	0	0
DIN	*Gyrodinium lachryma* (Meunier) Kofoid et Swezy	-	+	+	0	0	2	5	0	0	4	0

DIN	*Gyrodinium obtusum* (Schütt) Kofoid et Swezy	-	+	-	0	0	0	2	0	0	0	0
DIN	*Gyrodinium opimum* (Schütt) Lebour	+	+	+	0	20	5	7	5	8	4	0
DIN	*Gyrodinium ovatum* (Gourret) Kofoid et Swezy	-	+	-	0	0	2	7	0	0	0	0
DIN	*Gyrodinium pepo* (Schütt) Kofoid et Swezy	+	-	-	3	0	0	0	0	0	0	0
DIN	*Gyrodinium pingue* (Schütt) Kofoid et Swezy	+	+	+	16	15	25	25	5	21	17	17
DIN	*Gyrodinium* spp.	+	+	+	11	0	7	11	5	0	8	0
DIN	*Hermesinum adriaticum* Zacharias	+	+	-	3	0	0	2	0	0	0	0
DIN	*Heterocapsa* spp.	-	+	-	0	0	0	2	0	0	0	0
DIN	*Karenia* spp.	-	+	+	0	0	0	5	0	0	0	8
DIN	*Lingulodinium polyedrum* (Stein) Dodge	+	+	-	3	0	0	14	0	0	0	0
DIN	*Ostreopsis siamensis* Schmidt	-	+	-	0	0	0	2	0	0	0	0
DIN	*Oxytoxum adriaticum* Schiller	+	+	+	5	5	3	2	0	0	4	0
DIN	*Oxytoxum caudatum* Schiller	-	+	-	0	0	2	5	3	4	0	0
DIN	*Oxytoxum elegans* Pavillard	-	+	-	0	0	0	2	0	0	0	0
DIN	*Oxytoxum longum* Schiller	+	-	-	0	5	0	0	0	0	0	0
DIN	*Oxytoxum sceptrum* (Stein) Schröder	-	+	-	0	0	0	2	0	0	0	0
DIN	*Oxytoxum scolopax* Stein	+	+	-	3	0	2	0	0	0	0	0
DIN	*Oxytoxum sphaeroideum* Stein	-	-	+	0	0	0	0	0	0	4	0
DIN	*Oxytoxum viride* Schiller	-	+	+	0	0	0	7	3	4	0	8
DIN	*Phalacroma rotundatum* Kofoid et Michener	-	+	-	0	0	2	0	0	0	0	0
DIN	*Polykrikos schwartzii* Bütschli	-	+	-	0	0	2	0	0	0	0	0
DIN	*Pronoctiluca spinifera* (Lohmann) Schiller	+	+	-	5	0	3	14	0	8	0	0
DIN	*Prorocentrum arcuatum* Issel	-	+	-	0	0	0	2	0	0	0	0
DIN	*Prorocentrum compressum* Abé ex Dodge	+	+	+	5	0	2	2	0	0	4	0
DIN	*Prorocentrum dentatum* Stein	-	+	-	0	0	0	2	0	0	0	0
DIN	*Prorocentrum obtusidens* Schiller	-	+	-	0	0	2	0	0	0	0	0
DIN	*Prorocentrum lima* (Ehrenberg) Dodge	-	+	-	0	0	0	0	3	0	0	0
DIN	*Prorocentrum micans* Ehrenberg	+	+	+	5	5	2	18	3	0	8	17
DIN	*Prorocentrum minimum* (Pavillard) Schiller	+	+	+	13	5	17	9	5	13	8	0
DIN	*Prorocentrum scutellum* Schröder	+	-	+	0	5	0	0	0	0	4	0
DIN	*Prorocentrum triestinum* Schiller	+	+	+	18	20	13	55	5	13	13	8

