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CHANGES IN THE BENTHIC ALGAL ASSOCIATIONS OF THE VICINITY OF ROVINJ (ISTRIAN COAST, NORTH ADRIATIC) CAUSED BY ORGANIC WASTES

SPREMEMBE ASOCIACIJ BENTOŠKIH ALG OKOLICE ROVINJA (ISTRSKA OBALA, SEVERNI JADRAN) POD VPLIVOM ORGANSKIH ODPLAK

Ivka M. Munda

Biological Institute, Slovene Academy of Science and Arts, Ljubljana

This paper provides a description of the benthic algal vegetation of the vicinity of Rovinj, which has changed radically during the last decade due to increased pollution by domestic sewage. The distribution of the main species in the area is given and changes in the vegetation pattern described with reference to the state for a decade ago. Some algal associations characteristic for polluted habitats were recognized on the basis of field observations.

INTRODUCTION

During the last decade profound changes in the benthic algal vegetation of the vicinity of Rovinj (Istrian Coast, North Adriatic) have become apparent. They are first of all due to the disturbing effects of domestic sewage exchange, which has increased during the last few years due to urbanization and tourism.

The benthic algal vegetation is an important indicator for long-term pollution perturbances in the marine environment. The severe pollution by domestic effluents has eliminated many algal species and radically changed the vegetation pattern. Pollution effects on benthic algae have been studied in many areas and have also included diversity analyses (e. g. Borowitzka, 1972; North, 1964; Littler and Murray, 1975, 1978; Murray and Littler, 1974, 1976, 1978; Edwards, 1972, 1975; Burrows, 1971; Andrews, 1976; Letts and Richards, 1911; Cotton, 1911; Stein and Denison, 1967; Häyren, 1937; Widdowson, 1971 etc). Golubić (1970) reported on pollution-induced changes in the Adriatic and Gunarsson and Thórisson (1971) on the effect of sewage on species distribution in an almost unpolluted area in Iceland. The Oslofjord has been studied in successive years by different authors who have documented increasing pollution effects on the benthic vegetation (Sundene, 1953; Grenager, 1957; Klavestad, 1967, 1978; Rueness, 1973; Bokn and Lein, 1978).

The immediate vicinity of the town of Rovinj as well as the neighbouring islands are greatly influenced by human activity. This influence has developed gradually. In a previous survey Golubić (1968) reported on the effect of domestic wastes on the benthic algal vegetation of this particular area. The present author 's investigations of the benthic algal vegetation of the vicinity of Rovinj and the neighbouring islands were carried out between 1967 and 1970. During this period the rocky eulittoral was still populated by *Fucus virsoides* and *Cystoseira* spp. settlements and in the upper sublittoral *Cystoseira* and *Sargassum* populations prevailed (Munda, 1972 a, b, 1974 b, 1975, in press). Seasonal associations of red, brown and green algae were prolific. Later changes in the vegetation pattern and biomass of the algal settlements were reported briefly (Munda, 1974 a, Zavodnik, N., 1977). The cumulative effects of environmental stresses during the last decade became visible recently in a marked reduction of the intertidal and upper subtidal biota.

During the spring of 1978 and 1979 observations were repeated in the same area. The disapearence of fucoid settlements and general drastic changes in the vegetation pattern of rocky sites deserve special attention.

The very first extensive study of the algal flora and vegetation of the vicinity of Rovinj was carried out at the end of the last centoury by P. Kuckuck. His data are present in as yet unpublished diaries and indicate a rich flora and vegetation in the area under discussion. Calcareous algae collected by Kuckuck were treated by Foslie (1906) and some representatives of the Ectocarpales were described by Kuckuck (1964). Data on the summer vegetation of Rovinj were given by Schiffner (1915). Later a compilation was contributed by Vatova (1928, 1948). Scattered data on benthic algae with limited taxonomic lists are to be found in zoological contributions of Zavodnik D. (e. g. 1962, 1965, 1967 a, b, 1969, 1971, 1973). The aut or deals with communities of diverse benthic algae, stressing the animal component in the settlements.

This contribution provides a further description of the benthic algal vegetation, based on observations during the spring of 1978 and 1979.

ECOLOGICAL PARAMETERS AND INVESTIGATED AREA

The investigated area extends from the bay of Faborsa outside Limski kanal (Lim fjord) to the bay of Škaraba and includes some islands of the Rovinj archipelago (Sv. Katarina, Velika Figarola, Mala Figarola, Crveni otok (Red Island), San Giovanni, Sturago). As a reference locality which is relatively unpolluted, Palu was included during recent surveys. Rocky sites, consisting of dolomitic limestone, were considered primarily. The Istrian coast consists of very pure Mesozoic limestone with some intercalated dolomitic horizons. The limestone is locally ovarlain by a thin terra rossa layer on the mainland (Meischner, 1973). The sediments of the Istrian coast were described by Fütterer (1969). The fine carbonate sands which cover the sublittoral zone are mainly biogenic carbonates produced by breakdown of shell material.

The present hydrography of the North Adriatic as a whole is primarily determined by an anticlockwise convection current which enters the Istrian area from the southeast (Mosetti, 1967). The tidal system is a perimposed on this current. The maximum tidal range in the area is approx. 1 m. The salinity of the North Adriatic basin is further a function of the influx of fresh water from the North Italian rivers, among which the Po is the dominant. Seasonal variations in precipitation are also decisive for salinity values in the upper water layers.

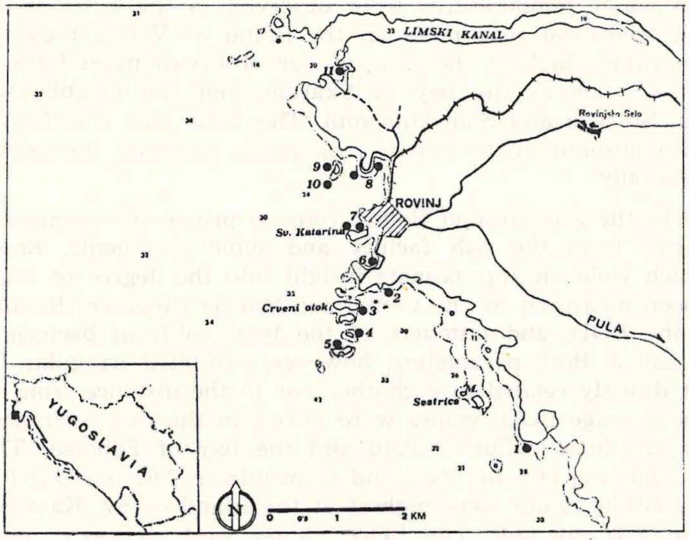

Fig. 1. Map of the area: 1 — Palu, 2 — Škaraba, 3 — Crveni otok (Red Island), 4 — Sturago, 5 — San Giovanni, 6 — Val di Lone, 7 — island of Sv. Katarina, 8 — vicinity of the Rovinj hospital and Val di Lesso, 9 — island of Velika Figarola, 10 — island of Mala Figarola, 11 — Faborsa

Ecological parameters for the period from March 1978 to February 1979 were kindly placed at my disposal by Mg. D. Fuks, Center for Marine Research, Rovinj. They comprise data on water temperature, salinity, BOD values and total coliform bacteria and are presented in Table 2 and 3 and Figs. 2, 3, and 4.

Temperature and salinity measurements were likewise carried out during the time of algal samplings in April 1978.

In all the localities observed, water temperature peaks were found in August, coinciding with minima in salinity. Elevated water temperatures were found from June to September and minima, as is usual in the North Adriatic, in February. The seasonal course in salinity was inverse to that of water temperature. Summer minima in salinity were most pronounced in the vicinity of the Rovinj hospital and in the bay of Škaraba (mid-August). In most of the localities salinity values were somewhat elevated towards the end of August and declined again in autumn. The yearly course of salinity was irregular in the reference locality of Palu due to variations in the fresh water influx from a small river which drains a marsh area. The fresh water influx was highly increased in March. The summer minimum in salinity was inconspicuous here, as was the temperature maximum.

Temperature and salinity values measured simultaneously with algal samplings in April 1978 revealed rather low water temperatures in most sites. Temperatures were the highest in sheltered bays such as Val di Lone and Faborsa as well as in the vicinity of Palu and the island of San Giovanni. Rather high water temperatures were observed in the brackish marshes at Palu and in terrestrial rock pools on the island of Velika Figarola. Salinity values were rather high at the time of our observations and the highest in open localities, such as the bay of Škaraba and the neighbouring islands Crveni otok, Sturago and Sain Giovanni. The same was true for the vicinty of the Rovinj hospital. In terrestrial rock pools, however, the salinity droped down to 35‰ only.

Sewage in the area around Rovinj consists primarily of untreated human wastes, wastes from the fish factory and some detergents. Environmental features which yield an approximate insight into the degree of organic pollution have been measured by the Center for Marine Research, Rovinj. Monthly values for the BOD_5 and numbers of the total coliform bacteria are given in Table 2 and 3. Both parameters, however, exhibited irregular fluctuations and are not directly related to eachother nor to the distance from the sewage outfalls. The average BOD_5 values were lowest in the two reference localities, which were the least polluted: Palu and the bay of Faborsa. They ranged from 0.02 to 2.85 mg O_2/l for Palu and from 0.18 to 2.62 mg O_2/l for Faborsa. The average BOD_5 values were highest at the island of Sv. Katarina, ranging from 0.05 to 3.33 mg O_2/l. The BOD_5 values were, however, lower in the vicinity of the hospital. The coliform group of bacteria, including *Escherichia coli* and related species as well as fecal streptococci, yields by its presence evidence of fecal pollution. This proved to be the most severe in Val di Lone and next to it was the island of Sv. Katarina. Average bacterial pollution was relatively low in the vicinity of the hospital and the lowest in Palu.

Table 1 Temperature and salinity values for April 1978

localities	temperature (°C)	salinity (‰)
SV. KATARINA I.	10.2	36.96
SV. KATARINA II.	10.3	36.67
VAL DI LONE	11.2	36.98
	12.5	36.59
VELIKA FIGAROLA	11.0	36.35
terrestrial pool	17.0	35.98
MALA FIGAROLA	11.0	36.01
HOSPITAL	11.6	37.34
FABORSA I.	12.0	36.90
FABORSA II.	11.8	36.92
ŠKARABA	11.0	37.30
PALU — fresh water (marches)	16.0	2.92
sea	12.0	36.33
CRVENI OTOK (RED ISLAND)	11.8	37.31
STURAGO	11.9	37.73
SAN GIOVANNI	12.1	37.27

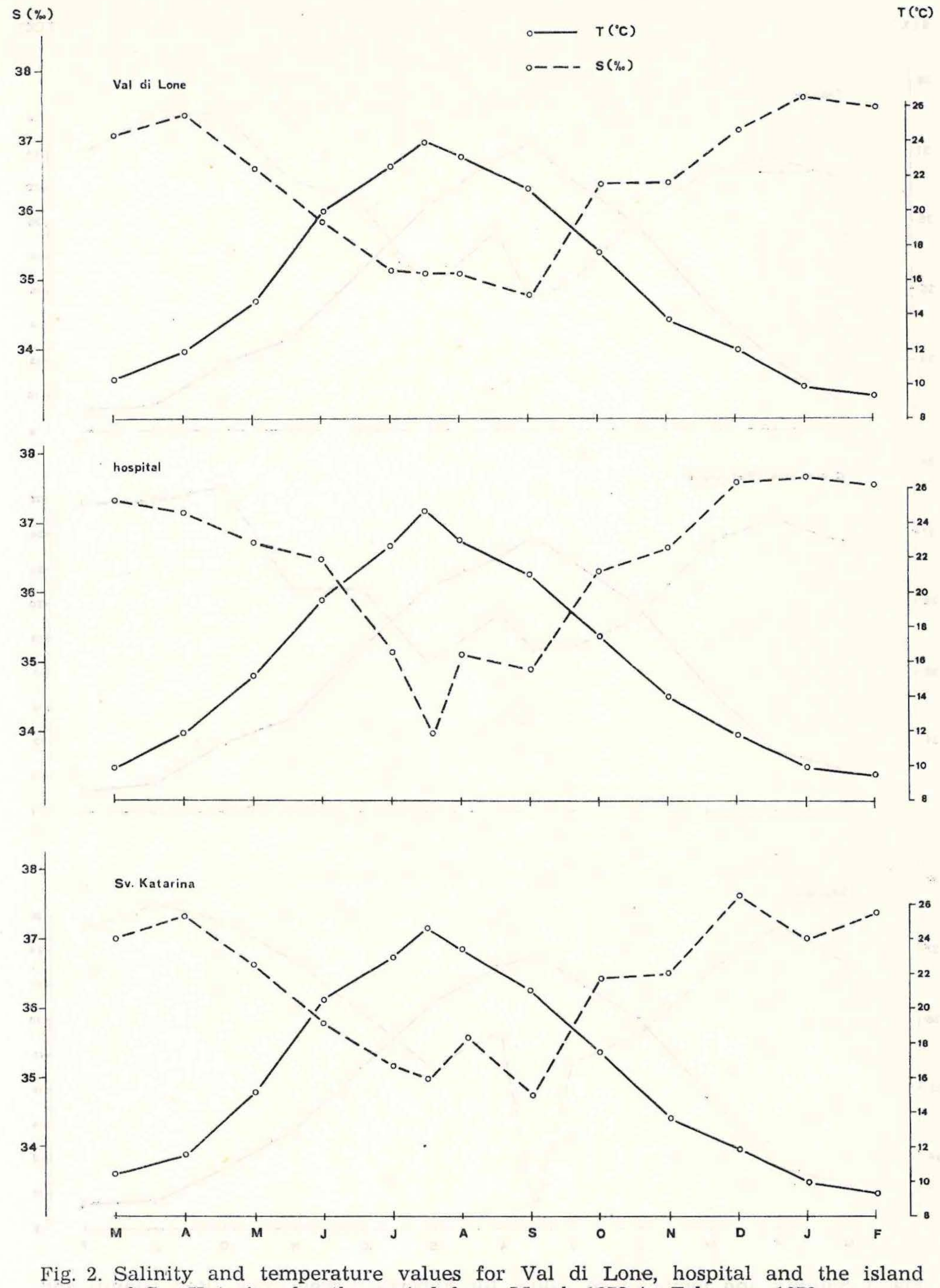

Fig. 2. Salinity and temperature values for Val di Lone, hospital and the island of Sv. Katarina for the period from March 1978 to February 1979

