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TAXONOMIC COMPOSITION AND SEASONAL DISTRIBUTION OF MICROPHYTOPLANKTON IN MALI STON BAY (EASTERN ADRIATIC)

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Mali Ston Bay is an elongated, sparsely inhabited neritic environment and traditionally important shellfish-farming region in the south-eastern part of the Adriatic coast. The hydrography of the bay is influenced by the specific karstic hydrology (underwater springs in the inner part of the bay), and the Neretva River discharging into the outer part of the bay. Due to the estuarine circulation in winter, a stratified water column is formed, the surface layer being mostly formed above, and the subsurface layer below 6 m in depth. This vertical structure was detected on the basis of temperature, salinity, and phytoplankton and non-living suspended particle distribution. Phytoplankton accumulated most frequently in the surface layer in more stable conditions, and below the halocline during greater input of freshwater. Due to the relatively low phytoplankton cell density, the cell density of species indicating nutrient enrichment, as well as high species diversity and transparency, Mali Ston Bay may be indirectly classified as moderately eutrophic ecosystem, and recommended for the further development of shellfish farming activities.

Key words: Phytoplankton, halocline, stratification, cell density, chlorophyll, thermohaline conditions, suspended particles, Neretva river

Introduction

Mali Ston Bay is an elongated, eastern Adriatic coastal environment (Fig. 1), providing favourable conditions for the development of shellfish larvae and shellfish farming activities (VILIČIĆ et al. 1994, JASPRICA et al. 1997). The coasts of the bay are sparsely inhabited, and covered with dense Mediterranean vegetation. The hydrographic conditions in the bay are influenced by 1) the general circulation along the eastern Adriatic coast (ZORE-ARMANDA 1969, BULJAN and ZORE-ARMANDA 1976), 2) the hydrology of the Neretva River, the pluviometric regime (B. and I. PENZAR 1980), as well as the position of the mouth of the Neretva River in the outer part of the bay, and underwater springs in the inner part of the bay.

Since the limestone in the surrounding hinterland is very permeable, water circulation takes place mostly through underground connections between swallow holes ("ponors") and submarine springs ("vruljas"), with a high gradient (0.1–5 cm s^{-1}) of ground water discharge towards the sea (HERAK 1972, BAHUN 1981).The Neretva River discharges into the sea in the NW part of the bay. Maximum input of fresh water into the sea occurs during the rainy period in November-December, and during the period in which snow melts in the Dinaric Alps, in April (B. and I. PENZAR 1980, Croatian Meteorological and Hydrological Service unpublished data).

Mali Ston Bay is influenced by winds blowing from two directions (along the elongated bay). The south wind ("jugo") induces an outgoing surface current, and an ingoing bottom current, while the north wind ("bura") and the west wind ("maestral", mostly in summer) induce an ingoing surface current, and an outgoing bottom current in the bay (VUČAK et al. 1981). The phase-lag between surface and bottom current velocity is 180°. According to the vertical distribution of current velocities, the surface layer thickness was estimated as being in the range of between 10 and 15 m in the outer part of the bay, and about 5 m in the inner part of the bay (at the Usko station). During winter, estuarine circulation prevails, while during summer, both ingoing and outgoing surface velocities are present, depending only on the wind direction.

Mali Ston bay has been the object of seasonal investigations in the periods 1979–1985 and 1988–1989, resulting in several publications on phytoplankton taxonomy (VILIČIĆ 1985a) and ecology (MARASOVIĆ and PUCHER-PETKOVIĆ 1981; VILIČIĆ 1981, 1985b, 1989; VILIČIĆ et al. 1994; CARIĆ et al. 1992; JASPRICA et al. 1994).

According to the frequency distribution of phytoplankton cell density values and phosphate concentrations, the bay has been qualified as moderately/naturally eutrophicated ecosystem (VILIČIĆ 1989). In such conditions, the production and distribution of mussels and oysters (and their larvae) have been shown to respond mostly to thermohaline conditions and successive feeding on valuable suspended particles such as: nanoplankton, microzooplankton, non-living organic particles (detritus), and inorganic particles coated with organic film and attached bacteria (VILIČIĆ et al. 1994, JASPRICA et al. 1994).

The scope of this paper is to present: 1) monthly variations of phytoplankton cell density during the five years of investigation, 2) the taxonomic composition of phytoplankton, with population density values and corresponding frequency of findings, and 3) tolerance of phytoplankton to thermohaline conditions.

Materials and methods

Water samples for the analyses of phytoplankton were collected at the 12 m deep Usko station, in the inner part of Mali Ston Bay (Fig. 1), in the periods July 1979–July 1980, December 1981–November 1982, March 1983-February 1984, July 1984–July 1985, and February 1988–July 1989. During 1979/80, samples were taken at five stations, from the outer to the inner part of the bay. Phytoplankton was sampled using 5-liter Niskin bottles at 0, 5 and 10 m depths (during 1979/80, 1981/82 and 1983/84), and at 0, 2, 4, 6, 8, 10 and 12 m (during 1988/89), respectively. Samples were preserved in a 2 % (final concentration) neutralised formaldehyde solution. The cell counts were obtained by the inverted microscope method (UTERMÖHL 1958). Subsamples of 25 and 50 mL were analysed microscopically, after a sedimentation time of 48 h, within 2 months of the cruise. Cells longer than 20 μm were designated as microphytoplankton (MICRO). Cells were counted at a magnification of 400 X (1 to 2 transacts) and 100 X (transacts along the rest of the counting chamber base plate. Cells 2 to 20 μm long were designated as nanoplankton (NANO). NANO cells were counted in 10–20 randomly selected fields of vision along the counting chamber base--plate, at a magnification of 400 X). The precision of the counting method for MICRO was ±10 %.

The amount and size distribution of suspended organic matter (not including phytoplankton) was determined according to LENZ (1974).

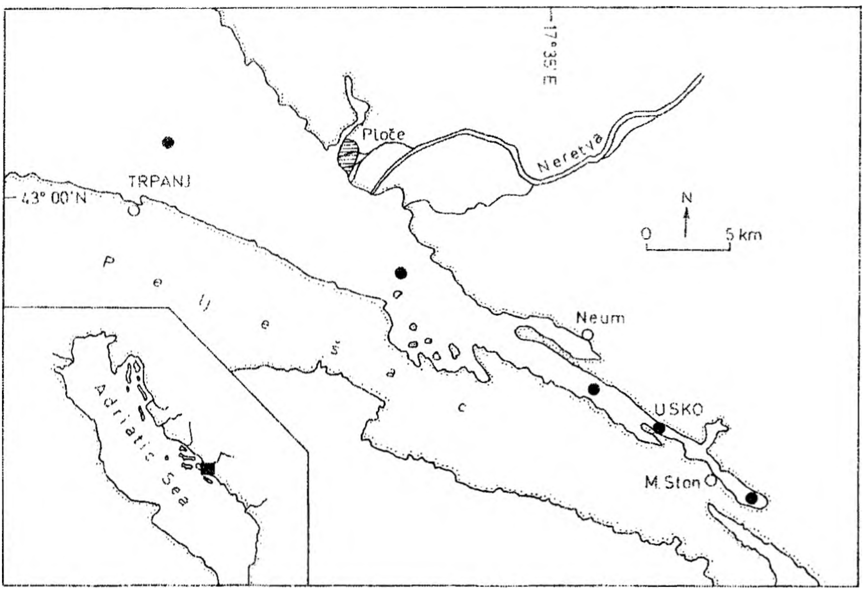

Fig. 1. Location of stations in Mali Ston Bay

Chlorophyll a (Chl a) concentrations were estimated using a 112 Turner design fluorometer, following the method of PARSONS et al. (1984). For this purpose, subsamples (500 mL) were filtered using Whatman GF/C filters (1.2 µm mean pore size). Distribution of rare MICRO species (not found in bottle samples) was determined using plankton closing net (53 µm pore size) samples (vertical hauls). The frequency of findings in Table 2 was calculated using data from both bottle and net samples.

