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PHYTOPLANKTON COMMUNITIES OF THE SOUTH ADRIATIC IN THE GREATER VICINITY OF DUBROVNIK

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In four ecologically different habitats (at 9 stations) in the southern Adriatic, four phytoplankton associations, which could be united in two alliances and one order, have been determined. The criterion for determining associations and other communities (alliances and order) was the fidelity of species towards the principles of the Zürich-Montpellier phytocoenologic school. The largest number of the characteristic species of the communities described belongs to the group of *Dinophyta*, even though they are less abundant than *Bacillariophyceae*. The characteristic species of *Haptophyceae* are important only in the open sea community. Acording to the assumption made in this work about some groups of phytoplankton species showing ecological distribution, the associations described can be used as ecological indicators. Because of the complex three-dimensional nature of the marine ecosystem (i. e. horizontal, vertical and time dynamics), the results should be checked in forthcoming investigations.

Introduction

Phytoplankton communities should be described as three-dimensional cell groups shaped like a cloud, whose development has spatial and time dynamics. Winds and currents mix the populations which develop under different ecological conditions. Consequently, the determination of phytoplankton communities is not an easy task. Even today, theories about phytoplankton communities have their followers and adversaries. There is a number of works in which groups or associations of phytoplankton species in various seas are determined by different methods (Margalef 1966, Venrick 1971, Reyssac and Roux 1972, Legendre

1973, Valentine 1973, Zeitzschel 1978, Watling et al. 1979, Maddock et al. 1981, Ohtake et al. 1981 and others). According to Williams and Lambert (1959) the term »community« in phytoplanktonology refers to a group of species that grow together and for whose determination no statistical or ecological analysis is needed. The term »association« usually refers to a stable group of species which are together present at a significant rate. This is determined by established rules (Legendre L. and Legendre P. 1978). Adversaries of the idea that phytoplankton associations do exist claim that all world seas should be regarded in a geobotanical sense as one ocean with an equal composition of species (Williams et al. 1981). However, on the basis of computer analysis of data on distribution of diatoms, the same authors recognize that besides cosmopolitan species there exist also other species that are characteristic of one of the 16 geobotanically defined areas, one of them being the Mediterranean sea.

For the purpose of determining associations of phytoplankton species a number of procedures has been worked out. At first, this work was handled empirically, later with the help of computers. The use of computers in phytosociology found its application in direct and indirect analysis of gradients, both in land and water ecosystems (Sneath and Sokal 1973, Spatz and Siegmund 1973, Legendre L. and Legendre P. 1978, Whittaker 1978). All these procedures have two common goals: first, to determine which species go together; second, to make certain that the assertion made is realistic. To do that, phytoplankton should be collected by using a specific experimental strategy where geographic characteristics of a region should be considered as well as work at various depth or in specific time intervals.

The phytoplankton communities of the southern Adriatic were defined according to the principles of Zürich-Montpellier phytosociological school, which are used in the investigations of terrestrial vegetation. The terminology of phytoplankton communities in this paper is adjusted according to accepted principles.

To date, phytosociological studies of phytoplankton have not yet been performed in the Adriatic Sea in detail. Only Revelante and Gilmartin (1977) have analyzed the results obtained at one autumn cruise in the open waters of the Adriatic Sea. They made a distinction among three groups of stations with three groups of species living on them: a group of species along the eastern coast, a group along the western coast, and a group in the central part of the Adriatic. Differences in the composition of the phytoplankton were more pronounced in the direction east-west than in the direction north-south.

According to the topographic and oceanographic characteristics, the Adriatic Sea is divided into three parts: north, central and south. The south Adriatic is the deepest and the widest and therefore contains 4.1 times more water than the other two parts together. The south Adriatic depression is located here with its maximum depth of 1243 m. A strong continental influence on the Adriatic Sea and its connection with the eastern Mediterranean through the Otranto Strait result in a specific rhythm in the exchange of water masses between these two systems (Buljan and Zore-Armanda 1976). Besides the currents that are more or less parallel with the Adriatic coasts and besides the vertical currents, there are also transversal currents which go mainly from the eastern to western coast of the Adriatic and are most pronounced in spring and in autumn (Vučak 1965, Zore-Armanma 1968). In the Maloston Bay, there is an irregular circulation influenced by wind in summer, and an marked probable estuarine type of circulation during winter (Vučak et al. 1981).

Temperature and salinity are influenced by the current system and show variations from year to year. These changes are the result of different effects of eastern Mediterranean waters on the Adriatic. A period of increased salinity is a good indicator of the eastern Mediterranean's increased influence on the Adriatic, i.e. Adriatic ingression (Zore-Armanda and Pucher-Petković 1976).

Materials and Methods

Samples for the phytoplankton analysis and for the determination of the basic hydrographic parameters were collected at 9 stations in the open sea and in the coastal region (Fig. 1). The position of the stations and the programme of sample collection, was defined considering the predictable ecological conditions in the south Adriatic.