DIN	*Protoperidinium bipes* (Paulsen) Balech	-	+	+	0	0	0	2	0	0	4	0
DIN	*Protoperidinium bispinum* (Paulsen) Balech	-	+	-	0	0	0	0	0	4	0	0
DIN	*Protoperidinium breve* Paulsen	+	+	+	3	0	0	2	0	0	4	0
DIN	*Protoperidinium brevipes* (Paulsen) Balech	-	+	-	0	0	0	0	0	4	0	0
DIN	*Protoperidinium conicum* (Gran) Balech	-	+	-	0	0	0	2	0	0	0	0
DIN	*Protoperidinium diabolus* (Cleve) Balech	+	+	-	3	0	2	9	3	0	0	0
DIN	*Protoperidinium divergens (Ehrenberg) Balech*	+	+	-	0	5	0	7	0	0	0	0
DIN	*Protoperidinium globulus* (Stein) Balech	-	+	-	0	0	0	7	0	0	0	0
DIN	*Protoperidinium grande* (Kofoid) Balech	-	+	-	0	0	0	2	0	0	0	0
DIN	*Protoperidinium granii* Ostenfeld	+	+	-	3	5	0	2	0	0	0	0
DIN	*Protoperidinium minusculum* Pavillard	-	+	-	0	0	7	14	0	0	0	0
DIN	*Protoperidinium oceanicum* (Vanhöffen) Balech	-	+	-	0	0	0	2	0	0	0	0
DIN	*Protoperidinium ovum* (Schiller) Balech	+	+	-	3	0	2	2	0	0	0	0
DIN	*Protoperidinium tubum* (Schiller) Balech	+	+	-	8	10	3	16	5	0	0	0
DIN	*Pseliodinium vaubanii* Sournia	-	+	+	0	0	2	0	0	0	4	0
DIN	*Scripsiella trochoidea* (Stein) Loeblich	+	+	+	13	0	12	43	5	4	4	8
DIN	*Torodinium robustum* Kofoid & Swezy	-	-	+	0	0	0	0	0	0	4	0
DIN	*Warnowia atra* (Kofoid et Swezy) Schiller	-	+	-	0	0	0	2	0	0	0	0
DIN	*Warnowia* spp.	-	+	-	0	0	0	0	3	0	0	0
SI	*Dictyocha fibula* Ehrenberg	-	+	-	0	0	3	7	0	17	0	0
SI	*Dictyocha speculum* Ehrenberg	+	+	-	5	0	2	9	3	0	0	0
CO	*Coccolithophoridae* spp.	+	+	+	53	55	52	43	63	42	50	25
CO	*Algirosphaera oryza* Schlauder	-	+	-	0	0	0	0	0	4	0	0
CO	*Calciosolenia murrayi* Gran	+	+	+	8	10	7	11	3	0	4	0
CO	*Calyptosphaera sphaeroidea* Schiller	+	+	+	18	15	5	11	0	33	21	33
CO	*Halopappus adriaticus* Schiller	-	+	-	0	0	5	0	0	0	0	0
CO	*Ophiaster hydroideus* Lohmann	+	+	-	0	10	3	7	0	0	0	0
CO	*Rhabdosphaera tignifer* Schiller	+	+	-	8	0	8	0	3	0	0	0
CO	*Syracosphaera apsteinii* Lohmann	-	+	-	0	0	0	0	0	4	0	0

CO	*Syracosphaera pulchra* Lohmann	+	+	+	5	5	15	16	11	8	13	25
EU	*Eutreptiella* spp.	+	+	+	5	0	5	7	5	4	0	8
EU	*Eutreptia lanowii* Steuer	+	+	+	34	20	8	16	3	8	8	0
EU	*Eutreptiella pasheri* (Schiller) Pascher	-	+	-	0	0	2	2	0	4	0	0
EU	*Euglena ascusformis* Schiller	-	+	-	0	0	0	2	0	0	0	0
CHL	*Pyramimonas* spp.	+	+	+	5	0	2	2	8	4	8	17
CHL	*Pyramimonas orientalis* Butcher	+	-	-	3	0	0	0	0	0	0	0
MIC	*Mikroflagella* spp.	+	+	+	92	100	100	100	97	100	100	100
CR	*Hillea fusiformis* Schiller	+	+	+	42	55	33	66	63	67	71	75
CR	*Hillea marina* Butcher	+	+	+	13	10	0	14	0	8	8	25
CR	*Leucocryptos marina* (Braarud) Butcher	+	-	+	3	0	0	0	0	0	8	8

*DIA- Diatoms; DIN- Dinoflagellates; SI- Silicoflagellates; CO- Cocolithophorids; EU- Euglenophyta; CHL- Chlorophyta; CR- Criptophyta; MIC- microflagella group

Šibenik Bay area

Vertical distribution of chlorophyll *a* concentrations (mg m^{-3}) at investigated stations in Šibenik Bay are shown in Fig. 5. Chlorophyll *a* concentrations were found in wide range from 0.07 to 4.73 mg m^{-3}. The highest chl *a* value was measured at the station SB103 in May in the surface layer, and the minimum value was recorded in July at station SB203 in the bottom layer. Seasonal distribution of phytoplankton biomass was in accordance with seasonal distribution in temperate seas, with maximal biomass in spring and autumn-winter period due to nutrients distribution (SIOKOU-FRANGOU *et al.*, 2002). High biomass in spring period is a result of increased light intensity and sufficient concentration of nutrients in euphotic zone. Summer is characterized with low biomass due to stratification process that disables inflow of nutrients in euphotic layer. During autumn, mixing period started due to cooling process that caused high value of phytoplankton biomass in that period. The highest values were recorded in surface layer during the whole investigation period (Fig. 5). During a summer period higher values in surface layer indicate inflow of nutrients in surface layer due to anthropogenic influence. Spearman rank correlation between the concentration of chl *a* and environmental parameters (temperature, salinity, nitrate, nitrite, TIN, phosphate and silicate) revealed strong influence of freshwater inflow on phytoplankton biomass (Table 6).