The diversity of microphytoplankton species was estimated according to SHANNON and WEAVER (1963).

Salinity and temperature were determined using an Autolab-MK-IV inductive salinometer and Richter-Wiese reversing thermometers. A white Secchi disc (30 cm in diameter) was used for estimating transparency.

Results

General hydrographical and biological characteristics (range, average and modal values) of the Usko station in Mali Ston Bay are specified in Table 1.

Due to the seasonal distribution of microphytoplankton cell density, there is no single, general pattern of phytoplankton succession, with one spring and another autumn maximum, as has already been revealed (MARRASÉ et al. 1989). Two annual maxima were most frequently dispersed in the period from March to September (Fig. 2); i.e. in March 1988, July 1980 and 1884, August 1982 and September 1983. Alternations between maxima of phytoplankton cell density and the Neretva River discharge (river water-level) were revealed during 1979/80 and 1984/85. Maximum water level was recorded in the period from October–December (1979, 1981, 1984), and in February (1983). There are no water-level data for 1988. Maximum MICRO cell density was recorded in July 1980 (2.13×10^6 cells L^{-1}).

There is a significant positive correlation ($p<0.001$) between MICRO cell density and chlorophyll a concentration in cell size fraction larger than 20 µm during 1988/89 (Fig. 3).

T-S-phytoplankton diagrams indicate groups: diatoms, dinoflagellates and nanoplankton, which develop in different environmental conditions (Fig. 4). Growth of diatoms is limited to more saline environment, while dinoflagellates (DINO) may be successful in brackish water. Diatoms were most abundant in periods with temperature between 16 and 24 °C, dinoflagellates in periods with temperatures higher than 24 °C.

Number of suspended particles (except phytoplankton) most frequently increased below the depth of 6 m (Fig. 5). The largest particles mostly accumulated in the middle of the water column (at the depth of about 6 m).

Seasonal appearance of particular species is presented in table 2. However, poor replicability of population density was found.

One hundred ninety five taxa have been determined by light microscopy (2 silicoflagellates, 7 prymnesiophytes, 101 diatoms, 84 dinoflagellates and 1 euglenophyte) (Tab. 3). Among diatoms, centric diatoms were most common. Pennate diatoms contributed only 36 taxa. Diatoms such as: *Nitzschia longissima, Pseudonitzschia spp., Rhizosolenia stolterfothii, Thalassionema nitzschioides,* and gymnodinoid dinoflagellates, were most frequently found ($F > 40\%$). The

Table 1. Basic hydrographic and phytoplankton parameters in Mali Ston Bay (at station Usko)

Parameter	*n*	Min	Max	Avg	Mod	Period of measurements
MICRO cell density (cells L^{-1})	61	4470	2.1×10^{6}	1×10^{5}	6×10^{4}	Jul. 1979–Nov. 1982
Biomass (μg L^{-1} Chl *a*)	83	0.21	6.73	1.45	0.69	Feb. 1988–Jul. 1989
Diversity index (H')	39	0.10	4.2	2.61	2.52	Jul.1979–Jul. 1980
Temperature (°C)	159	12.30	22.7	18.58	13.6	Jul. 1979–Nov. 1982, Feb. 1988–Jul. 1989
Salinity (‰)	159	21.97	38.65	37.49	37.63	Jul. 1979–Nov. 1982
Transparency (m)	74	3	12	7	9	Jul. 1979–Nov. 1982
Oxygen (saturation, %)	84	86	132	109	119	Feb. 1988–Jul. 1989
PO_4 (μmol L^{-1})	83	0.01	0.33	1.29	0.10	Feb. 1988–Jul. 1989
SiO_4 (μmol L^{-1})	83	0.21	6.24	2.3	2.1	Feb. 1988–Jul. 1989
NO_3 (μmol L^{-1})	83	0.17	9.73	1.8	1.6	Feb. 1988–Jul. 1989