Samples were taken approximately once a month in the period from June 1979 to July 1980 with Nansen reversing bottles at standard depths and a plankton closing net (mesh size 53 μm) in the layers (Fig. 2).

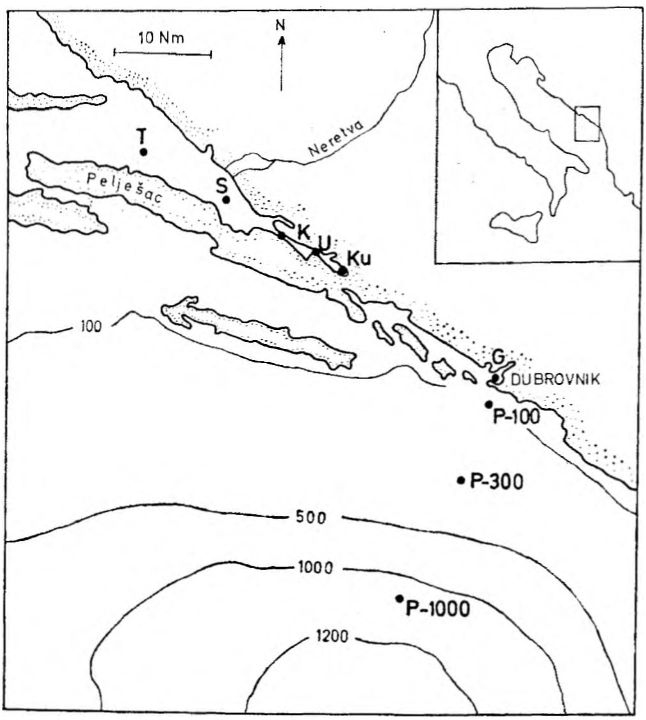

Fig. 1. Map of the area investigated with location of stations. Coastal stations are marked as follows: G = Gruž Bay, T = Trpanj, S = Sreser, K = = Krušica, U = Usko, Ku = Kuta. Stations T, S, K, U and Ku are in the wider area of the Maloston Bay.

Samples were fixed with 2 per cent solution of neutralized formaldehyde. By analyzing the samples collected with Nansen bottles data were obtained on the species of phytoplankton which passed through the plankton net. The qualitative analysis of the phytoplankton was done with a common light microscope, under low and high magnification. The taxonomic nomenclature was coordinated in comparison to Gemeinhardt (1930) for the family *Chrysophyceae*, Schiller (1930) for *Haptophyceae*, Travers A. and Travers M. (1975) and Hendey (1974) for *Bacillariophyceae* and *Prasinophyceae*, and Travers A. and Travers M. (1975) and Schiller (1933—1937) for *Dinophyta*.

The proposed classification of phytoplankton communities were performed on the basis of the established characteristic species, according to the principles of the Zürich-Montpellier phytosociological school, which are used in the investigations of terrestrial vegetation (Braun-Blanquet 1964). Therefore, the criterion for determination of phytoplankton communities was fidelity of species, as a more important property than the number of individuals. Fidelity of species is determined by the comparison of its presence in various stands. It can be presumed that one investigated station is represented by one stand (Fig. 2). The floristic composition in one stand was defined by the analyses of one or more layers, i.e. vegetation records. One vegetation record includes the species found in Nansen bottle samples and net sample. The presence of the species is expressed by the fraction of a number whose numerator represents the number of findings of the species and the denominator represents the total number of the layers analyzed (vegetation records) in the stand investigated, i.e. at one station. Species characteristic of the communities in the south Adriatic are defined statistically on the basis of their presence, in the following way:

— A species is characteristic of the association if its presence there is at least 75 per cent greater than in the other communities.
— A species is characteristic of an alliance if in each of the communities that is connected by allliance its presence is at least 50 per cent greater than in the other communities.
— A species is characteristic of an order if its presence in each community of that order is at least 75 per cent or more.

Results and Discussion

The stations investigated differed in salinity and temperature (Fig. 3). At open sea, at the station P-1000 and P-300 salinity is high during the whole year, with small annual variations (37.09 — 38.96‰). At the station P-100, which is closer to the coast, yearly variations of salinity are somewhat more pronounced (37.71 — 38.90‰). The greatest variations in salinity are at the stations which are closest to the coast; 28.80 — 38.70‰ in the Gruž Bay, and 19.00 — 38.83‰ in the Maloston Bay area. The temperature span at station P-1000 was smaller (13.8 — 24.1° C) than at station P-100 (12.5 — 23.2° C), and in the Gruž Bay it was smaller 12.5 — 24.6° C) than in the Maloston Bay area (10.3 — 24.1° C). The water transparency, measured by a Secchi disc, at the station P-1000 has 27 to 32 m value. In the Maloston Bay area, and in the Gruž Bay, Secchi disc visibility ranged from 3 to 10 m.