With qualitative analysis of the phytoplankton composition at the investigated area of Šibenik Bay, 114 phytoplankton taxa have been

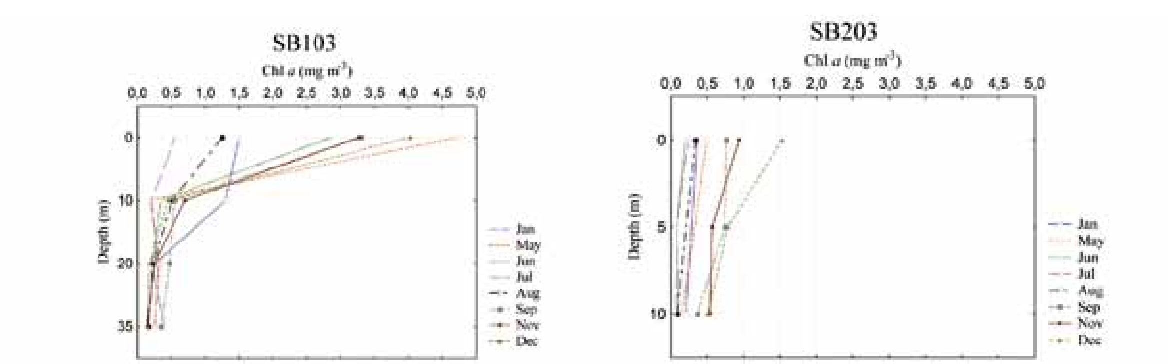

Fig. 5. Vertical distribution of chlorophyll a *concentrations (mg m^{-3}) at investigated stations in Šibenik Bay*

Table 6. Spearman rank correlation between the concentration of chl a and environmental parameters (temperature, salinity, nitrate, nitrite, TIN, phosphate and silicate) at all sampling depths

	Temp.	**Sal.**	**NO_3^-**	**NO_2^-**	**NH_4^+**	**TIN**	**PO_4^{3-}**	**SiO_4^{4-}**
Šibenik Bay SB103, SB203	0.06	**-0.49***	0.17	0.16	0.16	0.19	**-0.30***	**0.44***
Kaštela Bay, including the stations inside of the Bay ST101, ST 103	0.09	**-0.34***	-0.12	0.01	0.04	-0.02	-0.05	-0.08
Kaštela Bay, including the stations outside of Bay ST203b, CJ007	**0.50***	**0.42***	**0.55***	**0.59***	**0.57***	**0.61***	**0.51***	**0.53***
Mali Ston Bay PL102, PL105	-0.17	0.15	**0.36***	**0.53***	**0.42***	**0.58***	-0.33	**0.55***
All investigated areas	-0.01	**-0.26***	0.11	**0.17***	**0.13***	**0.20***	-0.08	**0.13***

*$p<0.05$

determined. The most diverse phytoplankton groups were diatoms (61) and dinoflagellates (37). Coccolithophorids contributed with 6, cryptophytes with 3, silicoflagellates, euglenophytes and chlorophytes with 2 taxa. Diverse flagellate group of phytoplankton, which is placed by size in microflagella group, were present in the whole area with a high frequency of findings. Most diverse station in this area, with 100 recorded taxa has been SB103, which is located in the Šibenik harbor and is under strong influence of freshwater and urban waste waters, the city port and marina, while on the SB203 station 66 taxa were found. Diatoms with the highest frequency of findings in this area were *Pennatae indeterm, Pseudonitzschia* spp., *Leptocylindrus danicus*, *Chaetoceros* spp. and *Cylindrotheca closterium*. *Pennatae indeterm* are diverse diatom group composed mainly of small pennatae diatoms. Succession of diatoms bloom characterizes the station SB 103. Bloom of *Skeletonema* cf. *costatum* (3870000 cells L^{-1}) has been recorded in July, *Chaetoceros* spp. bloom (1630000 cells L-1) has been recorded in September and *Pseudonitzschia* spp. bloom (1210000 cells L^{-1}) in January. Dinoflagellates taxa that had the highest frequency of findings in this area were *Gymnodinium* spp., *Gyrodinium* spp. and *Prorocentrum triestinum*. The highest abundance of dinoflagellate taxa *Gymnodinium* spp. (88100 cells L^{-1}) reported at the SB103 station in September on the surface and *Gyrodinium* spp. (42600 cells L^{-1}) at the same station in July in the surface layer. At the SB103 station blooming of euglenophyta *Eutreptia lanowii* (5090000 cells L^{-1}) occurs in June at the surface. The temporal distribution of total phytoplankton abundance at the surface and bottom layer in Šibenik Bay is shown in Fig. 6.