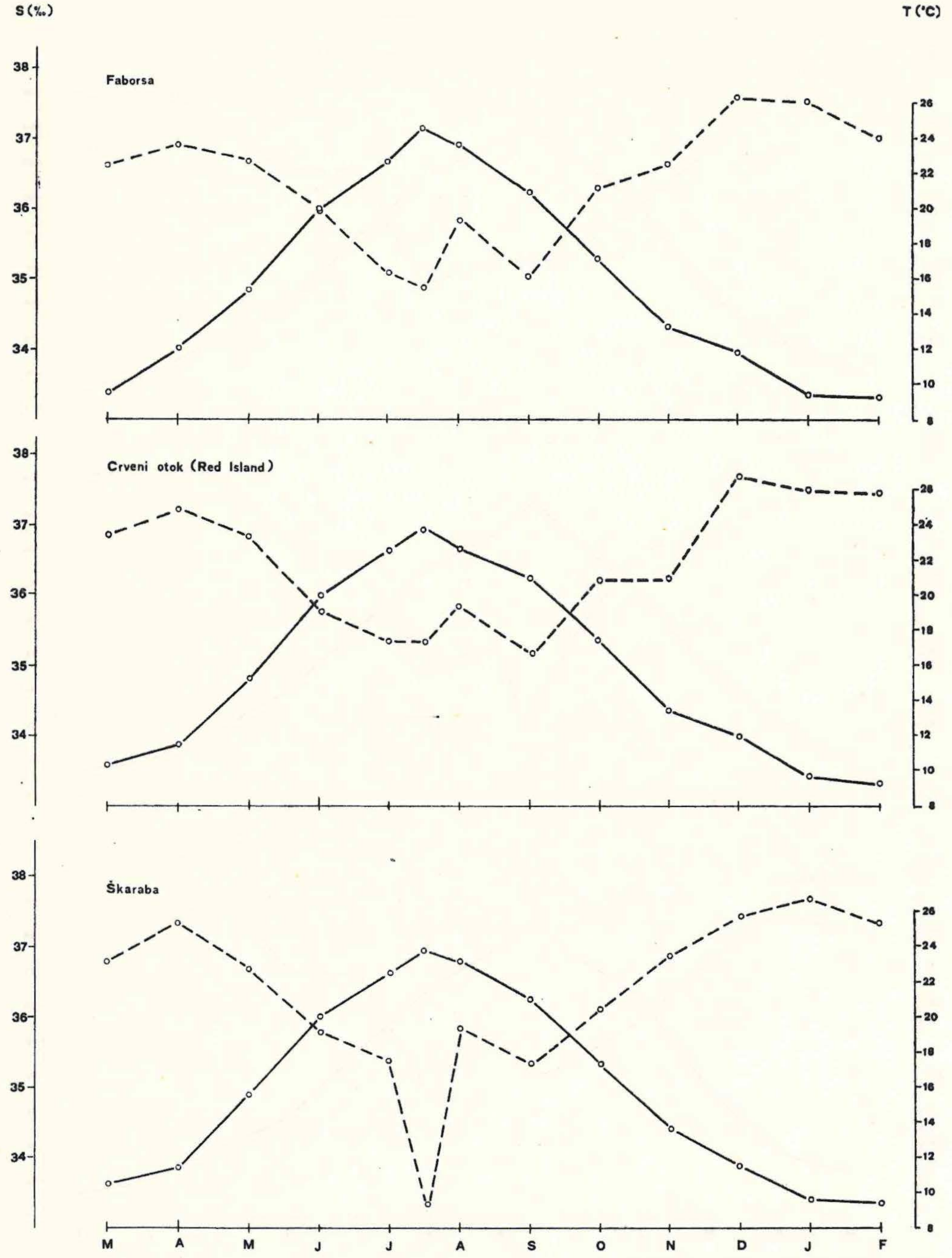

Fig. 3. Salinity and temperature values for Faborsa, Crveni otok (Red Island) and Škaraba for the period from March 1978 to February 1979

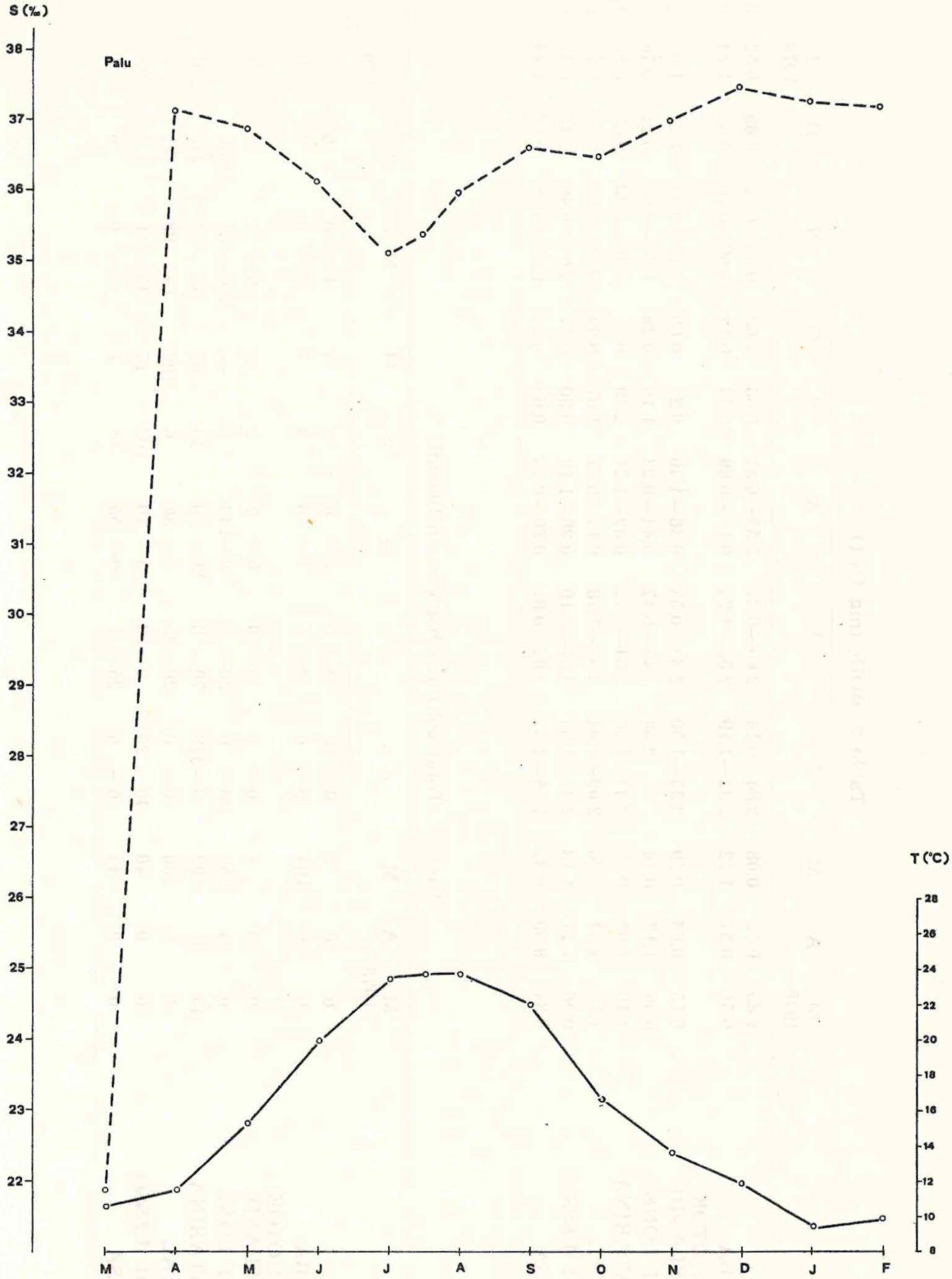

Fig. 4. Salinity and temperature values for Palu for the period from March 1978 to February 1979

Table 2. BOD_5 (mg O_2/1)

	M 1978	A	M	J	J	A	S	O	N	D	J 1979	F
PALU	1.85	0.32	0.08	2.84—0.14	2.60—0.27	1.53—0.31	0.63	1.69	0.35—0.40	0.69	0.52	0.02
ŠKARABA	0.51	0.57	1.12	2.32—1.19	2.53—1.23	0.13—0.89	0.79	0.18	1.66—0.76	0.93	1.23	0.37
CRVENI OTOK (RED ISLAND)	0.15	0.66	0.59	3.85—1.50	2.33—0.53	0.36—1.46	0.22	0.08	2.15—0.36	1.21	1.03	0.77
VAL DI LONE	0.96	1.17	0.76	2.98	2.45—0.42	0.44—0.23	1.10	0.29	1.80—0.63	0.21	0.76	0.64
SV. KATARINA	1.16	1.08	0.80	3.33—1.20	1.84—1.72	0.89—1.21	2.49	0.91	2.36—0.38	0.67	0.50	1.13
HOSPITAL	1.14	1.34	1.36	2.09—1.94	2.51—1.78	0.17—0.77	1.07	0.99	0.88—0.61	0.08	0.78	0.67
VAL DI LESSO	0.96	1.17	1.13	2.31—1.89	2.21—1.10	0.26—1.18	0.80	0.47	2.64—0.46	0.43	0.52	0.60
FABORSA	0.34	0.99	0.32	1.15—1.37	2.62—0.81	0.26—0.73	0.65	0.24	0.98—0.48	0.18	1.44	0.43

Table 3. Total coliform bacteria (n/100 ml)

	M 1978	A	M	J	J	A	S	O	N	D	J 1979	F
PALU	0	0	2	0— 0	0— 0	1— 0	0	3	4— 0	0	3	0
ŠKARABA	0	0	164	0— 0	0— 1	1— 0	0	7	5— 0	0	1	0
CRVENI OTOK (RED ISLAND)	0	0	4	0— 0	0— 0	0— 2	2	0	16— 2	4	0	0
VAL DI LONE	0	93	250	20— 0	20— 7	0—143	3	—	236— 84	2700	35	25
SV. KATARINA	45	31	90	0—378	70— 8	11— 20	40	87	53— 27	248	236	63
HOSPITAL	1	9	130	0— 0	20—23	4— 38	6	100	19—108	31	7	135
VAL DI LESSO	0	0	40	40— 25	0—58	5— 10	102	17	35— 6	1	20	70
FABORSA	0	0	43	0— 6	25— 7	0— 55	14	1	2— 0	0	2	21

The gradients in the average values of the BOD_5 do not coincide with those of the total coliform bacteria. As mentioned, the highest bacterial pollution was found at Sv. Katarina and in Val di Lone. Considerably lower average values were detected near the hospital and in Val di Lesso and next were the bays of Škaraba and Faborsa. Bacterial pollution was negligible at Crveni otk and in Palu. Regarding the BOD_5 values another gradient in pollution was observable: the highest average values were at Sv. Katarina, near the hospital and in Val di Lesso; as well as on the island Crveni otok (Red Island). The next group represents the bay of Škaraba and Val di Lone and the last Palu and Faborsa.

CHANGES IN THE VEGETATION PATTERN

Changes in the benthic algal vegetation that took place during the last decade are referred to spring (April 1978, 1979) and compared with the previous state during spring months 1967, 1968 and 1969 (Munda, 1972 a, b, 1975, 1977 in press). These changes, caused primarily by the increased pollution by organic wastes resulted in a disappearence of the fucoid settlements and thus altered associations in the eulittoral and upper sublittoral levels, along with a decreased degree of covering by macrophytes and a decline in species diversity. Secondary to pollution effects, grazing by sea urchins became critical in some sites. Wide rocky surfaces were denuded and even the undergrowth consisting of dendritic and crustaceous species was destroyed. Hence the recent state of the vegetation reflects long-term disturbances in this arhia. area. The most severe effects of pollution on the marine vegetation are, however, visible in the vicinity of the town on the mainlad and on the nearshore islands.