The nutrient salts concentration was measured during some previous investigations. The concentration of free phosphorous in the South Adria-

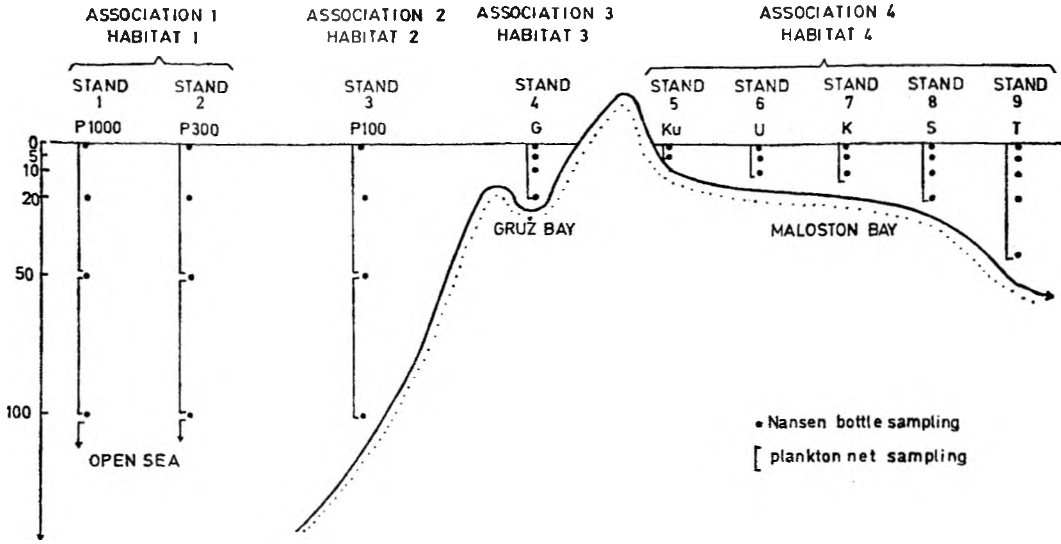

Fig. 2. Depths of sample collections by station and phytosociological terminology applied.

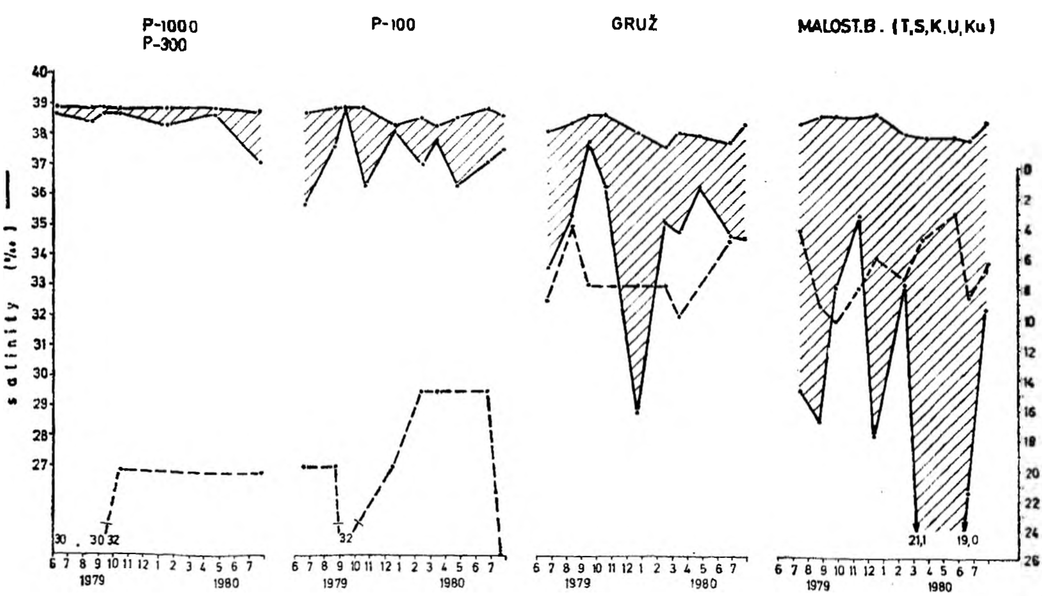

Fig. 3. Range of salinity data and transparency at the stations investigated.