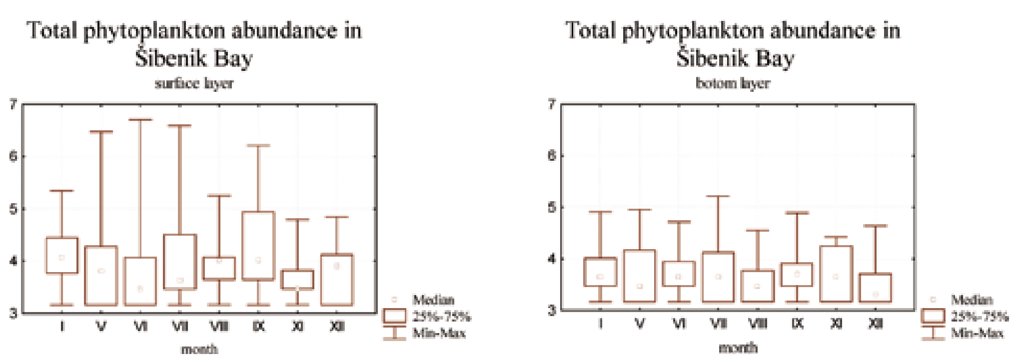

Fig. 6. Temporal distribution of total phytoplankton abundance (log values) at the surface (0-5 m) and bottom layer (last sampling depth) in Šibenik Bay

Kaštela Bay area

Vertical distribution of chlorophyll *a* concentrations (mg m^{-3}) at investigated stations in Kaštela Bay are shown in Fig. 7. Maximum values of chlorophyll *a* were recorded at the ST103 station in September, throughout the water column (2.17 - 2.79 mg m^{-3}). Higher biomasses were recorded at stations in Kaštela Bay (ST101, ST103) in relation to stations out of the Bay area (ST203, CJ007). High biomass and vertical distribution of biomass in the summer with higher values in surface layer in relation to the bottom reflect the anthropogenic influence at stations in Kaštela Bay. At the stations located inside of the Bay chlorophyll *a* concentrations were negatively correlated with salinity (Table 6). When all stations (located inside and outside of the Bay) were included in analysis, chlorophyll *a* showed significant correlation with all analyzed parameters due to gradually increase of distance from the coast.

In the investigated area of Kaštela Bay total of 193 phytoplankton taxa have been recorded. Dinoflagellate group was the most diverse with 92 taxa, followed by diatoms (80), coccolithophorids (9), silicoflagellates and euglenophytes (4), cryptophytes (2) and chlorophyte (1). Microflagella group had also a high frequency of findings in this area. The station with the most recorded phytoplankton taxa has been ST103 (140 taxa), which is situated deepest in the bay and under the direct influence of river Jadro and strong anthropogenic influence. Slightly smaller number of taxa were recorded at the station ST101 (108 taxa), while station ST203B with 84 and CJ007 with 82 taxa recorded, had the lowest diversity in this area, due the influence of canal waters and currents as well as distance from the land (FLO *et al.*2011). Diatoms with a high frequency of findings in this area (> 50%) were *Chaetoceros* spp., *Cylindrotheca closterium,* small pennatae diatoms*, Pseudonitzschia* spp. and *Guinardia striata*. The maximum abundance of diatoms were recorded at the ST103 station in June and July throughout the water column, where we recorded blooming of species *Leptocylindrus minimus* with maximum abundance in the surface layer of 4480000 cells L^{-1} in June and 2990000 cells L^{-1} in July. High abundance of taxa *Pseudonitzschia* spp. occurs