VAL DI LONE

This wide and relatively sheltered bay exhibits a rather high degree of pollution in term of the total coliforms. Its vegetation was radically altered. A decade ago the rocky eulittoral was covered by a prolific belt of *Fucus virsoides* settlements duo to both, mechanical destruction by human activites *Ceramium diaphanum* was interimposed between the two fucoid belts.

Obesrvations in spring 1978 revealed a total deterioration of the *Fucus virsoides* settlements due to both, mechanical destruction by human activities and pollution effects. In 1979 a partial, scattered restitution of *Fucus virsoides* belts was not. The greater part of the rocky eulittaral was denuded. Only in small pools and rocky depressions were patches of *Enteromoropha* spp. found, mainly represented by *E. intestinalis* and in a few spots also by *E. prolifera.* Some small pools were occuppied by *Cladophora dalmatica.* Locally there were patches of *Blidingia minima* and *Enteromorpha intestinalis* on smooth horizontal surfaces. In the level of the littoral fringe patches of *Rivularia atra* were found.

In the upper sublittoral *Cystoseira barbata* stands became replaced by a nitrophilous association of *Halopteris scoparia* and an association of *Dictyota* *dichotoma,* which covered wide surfaces. Both associations were spatially separated but in a few spots they intergraded into a mozaic pattern. In sites where pollution was most severe and the water turbid, *Ulva rigida* along with *Scytosiphon lomentaria* formed dense stands of huge specimens. Near the surface *Enteromorpha clathrata* along with *E. ramulosa* and *E. multiramosa* occurred in such sites. A further association characteristic for this polluted bay was that of diverse filamentous brown algae represented by *Ectocarpus siliculosus, Scytosiphon lomentaria, Stictyosiphon adriaticus, Cutleria multifida.* This associatoin was prolific in a deep artificial pool and sheltered sites around it. Furthermore rather wide surfaces covered by *Colpomenia sinuosa* were characteristic for the sublittoral vegetation. In the driftweed *Codium fragile* was frequent.

The red algal component in the vegetation was reduced to a minimum. Tiny Ceramiaceae were poorly represented and *Ceramium diaphanum* replaced by single specimens of *C. ciliatum.* Patches of small dendritic representatives of the genera *Gelidium* and *Gelidiella* were locally found.

ISLAND OF SV. KATARINA

The water around this nearshore island is rather strongly polluted. The same two localities were observed as during previous surveys.

At locality 1 there are rocky pools and the slopes are relatively steep whereas on locality 2 which is situated near a small harbour the slopes are almost horizontal. There was a certain difference in the vegetation between two localities during previous surveys. In locality 1 there was a prolific *Fucus virsoides* association in the eulittoral level which recently deteriorated. Only single dwarf *Fucus* plants were still found in this site. As in Val di Lone the eulittoral growth was represented by patches of *Enteromorpha* species. Sublittorally *Cystoseira compressa* and *Halopteris scoparia* occurred as associated codominants and even lower down the sublittoral *Sargassum hornschouchii* and *Sargassum acinarium* associations occurred in a vertical seguence. (M u n d a, in press). The *Sargassum* associations totally disapeared from the vegetation whereas the *Cystoseira compressa -Halopteris scoparia* association was floristically altered with a reduced degree of covering and a broken distribution pattern. In some sites there were bare rocky surfaces below a *Mytilus galloprovincialis* zone. Where still present, the *Cystoseira* association was mixed with *Halopteris scoparia* and *Dictyota dichotoma* to such a degree that it locally became subordinate. In the undergrowth crustose corallines *Erhymatolithon lenormandii, P. polymorphum), Hildenbrandia rubra* and *Corallina officinalis,* were still present. The floristic diversity was higher than in Val di Lone, though the tiny Ceramiaceae (representatives of the genera *Ceramium, Callithamnion, Antithamnion, Aglaothamnion)* were also here reduced in quantity and diversity. If compared with the previous state the vegetation was the least altered in the rocky pools. In some shallow pools *Cystoseira* species were still present, though scattered *(C. compressa, C. barbata, C. spicata).* In a deeper pool, *Dictyota dichotoma* was dominant as in previous years, while the quantity of *Dictyopteris membranacea* was reduced. There was a rather high floristic diversity in such pools and red algae were still represented, though in reduced quantities (e. g. *Ceramium diaphanum, C. ciliatum, C. tenerrimum, C. tenuissimum, Callithamnion corymbosum, Antithamnion plumula, Lomentaria clevellosa* etc). The previously abundant *Griffithsia opuntioides* disapeared and *Nitophyllum punctatum* which had bean prolific appeared only in single specimens. A rather prolific growth of *Corallina officinalis,* fringing the pool, is noteworthy, as well as the presence of much *Cystoseira spicata.*

In spite of the increased pollution the tide pool vegetation of this particular site was still rich regarding the degree of covering and floristic diversity. Rather drastic changes took place, on the other hand, on the eulittoral and sublittoral slopes where the *Fucus virsoides* and *Sargassum* settlements disappeared and that of *Cystoseira* species were reduced. As an extreme reduction in zonation the following pattern was observed locally: *Enteromorpha intestinalis*- bare rock- dwarf *Ulva rigida-Mytilus galloprovincialis*- bare rock all the may to the sandy slopes. In the second locality, which is located nearer the Rovinj harbour, the pollution effects are more pronounced. Previously *Fucus virsoides* was present here associated with *Enteromorpha ramulosa* and *E. multiramosa* (M u n d a, 1972 a). Lower down there was a low covering of dendritic species among which *Sphacelaria britaannica, Gelidium* and *Gelidiella* species were dominant *(Gelidium melanoideum, G. spathulatum, Gelidiella lubrica, G. nigrescens, G. tenuissima).* Eulittorally the *Fucus virsoides* girdle disapeared and was replaced by patcehs of *Enteromorpha intestinalis.* The mentioned *Gelidium-Gelidiella* covering was still present, though reduced. The spring vegetation was dominated by a prolific growth of *Scytosiphon lomentaria* and *Ulva rigida,* both present as giant specimens.

VAL DI LESSO AND VICINITY OF THE ROVINJ HOSPITAL

During previous studies the eulittoral and upper sublittoral vegetation of Val di Lesso and its vicinity was dominated by dense and prolific settlements of *Cystoseira adriatica.* This association in which *Jania rubens* was outstanding, has been described (M u n d a, in press). On its upper limit it touched *Fucus virsoides* belts whereas where the exposure was high the *Cystoseira* association was lifted up into the eulittoral level. During 1978 the fucoid settlements were completely deteriorated in these heavily polluted sites. The vegetation was represented by patches of *Enteromorpha intestinalis* and *E. prolifera* eulittorally and lower down by settlements of *Scytosiphon lomentaria* and *Ulva rigida.* There were numerous epipyhtes on the giant *Scytosiphon* plants here, such as *Ectocarpus siliculosus, Porphyra leucosticta* and diatoms. The presence of several *Enteromorpha* and *Cladophora* species as well as of *Punctaria latifolia, Ceramium ciliatum* and *Gelidium spinulosum* of is further noteworthy for this heavily polluted area.

ISLAND OF VELIKA FIGAROLA

There was a prolific fucoid vegetation on this island a decade ago, with broad and dense *Fucus virsoides* belts eulittorally (M u n d a, 1972 a, b) and a well developed asscociation of *Cystoseria barbata* with numerous epiphytes and companion species sublittorally. Lower down the sublittoral followed *Cystoseria adriatica* in dense stands (M u n d a, 1974 b).

This prolific vegetation which likewise exhibited high biomass values (Munda, 1972 b, 1974 b) deteriorated recently. *Fucus virsoides* belts disapeared completely from the eastern slopes, where it had been most prolific and remained in fragments on the western seaward shore of the island. The same was true for the spring association of *Ceramium diaphanum* in which *Laurencia obtusa* was well represented. Fragments of *Cystoseira* stands were likewise found on the seaward banks while they were totaly absent on the western side of the island.

Eulittorally *Enteromorpha* species *(E. prolifera, E. intestinalis, E. clathrata)* and *Cladophora dalmatica* as well as *Cl. ruchingeri* were found in small pools and eulittoral depressions. *Enteromorpha* stands were likewise found in terrestrial pools. Sublittorally and in the level of the eulittoral/sublittoral junction *Gelidium* spp.-*Gelidiella* spp. mats were well developed and covered considerable surfaces. The sublittoral vegetation was dominated by prolific settlemnts of both *Halopteris scoparia* and *Dictyota dichotoma,* which occurred in separate associations. Locally, however, the sublittoral rocky surfaces are bare and coated only by a thin layer of colonial diatoms.

ISLAND OF MALA FIGAROLA

Vegatation changes were similar on the small neighbouring island. Here some deep tide pools were found, still covered with *Cystoseira* species *(C. barbata, C. spicata, C. compressa)* while the slopes were likewise covered by *Enteromorpha, Halopteris* and *Dictyota* stands.

FABORSA

This open bay, situated in the outer area of the Limski kanal (Lim fjord) was chosen as a control locality due to its distance from the town of Rovinj and thus minor pollution effects. Consequently changes in the benthic algal vegetation were less severe.

The *Fucus virsoides* belt in the eulittoral was still prolific and well developed as was the spring association of *Ceramium diaphanum* below it. Furthermore, *Polysiphonia* stands were prolific in the spring vegetation, represented by *Polysiphonia furcellata, P. elongata, P. variegata.* On pebbles *Callithamnion corymbosum* and *Antithamnion plumula* were found in notable quantities. Red algae were in general well represented in the spring vegetation of this bay (see Table 4). In the eulittoral *Cladophora dalmatica, Cl. ruchingeri* and *Enteromorpha* species occurred together with *Fucus virsoides* and also as its epiphytes. It is further noteworthy that in rocky fissures of the littoral fringe *Catenella caespitosa* formed dense stands.

The vegetation was somewhat reduced on the sublittoral slopes, though *Cystoseira barbata* stands were still found in fragments. As usual, this association was accompanied by *C. compressa* and *C. spicata* (Munda, in press). The widest surfaces of the sublittoral slopes were, however, occuppied by associa ions of *Halopteris scoparia* and *Dictyota dichotoma.* Locally the slopes were totally denuded. The vegetation of rocky pools was, on the other hand, rather unchanged with ***Cystoseira*** and ***Laurencia*** species, ***Alsidium corallinun***, ***Cladophora ruchingeri***, ***Polysiphonia*** and ***Ceramium*** species as well as representatives of the Champiaceae (Table 4).

In the bay of Faborsa, however, vegetation changes mainly concern the sublittoral growth while the eulittoral one and that of the tide pools was almost unchanged and exhibited a high floristic diversity during spring.

ŠKARABA

The bay of Škaraba and the open coast in its vicinity had a prolific vegetation a decade ago. The eulittoral zone in the bay was occupied by *Fucus virsoides* settlements followed by a belt of *Ceramium diaphanum* and *Polysiphonia* species. Both *Ceramium diaphanum* and diverse *Polysiphonia* species were likewise prolific in the tide pools. The sublittoral slopes were overgrown by dense and extremely prolific *Cystoseira* stands, which exhibited in this particular locality the highest biomass and floristic diversity (Munda, 1972 b, in press). A variant of the *Cystoseira barbata* association, with *C. spicata* as codominant was described for this bay while along the open coast a pure *C. spicata* association was found (Munda, in press) There this association was lifted up into the eulittoral level, where also dense mats of *Cladophora dalmatica* were found locally.

This prolific vegetation deteriorated drastically. In the eulittoral patches of *Enteromorpha intestinalis* and *Cladophora dalmatica* were found on otherwise denuded rocky surfaces. Thery represented the only local benthic vegetation. In such cases the algal growth was substituted by belts of *Mytilus galloprovincialis* both in the eulittoral and upper sublittoral. Grazing by sea urchins had a further deteriorating effect on the vegetation of this bay. Locally there were dense carpets formed by dendritic *Gelidium* and *Gelidiella* species and discontinuos settlements of *Halopteris scoparia* and *Dictyota dichotoma* sublittorally.

It seems likely that the deteriorating effects of both organic pollution and grazing were most severe in Škaraba. The previously prolific vegetation became reduced in terms of biomass, degree of covering and floristic diversity. In the sublittoral, however, bare rocky surfaces prevailed.

CRVENI OTOK (RED ISLAND)

On this island pollution was increased by tourism during the last few years. Though the average bacterial pollution is negligible, a relatively high avrage BOD value was detected along with radical changes in the vegetation pattern. Previously the sublittoral slopes were occupied by a *Cystoseira crinita* association and in shallow splash pools *C. compressa* dominated, forming a low covering. Recent observations revealed that *Cystoseira* species disappeared from the vegetation of this island. Only a few scattered specimens of *Cystoseira spicata*, accompanied by *Padina pavonia* were found in one spot. A few rudimentary specimens of *Fucus virsoides* were likewise detected.