Table 1. LIST OF PHYTOPLANKTON COMMUNITIES
N = number of analyzed layers

	P-1000 P-300 N=30	P-100 N=18	GRUŽ N=10	TSKUKu N=42	
Characteristic species of the assoc. *Discosphaero thomsonii— Coscinodiscetum stellaris*					
Cocsinodiscus stellaris Roper	40	.	.	.	
Coscinodiscus lineatus Ehr.	33	.	.	.	
Discosphaera thomsonii Ostenf.	26	.	.	.	
Gossleriella tropica Schütt	20	.	.	.	
Cladopyxis brachiolata Stein	20	.	.	.	
Dinophysis uracantha Stein	20	.	.	.	a 1
Heterodinium milneri (Murr. et. W.) Kof.	17	.	.	.	
Thorosphaera elegans Ostenf.	13	.	.	.	
Ceratium gravidum Gourr.	27	5	.	.	
Ceratium concilians Jörg.	23	5	.	.	
Planktoniella sol (Wall.) Schütt	20	5	.	.	
Chaetoceros messanensis Castr.	40	5	.	6	
Characteristic species of the assoc. *Dinophysetum tripodis*					
Biddulphia titiana Grun.	.	11	.	.	
Ornithocercus steinii Schütt	.	11	.	.	
Oxytoxum gladiolus Stein	.	11	.	2	a 2
Dinophysis tripos Gourr.	13	50	.	2	
Bacillaria paxillifer (Müll.) Hend.	3	44	10	5	
Ceratium ranipes Cl.	13	55	10	12	
Characteristic species of the alliance *Oxytoxion reticulati*					
Cladopyxis caryophyllum (Kof.) Pav.	27	17	.	.	
Rhizosolenia castracaneii Pér.	17	17	.	.	
Spiraulax kofoidii Graham	20	11	.	.	
Oxytoxum reticulatum (Stein) Schütt	20	11	.	.	
Ceratocorys armata (Schütt) Kof.	13	17	.	.	
Phalacroma acutum (Schütt) Pav.	10	17	.	.	s 1
Dinophysis schuettii Murr. et W.	13	11	.	.	
Dinophysis hastata Stein	20	28	.	5	
Ceratium arietinum Cl.	53	78	20	5	
Bacteriastrum elongatum Cl.	67	33	10	2	
Ornithocercus quadratus Schütt	53	33	10	4	
Goniaulax hyalina Ost. et Schm.	30	22	10	7	
Characteristic species of the assoc. *Cocconeidetum scutelli*					
Campylodiscus thuretii Bréb.	.	.	20	.	
Surirella gemma (Ehr.) Kütz.	.	.	20	.	
Synedra crystallina (Ag.) Kütz.	.	.	20	.	
Cocconeis scutellum Ehr.	.	.	50	2	a 3
Goniaulax polyedra Stein	.	.	40	5	
Tropidoneis lepidoptera (Greg.) Cl.	.	.	30	7	
Melosira nummuloides (Dillw.) Ag.	3	.	30	7	
Achnanthes longipes Ag.	.	17	70	7	

▶

	P-1000 P-300 N=30	P-100 N=18	GRUŽ N=10	TSKUKu N=42	
Characteristic species of the assoc. *Oxytoxetum longicepis*					
Peridinium spiniferum Sch.	.	.	.	26	
Oxytoxum longiceps Sch.	3	.	.	33	a 4
Chaetoceros delicatulus Ost.	3	.	.	17	
Characteristic species of the alliance *Peridinion*					
Peridinium diabolus Cl.	7	5	50	48	
Peridinium pyriforme Pauls.	7	5	50	36	
Nitzschia incerta Grun.	3	16	50	33	s 2
Chaetoceros perpusillus Cl.	3	5	30	21	
Eucampia cornuta (Cl.) Grun.	10	.	20	24	
Prorocentrum micans Ehr.	23	33	70	78	
Nitzschia delicatissima Cl.	37	44	90	93	
Characteristic species of the order *Rhizosolenietalia*					
Thalassiothrix frauenfeldii (Grun.) Cl. M.	97	100	100	100	
Hemiaulus hauckii Grun.	93	100	100	90	
Rhizosolenia alata Br. f. grac. (Cl.) Gr.	93	100	90	90	
Chaetoceros decipiens Cl.	83	100	80	90	
Ceratium fusus (Ehr.) Duj.	83	89	90	90	
Peridinum globulus Stein	87	89	80	83	
Other species					
Divisio *CYANOPHYTA*					
Classis *CYANOPHYCEAE*					
Oscillatoria sp.	27	11	40	0	
Divisio *CHRYSOPHYTA*					
Classis *CHRYSOPHYCEAE*					
Dinobryon sp.	0	5	0	21	
Dictyocha fibula Ehrenb.	66	55	60	33	
Dictyocha speculum Ehrenb.	3	5	0	17	
Classis *HAPTOPHYCEAE*					
Acanthoica sp.	3	0	10	2	
Calciosolenia granii Schiller	36	39	20	43	
C. murrayii Gran in Murray et Hjort	10	0	10	5	
Calyptrosphaera oblonga Lohm.	53	33	0	21	
Coccolithus pelagicus Wallich	13	5	0	12	
Discosphaera tubifera (Murray et Black.) Ostenf.	10	5	0	0	
Rhabdosphaera clavigera Murray et Black.	13	0	0	10	
R. hispida Lohm.	3	0	0	0	
R. stylifera Lohm.	30	11	30	14	
R. tignifer Schiller	56	22	40	21	
Scyphosphaera apsteinii Lohm.	17	0	10	0	
Syracosphaera pulchra Lohm.	67	39	50	48	
Classis *BACILLARIOPHYCEAE*					
Actinocyclus octonarius Ehrenb.	10	0	10	10	
A. octonarius Ehrenb. var. *tenella* (Bréb.) Hendey	3	0	0	0	