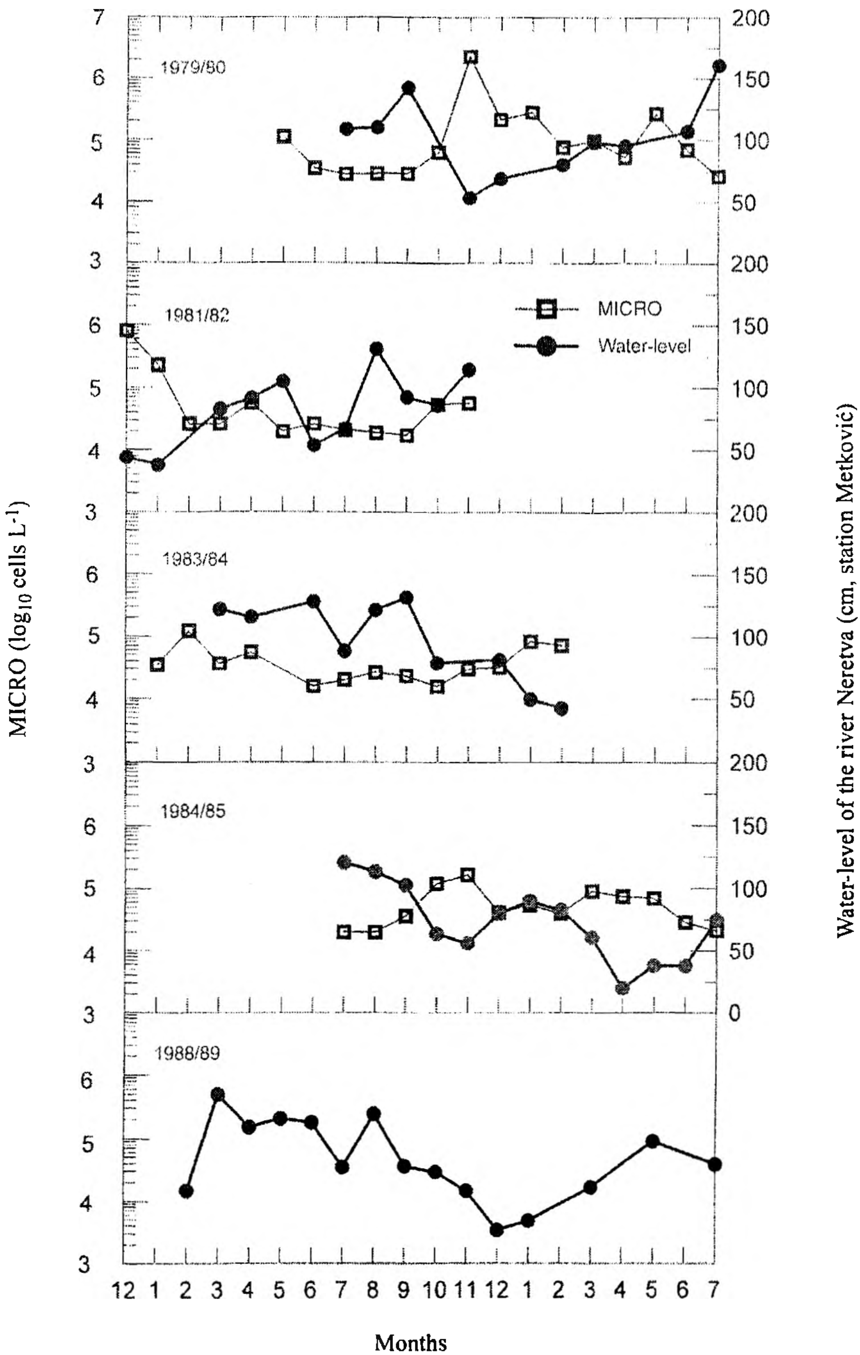

Fig. 2. Seasonal distribution of microphytoplankton (MICRO) cell density (water column average) at the Usko station, compared to the impact of the Neretva River discharge (indirectly indicated by the water-level)

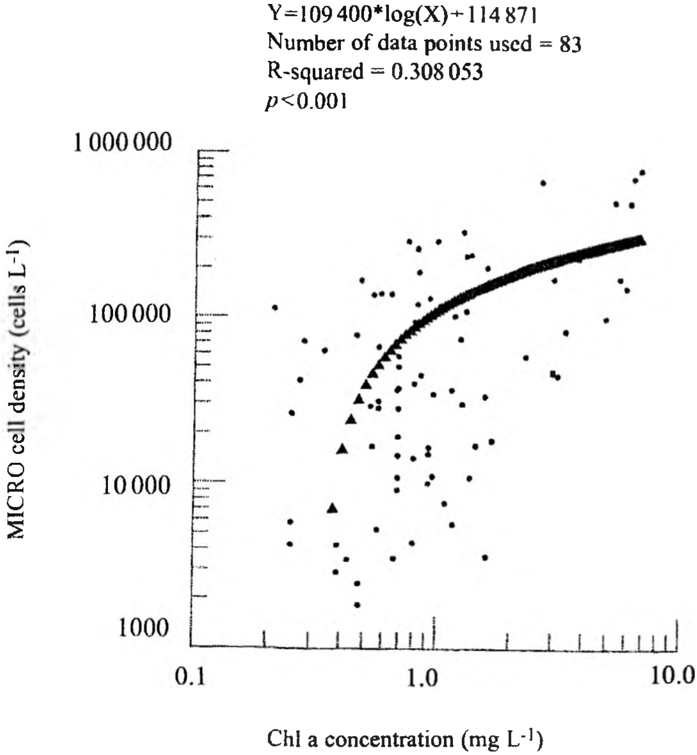

Fig. 3. Correlation between microphytoplankton (MICRO) cell density and phytoplankton biomass (chlorophyll a concentration) in Mali Ston Bay (at the Usko station), during 1988/89

most abundant diatoms were those with cell density $>10^5$ cell L^{-1}, such as: *Chaetoceros compressus* (1.2×10^6), *Ch. brevis* (2.2×10^5), *Ch. vixvisibilis* (7.1×10^5), *Leptocylindrus danicus* (1.8×10^5) and *Pseudonitzschia spp.* (1.1×10^5). Among coccolithophorids (prymnesiophytes), two species: *Anoplosolenia brasiliensis* and *Syracosphaera puchra*) were most frequently recorded ($F < 20$ %).

Among diatoms, most species were represented by the genus *Chaetoceros* (26), among dinoflagellates *Ceratium* (19), *Oxytoxum* (10) and *Protoperidinium* (14), which provided representative species of the neritic community of this region.

Discussion

Longitudinal and vertical distribution of salinity and temperature in Mali Ston Bay was analysed elsewhere (Viličić et al. 1994, Jasprica 1987). There are two periods of stratification: in summer and in winter. In summer it is influenced by solar heating and impact of the Neretva River, in winter by freshwater input through underwater springs in the inner part of the bay. At the Usko station, the halocline is most frequently in the layer between 2–5 m depth.

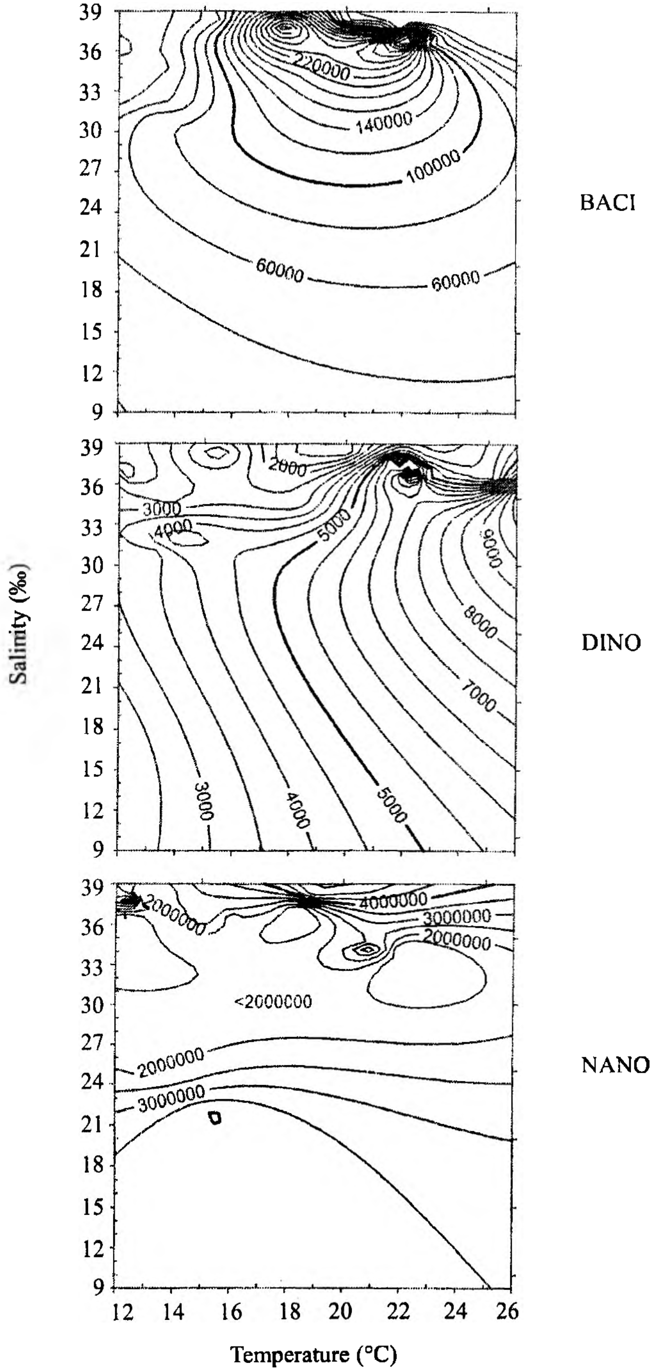

Fig. 4. T-S-phytoplankton diagrams constructed for diatoms (BACI), dinoflagellates (DINO) and nanoplankton (NANO) at the Usko station, in the period 1979–1985 and 1988–1989.