As in Škaraba the eulittoral growth was represented by patches of *Cladophora dalmatica* and *Enteromorpha intestinalis* on otherwise denuded rocky surfaces. Around the eulittoral/sublittoral junction and in the uppermost sublittoral dense carpets consisting of diverse *Gelidium* and *Gelidiella* species were frequent. Lower down the sublittoral settlements of *Halopteris scoparia* and *Dictyota dichotoma* occurred scattered and were interrupted by bare rocky surfaces on which there was a tiny layer consisting of colonial diatoms.

Enclaves of *Ceramium* species were found locally.

STURAGO

This small rocky island, situated farther offshore exhibited a richer vegetation that the neighbouring one just described. Previously the association of *Corallina officinalis* was studied here in detail (Munda, 1977). Recently *Corallina* settlements were poorly developed here and did not deserve an association rank. The *Fucus virsoides* association was absent on this island due to the strong exposure and steep slopes and *Cystoseira* settlements protruded locally into the eulittoral level. Recently the *Cystoseira* vegetation on this island diminished notably. Girdles of *Cystoseira spicata* were found locally around the eulittoral/sublittoral junction and in the uppermost sublittoral. The same species occurred in deep rocky pools together with *C. compressa* and *Padina pavonia*. Steep sublittoral slopes appeared bare of algal growth; whereas where the slopes were moderate *Halopteris scoparia* and *Dictyota dichotoma* associations prevailed. In the eulittoral patches of *Enteromorpha intestinalis* and *Cladophora dalmatica* were common as were *Gelidium-Gelidiella* carpets lower down, as on Crveni otok. Further algal settlements characteristic for the spring aspect of this island were those of *Lomentaria clavellosa* and *Laurencia obtusa*, both in rocky pools and on emerged slopes. *Ceramium* species were rare on these islands and the same was true for representatives of the genera *Polysiphonia, Callithamnion* and *Antithamnion*. *Amphiroa* species *(A. rigida, A. cryptarthrodia)* were found intermingled in *Lomentaria clavellosa* stands, as was *Corallina officinalis*.

The vegetation of this island still exhibits a rather high floristic diversity, though less of most of the species than found previously. Changes in the vegetation pattern center on the reduction of the *Corallina officinalis* and *Cystoseira* stands and on a rather prolific development of the *Halopteris scoparia* and *Dictyota dichotoma* associations.

ISLAND OF SAN GIOVANNI

The island of San Giovanni, which is situated even farther offshore still exhibited a rich and variegated vegetation. Due to strong exposure both *Fucus virsoides* and *Cystoseira* settlements were previously badly developed here.

In the level of the littoral fringe *Bangia atropurpurea* was found in patches and *Catenella caespitosa* coated rocky fissures. In sheltered sites of the eulittoral level fragmentary *Fucus virsoides* girdles were found. As in the rest of the Rovinj area *Cladophora dalmatica* and *Enteromorpha intestinalis* occurred in patches in the same level. Lower down in the eulittoral as well in rocky pools the *Ceramium diaphanum* association was prolific and well developed as were settlements of diverse *Polysiphonia* species. Around the eulittoral/sublittoral junction there were dense and continuous populations of *Lomentaria clavellosa* and *Laurencia obtusa,* with numerous companion species in between. In the upper sublittoral the *Corallina officinalis* association was found locally and was well developed, with a high floristic diversity and a 100% degree of covering. In shallow and extensive rocky pools there were prolific settlements of *Cystoseira* spacies *(C. barbata, C. compressa, C. spicata, C. crinita, C. corniculata)* intermingled with *Padina pavonia.* Such settlements were, however, rare and scattered on sublittoral slopes where *Halopteris scoparia* and *Dictyota dichotoma* associations prevailed.

Considering the three islands: Crveni otok-Sturago-San Giovanni a gradient of pollution effects on the benthic vegetation is visible. The vegetation was the richest and the floristic diversity the highest on the offshore island of San Giovanni, where *Corallina officinalis* and fucoid settlements were still well developed and the red alga/component well represented in the spring vegetation. Pollution effects were, however, expressed in a reduction of the *Cystoseira* settlements, which were mainly limited to rocky pools and in the prolific development of the *Halopteris scoparia* and *Dictyota dichotoma* associations.

PALU

The rocky coast which fringes brackish marshes at Palu was chosen as a reference locality due to its distance from the town and thus minimal water pollution. In spite of the considerable distance from the town with its sewage outlets the sublittoral vegetation seemed influenced by deteriorating effects of organic pollution. This was first of all visible on sublittoral slopes, where *Halopteris acoparia* and *Dictyota dichotoma* associations dominated while *Cystoseira* associations were sparse. The *Cystoseira* vegetation was also here mainly limited to shallow rocky pools, where continuous mats of *C. barbata* and *C. compressa* were usual, accompanied by *Padina pavonia* and *Laurencia obtusa. Lomentaria clavellosa* formed dense mats around the eulittoral/sublittoral junction and in rocky pools. The *Ceramium diaphanum* association was prolific and red algae in general well represented in the vegetation. As an additional association that of *Nemalion multifidum* was detected. In the eulittoral level rudimentary belts of *Fucus virsoides* were found locally as well as the usual settlements of *Cladophora dalmatica* and *Enteromorpha inestinalis.* On almost horizontal rocky surfaces, in the level of the littoral fringe, *Rivularia atra* formed broad belts in this particular area.

It is further noteworthy that species which were characteristic for heavily polluted sites near the town, i. e. *Ulva rigida* and *Scytosiphon lomentaria* were absent from the vegetation at Palu.

ALGAL ASSOCIATIONS OF POLLUTED HABITATS

Some vegetation units, characteristic for polluted sites in the Rovinj area have been established. Some of them replaced fucoid settlements and others, previously present, expanded due to lack of competition with fucoids and red algae.

Table 4. Species distribution in the investigated area

	1 G	2 S	3 CO	4 CO	5 Š	6 Š	7 Fa	8 Fi	9 K1	10 K2	11 Lo	12 Le
RHODOPHYTA												
Catenella caespitosa	+	+					+	+	+			
Ceramium diaphanum	+	+		+			+	+	+			
Ceramium ciliatum	+	+		+	+	+	+	+	+	+	+	+
Ceramium tenerrimum	+	+		+			+	+	+			
Ceramium tenuissimum	+	+		+			+	+				
Ceramium gracillimum	+	+		+	+							
Callithamnion corymbosum	+	+					+	+	+		+	
Antithamnion plumula	+	+					+	+	+		+	
Antithamnion cruciatum	+						+	+	+			
Aglaothamnion sp.	+	+					+	+	+			
Crouania attenuata	+	+					+	+	+			
Spirydia filamentosa		+		+			+		+			
Corallina officinalis	+	+		+		+	+	+	+			
Amphiroa cryptarthrodia	+	+					+	+				
Amphiroa rigida	+	+			+	+	+					
Hildenbrandia rubra	+	+		+		+	+	+				
Lomentaria clavellosa	+	+		+	+	+	+	+	+	+		
Champia parvula	+	+			+	+	+	+		+		
Gastroclonium clavatum	+	+				+	+					
Alsidium corallinum						+	+					
Gelidium spinulosum cf.						+						
Gelidium melanoideum	+	+	+	+								+
Gelidium spp.; *Gelidiella* spp.	+	+	+	+	+	+	+	+	+	+		
Bangia atropurpurae	+				+	+	+	+	+	+		
Phymatolithon lenormandii	+	+	+	+	+	+	+	+	+	+		
Phymatolithon polymorphum	+	+	+	+	+	+	+	+				
Polysiphonia furcellata	+	+					+	+	+			
Polysiphonia elongata	+	+					+					
Polysiphonia surtularioides	+						+					
Polysiphonia variegata	+	+		+			+	+	+			
Porphyra leucosticta									+	+	+	+
Ptilothamnion pluma	+											
Fauchea repens	+	+						+	+			
Chondrya tenussima	+	+		+					+			
Chondrya dasyphylla	+	+		+								

Compsothamnion thuyoides	+										
Dipterosiphonia rigens	+	+	+		+	+	+	+		+	
Jania rubens	+	+				+	+	+			
Laurencia obtusa	+	+	+		+	+	+	+		+	
Laurencia pinnatifida	+	+				+	+				
Laurencia papillosa	+										
Nitophyllum punctatum	+	+				+	+	+			
Fosliella sp.	+	+	+		+	+	+	+			
Crodelia expansa	+										
CYANOPHYTA											
Rivularia atra	+	+					+	+	+		
PHAEOPHYTA											
Fucus virsoides	+		+			+	+			+	
Cystoseira spicata	+	+	+		+	+	+	+			
Cystoseira barbata	+					+	+	+			
Cystoseira corniculata	+										
Cystoseira crinita	+	+									
Cystoseira compressa	+	+	+								
Acinetospore vidovichii	+						+	+	+		+
Acinetospora crinita	+					+		+			
Ectocarpus siliculosus	+	+	+	+	+	+	+	+	+	+	+
Ectocarpus fasciculatus	+	+				+					
Colpomenia sinuosa								+	+	+	
Punctaria latifolia											+
Cladostephus verticillatus						+					
Sphacelaria britanica	+	+	+	+	+	+	+	+	+	+	
Sphacelaria cirrosa	+	+				+	+	+			
Halopteris scoparia	+	+	+	+	+	+	+	+	+	+	
Mesogloia leveillei						+		+		+	
Stictyosiphon adriaticus								+		+	+
Scytosiphon lomentaria			+		+		+		+	+	+
Dictyota dichotoma	+	+	+	+	+	+	+	+	+	+	
Dictyopteris membranacea						+		+			
Cutleria multifida										+	
Padina pavonia	+	+	+	+	+	+	+	+	+	+	
Giffordia hincksiae						+					
Ralfsia verrucosa	+	+			+	+	+	+	+	+	
Dilophus fasciola								+	+	+	

Table 4. Ending

	1 G	2 S	3 CO	4 CO	5 Š	6 Š	7 Fa	8 Fi	9 Kl	10 K2	11 Lo	12 Le
CHLOROPHYTA												
Blidingia minima					+	+			+	+	+	
Bryopsis plumosa	+	+					+	+	+			
Pseudochlorodesmis furcellata	+	+		+			+	+	+			
Derbesia lamourouxii	+						+					
Derbesia tenuissima	+						+		+			
Cladophora dalmatica	+	+		+	+	+	+	+	+	+	+	
Cladophora ruchingeri	+	+					+	+	+			
Cladophora sp.												+
Chaetomorpha sp.												+
Ulva rigida	+	+		+		+	+	+	+	+	+	+
Ulvaria oxysperma								+				
Codium fragile							+	+	+		+	
Enteromorpha intestinalis	+	+		+	+	+	+	+	+	+	+	+
E. clathrata								+		+	+	+
E. compressa												+
E. ramulosa										+	+	+
E. multiramosa										+	+	+
E. prolifera							+	+	+	+	+	+

Localities: 1 G — San Giovanni, 2 S — Sturago, 3 CO — Crveni otok (Red Island) — west side, 4 CO — Crveni otok (Red Island) — east side, 5 Š — Škaraba — open site, 6 Š — bay of Škaraba, 7 Fa — bay of Faborsa, 8 Fi — island of Velika Figarola, 9 K1 — Sv. Katarina I, 10 K2 — Sv. Katarina II (little harbour), 11 Lo — Val di Lone, 12 Le — Val di Lesso and vicinity of the hospital

Eulittoral associations

Blidingia minima. This one-layered association was found in the eulittoral zone of some polluted habitats covering rather extensive surfaces on otherwise bare rocks.

Enteromorpha intestinalis. This association was likewise one layered and exhibited a wide distribution in the eulittoral of the entire investigated area. It occurred in patches of pure growth on emerged surfaces and in small eulittoral depressions. It had been present in the area previously, but had had a subordinate role in the vegetation pattern. Recently, due to the disappearence of *Fucus virsoidies* settlements it was able to expand on wider surfaces and to dominate the eulittoral growth.

Cladophora dalmatica. This characteristic spring association has a similar mode of occurrence as the association just described. Previously it was well developed on highly exposed rocky slopes, as e. g. on the island of Pirozi, on the Red Island and in Škaraba. Recently it was still found in similar habitats and was also encountered in the bay Val di Lone, which is considerably polluted.