►

	P-1000 P-300 N=30	P-100 N=18	GRUŽ N=10	TSKUKu N=24
Amphora ostrearia Bréb.	0	22	10	0
Amphiprora alata Ehrenb.	0	5	0	0
A. decussata (Grun.) Cleve	0	0	0	7
A. pulchra Bail.	0	0	0	2
A. sulcata O'Meara	0	28	10	2
Asterionella bleakeleyii W. Sm.	0	17	0	12
A. japonica Cleve	13	33	4	21
Asteromphalus heptactis (Bréb.) Ralfs.	23	11	0	5
A. flabellatus (Bréb.) Greville	7	0	0	0
Asterolampra marylandica Ehrenb.	73	61	40	26
A. grevilleii (Walich) Greville	17	0	10	0
Auricula adriatica Pav.	0	5	0	0
A. insecta (Grun.) Cleve	0	5	10	2
Bacteriastrum biconicum Pav.	3	5	0	2
B. delicatulum Cleve	80	72	90	93
B. elegans Pav.	0	5	0	0
B. hyalinum Lauder var. *princeps* Castr.	20	22	30	24
Biddulphia mobiliensis (Bail.) Grun.	0	17	20	2
B. pulchella Gray	0	5	0	0
Cerataulina pelagica (Cleve) Hendey	37	78	90	93
Cerataulus smithii Ralfs.	0	0	5	0
Chaetoceros affinis Laud.	56	72	80	88
Ch. anastomosans Grun.	60	22	20	38
Ch. atlanticus Cleve var. *neapolitanus* (Schröder) Hustedt	23	27	10	12
Ch. brevis Schütt	16	33	44	64
Ch. coarctatus Laud.	10	22	0	14
Ch. compressus Laud.	76	67	80	100
Ch. convolutus Castr.	66	50	60	43
Ch. costatus Pav.	13	0	20	12
Ch. curvisetus Cleve	67	67	70	69
Ch. dadayii Pav.	23	22	30	9
Ch. danicus Cleve	0	28	20	9
Ch. densus (Cleve) Cleve	3	0	20	0
Ch. didymus Ehrenb.	13	0	0	7
Ch. diversus Cleve	70	72	80	90
Ch. lauderi Ralfs	10	72	40	24
Ch. lorenzianus Grun.	47	5	10	14
Ch. peruvianus Brightw.	13	5	0	2
Ch. rostratus Laud.	27	83	60	69
Ch. simplex Ostenf.	50	27	30	31
Ch. tetrastichon Cleve	13	33	30	14
Ch. tortissimus Gran	16	50	50	71
Ch. vixvisiblis Schiller	50	50	40	69
Ch. wighamii Brightw.	33	17	10	36
Coscinodiscus curvatulus var. *minor* (Ehrenb.) Grun.	7	11	10	17
C. excentricus Ehrenb.	57	33	20	21
C. granii Gough	17	0	0	0
C. janischii Schm.	3	11	10	5
C. perforatus Ehrenb.	16	11	30	19
C. thorii Pav.	13	22	20	31
Cyclotella sp.	16	11	10	52
Cy. ocellata Pantocsek?	0	0	0	5
Dactyliosolen mediterraneus (Pérag.) Pérag.	90	94	90	76
Diploneis bombus Ehrenb.	30	38	60	52
D. crabro Ehrenb.	0	5	0	0
D. smithii (Bréb.) Cleve	0	5	0	0