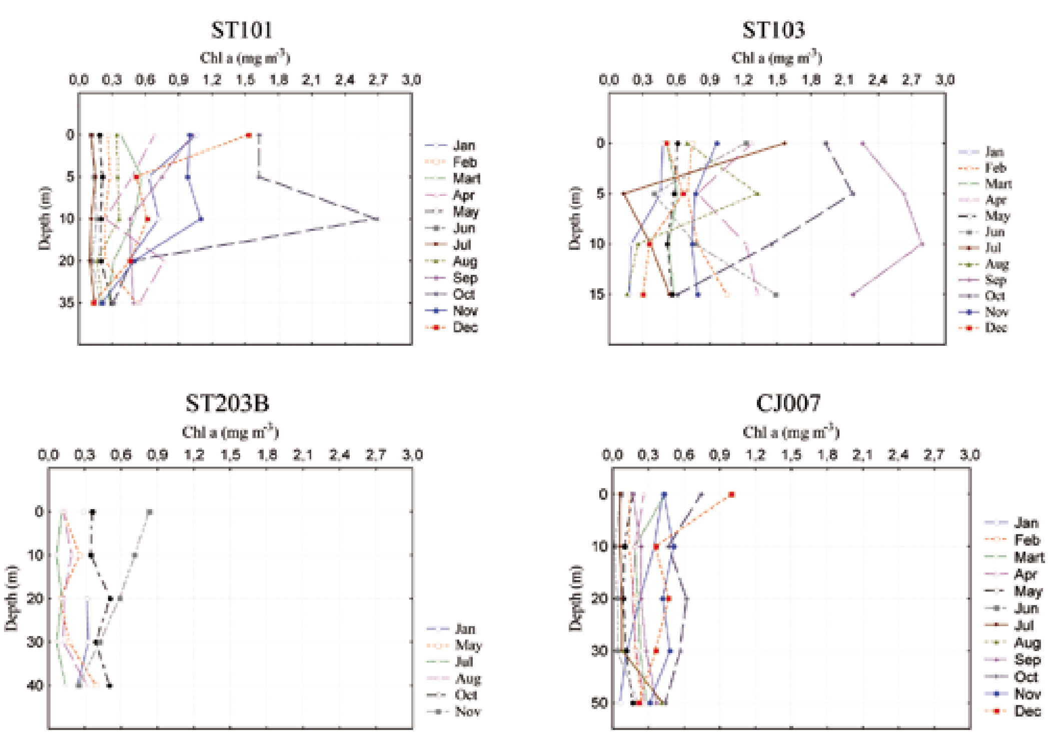

Fig. 7. Vertical distribution of chlorophyll a concentrations (mg m^{-3}) at investigated stations in Kaštela Bay

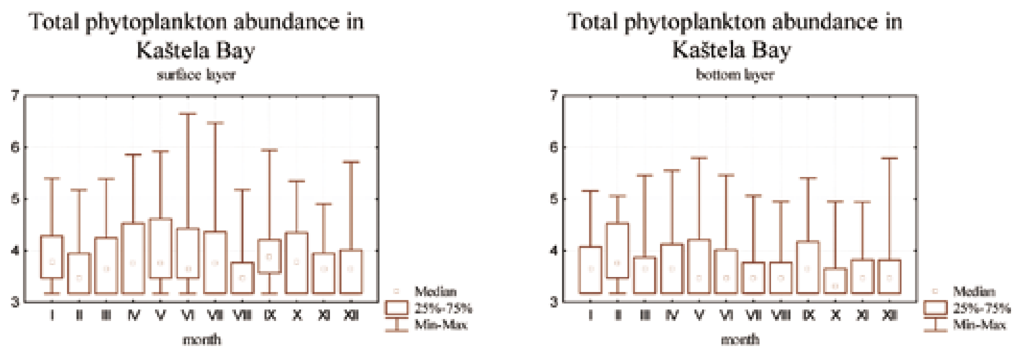

Fig. 8. Temporal distribution of total phytoplankton abundance (log values) at the surface (0-5 m) and bottom layer (last sampling depth) in Kaštela Bay

in September at stations ST101 (813000 cells L^{-1}) and ST103 (709000 cells L^{-1}) in a layer of 5 m depth. Dinoflagellates that had the highest frequency of findings in this area were *Gymnodinium* spp., *Gyrodinium* spp., *Scrippsiella trochoidea, Prorocentrum triestinum* and at ST103 station *Dinophysis sacculus*. Maximum abundance of taxa *Gymnodinium* spp. (163000 cells L^{-1}) were recorded on ST103 station in June, while the species *Prorocentrum micans* reached its maximum value of 110000 cells L^{-1} in July on the same station. *Prorocentrum triestinum* species had a high abundance at the station ST103 throughout the warm period, with a maximum abundance of 489000 cells L^{-1} in September at 10m of depth. It is worth mentioning not so high, but significantly increased abundance of potentially toxic dinoflagellate *Lingulodinium polyedra* (17600 cells L^{-1}) at the station ST103 in September at 10 m of depth, while on the surface there was increase abundance of coccolithophorids 669000 cells L^{-1}. Dinoflagellate *L. polyedrum* made intensive bloom in Kaštela bay in a period from 1980s to 1990s which occasionally had been associated with marine organisms mortality (MARASOVIĆ *et al.,* 1991) This bloom decreased and almost disappear from the bay in the mid of 1990s (NINČEVIĆ GLADAN *et al.*, 2010). The temporal distribution of total phytoplankton abundance at the surface and bottom layer in Kaštela Bay is shown in Fig. 8.