The three associations, however, became outstanding in the eulittoral vegetation due to lack of competition with *Fucus virsoides.* In contrary, an association of *Enteromorpha* spp. had developed recently in sites subjected to pollution. It differs from the above mentioned *E. intestinalis* association in its zonal position and physiognomy. The species represented in it were present in long tufts and formed girdles around the eulittoral/sublittoral junction in sites subjected to relatively strong pollution effects (e. g. Val di Lone, vicinity of the Rovinj hospital, island of Velika Figarola). The principal species encountered were: *Enteromorpha clathrata, E. prolifera, E. ramulosa, E. Multiramosa.*

Gelidium spp.-*Gelidiella* spp. This association is widely distributed in the Rovinj area and it is likely that it prefers habitats with a medium degree of organic pollution (e. g. island of Velika Figarola, Škaraba, Crven otok (Red Island), Sturago). Its zonal position is the lower eulittoral and the level of the eulittoral/sublittoral junction. Locally it protrudes into the uppermost sublittoral level. This association apparently replaced fucoid settlements in this particular level, i. e. either *Fucus virsoides* or *Cystoseira* settlements. The association is one layered and the dendritic species represented in it are as a rule interwoven into shell sand. Several *Gelidium* and *Gelidiella* species were recognized in it (e. g. *Gelidium malanoideum, G. spathulatum, G. pusillum, Gelidiella lubrica, G. nigrescens, G. tenuissima)* as well as *Sphacelaria britannica.*

Sublittoral associations

In the eulittoral level *Fucus virsoides* stands disappeared in polluted habitats and in the sublittoral the *Cystoseira* and *Sargassum* settlements deteriorated. Field observations revealed that the latter are even more sensitive to pollution stresses than *Fucus virsoides.* In poorly poluted control habitats, where *Fucus* belts still dominated, the *Cystoseira* stands disappeared or were strongly reduced.

Halopteris scoparia. The association of this nitrophilous species recently became the dominant one in the sublittoral of the investigated area (Munda, 1974 a). It was only absent in sites where pollution was the strongest and where seasonal associations dominated during spring. This association was found in widely different habitats, from the relatively clean control localities Palu, San Giovanni and Faborsa to heavily polluted ones in the vicinity of the town itself. Its vertical distribution is locally extensive and it touches sandy slopes. In its undergrowth crustaceous species such as *Phymatolithon polymorphum, P. lenormandii, Hildenbrandia rubra, Ralfsia verrucosa* were usual. As companion species *Dictyota dichotoma* and *Dilophus fasciola* were occasionally found. In the epiphytic cover only colonial diatoms and *Ectocarpus siliculosus* along with diverse *Enteromorpha* species could occur.

Dictyota dichotoma. Like *Halopteris scoparia* this species froms the next dominnt association on sublittoral slopes of the area. As mentioned, the two named associations intergrade locally in a mozaic pattern but do not mingle. *Dictyota dichotoma* obviously expanded on wide sublittoral surfaces due to lack of competition with *Cystoseira* species. It is widely distributed in the entire area but apparently avoids sites where pollution is the most severe. The same crustaceous floristic elements as mentioned for the *Halopteris scoparia* association were found in its undergrowth and *Dictyopteris membranacea* and *Dilophus fasciola* could be found as its companion species. The number of companion species was increased where the same association was found in rocky pools, as e. g. on the island of Sv. Katarina *(Padina pavonia, Ulva rigida, Ceramium diaphanum, Polysiphonia furcellata, Jania rubens, Colpomenia sinuosa).* In such cases *Dipterosiphonia rigens* joined the undergrowth. The epiphytic layer is lacking in this association.

Colpomenia sinuosa. This association was found in the sublittoral of polluted bays, as e. g. in Val di Lone. It formed rather extensive patches which interrupted the *Halopteris scoparia. Ulva rigida* or *Dictyota dichotoma* settlements. It is one-layered without companion species and undergrowth.

Association of diverse filamentous brown algae. An association in which diverse filamentous algae were represented as codominant was found in sheltered sites, on a sandy-muddy bottom and in an artificial basin in Val di Lone. The dominant floristic elements occurred in long, interwoven tufts *(Stictyosiphon adriaticus, Ectocarups siliculosus, Cutleria multifida, Scytosiphon lomentaria). Dilophus fasciola, Striaria attenuata, Mesogloia leveillei, Ulva rigida, Enteromorpha prolifera* and *E. clathrata* were found within the same association. In its epiphytic cover *Ectocarpus siliculosus*, colonial diatoms and *Porphyra leucosticta* were found.

This association has not been observed previously. Its distribution in the area is rather limited since it prefers soft substrata, extreme shelter and a high degree of organic pollution.

Scytosiphon lomentaria is a characteristic spring association for the North Adriatic (Munda, 1975). A decade ago it was poorly developed in the Rovinj area and found only locally on the island of Velika Figarola. Due to increased pollution by organic wastes this association recently became prolific and widespread. The dominant species is usually present in giant, up to 1 m long and

1 cm broad plants which are heavily epihytized. Previously the species appeared in only up to 15 cm long and narrow specimens bare of epiphytic cover.

This spring association was prolific in Val di Lone, on the island of Sv. Katarina and in the vicinity of the Rovinj hospital. Undergrowth was usually lacking. Only in a few cases it was superimposed on the *Gelidium* spp.-*Gelidiella* spp. association. The floristic composition of the association varied from spot to spot and it could locally mingle with the *Ulva/rigida* association. The most common companion species were the following: *Punctaria latifolia, Stictyosiphon adriaticus, Enteromorpha prolifera, E. clathrata, Ulva rigida.* In the epiphytic cover of the dominant species *Ectocarpus siliculosus,* colonial diatoms, *Enteromorpha* species and *Porphyra leucosticta* were found.

Ulva rigida is the second spring association characteristic for polluted sites around Rovinj (Val di Lone, island of Sv. Katarina, vicinity of the hospital). *Ulva* formed prolific settlements of giant plants, mostly in pure/stands. *Ulva* species are a good indicator for increased pollution by sewage (Cotton, 1911, Letts and Richards, 1911) as is likewise the case in the area under discussion.

DISCUSION AND CONCLUSIONS

During the last decade pollution by sewage increased drastically in the area, around Rovinj and caused profound changes in the benthic algal associations in terms of species composition, abundance and biomass. It is, however, well known that benthic marine communities undergo changes in sewage impacted areas (Munda, 1967; Golubić, 1970; Littler and Murray, 1975; Borowitzka, 1972; Edwards, 1972, 1975; Rueness, 1973; Bokn and Lein, 1978). A reduction in species diversity is a general feature of polluted biotopes (Andrews, 1976; Goodwin, 1975).

Benthic algae are a valuable indicator for longterm pollution impact which results in an unstable stressenvironment with increased amounts of nutritive salts, suspended and colliodal particles and bacteria. Attempts were made to discover indicator organisms (Stein and Denison, 1967; Storrs et al. 1969) and it was recongized that biological indicators are superior to merely chemical and physical ones.

The dominant populations of *Fucus virsoides, Cystoseira* and *Sargassum* species disapeared near the outfall areas in Rovinj and its vicinty and were replaced by other associations. In the eulittoral *Enteromorpha intestinalis* and *Cladophora dalmatica* occurred in patches of pure growth on otherwise denuded rocky surfaces. The expansion of their settlements is to the disappearence of the *Fucus virsoides* belts rather than true succession since they were present in the eulittoral in smaller amounts before the critical sewage pollution impact. A spring assocation of diverse *Enteromorpha* species *(E. prolifera, E. clathrata, E. ramulosa),* appeared, on the other hand, in strongly polluted habitats in the lower eulittoral. Turf-forming *Gelidium* and *Gelidiella* species, interwoven into shell sand, covered wide surfaces around the eulittoral-sublittoral junction in most of the polluted sites.

In sites distant from the outfalls the eulittoral vegetation was still undisturbed, with *Fucus virsoides* belts in the eulittoral and *Ceramium* and *Polysiphonia* settlements below it. Furthermore, *Lomentaria clavellosa* and *Laurencia obtusa* formed dense mats in the relatively unpolluted control localities.

Contrary to the eulittoral vegetation, the sublittoral one was reduced and changed all throughout the investigated area. Even in control localities distant from the outfalls, *Cystoseira* settlements were reduced and mainly replaced by associations of *Halopteris scoparia* and *Dictyota dichotoma*. The two mentioned associations became dominant on the sublittoral slopes and obviously succeeded the diverse *Cystoseira* and *Sargassum* associations. Limited *Cystoseira* settlements were found only in rocky pools of the control localities (Palu, Faborsa, San Giovanni and Sturago) and occassionally formed narrow belts in the upermost sublittoral. Everywhere in the area the previously dominant *Cystoseira* component became subordinate in the vegetation and the *Sargassum* component disappeared.

The recent sublittoral benthic vegetation of the Rovinj area is thus dominanted by settlements of the nitrophilous species *Halopteris scoparia* and that of *Haloperis scoparia* and of *Dictyota dichotoma,* avoid localities where of diverse codominant filamntous brown algae *(Stictyosiphon adriaticus, Ectocarpus siliculosus, Cutleria multifida* etc) was found occasionally in highly polluted sites. Field observations indicated that both dominant associations, that of *Haloperis scoparia* and of *Dictyota dichotoma,* avoid localities where the pollution impact is the strongest. There, during the spring aspect, seasonal associations of *Scytosiphon lomentaria* and of *Ulva rigida* dominated and were extremely prolific. *Ulva* species are, however, a good indicator for sewage pollution (Burrows 1971; Cotton, 1911; Letts and Richards, 1911; Borowitzka, 1972). No blue-green alga mats were found near the outfalls in the localities observed here. Blue-green algae are, however, an indicator for pollution by sewage and were as such reported by Golubić (1970) for the Adriatic. Similar observations were carried out in western Norway (Munda, 1967, 1974 a) where mats of blue-green algae were found near the sewage outlets and a certain gradient in the vegetation pattern with increasing distance from the pollution source. No clear gradients in the vegetation pattern were observed in the Rovinj area.

It is noteworthy that the destruction of algal settlements is partly due to the grazing by sea urchins, an effect which is secondary to that of pollution.

Observations in the Rovinj area reported here refer to spring, when the floristic diversity is at its maximum. The distribution of the main species in the investigated area is given, indicating the highest diversity in the control localities (Table 4). In Table 5 a survey of the species found in the upper water levels during spring is given. This Table includes only the most common species and is not meant as a complete floristic inventary of the area. It includes 71 species of Rhodophyta, 37 Phaeophyta and 20 Chlorophyta. Of the total red algae 70% were found in the control localities and 42% of the total number occurred also in polluted sites whereas 23% disappeared apparently from the vegetation. Of the browns 62% were found in the control localities, 18% in polluted sites and 21% of the total numbre were not found. Of the greens, on the other hand, 80% of the total occurred in polluted sites, 55% also in the control localities and 10% apparently disappeared during the last few years.

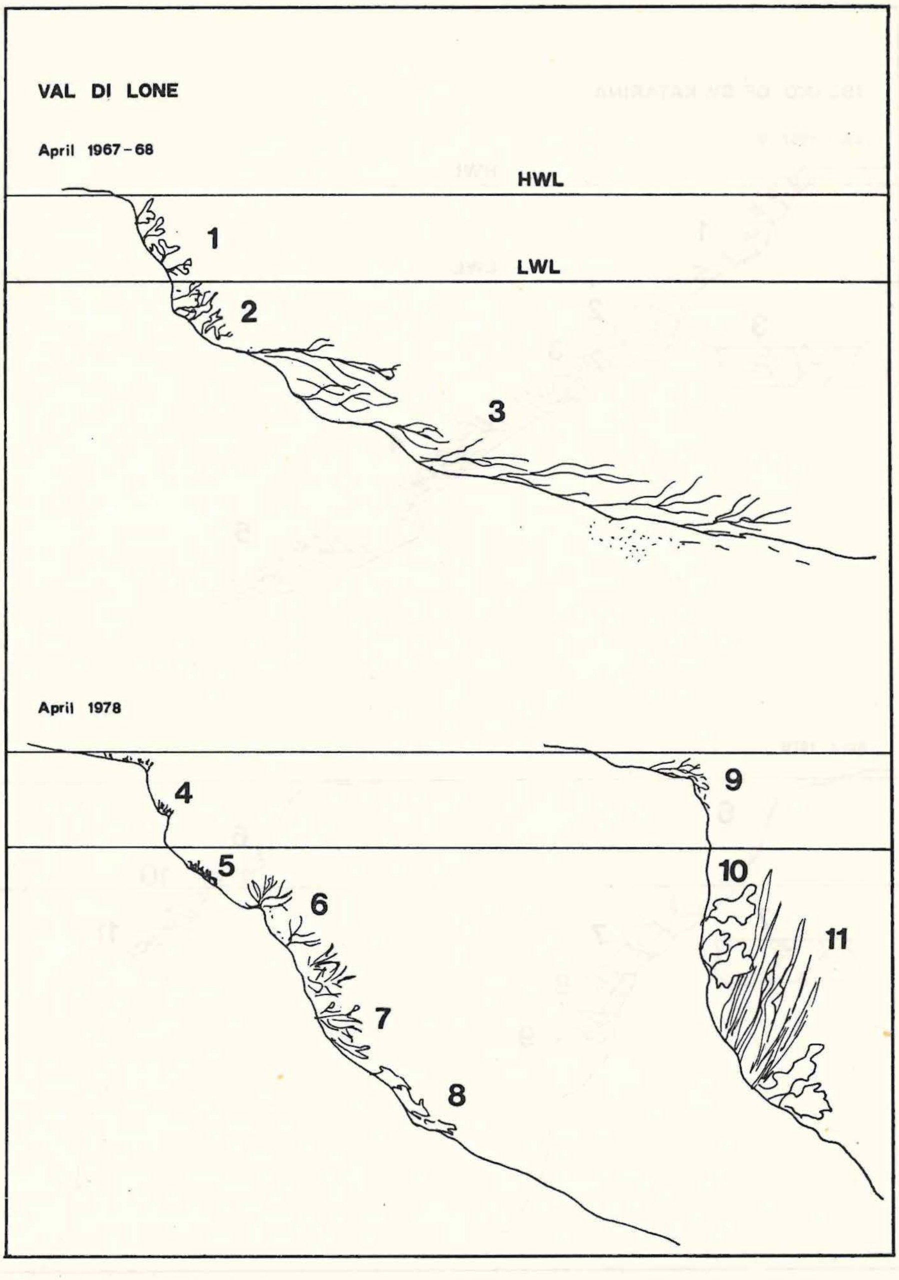

Fig. 5. Changes in the zonation pattern, VAL DI LONE:
1 — *Fucus virsoides*, 2 — *Ceramium diaphanum*, 3 — *Cystoseria barbata*, 4 — *Sargassum hornschuchii*, 5 — *Sargassum acinarium*, 6 — *Enteromorpha intescoparia*, 7 — *Dictyota dichotoma*, 8 — *Colpomenia sinuosa*, 9 — *Enteromorpha clathrata* — *E. ramulosa* — *E. multiramosa*, 10 — *Ulva rigida*, 11 — *Scytosiphon lomentaria*