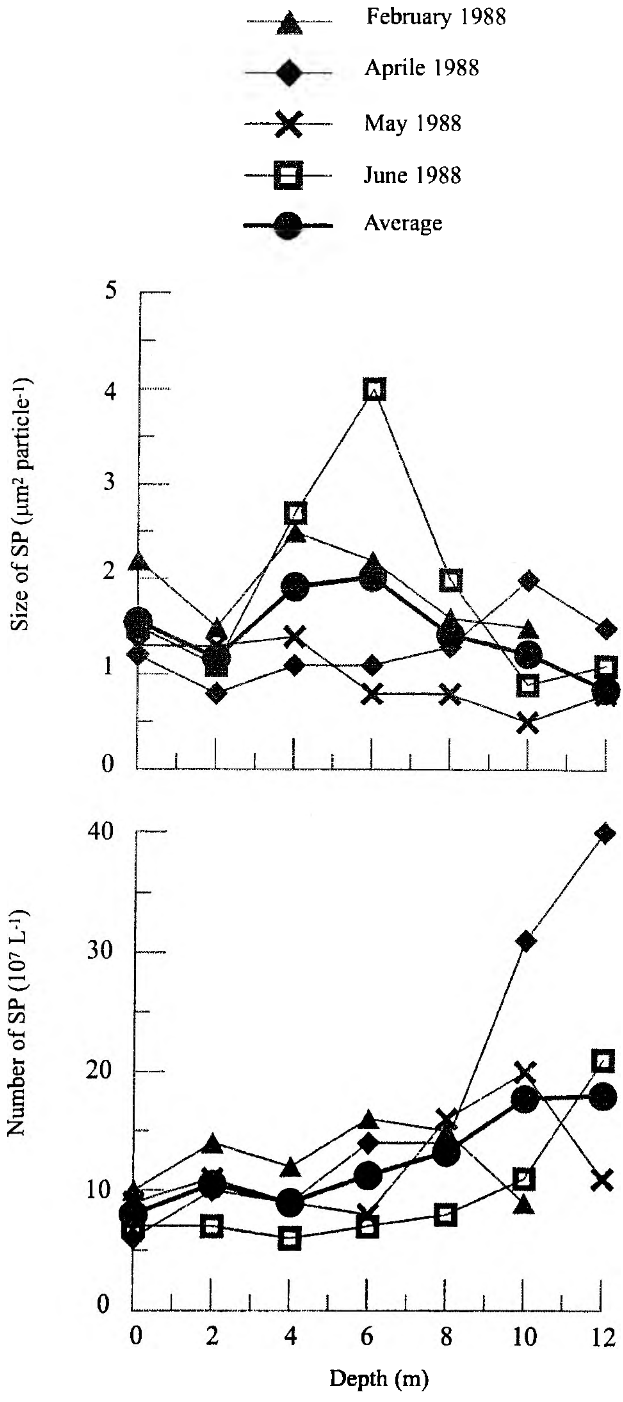

Fig. 5. Vertical distribution and size of non-living suspended particles (SP) in the water column, at the Usko station

Tab. 2. Seasonal distribution of microphytoplankton taxa showing mean cell density (cells L^{-1}) at Station Usko, during 1979/80, 1981/82, 1983/84 and 1988/89. Number of samples is 173. Numbers in bold indicate three annual maximum values. Species are ranked according to successional appearance throughout the year

Taxa	Months											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Bacteriastrum hyalinum Lauder	0	0	**2253**	**497**	262	**1327**	0	103	0	0	0	0
Prorocentrum micans Ehrenb.	67	**630**	**597**	**988**	223	358	205	250	137	516	170	35
Chaetoceros curvisetus Cleve	95	**1162**	**1660**	0	58	0	84	1118	10	454	**3892**	160
Rhizosolenia imbricata Brightw.	80	64	**10245**	**5399**	**1594**	435	165	257	70	123	18	87
Chaetoceros danicus Cleve	**146**	52	**247**	0	0	56	0	85	45	12	**479**	43
Calciosolenia murrayii Gran	119	24	0	0	0	0	0	0	2	**1319**	**3656**	**208**
Dictyocha speculum Ehrenb.	**55**	**98**	52	0	0	0	0	0	5	**113**	29	45
Anoplosolenia brasiliensis (Lohm.) Gerl.	67	24	38	247	0	40	16	210	163	**765**	**568**	**1415**
Dinophysis caudata Seville – Kent	0	7	12	**112**	0	7	0	0	0	0	**45**	**15**
Guinardia striata **(Stolt.) Hasle**	218	**2969**	**38779**	**11236**	734	81	248	1695	1230	527	1135	137
Bacteriastrum delicatulum Cleve	0	6	**1604**	642	291	1065	**2091**	**1341**	37	0	0	0
Cerataulina pelagica (Cleve) Hendey	75	544	**2624**	**1897**	1231	180	694	**5125**	397	12	1477	479
Chaetoceros compressus Laud.	0	30	**102929**	22726	**82838**	28024	**137767**	19974	38038	666	0	0
Leptocylindrus danicus Cleve	328	540	2167	**16160**	5020	1115	3618	**23661**	**10507**	9313	19818	5867
Nitzschia longissima (Breb.) Ralfs.	464	123	**3833**	2750	1574	1422	1716	**3273**	3014	**5403**	2136	1964
Dactyliosolen fragilissimus **(Berg.) Hasle**	76	295	**2172**	**1662**	306	915	1186	**2610**	734	574	199	97
Pseudonitzschia spp.	195	2688	**12271**	11349	8328	11517	9590	**15146**	**24502**	2286	1391	1031
Thalassionema nitzschioides Grun.	480	544	**6721**	1057	704	193	324	**3956**	**8788**	986	2031	841
Ceratium fusus (Ehrenb.) Dujardin	33	12	71	**159**	90	89	61	73	96	**107**	**105**	3
Ceratium tripos (Mûll.) Nitzsch	0	12	**218**	28	**138**	**128**	39	20	17	95	34	2
Asterionella bleakeleyii W. Sm.	0	0	**134**	0	0	0	**421**	0	**319**	0	0	0
Chaetoceros vixvisibilis Schiller	543	247	1686	257	10105	**87760**	**68048**	**48081**	44856	393	0	0
Proboscia alata **(Brightw.) Sund.**	61	24	235	327	697	**3206**	2430	**6391**	**6786**	347	230	67
Syracosphaera pulchra Lohm.	105	0	0	64	58	0	0	**888**	386	**400**	**940**	66
Thalassiothrix mediterranea Pav.	0	0	6	0	0	0	46	60	**1771**	**730**	0	**102**

Tab. 3. List of determined phytoplankton species in Mali Ston Bay (Usko). Samples taken in 1979/80 and 1981/82. *F* – denotes frequency of findings; *F* (%) – relative frequency of findings; AVG – average population density (cells L^{-1}); MAX – maximum population density; n – number of samples. 63 bottle samples and 24 net samples were analyzed. *n* of species found in net samples only is 63+24. Species found in net samples only are denoted by * and *N* (<40 cells L^{-1}).