Mali Ston Bay area

Vertical distribution of chlorophyll *a* concentrations (mg m^{-3}) at investigated stations in the Mali Ston Bay are shown in Fig. 9. Maximum values of chlorophyll *a* (1.26 mg m^{-3}) were recorded at the station PL105 in November in the bottom layer, and the minimum value (0.04 mg m^{-3}) was recorded at the station PL102 in July at a depth of 10 m. Chlorophyll *a* concentrations in Mali Ston Bay have been positively correlated with nitrogen nutrient and silicates (Table 6).

In the Mali Ston Bay a total of 88 phytoplankton taxa have been found, with 39 diatoms, 36 dinoflagellates, 2 silicoflagellates, 4 coccolithophorids, 2 euglenophytes, 1 chllorophyte and 3 chrisophyte taxa. A diverse microflagella group had a high frequency of findings in this area (100%). Station PL102 that is under the direct influence of the river Neretva was more diverse, with 72 taxa recorded, while at the station PL105 49 taxa were found. Diatom taxa with frequency of findings greater than 50% were *Pseudonitzschia* spp. and small pennatae diatoms, somewhat lower frequency of findings (>30%) had *Chaetoceros* spp, *Cylindrotheca closterium*, *Hemiaulus hauckii*, *Nitzschia longissima* and *Proboscia alata*. Dinoflagellates in this area had a low frequency of findings (<30%), excluding *Gymnodinium* spp. taxa that had 100% frequency of findings at the both stations. Somewhat more frequent taxa from the dinoflagellate group were *Gyrodinium fusiforme* (25%). Coccolithophorids have had around 50% frequency of findings in this area and they contributed more to the community composition, then in other areas of research. The maximum abundance of diatoms were recorded in May,

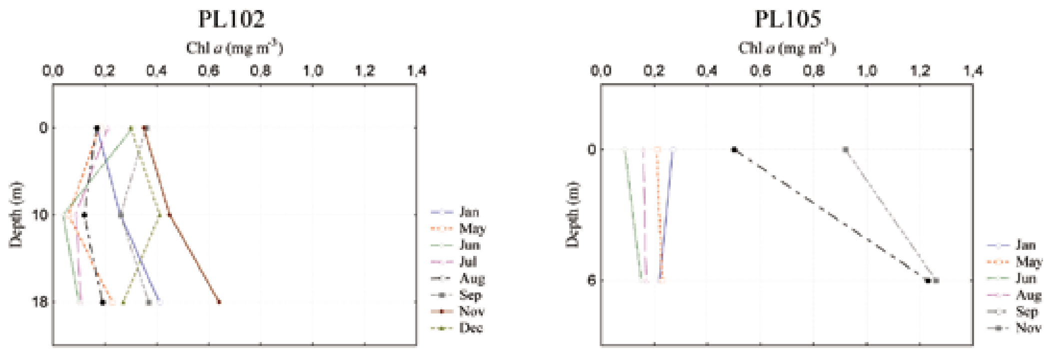

Fig. 9. Vertical distribution of chlorophyll a concentrations (mg m^{-3}) at investigated stations in Mali Ston Bay

when blooming of *Chaetoceros* spp. (2770000 cells L^{-1}) occurred at the PL102 station, although the high abundances were recorded throughout the warm period (May to August) and through the entire water column. Abundance of dinoflagellates was very low in this area. The maximum abundance of taxa *Gymnodinium* spp. (42600 cells L^{-1}) occurred in May at the surface of the PL102 station and remained until August. Increased values of coccolithophorid *Calyptrosphaera sphaeroidea* were recorded in September at the both stations PL102 and PL105 with abundances of 17640 and 52920 cells L^{-1} respectively and stayed elevated through the November. The temporal distribution of total phytoplankton abundance at the surface and bottom layer in Mali Ston Bay is shown in Fig. 10.