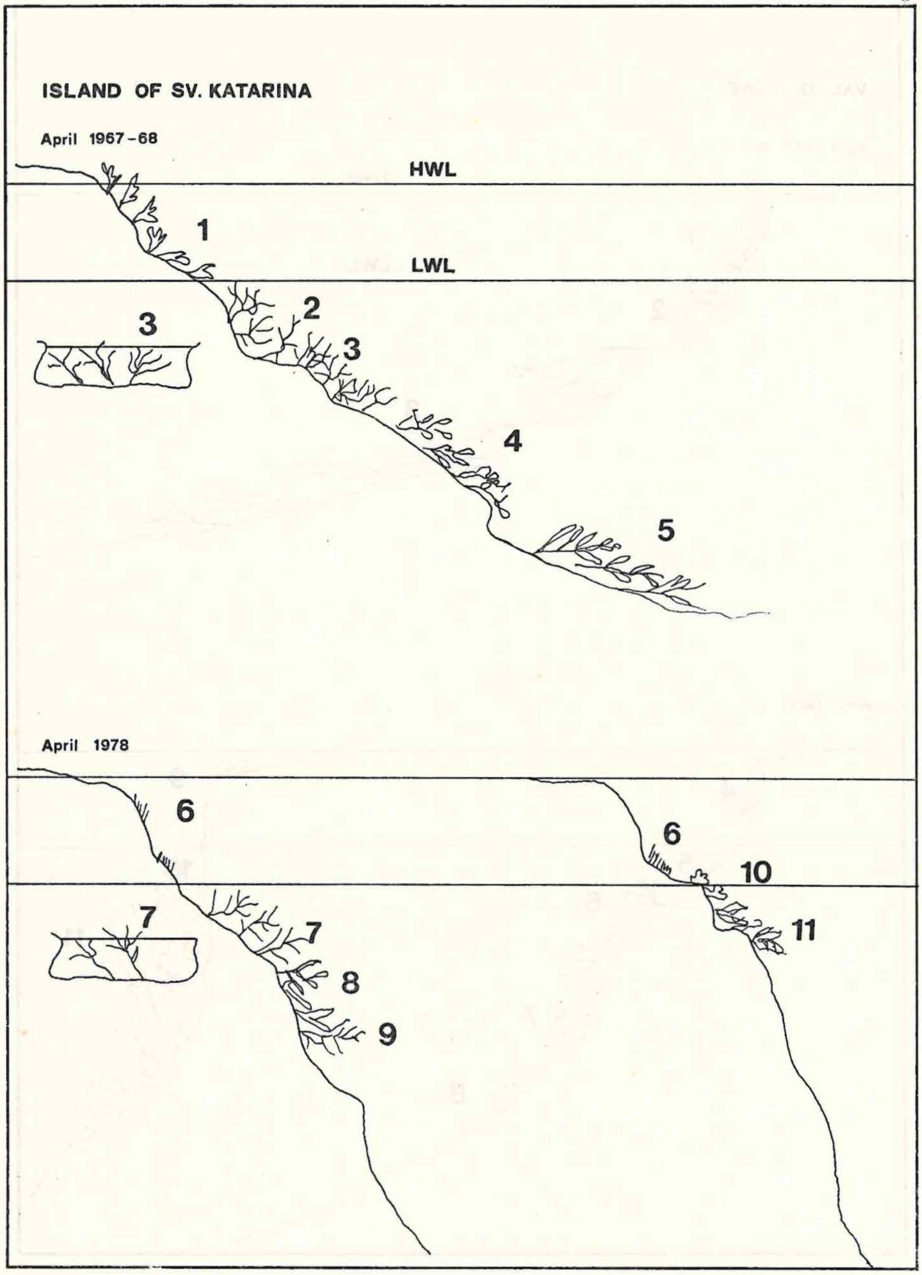

Fig. 6. Changes in the zonation pattern, ISLAND OF SV. KATARINA: 1 — *Fucus virsoides*, 2 — *Cystoseira compressa*, 3 — *Halopteris svoparia*, 4 — *Sargassum hornschuchii*, 5 — *Sargassum acinarium*, 6 — *Enteromorpha intestinalis*, 7 — *Cystoseira compressa*, 8 — *Dictyota dichotoma*, 9 — *Halopteris scorpia*, 10 — *Ulva rigida*, 11 — *Mytilus galloprovincialis*

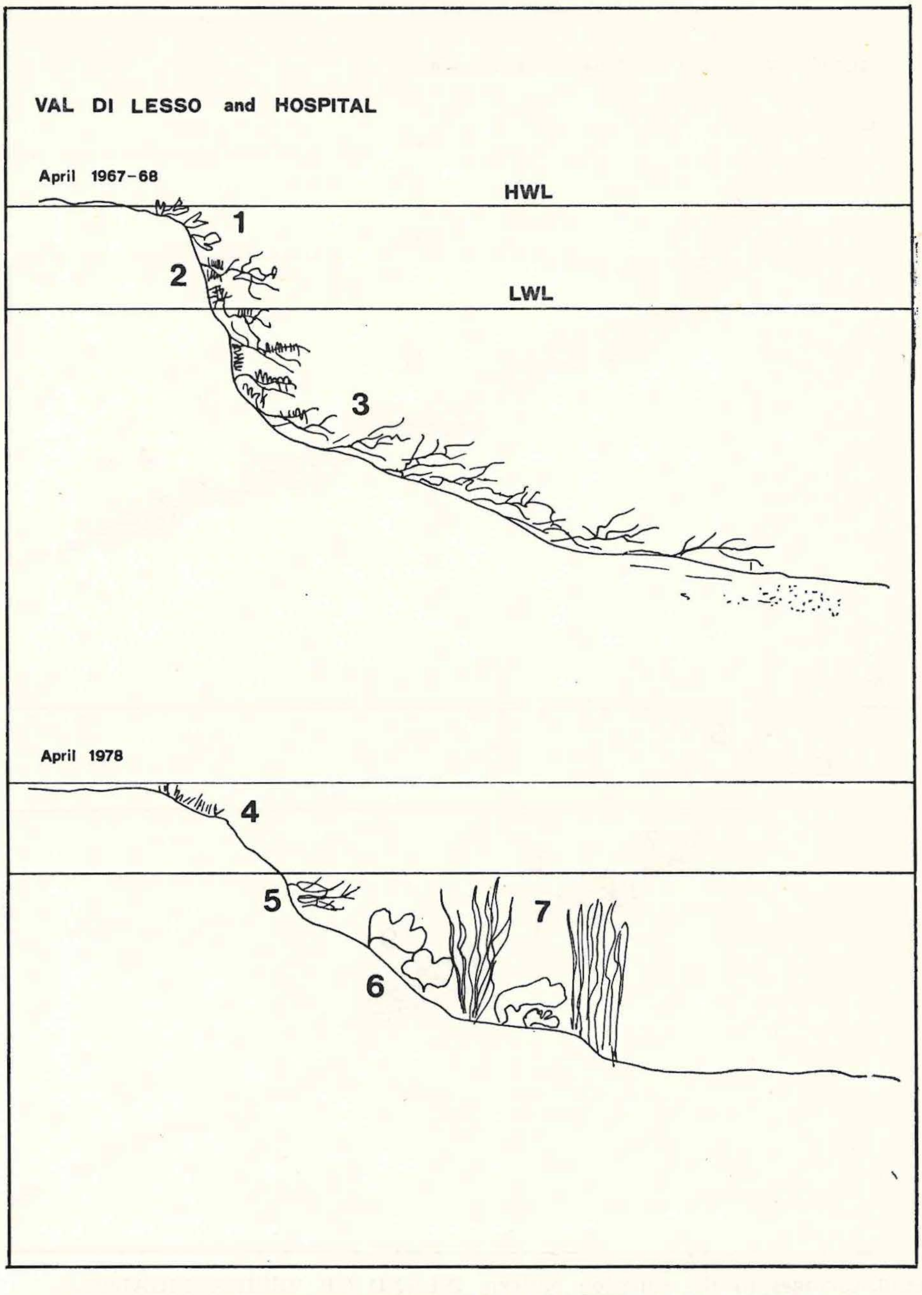

Fig. 7. Changes in the zonation pattern, VAL DI LESSO AND HOSPITAL:
1 — *Fucus virsoides*, 2 — *Jania rubens*, 3 — *Cystoseira adriatica*, 4 — *Enteromorpha intestinalis*, 5 — *Enteromorpha prolifera*, 6 — *Ulva rigida*, 7 — *Scytosiphon lomentaria*

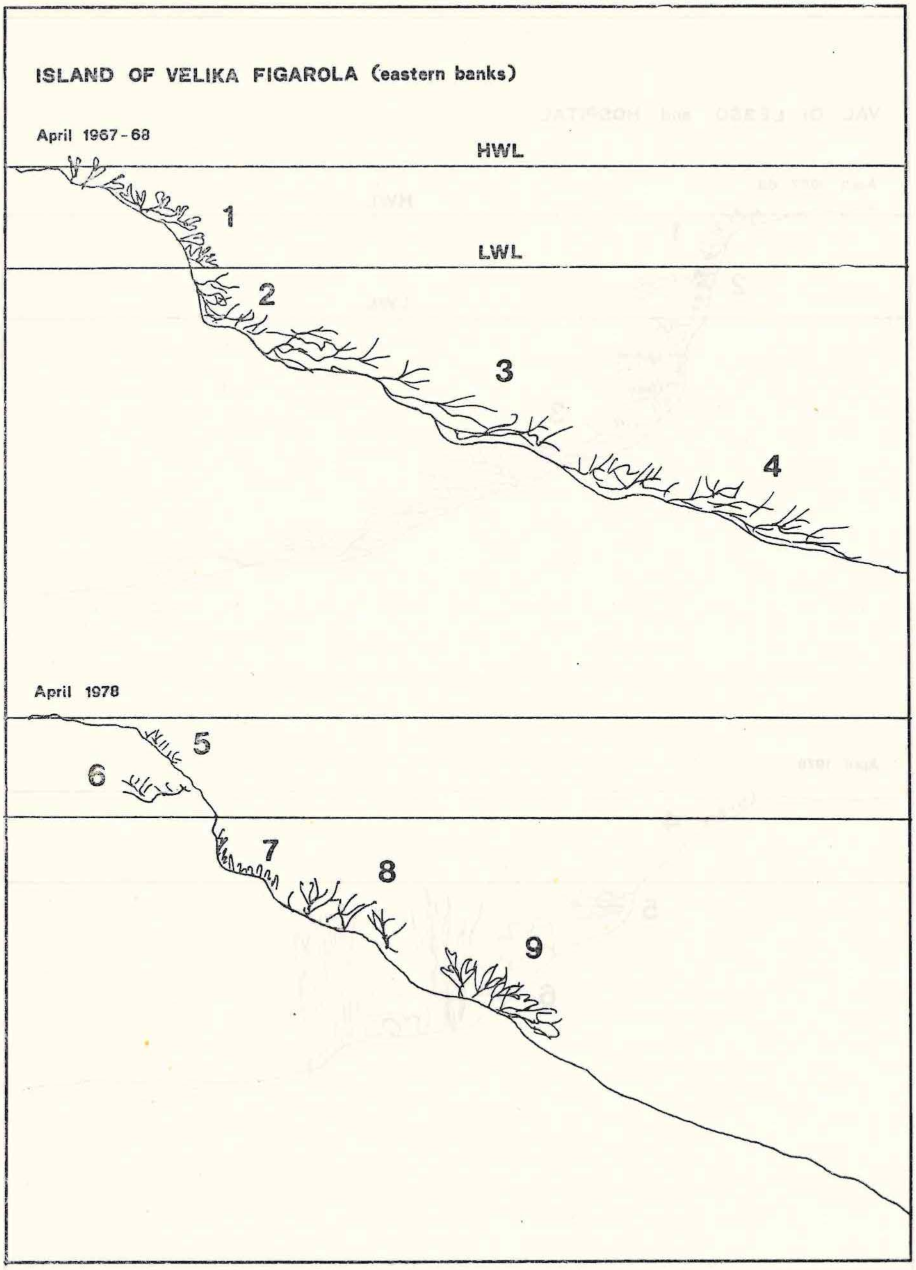

Fig. 8. Changes in the zonation pattern, ISLAND OF VELIKA FIGAROLA: 1 — *Fucus virsoides*, 2 — *Ceramium diaphanum*, 3 — *Cystoseira barbata*, 4 — *Cystoseira adriatica*, 5 — *Enteromorpha intestinalis*, 6 — *Cladophora dalmatica*, 7 — *Gelidium spp.* — *Gelidiella spp.*, 8 — *Halopteris scoparia*, 9 — *Dictyota dichotoma*