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	P-1000 P-300 N=30	P-100 N=18	GRUŽ N=10	TSKUKu N=24
Donkinia recta Grun.	0	0	10	0
Fragillaria sp.	7	11	20	0
Grammatophora marina (Lyngb.) Kütz.	0	11	10	5
Guinardia blavyana Pérag.	50	67	60	40
G. flaccida (Castr.) Pérag.	67	95	90	95
Gyrosigma balticum (Ehrenb.) Rabenh.	0	5	0	2
Hemiaulus sinensis Grev.	23	28	50	67
Leptocylindrus adriaticus Schröder	50	63	80	80
L. danicus Cleve	45	78	80	82
L. minimus Gran	0	11	10	5
Licmophora ehrenbergii (Kütz.) Grun.	0	0	0	2
Li. flabellata (Carm.) Agardh	3	17	20	19
Li. gracilis (Ehrenb.) Grun.	0	0	30	12
Li. lyngbyei (Kütz.) Grun.	0	5	0	0
Li. paradoxa (Lyngb.) Agardh	3	0	10	0
Li. reichardtii Grun.	0	0	10	0
Lithodesmium undulatum Ehrenb.	10	33	60	2
Melosira moniliformis (Müll.) Agardh	0	5	20	0
M. sulcata (Ehrenb.) Kütz.	37	11	60	9
Navicula cancellata Donk.	0	17	20	7
N. lyra Ehrenb.	0	0	10	0
N. distans (Sm.) Cleve	0	0	10	7
Nitzschia closterium (Ehrenb.) W. Sm.	26	44	50	86
Ni. longissima (Bréb.) Ralfs	50	83	80	93
Ni. lorenziana Grun.	0	0	10	5
Ni. panduriformis Greg.	0	5	10	28
Ni. seriata Cleve	57	44	60	93
Pleurosigma angulatum (Quekett) W. Sm.	27	50	90	81
P. attenuatum (Kütz.) Sm.	0	0	10	5
P. axsul Cleve	0	0	0	5
P. elongatum W. Sm.	3	11	20	0
P. formosum W. Sm.	0	5	0	7
P. macrum W. Sm.	0	5	10	7
Rhabdonema adriaticum Kütz.	3	5	0	0
Rhizosolenia acuminata (Pérag.) Gran	13	5	0	0
R. alata Brightw. f. *indica* (Pérag.) Gran	43	55	40	78
R. calcar-avis Schultze	83	89	70	76
R. fragilissima Berg.	10	33	40	69
R. hebetata Bailey	3	0	0	0
R. imbricata Brightw. var. *shrubsolei* (Cleve) Schröder	90	78	60	93
R. robusta Norm.	13	55	40	36
R. stolterfothii Pérag.	63	89	10	93
Schroederella delicatula (Pérag.) Pav.	37	0	0	17
Skeletonema costatum (Grev.) Cleve	7	50	80	36
Striatella interrupta (Ehrenb. Heib.	3	0	0	0
S. unipunctata (Lyngb.) Agardh	3	44	60	43
Surirella sp.	10	10	20	5
Synedra fulgens (Grev.) W. Sm.	3	28	30	5
S. longissima Sm.	0	0	0	2
S. toxoneides Castr.	0	0	20	2
S. undulata (Bailey) Gregory	0	17	30	14
Thalassionema nitzschioides Grun.	30	17	40	43
Thalassiosira decipiens (Grun.) Jörg.	3	22	30	31
Th. nordenskioeldii Clave	0	0	0	2
Thalassiothrix mediterranea Pav.	40	50	40	45
T. longissima Cleve et Grun.	0	0	0	2

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	P-1000 P-300 N=30	P-100 N=18	GRUŽ N=10	TSKUKu N=42
Toxonidea balearica Grun.	0	0	0	2
Triceratium shadboltianum Grev.	0	0	20	2
Divisio *DINOPHYTA*				
Classis *DESMOPHYCEAE*				
Prorocentum compressum (Ostenf.) Abé	17	17	0	12
P. scutellum Schröder	10	11	0	5
P. triestinum Schiller	0	5	20	0
Classis *DINOPHYCEAE*				
Amphidinium acutissimum Schiller	0	5	0	0
Amphisolenia spinulosa Kof.	7	0	0	0
A. bidentata Schröder	7	0	20	0
A. globifera Stein	7	0	0	0
Centrodinium eminens Böhm.	10	0	0	0
Ceratocorys gourretii Paulsen	37	50	40	2
C. horrida Stein	0	5	10	0
Ceratium buceros Zacharias	23	28	30	50
C. candelabrum (Ehrenb.) Stein	47	78	60	26
C. carriense Gourr. var. *volans* (Cleve) Jörg.	57	44	60	24
C. euarcuatum Jörg.	10	5	30	7
C. extensum (Gourr.) Cleve	47	44	40	36
C. furca (Ehrenb.) Clap. et Lachm.	50	72	70	98
C. gibberum Gourr.	10	56	20	7
C. hexacanthum Gourr.	37	50	70	21
C.karstenii Pav.	37	56	50	31
C. kofoidi Jörg.	0	17	20	0
C. longirostrum Gourr.	17	17	20	38
C. macroceros (Ehrenb.) Cleve	80	83	90	40
C. massiliense (Gourr.) Jörg.	50	72	70	45
C. pavillardii Jörg.	10	11	10	0
C. pentagonum Gourr.	83	55	60	14
C. platycorne Daday f. *dilatatum* (Kars.) Jörg.	3	0	0	0
C. setaceum Jörg.	20	11	10	0
C. symetricum Pav.	53	83	50	21
C. teres Kof.	17	17	10	7
C. trichoceros (Ehrenb.) Kof.	77	94	70	45
C. tripos (Müll.) Nitzsch var. *pulchellum* (Schröder) López	53	50	30	26
C. tripos (Müll.) Nitzsch	30	28	40	76
C. vultur Cleve	3	0	0	0
Dinophysis acuminata Clap. et Lachm.	0	0	10	0
D. acuta Ehrenb.	10	11	10	5
D. caudata Seville-Kent	27	33	50	81
D. sphaerica Stein	13	11	10	48
Goniaulax birostris Stein	3	0	0	0
G. diacantha (Meunier) Schiller	0	5	0	16
G. digitale (Pouchet) Kof.	10	5	0	5
G. gracilis Schiller	13	14	50	52
G. fragilis (Schütt) Kof.	0	0	0	2
G. kofoidii Pav.	3	0	0	0
G. polygramma Stein	47	39	50	55
G. sp.	10	5	40	67
Goniodoma polyedricum (Pouchet) Jörg.	77	89	60	86
Gymnodinium cucumis Schütt	3	0	0	0
Gyrodinium fusiformis Kof. et Sw.	0	5	0	0
Heterodinium richardii Pav.	3	0	0	0