Taxon	*n*	*F*	*F(%)*	*AVG*	*MAX*
CHRYSOPHYTA -CHRYSOPHYCEAE					
Dictyocha fibula Ehrenb.	63	9	14.3	187.9	10220
Dictyocha speculum Ehrenb.	63	5	7.9	31.7	640
PRYMNESIOPHYCEAE					
Anoplosolenia brasiliensis (Lohm.) Gerl.	63	18	28.6	607.1	16000
Calciosolenia murrayii Gran	63	10	15.9	942.9	38300
Calyptrosphaera oblonga Lohm.	63	6	9.5	225.9	9590
Rhabdosphaera clavigera Murray et Black.*	87	4	4.6	(*N*)	<40
Rhabdosphaera stylifer Lohm.*	87	6	6.9	(*N*)	<40
Rhabdosphaera tignifer Schiller*	87	9	10.3	(*N*)	<40
Syracosphaera pulchra Lohm.	63	17	27.0	387.3	19170
BACILLARIOPHYCEAE					
Achnanthes longipes Agardh*	87	4	4.6	(*N*)	<40
Actynocyclus octonarius Ehrenb.*	87	4	4.6	(*N*)	<40
Amphiprora decussata (Grun.) Cleve*	87	3	3.4	(*N*)	<40
Amphiprora pulchra Bail.*	87	1	1.1	(*N*)	<40
Amphiprora sulcata O'Meara*	87	1	1.1	(*N*)	<40
Amphora ostrearia Bréb.*	87	3	3.4	(*N*)	<40
*Asterolampra mary*landica Ehrenb.*	87	11	12.6	(*N*)	<40
Asterionella bleakeleyii W.Sm.	63	32	50.8	40.6	1280
Asterionella glacialis Castr.	63	35	55.6	26.3	960
Asteromphalus heptactis (Bréb.) Ralfs	63	4	6.3	12.7	400
Auricula insecta (Grun.) Cleve*	87	1	1.1	(*N*)	<40
Bacillaria paxillifer (Muell.) Hendey*	87	2	2.3	(*N*)	<40
Bacteriastrum biconicum Pav.*	87	1	1.1	(*N*)	<40
Bacteriastrum elongatum Cleve*	87	1	1.1	(*N*)	<40
Bacteriastrum delicatulum Cleve	63	20	31.7	1137.9	16700
Bacteriastrum hyalinum Lauder	63	6	9.5	764.4	40260
Campylodiscus thuretii Bréb.*	87	1	1.1	(*N*)	<40
Cerataulina pelagica (Cleve) Hendey	63	32	50.8	1466.2	70680
Chaetoceros affinis Laud.	63	15	23.8	751.1	20530
Chaetoceros anastomosans Grun.	63	34	54.0	999.7	35180
Chaetoceros atlanticus Cleve	63	31	49.2	60.8	3830
Chaetoceros brevis Schutt	63	8	12.7	4560.0	223890
Chaetoceros coarctatus Laud.	63	31	49.2	3.2	480
Chaetoceros compressus Laud.	63	24	38.1	60364.3	1210590
Chaetoceros convolutus Castr.	63	4	6.3	141.6	8000
Chaetoceros costatus Pav.	63	31	49.2	111.6	7030
Chaetoceros curvisetus Cleve	63	10	15.9	1001.4	11480
Chaetoceros dadayi Pav.	63	2	3.2	7.6	240
Chaetoceros danicus Cleve	63	8	12.7	173.7	5470

Tab. 3. – continued	*n*	*F*	*F(%)*	*AVG*	*MAX*
Chaetoceros decipiens Cleve	63	26	41.3	1063.2	55160
Chaetoceros delicatulus Ostenf.*	87	7	8.0	(*N*)	<40
Chaetoceros didymus Ehrenb.	63	31	49.2	121.7	7670
Chaetoceros diversus Cleve	63	13	20.6	250.5	4800
Chaetoceros lauderi Ralfs	63	2	3.2	6.5	250
Chaetoceros lorenzianus Grun.*	87	7	8.0	(*N*)	<40
Chaetoceros messanensis Castr.*	87	3	3.4	(*N*)	<40
Chaetoceros perpusillus Cleve*	87	9	10.3	(*N*)	<40
Chaetoceros peruvianus Brightw.*	87	1	1.1	(*N*)	<40
Chaetoceros rostratus Laud.	63	5	7.9	443.8	27640
Chaetoceros simplex Ostenf.	63	4	6.3	101.6	5120
Chaetoceros tetrastichon Cleve	63	31	49.2	3.8	480
Chaetoceros tortissimus Gran*	87	1	1.1	(*N*)	<40
Chaetoceros vixvisibilis Schiller	63	21	33.3	47068.1	711000
Chaetoceros wighamii Brightw.*	87	2	2.3	(*N*)	<40
Cocconeis scutellum Ehrenb.*	87	3	3.4	(*N*)	<40
Coscinodiscus janischii Schm.*	87	2	2.3	(*N*)	<40
Coscinodiscus perforatus Ehrenb.	87	2	2.3	1.3	40
Coscinodiscus thorii Pav.*	87	4	4.6	(*N*)	<40
Dactyliosolen blavyanus (Perag.) Hasle (=*Guinardia blavyana* Perag.)	63	3	4.8	25.4	1280
Dactyliosolen fragilissimus (Berg.) Hasle (=*Rhizosolenia fragilissima* Berg.)	63	23	36.5	744.9	19360
Detonula pumila (Castr.) Schütt	63	31	49.2	3.8	480
Diploneis bombus Ehrenb.	63	23	36.5	435.2	12480
Eucampia cornuta (Cleve) Grun.	63	6	9.5	41.9	640
Guinardia flacida (Castr.) Perag.	63	29	46.0	323.0	6740
Guinardia striata (Stolt.) Hasle (=*Rhizosolenia stolterfothii* Perag.)	63	46	73.0	1024.6	12780
Gyrosigma balticum (Ehrenb.) Rabenh.*	87	1	1.1	(*N*)	<40
Hemiaulus hauckii Grun.	63	22	34.9	297.5	10220
Hemiaulus sinensis Grev.	63	15	23.8	306.8	7340
Leptocylindrus danicus Cleve	63	36	57.1	6887.0	179000
Leptocylindrus minimus Gran	63	4	6.3	643.8	33200
Leptocylindrus mediterraneus (Perag.) Hasle	63	6	9.5	73.7	2400
Licmophora ehrenbergii (Kütz.) Grun.*	87	1	1.1	(*N*)	<40
Licmophora flabellata (Carm.) Agardh.	63	2	3.2	5.7	320
Licmophora gracilis (Ehrenb.) Grun.	63	10	15.9	48.4	1600
Lithodesmium undulatum Ehrenb.	63	2	3.2	20.3	640
Melosira nummuloides (Dillw.) Agardh.	63	1	1.6	20.3	1280
Navicula distans (Sm.) Cleve*	87	3	3.4	(*N*)	<40
Nitzschia incerta Grun.	63	8	12.7	84.4	2560
Nitzschia longissima (Brèb.) Ralfs.	63	50	79.4	2019.8	12780
Nitzschia lorenziana Grun.*	87	3	3.4	(*N*)	<40
Nitzschia panduriformis Greg.	63	8	12.7	118.1	2560
Odontella mobiliensis (Bail.) Grun.*	87	2	2.3	(*N*)	<40
Paralia sulcata (Ehrenb.) (=*Melosira sulcata* Ehrenb.) Kutz.	63	2	3.2	5.7	320
Pleurosigma angulatum (Quekett) W.Sm.	63	7	11.1	306.0	11500
Pleurosigma attenuatum (Kütz.) Sm.*	87	2	2.3	(*N*)	<40
Pleurosigma axsul Cleve*	87	2	2.3	(*N*)	<40