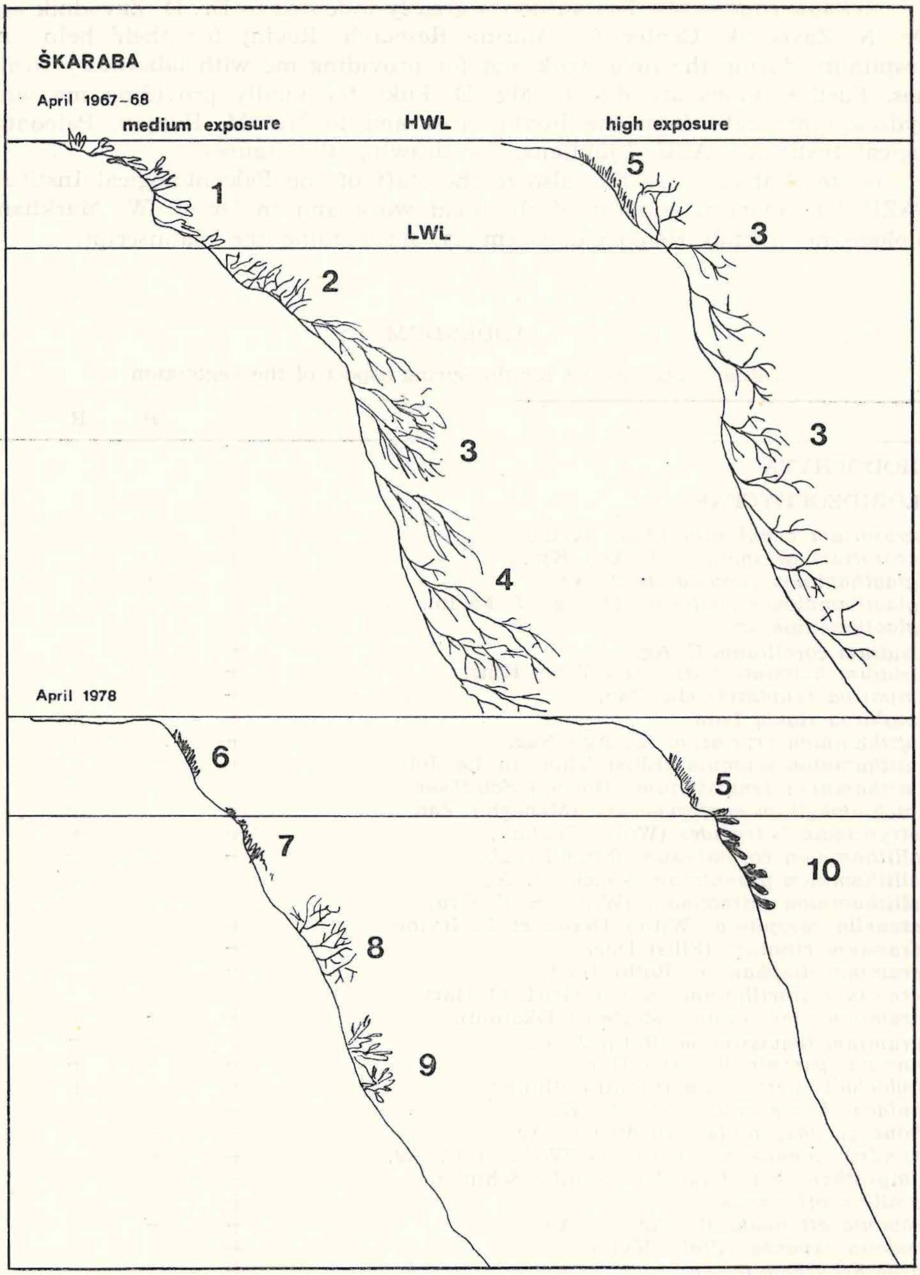

Fig. 9. Changes in the zonation pattern, ŠKARABA:
1 — *Fucus virsoides*, 2 — *Ceramium diaphanum* and *Polysiphonia species*, 3 — *Cystoseira spicata*, 4 — *Cystoseira barbata*, 5 — *Cladophora dalmatica*, 6 — *Enteromorpha intestinalis*, 7 — *Gelidium and Gelidiella species*, 8 — *Halopteris scoparia*, 9 — *Dictyota dichotoma*, 10 — *Mytilus galloprovincialis*

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ADDENDUM

Table 5. Species list for the spring aspect of the vegetation

	C	P	R	A
RHODOPHYTA				
FLORIDEOPHYCEAE				
Acrosorium venulosum (Zan.) Kylin	+			
Acrosorium uncinatum (J. Ag.) Kylin	+			
Aglaothamnion furcellariae J. Ag.				+
Aglaothamnion scopulorum (J. Ag.) J. Feldm.				+
Aglaothamnion sp.	+			
Alsidium corallinum C. Ag.	+			
Alsidium helmintochortos (La Tour) Kütz.	+			
Amphiroa cryptarthrodia Zan.	+		+	
Amphiroa rigida Lam.	+		+	
Antithamnion cruciatum (C. Ag.) Näg.	+		+	
Antithamnion plumula (Ellis) Thur. in Le Jol.	+	+		
Antithamnion tenuissimum (Hauck.) Schiffner				+
Arachnophyllum confervaceum (Menegh.) Zan.	+		+	
Botryocladia botryoides (Wulf.) Feldm.	+		+	
Callithamnion corymbosum (Sm.) Lyngb.	+	+	+	
Callithamnion granulatum (Ducl.) C. Ag.				+
Callithamnion tetragonum (With.) S. F. Gray				+
Catenella caespitosa (With.) Dixon et L. Irvine	+			
Ceramium ciliatum (Ellis) Ducl.	+	+		
Ceramium diaphanum (Roth) Harv.	+			
Ceramium gracillimum (Kütz.) Griff. et Harv.				+
Ceramium tenerrimum (Mertens) Okamura	+	+	+	
Ceramium tenuissimum (Roth) J. Ag	+	+	+	
Champia parvula (C. Ag.) Harv.	+		+	
Chylocladia verticillata (Lightf.) Bliding	+		+	
Caulacanthus ustulatus (Mert.) Kütz.	+			
Chondrya dasyphylla (Woodw.) C. Ag.	+	+		
Chondrya tenuissima (Good. et Woodw.) C. Ag.	+	+		
Compsothamnion thuyoides (Smith) Schmitz	+		+	
Corallina officinalis L.	+			
Crouania attenuata (C. Ag.) J. Ag.	+	+		
Crodelia expansa (Phil.) Kylin	+		+	
Dasya arbuscula C. Ag.	+			
Dasya corymbifera J. Ag.				+
Dasyopsis plana (C. Ag.) Zan.				+
Dipterosiphonia rigens (Schousb.) Falkering	+	+		
Erythroglossum sandrianum (Zan.) Kylin				+
Epilithon membranacea, (Esper.) Heydr.	+		+	
Falkenbergia rufolanosa (Harv.) Schmitz	+			

	C	P	R	A
Fauches repens (J. Ag.) Mont.	+		+	
Fosliella sp.	+		+	
Gastroclonium clavatum (Roth) Aresch.	+	+		
Gelidium melanoideum (Schousb.) Born.	+	+		
Gelidium spathulatum (Kütz.) Born.	+	+		
Gelidium pusillum (Stackh.) Le Jol.		+		
Gelidium spinulosum (C. Ag.) J. Ag.		+		
Gelidium latifolium (Grev.) Thur. et Born.	+		+	
Gelidiella lubrica (Kütz.) Feldm. et Hamel	+	+		
Gelidiella tenuissima Feldm. et Hamel	+	+		
Griffithsia barbata (Sm.) C. Ag.				+
Griffithsia opuntioides J. Ag.				+
Halodyction mirabile Zan.				+
Hildenbrandira ruora (Sommerf.) Menegh.	+	+		
Hypoglossum woodwardii Kütz.	+			
Jania rubens (L.) Lam.	+	+	+	
Laurencia obtusa (Huds.) Lam.	+	+		
Laurencia papillosa (Forskal) Grev.	+			
Laurencia pinnatifida (Huds.) Lam.	+			
Lomentaria clavellosa (Turn.) Gaill.	+	+		
Lithothamnion fruticulosum (Kütz.) Foslie	+			
Lithophyllum incrustans Phill.	+			
Liagora viscida (Forskal) C. Ag.	+			
Neomonospora pedicellata (Smith) G. Feldm. et Hamel	+		+	
Nemalion helminthoides (Vell. in With.) Batt.	+		+	
Nitophyllum punctatum (Stackh.) Grev.	+	+	+	
Peyssonnelia squamaria (Gmel.) Decne	+			
Peyssonnelia rubra (Grev.) J. Ag				+
Phymatolithon lenormandii (Aresch. in J. Ag.) Adey	+	+		
Phymatolithon polymorphum (L.) Foslie	+	+		
Polysiphonia elongata (Huds.) Spreng.	+			
Polysiphonia furcellata (C. Ag.) Harv. in Hook.	+	+		
Polysiphonia sertularioides (Grat.) J. Ag.	+		+	
Polysiphonia variegata (J. Ag.) Zan.	+	+		
Ptilothamnion pluma (Dillw.) Turn in Le Jol.	+		+	
Rytiphlaea tinctoria (Clem.) C. Ag.	+			
Seirospora seirosperma (Harv.) Dixon				+
Spermothamnion repens (Dillw.) Rosenv.				+
Spyridia filamentosa (Wulf.) Harv. in Hook.	+	+		
BANGIOPHYCEAE				
Bangia atropurpurea (Roth) C. Ag.	+		+	
Porphyra leucosticta Thur. in Le Jol.	+	+	+	
PHAEOPHYTA				
Acinetospora crinita (Carm. ex Harv. in Hook.) Kornm.	+		+	
Acinetospora vidovichii (Menegh,) Sauv.	+	+		
Asperococcus turneri (Sm.) Hook.		+	+	
Cladostephus spongiosus (Huds.) C. Ag. *f. verticillatus* (Lightf.) P. v R.	+		+	
Colpomenia sinuosa (Mert. in Roth) Derb. et Sol.		+		
Cutleria multifida (Sm.) Grev.		+		
Cystoseira adriatica Sauv.	+		+	
Cystoseira barbata (Good. et Woodw.) J. Ag.	+	+	+	
Cystoseira compressa (Esper) Gerloff et Nizzamuddin	+		+	
Cystoseira corniculata (Wulf.) Zan. in Hauck	+		+	
Cystoseira crinita (Desf.) Bory	+		+	
Cystoseira discors (L.) J. Ag. in Sauv. (= *C. ercegovichii* Giacc. et Bruni)				+

	C	P	R	A
Cystoseira fucoides Erc. (= *C. dubia* Valiante em. Erc.)				+
Cystoseira spicata Erc.	+			
Dictyota dichotoma (Huds.) Lam.	+	+		
Dictyopteris membranacea (Stackh.) Batt.	+			
Dilophus fasciola (Roth) Howe		+		
Ectocarpus siliculosus (Dillw.) Lyngb.	+	+		
Ectocarpus fasciculatus Harv.	+		+	
Fucus virsoides (Don.) J. Ag.	+		+	
Giffordia hincksiae (Harv.) Hamel	+		+	
Halopteris scoparia (L.) Sauv.	+	+		
Mesogloia leveillei (J. Ag.) Menegh.	+	+		
Padina pavonia (L.) Gaill.	+	+		
Punctaria latifolia Grev.		+		
Ralfsia verrucosa (Aresch.) J. Ag.	+	+		
Sargassum acinarium (L.) C. Ag.				+
Sargassum hornschuchii C. Ag.				+
Sauvageaugloia griffithsiana (Grev. ex Harv. in Hook.) Hamel				+
Scytosiphon lomentaria (Lyngb.) Link.	+	+		
Sphacelaria britannica Sauv. (= *S. olivacea)*	+	+		
Sphacelaria cirrosa (Roth) C. Ag.	+	+		
Stilophora rhizodes (Turn.) J. Ag.				+
Striaria attenuata (C. Ag.) Grev.	+	+		
Stictyosiphon adriaticus Kütz.		+		
Zanardinia prototypus (Nardo) Nardo			+	
CHLOROPHITA				
Blidinga minima (Näg. ex Kütz.) Kylin	+	+		
Bryopsis plumosa (Huds.) C. Ag.	+	+	+	
Chaetomorpha linum (Müll.) Kütz.	+	+		
Chaetomorpha capillaris (Kütz.) Börg.	+	+		
Cladophora dalmatica Kütz.	+	+		
Cladophora ruchingeri (J. Ag.) Kütz.	+	+		
Cladophora rupestris (L.) Kütz.				+
Cladophora coelothrix Kütz. (= *Cladophora repens)*			+	
Cladophora echinus (Bias.) Kütz.	+			
Cladophora sp.		+		
Codium fragile (Sur.) Hariot	+			
Codium adhaerens (Cabrera) C. Ag.	+			
Codium bursa (L.) C. Ag.	+			
Derbesia lamourouxii (J. Ag.) Sol.	+		+	
Derbesia tenuissima (De Not.) Crouan	+		+	
Enteromorpha clathrata (Roth) Grev.		+		
Enteromorpha compressa (L.) Grev.	+	+		
Enteromorpha intestinalis (L.) Link.	+	+		
Enteromorpha ramulosa (Smith.) Hook.		+		
Enteromorpha multiramosa Bliding		+		
Enteromorpha prolifera (O. F. Müll.) J. Ag.	+	+		