The highest phytoplankton biomass was recorded in Šibenik Bay at the station SB103 (4.73 mg m^{-3}), and in Kaštela Bay at the station ST103 (2.79 mg m^{-3}). Both stations are directly influenced by freshwater inflow and high anthropogenic impact. Chlorophyll *a* concentrations at other investigated stations were generally below 1 mg m^{-3}. During the investigated period there were a relatively small number of monospecific booms in all areas. Greatest number of species and highest abundance of phytoplankton were observed in the warmer period of the year. Seasonal distribution of phytoplankton abundance generally followed a seasonal distribution of phytoplankton biomass. The greatest difference occurred in the winter period that could be result of physiological adaptation of phytoplankton to decreased light intensity (VILIČIĆ, 2003). Vertical distribution of phytoplankton biomass is different at different bays. In Šibenik Bay, phytoplankton biomass is higher in surface layer in relation to subsurface during the whole investigation period. This distribution may be result of permanent halocline in Šibenik Bay and higher nutrient concentrations in surface layer (SVENSEN *et. al.*, 2007). In Kaštela Bay vertical distribution reflects the trophic status of

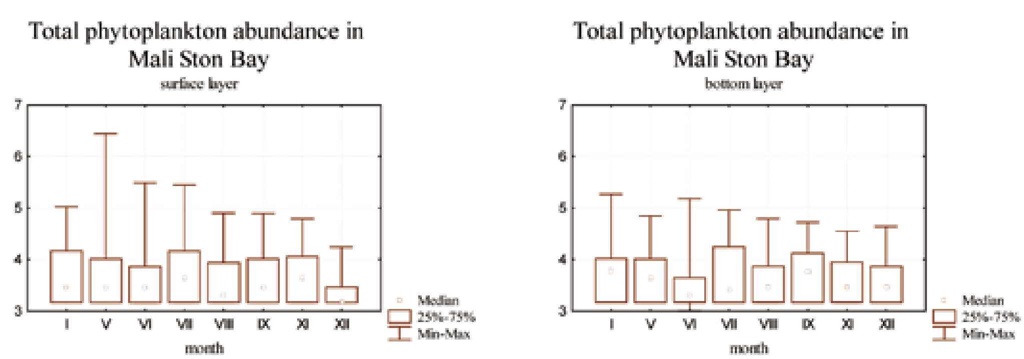

Fig. 10. Temporal distribution of total phytoplankton abundance (log values) at the surface (0-5 m) and bottom layer (last sampling depth) in Mali Ston Bay

investigated stations. At station ST103, which is the closest to the land and under the strongest anthropogenic influence, phytoplankton biomass was mostly uniformly distributed, except in summer, during stratification period when higher values were recorded in surface layer in relation to bottom. This distribution indicates additional inflow of nutrients in the surface layer due to anthropogenic activity (KUŠPILIĆ, 2005). At the ST101 station (placed further from the land than ST103) vertical distribution in summer period was uniform in the whole water column with slight increase in surface layer in August, indicating milder anthropogenic influence. At stations outside of Kaštela Bay (ST203, CJ007), phytoplankton biomass was uniform in water column or higher in surface layer during mixing period (winter) while during stratification period (summer) was higher in subsurface and bottom layers. This pattern is more pronounced at the CJ007 station that is the farthest from the land and reflects the phytoplankton seasonal cycles, that are characteristic for temperate seas without or with slight anthropogenic influence. Similarly, stations in Mali Ston Bay follow the same pattern and vertical distribution in summer period and are different at PL102 station placed in the vicinity of the city and estuary of the river Neretva then PL105 station. Obtained results revealed the vertical distribution, besides the concentrations of chlorophyll *a* as good indicator of trophic status. On the entire area of research the greatest proportion of the phytoplankton community had diatoms, and then dinoflagellate. The highest frequency of findings in diatoms had *Chaetoceros* spp, *Cylindrotheca closterium,* small pennatae diatoms and *Pseudonitzschia* spp., while the most frequent dinoflagellates were *Gymnodinium* spp., *Gyrodinium* spp. and *Prorocentrum triestinum*. Among dinoflagellates only *Gymnodinium* spp. had a frequency of findings greater than 50%. Maximum abundance from diatoms in Šibenik Bay reached species *Skeletonema* cf. *costatum*, in Kaštela Bay species *Leptocylindrus minimus*, and in Mali Ston Bay taxa *Chaetoceros* spp. Experimantal study reveald better growth of *Chaetoceros* species in low nutrient concentrations in comparison with *S. costatum* which are phosphorus limited (LAGUS *et al*., 2004). Contribution of microflagellate group in phytoplankton community was increased in spring-summer period. Monospecific bloom of euglenophyta *Eutreptia lanowii* was recorded in June at the station SB103, which occurred after a sudden rise in temperature of the surface layer. That is characteristic for diluted, warm and eutrophicated waters and this taxon is used as a biological indicator of organic pollution (STONIK & SELINA, 2001). Blooming of euglenophyta was replaced by blooming of diatom *Skeletonema* cf. *costatum* in beginning of July, which is characterized by strong growth with an increase of nitrate (DEMANCHE *et al.,* 1979) and makes it a better competitor among diatoms in eutrophicated conditions, so it is a good indicator species for eutrophication (COLLOS *et al*., 1997). Specific meteorological conditions which prevailed in 2005 (the entire spring and late summer were marked by a very high precipitation) have created conditions for greater development of taxa *Dinophysis* spp., which is mostly expressed in Kaštela Bay at the station ST103, where we have had a higher frequency of findings during the warm period of the year. Mali Ston Bay was marked by a smaller frequency of findings for most of the taxa, except small pennatae diatoms, *Pseudonitzschia* spp. and from a dinoflagellate group *Gymnodinium* spp. Coccolithophorids contributed more to the community composition in Mali Ston Bay area, then in other areas of research. Since, the highest phytoplankton biomass have been recorded at stations which are the closest to the land and under strong freshwater and urban influence, phytoplankton biomass has been confirmed as good indicator of eutrophication proces. Diatoms bloom in the summer period in Šibenik and Kaštela Bay indicate antropogenic influence. Phytoplankton community composition reflects the nutrient compositon in the bays. Diatoms bloom characterizes all three bays causing the significant correlation with silica at all investigated area. *Skeletonema costatum* is the most abundant in Šibenik Bay where nitrogen nutrients were in excess and phosphorus limited the growth, while