Tab. 3. – continued	*n*	*F*	*F(%)*	*AVG*	*MAX*
Pleurosigma formosum W. Sm.*	87	3	3.4	(*N*)	<40
Pleurosigma macrum W. Sm.*	87	2	2.3	(*N*)	<40
Proboscia alata (Brightw.) Sund. (=*Rhizosolenia alata* Brightw.)	63	28	44.4	1477.3	31120
Pseudonitzschia spp.	63	63	100.0	6800.0	111190
Rhizosolenia calcar-avis Schultze	63	15	23.8	17.9	200
Rhizosolenia imbricata Brightw.	63	31	49.2	595.1	6390
Rhizosolenia robusta Norm.*	87	8	9.2	(*N*)	<40
Skeletonema costatum (Grev.) Cleve	63	33	52.4	99.0	2560
Striatella unipunctata (Lyngb.) Agardh*	87	7	8.0	(*N*)	<40
Synedra fulgens (Grev.) W. Sm.*	87	2	2.3	(*N*)	<40
Synedra longissima Sm.*	87	1	1.1	(*N*)	<40
Synedra toxoneides Castr.*	87	1	1.1	(*N*)	<40
Synedra undulata (Bailey) Gregory*	87	7	8.0	(*N*)	<40
Thalassionema nitzschioides Grun.	63	56	88.9	3311.3	4350
Thalassiosira angulata (Greg.) Hasle (=*Thalassiosira decipiens* (Grun.) Jorg.)	63	32	50.8	7.6	480
Thalassiosira decipiens (Grun.) Jorg.	63	32	50.8	7.6	480
Thalassiosira excentrica (Ehrenb.) Cleve*	87	2	2.3	(*N*)	<40
Thalassiosira sp.	63	13	20.6	1828.7	37060
Thalassiothrix longissima Cleve et Grun.*	87	1	1.1	(*N*)	<40
Thalassiothrix mediterranea Pav	63	32	50.8	13.5	800
Toxoneidea balearica Grun.*	87	1	1.1	(*N*)	<40
Triceratium shadboltianum Grev.*	87	1	1.1	(*N*)	<40
Tropidoneis lepidoptera (Greg.) Cleve*	87	3	3.4	(*N*)	<40
DINOPHYTA					
Ceratium arietinum Cleve*	87	2	2.3	(*N*)	<40
Ceratium buceros Zacharias	63	11	17.5	35.6	920
Ceratium candelabrum Ehrenb.*	87	13	14.9	(*N*)	<40
Ceratium carriense var. *volans* (Cleve) Jörg.*	87	13	14.9	(*N*)	<40
Ceratium euarcuatum Jörg.*	87	4	4.6	(*N*)	<40
Ceratium extensum (Gourr.) Cleve*	87	6	6.9	(*N*)	<40
Ceratium furca (Efrenb.) Clap. et Lachm.	63	30	47.6	65.1	960
Ceratium fusus (Ehrenb.) Dujardin.	63	16	25.4	58.7	640
Ceratium gibberum Gourr.*	87	3	3.4	(*N*)	<40
Ceratium hexacanthum Gourr.*	87	10	11.5	(*N*)	<40
Ceratium karstenii Pav.*	87	10	11.5	(*N*)	<40
Ceratium longirostrum Gourr.*	87	10	11.5	(*N*)	<40
Ceratium macroceros (Ehrenb.) Cleve*	87	11	12.6	(*N*)	<40
Ceratium massiliense (Gourr.) Karsten*	87	12	13.8	(*N*)	<40
Ceratium pentagonum Gourr.*	87	7	8.0	(*N*)	<40
Ceratium ranipes Cleve*	87	2	2.3	(*N*)	<40
Ceratium symetricum Pav.*	87	12	13.8	(*N*)	<40
Ceratium teres Kof.*	87	3	3.4	(*N*)	<40
Ceratium trichoceros (Ehrenb.) Kof.	63	4	6.3	3.2	80
Ceratium tripos (Muell.) Nitzsch.	63	9	14.3	41.7	720
Ceratocorys gourretii Paulsen*	87	1	1.1	(*N*)	<40
Ceratocorys horrida Stein*	87	2	2.3	(*N*)	<40
Dinophysis acuta Ehrenb.*	87	2	2.3	(*N*)	<40
Dinophysis caudata Seville-Kent	63	5	7.9	5.7	160