	C	P	R	A
Pseudochlorodesmis furcellata (Zan.) Börg.	+	+		
Ulva lactuca L.		+		
Ulva rigida C. Ag.	+	+		
Ulvaria oxysperma (Kütz.) Bliding		+	+	
Ulothrix pseudoflacca Wille	+	+		
Ulothrix sublaccida Wille	+	+		
Valonia utricularis (Roth) C. Ag.			+	
CYANOPHYTA				
Rivularia atra Roth	+	+		
Isactis plana (Harv.) Thur.		+		
Calothrix spp.		+		
CHRYSOPHYTA				
BACILLARIOPHYCEAE				
colonial diatoms	+	+		

C — pecies from relatively unpolluted control localities (Palu, Faborsa, San Giovanni)
P — species from polluted sites
R — species which recently became rare in the area
A — species apparently absent from the vegetation

REFERENCES

Andrews, J. H. 1976. The pathology of marine algae. Biol. Rev., 51: 211—253.

Bokn, T. and Lein, T. E. 1978. Long-term changes in fucoid associations of the inner Oslofjord, Norway. Norw. Journ. Bot., 15 (1): 9—14.

Borowitzka, M. A. 1972. Intertidal algal species diversity and the effect of pollution. Aust. J. Mar. Freshwater Res., 23: 73—84.

Burrows, E. M. 1971. Assessment of pollution effects by the use of algae. Proc. Roy. Soc. London, Ser. B, 177: 295—306.

Cotton, A. D. 1911. On the growth of *Ulva latissima* in excessive quantity, with special reference to the *Ulva* nuissance in Belfast Lough. Royal Commission on Sewage Disposal, 7th report, 2 (4). Appendix. HMSO: 121—142.

Edvards, P. 1972. Benthic algae in polluted estuaries. Mar. Poll. Bull., 3: 55—60.

Edwards, P. 1975. An assessment of possible pollution effects over a centoury on the benthic marine algae of Co. Durham, England. Bot. J. Linn. Soc., 70: 269—305.

Foslie, M. H. 1906. Die Lithothamnien des Adriatischen Meeres und Marokko. Wiss. Meeresunt. Abt. Helgoland, 9, Folge. 7 (1/2): 1—38.

Fütterer, D. 1969. Die Sedimente der Nördlichen Adria vor der Küste Istriens. Gőttingen Arb. Geol. Paleont., 3: 1—57.

Golubić, S. 1968. Die Verteilung der Algenvegetation in der Umgebung von Rovinj(Istrien) unter den Einfluss häuslicher und industrieller Abwässer. Wasser und Abwasserforsch., 3: 87—95.

Golubić, S. 1970. Effect of organic pollution on benthic communities. Mar. Poll. Bull., NS 1: 56—57.

Goodwin, D. 1975. The theory of diversity -stability relationships in ecology. Quart. rev. biol. 50: 237—266.

Grenager, B. 1957. Algological observations in the polluted area of Oslofjord. Nytt Mag. Bot., 5: 41—60.

Gunnarsson, K. and K. Thórisson, 1977. The effect of sewage on the distribution and cover of littoral algae near Reykjavik. Preliminary results. Acta Bot. Isl., 4: 58—66.

Häyren, E. 1937. Iaktagelser rörande forörening och strandvegetasjon i Helsingfors hamnomrade ar 1936. Bidr. Känn. Finnl. Nat. och Folk., 88 (5): 1—120.

Klavestad, N. 1967. Undersökelser over benthos- algevegetasjonen in indre Oslofjord 1962—1965. In: Oslofjorden og dens forurensningsproblemer. I. Undersökelser 1962—1965. Rep. Norw. Inst. Water Res. 9: 1—119.

Klavestad, N. 1978. The marine algae of the polluted inner part of the Oslofjord. A survey carried out 1962—1966. Bot. Man., 21: 71—97.

Kuckuck, P. 1964. Ectocarpaceen Studien. Ed. P. Kornmann. Helgol. wiss. Meeresunt., I—IX. 1953 to 1963.

Letts, E. A. and E. H. Richards, 1911. Report on green seaweeds and especially *Ulva latissima* in relation to the pollution of the waters in which they occur. Royal Comm. on Sewage Disposal, 7th Rep. II (apendix 111) HMSO.

Littler, M. N. and N. S. Murray, 1974. The primary productivity of marine macrophytes from a rocky intertidal community. Mar. Biol., 27: 131—135.

Littler, M. M. and N. S. Murray, 1975. Impact of sewage on the distribution. abundance and community structure of rocky intertidal macro-organisms. Mar. Biol., 30: 277—291.

Littler, M. M. and N. S. Murray, 1978. Influence of domestic wastes on energetic pathways in rocky intertidal communities. Journ. Applied Ecol., 15: 583—595.

Meischner, D. 1973. Formation process and dispersal patterns of the sediments along the Istrien coast of the Adriatic. Rapp. Proc. verb. des réunions CIESM, 21 (11): 843—846.

Mosetti, F. 1967. Caratteristiche idrologiche dell Adriatico settentrionale. Atti Ist. Veneto Sci. Lett Arti, 125: 147—165.

Munda, I. 1972 a. Seasonal and ecologically conditioned variations in the *Fucus virsoides* association from the Istrian coast (North Adriatic). Diss. SAZU, 15 (1): 1—35. Ljubljana.

Munda, I. 1972 b. The production of biomass in the settlementa of benthic algae in the northernAdriatic. Bot. Mar., 15 (4): 218—244.

Munda, 1974 a. Changes and succession of the benthic algal associations of slightly polluted habitats. Rev. Internat. Oc. Med., 34: 37—52.

Munda, 1974 b. Spreminjanje biomase fitobentosa z globino. (Changes of the phytobenthos biomass according to depth). Acta Adriat., 16 (14): 235—242.

Munda, I. 1975. Some seasonal associations of benthic algae from the Northern Adriatic. Rap. Comm. Int. Mer Médit., 23 (2): 65—66.

Munda, I. 1967. Observations on the benthic algae in a landlocked fjord (Nordasvatnet)near Bergen, Western Norway. Nova Hedwigia, 14: 519—548; plates 128—133.

Munda, I 1977. A comparison of North and South European associations of *Corallina officinalis* L. Hydrobiologia, 52: 75—87. DenHaag.

Munda, in press. Some Fucacean associations from the vicinity of Rovinj, Northern Adriatic. Nova Hedwigia.

Murray, S. M. and M. M. Littler, 1974. Biological features of intertidal communities near the US Navy sewage outfall, Wilson Cove, San Clemente Island, California. Techn. papers, naval undersea center, San Diego. 396: 1—85.

Murray, S. N. and M. M. Littler, 1976. An experimental analysis of sewage impact on a macrophyte dominated rocky intertidal community. J. Phytol. 12 (suppl.): 15—16.

Murray, S. N. and M. M. Littler, 1978. Patterns of algal succession on a perturbated marine intertidal community. J. Phycol. 14: 506—512.

North, W. J. 1964. Ecology of the rochy nearshore environment in southern California and possible influence of discharged wastes. Proc. 1st Int. Conf. Wat. Pollut. Res., 5: 247—262.

Rueness, J. 1973. Pollution effect on littoral algal communities in the inner Oslofjord, with special reference to *Ascophyllum nodosum*. Helgol. wiss. Meeresunt., 24: 446—454.

Schiffner, V, 1915. Studien über die Algen des adriatischen Meeres. Wiss. Meeresunt. Abt. Helgoland, 9 Folge, 11 (2): 127—198.

Stein, J. E. and J. G. Denison 1967. Limitations of indicator organisms. In: Pollution and Marine Ecology. Oslon, T. A. and Burges, F. J. Edit. Interescience: 323—335.

Storre, P. N., E. A., Pearson, H. F. Ludwig, R. Walsh and E. J. Stan. 1969. Estuarine water quality and biological pollution indices. In: Jenkins S. J. Advances in water pollution research, 901—910, Pergamon Press, London.

Sundene, O. 1953. The algal vegetation of the Oslofjord. Skr. Norske Vidensk. Akad., I. Mat.—Nat. Kl., 2; 1—244.

Vatova, A. 1928. Compendio della flora e fauna del Mare Adriatico presso Rovigno. R. Comm. Thalass. Ital. Mem., 143: 1—614.

Vatova, A. 1948. Fenologia delle alghe marine di Rovigno. Nova Thalassia, 1 (1): 43—69.

Widdowson, T. B. Changes in the intertidal algal flora of the Los Angeles area since the survey by E. Yale Dawson in 1956—59. Bull. S. Calif. Acad. Sci., 70 (1): 2—16.

Zavodnik, D. Preliminary observations on the phytal populations of the rocky shore near Rovinj (Northern Adriatic). Publ. Staz. zool. Napoli, 32 (suppl.): 181—184.

Zavodnik, D. 1965. Quelques résultats des recherches actuelles sur le peuplement phytaux dans l'Adriatique du Nord. Rapp. et Proc. verb. des réunions CIESM., 28 (2): 102—106.

Zavodnik, D. 1967. a. The community of *Fucus virsoides* (Don.) J. Ag. on a rocky shore near Rovinj (Northern Adriatic). Thalassia jugosl., 3 (1/6): 105—113.

Zavodnik, D. 1967. b. Dinamika litoralnega fitala na zahodnoistrski obali. Diss. SAZU, 10 (1): 5—67.

Zavodnik, D. 1969. La Communauté à *Acetabularia mediterranea* Lamour. dans l'Adriatique du Nord. Int. Rev. Hydrobiol., 54 (4): 543—551.

Zavodnik, D. 1971. Contribution to the dynamics of benthic communities in the region of Rovinj (Northern Adriatic). Thalassia jugosl., 7 (2): 447—514.

Zavodnik, D. 1973. Note on the settlement of *Wrangelia penicillata* C. Ag. in the Northern Adriatic Sea. Rapp. Comm. Int. Mer Médit., 22 (4): 123—124.

Zavodnik, N., 1977. Long term changes of marine vegetation near Rovinj (North Adriatic). Rapp. Comm. Int. Mer Médit., 24 (4): 181—182.

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SPREMEMBE ASOCIACIJ BENTOŠKIH ALG OKOLICE ROVINJA (ISTRSKA OBALA, SEVERNI JADRAN) POD VPLIVOM ORGANSKIH ODPLAK

Ivka M. Munda

Biološki inštitut, Slovenska akademija znanosti in umetnosti, Ljubljana

POVZETEK

1 — Podan je opis vegetacije okolice Rovinja in otokov rovinjskega arhipelaga. Ta vegetacija se je v zadnjem desetletju radikalno spremenila, kar je pripisati vplivu naraščajoče organske polucije.

2 — Podana je razporeditiv najznačilnejših vrst v tem področju, opisana je vegetacija posamzenih lokalitet na obali in otokih in ugotovljene so bile asociacije alg, ki so značilne za poluirana področja.

3 — Pred enim desetletjem so v eulitoralu in zgornjem sublitoralu tega področja prevladovale asocijacije fukacej (*Fucus virsoides*, vrst rodov *Cystoseira* in *Sargassum*- Munda, 1972 a, 1979). Te asociacije so izginile iz poluiranih lokalitet. V eulitoralnem nivoju so naselja fukusa nadomestile asocijacije rezličnih zelenih alg (zastopnikov rodov *Blidingia, Enteromorpha* in *Cladophora).* Naselja cistozir pa so na večjem delu področja nadomestile asociacije vrst *Halopteris scoparia, Dictyota dichotoma, Gelidium* spp. — *Gelidiella* spp., ter v bližini odplak razne sezonske asocijacije kot n. pr. *Scytosiphon lomentaria, Ulva rigida, Enteromorpha* ssp.