Mali Ston Bay characterizes *Chaetoceros* species which has lowest phosphorus requirement.

ACKNOWLEDGEMENTS

This research was supported by the Croatian Ministry of Science, Education and Sports as a part of these research programs: Role of plankton communities in the energy and matter flow in the Adriatic Sea (project no. 001-0013077-0845) and Ecological Research of toxic phytoplankton and shellfish toxicity (project no. 001-0010501-0848). We wish to thank our Laboratory operatives Ivan PEZO and Heliodor PRELESNIK for the assistance in the field work, anonymous reviewers for constructive comments and all the people in our Laboratory for help and support.

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Received: 20 August 2012
Accepted: 22 October 2012

Struktura populacije i brojnost fitoplanktonske zajednice u tri zaljeva na istočnoj obali Jadrana, Šibenskom zaljevu, Kaštelanskom zaljevu i Malostonskom zaljevu

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SAŽETAK

U ovom radu je analizirana struktura fitoplanktonske zajednice i brojnosti fitoplanktona u tri zaljeva na istočnoj obali Jadrana (Šibenski zaljev, Kaštelanski zaljev i Malostonski zaljev) tijekom 2005. Najveća biomasa fitoplanktona (izražena preko klorofila *a*) je zabilježena na jednoj postaji u Šibenskom zaljevu (4,73 mg m^{-3}), te jednoj postaji u Kaštelanskom zaljevu (2,79 mg m^{-3}), dok su na svim ostalim postajama zabilježene vrijednosti bile niže od 1 mg m^{-3}. Na istraživanom području Šibenskog zaljeva određeno je ukupno 114 taksonomskih kategorija fitoplanktona. Najraznovrsnije su bile dijatomeje sa 61 i dinoflagelati sa 37 taksonomskih kategorija. Kokolitoforidi su pridonijeli sa 6, kriptofiti sa 3, silikoflagelati, euglenofiti i klorofiti sa 2 taksonomske kategorije. Na području Kaštelanskog zaljeva su zabilježene 193 taksonomske kategorije. Dinoflagelati su bili najraznovrsniji sa 92 taksonomske kategorije, slijede dijatomeje (80), kokolitoforidi (9), silikoflagelati i euglenofiti (4), kriptofiti (2) te klorofiti (1). U području Malostonskog zaljeva ukupno je pronađeno 88 fitoplanktonskih taksonomskih kategorija; dijatomeje 39, dinoflagelati 36, silikoflagelati 2, kokolitoforidi 4, euglenofiti 2, klorofiti 1, te krizofiti 3. Brojnost dinoflagelata u ovom području je bila niska dok su kokolitoforidi više doprinijeli sastavu zajednice u ovom području nego na drugim istraživanim područjima. Raznorodna grupa mikroflagelata je bila prisutna sa visokom frekvencijom pojavljivanja na svim istraživanim područjima. Za vrijeme istraživanog perioda pojavljuje se relativno mali broj monospecifičnih cvatnji. Statistička obrada okolišnih parametara i sastava fitoplanktonske zajednice je ukazala na najveći broj vrsta na postajama koje su pod snažnim utjecajem slatkovodnih dotoka i jakim antropogenim utjecajem.

Ključne riječi: fitoplankton, taksonomski sastav, klorofil *a*, istočna obala Jadrana