Tab. 3. – continued	*n*	*F*	*F(%)*	*AVG*	*MAX*
Dinophysis fortii Pav.*	87	1	1.1	(*N*)	<40
Dinophysis hastata Stein	63	2	3.2	20.3	640
Dinophysis parvula (Schütt) Jörg. Bal.*	87	4	4.6	(*N*)	<40
Dinophysis sphaerica Stein	63	35	55.6	9.8	480
Dinophysis tripos Gourr.	63	6	9.5	1.9	480
Diplopsalis lenticula Bergh*	87	6	6.9	(*N*)	<40
Goniodoma polyedricum (Pouchett) Jörg. (=*Triadinium polyedricum* (Pouchett) Dodge)	63	6	9.5	15.2	320
Gonyaulax diacantha (Meunier) Schiller	63	6	9.5	15.2	320
Gonyaulax digitale Kof.*	87	3	3.4	(*N*)	<40
Gonyaulax fragilis (Schütt) Kof.*	87	1	1.1	(*N*)	<40
Gonyaulax hyalina Ostenf. et Schm.*	87	3	3.4	(*N*)	<40
Gymnodinoid cells	63	54	85.7	2031.3	8950
Histioneis joergensenii Schiller*	87	1	1.1	(*N*)	<40
Kofoidinium velelloides Pav.*	87	5	5.7	(*N*)	<40
Lingulodinium polyedrum (Stein) Dodge (=*Gonyaulax polyedra* Stein)*	87	4	4.6	(*N*)	<40
Mesoporos perforatus (Gran) Lillick*	87	1	1.1	(*N*)	<40
Noctiluca scintilans (Macartney) Ehrenb.*	87	1	1.1	(*N*)	<40
Ornithocercus magnificus Stein*	87	2	2.3	(*N*)	<40
Ornithocercus quadratus Schütt*	87	2	2.3	(*N*)	<40
Oxytoxum caudatum Schiller	63	2	3.2	20.3	640
Oxytoxum constrictum (Stein) Buetschli*	87	1	1.1	(*N*)	<40
Oxytoxum gladiolus Stein*	87	1	1.1	(*N*)	<40
Oxytoxum laticeps Schiller*	87	1	1.1	(*N*)	<40
Oxytoxum reticulatum (Stein) Schütt*	87	1	1.1	(*N*)	<40
Oxytoxum sceptrum (Stein) Schröder	63	7	11.1	90.3	4170
Oxytoxum scolopax Stein	63	7	11.1	26.0	640
Oxytoxum sphaeroideum Stein*	87	10	11.5	(*N*)	<40
Oxytoxum tesselatum (Stein) Schütt*	87	2	2.3	(*N*)	<40
Oxytoxum variabile Schiller*	87	3	3.4	(*N*)	<40
Phalacroma argus Stein (=*Dinophysis argus* (Stein) Abe)*	87	1	1.1	(*N*)	<40
Phalacroma mitra Stein (=*Dinophysis mitra* (Schütt) Abe)*	87	6	6.9	(*N*)	<40
Podolampas bipes Stein*	87	6	6.9	(*N*)	<40
Podolampas elegans Schütt*	87	3	3.4	(*N*)	<40
Podolampas palmipes Stein*	87	1	1.1	(*N*)	<40
Protoperidinium brochii (Kof. et Sw.) Bal.*	87	2	2.3	(*N*)	<40
Protoperidinium conicum (Gran) Bal.	63	2	3.2	1.3	40
Protoperidinium crassipes (Kof.) Bal.*	87	11	12.6	(*N*)	<40
Protoperidinium depressum (Bailey) Bal.*	87	11	12.6	(*N*)	<40
Protoperidinium diabolus (Cleve) Bal.	63	6	9.5	7.6	160
Protoperidinium divergens (Ehrenb.) Bal.	63	13	20.6	36.2	640
Protoperidinium globulus (Stein) Bal.	63	7	11.1	33.7	800
Protoperidinium leonis (Pav.) Bal.*	87	13	14.9	(*N*)	<40
Protoperidinium oceanicum (Vanhoeffen) Bal.*	87	16	18.4	(*N*)	<40
Protoperidinium pallidum (Ostenf.) Bal.*	87	9	10.3	(*N*)	<40
Protoperidinium pellucidum Bergh*	87	8	9.2	(*N*)	<40
Protoperidinium pyriforme (Pauls.) Bal.	63	2	3.2	2.5	80
Protoperidinium steinii (Jörg.) Bal.	63	4	6.3	88.9	2560

Tab. 3. – continued	*n*	*F*	*F(%)*	*AVG*	*MAX*
Protoperidinium tubum (Schiller) Bal.	63	5	7.9	15.4	640
Prorocentrum compressum (Bailey) Abe	63	2	3.2	10.2	320
Prorocentrum micans Ehrenb.	63	34	54.0	300.3	3200
Prorocentrum minimum (Pav.) Schiller	63	2	3.2	2.5	80
Prorocentrum scutellum Schröder	63	8	12.7	35.6	640
Prorocentrum triestinum Schiller*	87	3	3.4	(*N*)	<40
Pseliodinium vaubanii Sournia	63	6	9.5	3.8	40
Pyrocystis elegans Pav.*	87	2	2.3	(*N*)	<40
Pyrophacus horologicum Stein	63	8	12.7	66.0	1280
Scrippsiella sp.	63	20	31.7	306.3	2560
EUGLENOPHYTA					
Eutreptia lanowii Steuer	63	4	6.3	61.0	1280

Figures 6 and 7 describe two summer case studies, presenting the distribution of phytoplankton during different salinity regimes. In July 1979, Mali Ston Bay was influenced by decreased Neretva discharge (confirmed by unpublished data of Croatian Meteorological and Hydrological Service), and the increased influence of deeper ingoing currents from the open sea, as compared to July 1980. This resulted in more stable and favourable conditions for phytoplankton growth in the surface layer in the middle and outer part of the Bay. In July 1980, Neretva discharge was increased, resulting in ecological destabilisation of the surface layer, and favourable growth conditions for phytoplankton below the halocline in the inner part of the Bay (Usko).

Due to most frequent changes in the vertical distribution of thermohaline conditions, phytoplankton, and quantity of non-living suspended particles, as well as current measurements (Vučak et al. 1981), the water column at the Usko station might be divided into two layers: the surface layer – from the surface to the depth of 6 m, and the subsurface layer – from the depth of 6 m to the bottom.

Mali Ston Bay is rich in oxygen (saturation varied from 86 to 128 % during 1988/89). Phytoplankton species composition and species diversity reflected stable conditions most of the year. Extensive phytoplankton blooms (red tides) have not been recorded. Although toxic dinoflagellates, some *Dinophysis* spp. were evident, species of this genus were recorded as rare and non-abundant. More serious is the possible impact of *Pseudonitzschia* spp. which produce domoic acid, a neurotoxin which may accumulate in shellfish (Bates et al. 1989, Lundholm et al. 1994), and may be toxic for people who consume such food.

The significant positive correlation ($p < 0.01$) between MICRO cell density and chlorophyll a concentration in cell size fraction larger than 1.2 µm (Fig. 3) might indicate 1) MICRO as a more dominant cell size fraction than nanoplankton, and 2) stable nanoplankton cell density (without larger variations) during the investigated period.

T-S-phytoplankton diagrams indicated 1) wide tolerant dinoflagellates which developed dense populations under variable thermohaline conditions during most of the year, and 2) narrow tolerant diatoms which developed dense populations during relatively short periods of the year.