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	P-1000 P-300 N=30	P-100 N=18	GRUŽ N=10	TSKUKu N=24
Histioneis joergensenii Schiller	3	0	20	2
Kofoidinium velelloides Pav.	60	50	50	9
Noctiluca miliaris Sur.	10	22	10	2
Ornithocercus carolinae Kof.	0	5	0	0
O. heteroporus Kof.	0	5	0	0
O. maginificus Stein	3	0	0	4
Oxytoxum caudatum Schiller	0	0	10	7
Ox. constrictum (Stein) Bütschli	13	0	10	2
Ox. elegans Pav.	3	5	10	0
Ox. laticeps Schiller	0	0	0	2
Ox. scolopax Stein	33	11	0	17
Ox. spaeroideum Stein	33	17	10	28
Ox. tesselatum (Stein) Schütt	3	0	0	0
Oxytoxum variabile Schiller	3	5	10	7
Peridinium brochii Kof. et Sw.	7	11	10	5
P. conicum (Gran) Ostenf. et Schm.	3	17	50	28
P. crassipes Kof.	30	17	30	70
P. depressum Bailey	30	33	50	74
P. divergens Ehrenb.	0	17	20	14
P. leonis Pav.	13	28	20	24
P. oceanicum Vanhöffen	13	28	50	31
P. pallidum Ostenf.	33	17	20	19
P. paulsenii Pav.	0	0	10	2
P. pellucidum (Bergh.) Schütt	30	17	40	17
P. steinii Jörg.	20	55	20	7
P. tuba Schiller	7	0	10	36
P. willei Huith. — Kaas	0	0	0	2
Phalacroma argus Stein	3	0	0	2
Ph. circumsutum Karsten	3	0	0	0
Ph. mitra Schütt	13	17	10	14
Ph. parvulum (Schütt) Jörg.	23	11	20	9
Ph. reticulatum Kof.	10	5	0	2
Ph. rotundatum (Clap. et Lachm.) Kof. et Mich.	7	0	0	0
Ph. striatum Kof.	3	0	0	0
Podolampas bipes Stein	27	38	20	14
P. elegans Schütt	17	5	20	7
P. palmipes Stein	23	11	0	2
Pyrocystis elegans Pav.	7	0	10	5
Py. lunula Schütt	3	5	20	0
Py. robusta Kof.	3	0	10	0
Pyrophacus horologicum Stein	23	28	50	55
P. horologicum Stein var. *steinii* Schiller	3	0	0	7
Triposolenia bicornis Kof.	3	0	0	0
T. truncata Kof.	3	0	0	0
Divisio *EUGLENOPHYTA* Classis *EUGLENOPHYCEAE*				
Eutreptiella sp.	0	0	10	2
Divisio *CHLOROPHYTA* Classis *PRASINOPHYCEAE*				
Halosphaera viridis Schm.	83	72	50	5
Classis *CHLOROPHYCEAE*				
Carteria sp.	10	11	20	2

tic pit (from surface to the depth of 200 m) totaled 0.09 — 0.10 μg-at PO_4-P/l (S t o j a n o s k i 1975), in the Malostan Bay area 0.03 — 0.61 μg-at PO_4-P/1, and in the area of Rijeka Dubrovačka (larger area of Gruž Bay) 0.04 — 0.21 μg-at PO_4-P/l (V u k a d i n and S t o j a n o s k i 1978).

During the research a total of 285 phytoplankton taxons were determined, of which 276 were species.

The species can be divided in two groups, by comparing their presence in particular stands: those that are more or less equally present at all stands investigated, and those that show more affinity towards the stands of the open sea (stations P-1000 and P-300), towards the stands of the coastal sea (stations G, T, S, K, U, Ku), or towards the stand in the transition zone between the open and coastal sea (station P-100). The phytoplankton in the two open sea stands did not differ floristically. This justifies the conclusion about only one association existing there. Only one association was determined in Maloston Bay area (stations: T, S, K, U, Ku). According to the hydrographical parameters and floristic composition in the investigated region, four associations in four habitats were determined (Fig. 2).