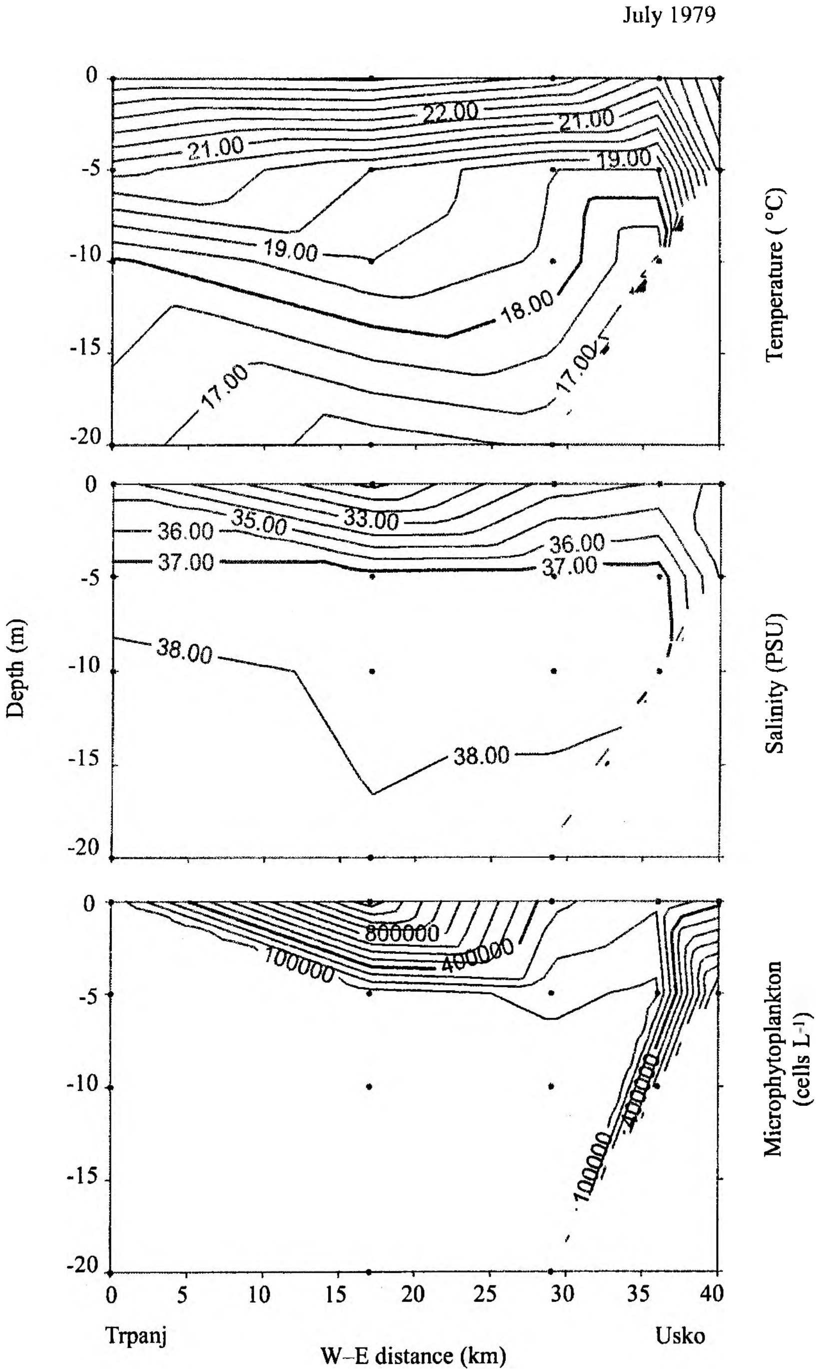

Fig. 6. Distribution of phytoplankton cell density in relation to thermohaline conditions along Mali Ston Bay, in the July 1979 case study

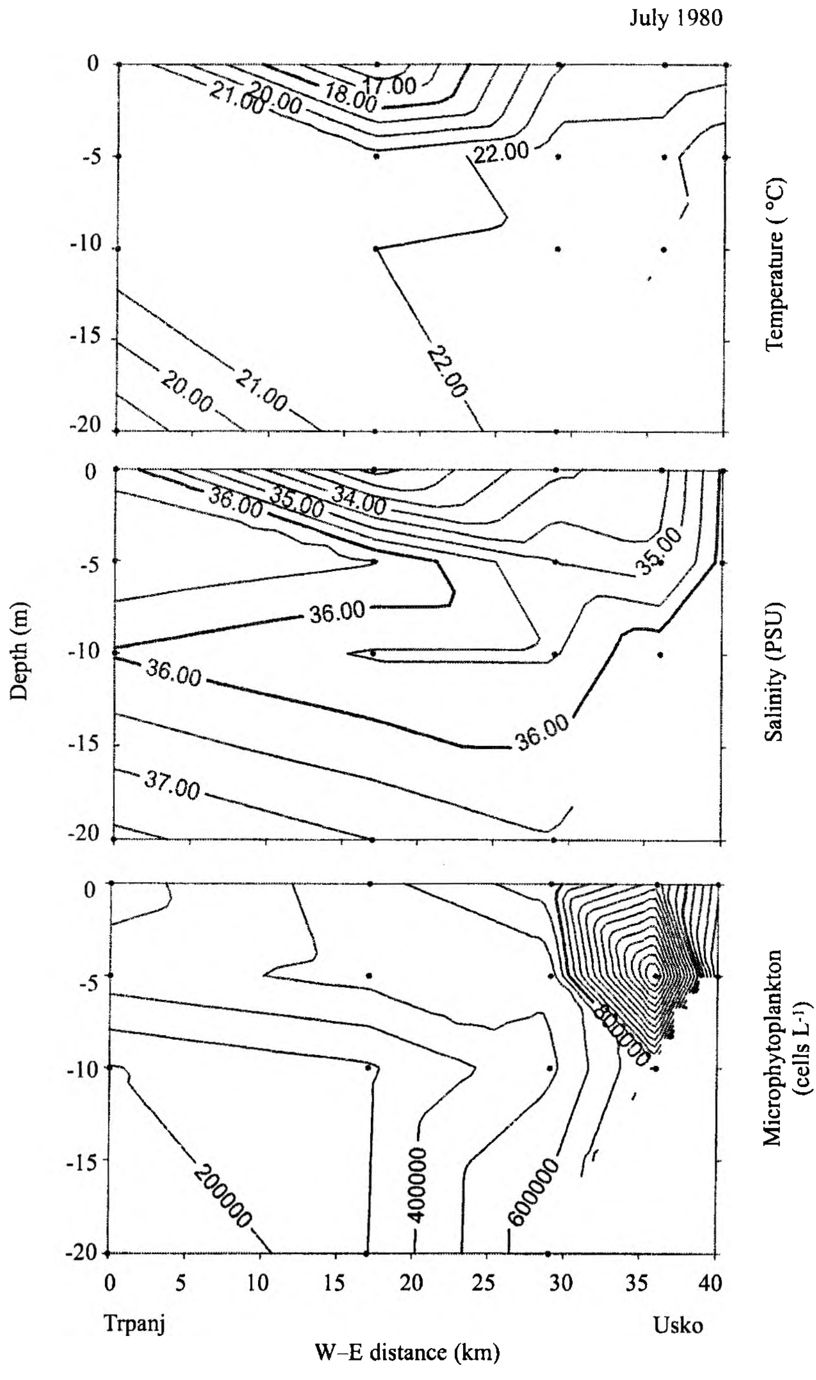

Fig. 7. Distribution of phytoplankton cell density in relation to thermohaline conditions along Mali Ston Bay, in the July 1980 case study

Due to the seasonal distribution of phytoplankton taxa, i.e. their tolerance to salinity and temperature, species might be considered as those characteristic of winter, spring, summer and autumn, respectively.

Range, average and modal values of hydrographical and biological parameters might be considered the result of circulation, trophic state and eutrophication. Results of biological parameters agree with previously determined values, indicating Mali Ston Bay as a moderately eutrophicated ecosystem (Viličić 1989). In addition, the same evidence was shown by low cell density of species which are known as indicators of eutrophic environments. Some indicator species are the diatoms *Leptocylindrus danicus, Skeletonema costatum,* and dinoflagellates belonging to the genus *Prorocentrum* (Yamada et al. 1980).

Detritus in the water column appeared mostly during the periods of precipitation (by the washing out of surrounded sediments, by discharge through rivers and submarine springs), during decay of plankton organisms or production of zooplankton faecal pellets. Particles might accumulate in a particular layer of the water column; in between two water masses of different origins (brackish and marine), as indicated by circulation and the position of the picnocline, halocline and thermocline. The halocline was a layer where the smallest size fraction of phytoplankton (pico-, and nanophytoplankton), as well as detritus accumulated, as has already been indicated in the nearby Krka estuary (Moreira-Turcq et al. 1993).

In Mali Ston Bay, Secchi disc visibility was mostly higher than the depth of the water column (12 m).

According to the physical-chemical and biological parameters analysed, Mali Ston Bay may be considered as an ecologically stable location suitable for the further development of shellfish farming activities.

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