The hierarchical classification of communities is formed in the following way:

Order: *Rhizosolenietalia*

Alliance: *Oxytoxion reticulati*

Association: *Discosphaero thomsonii-Coscinodiscetum stellaris*
Association: *Dinophysetum tripodis*

Alliance: *Peridinion*

Association: *Cocconeidetum scutelli*
Association: *Oxytoxetum longicepis*

Characteristic species of defined communities are listed in Table 1 according to the suggested criteria. The majority of characteristic species of the communities described belong to the group of *Dinophyta* (25 species). However, quantitatively they are less represented than *Bacillariophyceae. Chrysophyceae (Haptophyceae)* with two characteristic species are important only in the open sea community (Table 2).

T a b l e 2. The number of characteristic species by associations and alliances

	The number of characteristic species						
	by association				by alliance		total
	a1	a2	a3	a4	s1	s2	
DINO	5	4	1	2	10	3	25
BACI	5	2	7	1	2	4	21
HAPT	2	0	0	0	0	0	2

According to the principles used in terrestrial plant sociology, plant communities can be determined on the basis of only one analyzed stand, but it is suggested that ten or more stands be analyzed (Barkman et al. 1976). The phytoplankton community in the open sea of the south Adriatic was defined on the basis of the analysis of 30 vegetation records in two stands (at stations P-1000 and P-300). In the Maloston Bay area, the community was defined on the basis of 42 vegetation records in five stands (at stations T, S, K, U and Ku). The two remaining associations were determined on the basis of only one analyzed stand, at station G (10 vegetation records) and at station P-100 (18 vegetation records).

To date a few works have been published that justify the existence of phytoplankton communities in the sea. Zeitzschel (1978) claims that specific groups of phytoplankton can be indicators of »natural regions« of the ocean, which can be limited by the geographic latitude (indicators of boreal, subtropic or tropic regions) or geographic characteristics. Valentine (1973) defined »provincies« as regions in which communities contain a characteristic species composition and »communities« as associations of species which include a small percentage of all the species found. Legendre (1973) believes that an important characteristic of phytoplankton associations is their permanency along the gradients of ecological parameters, which means that the development of species population depends on the changes in the environment.

In all the seas of the world an ecological and biological difference exists between the open and the coastal sea. The open sea is ecologically monotonous whereas the coastal sea offers many varied ecological situations which are formed owing to specific hydrological properties of a specific area, as well as climatic properties of the continent and because of the anthropogenic influence. Terrestrial plant communities follow the ecological characteristic of a habitat and are most frequently clearly set apart from each other. The boundary between two hydrographically different water masses in the sea is not well defined because the ecological factors usually change gradually. The changes of hydrographic conditions are followed by a change in the floristic composition of phytoplankton. However, the position of the ecological parameter gradient field may vary during the year because of the dynamics of the current system. The spatial and time dynamics of phytoplankton species distribution can also be significant. Consequently, the characteristic species of the communities described in this paper have been defined by comparing the mean annual presence values in different habitats. By following the mean annual presence value the fidelity of species was defined. According to the chosen phytosociological principles, the characteristic phytoplankton species which define the community are not necessarily all present at one stand at any one moment, but one can be noticed at one time or another throughout the year (analogous by to terrestrial vegetation). Phytoplankton species, as well as other species, vary according to the ecological spectrum. The development of their populations is the most intensive in the region with the most favorable environmental conditions. For this reasons one should believe in the existence of phytoplankton communities in regions with repeated and periodically well maintained hydrographic conditions.

Vertical stratification analysis of phytoplankton was not taken into consideration during the phytosociological investigations. However, it is expressed more in the phytoplankton quantity than in the floristic composition. A more significant difference of floristic composition in the vertical direction can be determined during the thermal stratification in the warmer part of the year.

Because of the complex three-dimensional nature of the marine ecosystem (i.e. horizontal, vertical and time dynamics) the results obtained should be checked during the forthcoming investigations.

Conclusion

According to the assumption made in this work about some groups of phytoplanston species showing ecological distribution, the associations described can be used as ecological indicators.

*

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SAŽETAK

ISTRAŽIVANJA FITOPLANKTONSKIH ZAJEDNICA JUŽNOG JADRANA U ŠIROJ OKOLICI DUBROVNIKA

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U četiri ekološki različita staništa (na 9 postaja) u južnom Jadranu utvrđene su četiri asocijacije fitoplanktona koje se mogu ujediniti u dvije sveze i jedan red. Kao kriterij za određivanje asocijacija i ostalih zajednica poslužila je vezanost vrsta po principima fitocenološke škole Zürich-Montpellier. Najveći broj karakterističnih vrsta opisanih zajednica pripada skupini *Dinophyta*, iako su one kvantitativno slabije zastupljene nego *Bacillariophyceae*. *Haptophyceae* su sa 2 karakteristične vrste važne jedino u zajednici otvorenog mora. Prihvaćajući pretpostavku da određene skupine vrsta fitoplanktona pokazuju ekološku raspodjelu, utvrđene asocijacije mogu poslužiti kao ekološki indikatori. Zbog složene trodimenzionalne prirode morskog ekosistema (horizontalna, vertikalna i vremenska dinamika) pokazane rezultate je potrebno provjeriti na budućim istraživanjima.

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