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SURVEY OF THE ALGAL BIOMASS IN THE POLLUTED AREA AROUND ROVINJ (ISTRIAN COAST, NORTH ADRIATIC)

PREGLED BIOMASE ALG POLUIRANEGA PODROČJA OKOLICE ROVINJA (ISTRSKA OBALA, SEVERNI JADRAN)

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A survey of biomass values of algal populations in the eulittoral and sublittoral level is given for the vicinity of Rovinj (North Adriatic). The present state is compared with that of a decade ago, when fucoids dominated the vegetation. Recent measurements revealed a decrease in algal biomass near the outfalls in the eulittoral level. In the sublittoral, seasonal algal stands, exibiting high biomas values, were found near the outfalls. In a certain distance from the sewage outlets the algal biomass was extremely decreased and macroinvertebrates dominated. The present state of the subtidal vegetation is characterised by populations of *Halopteris scoparia* and *Dictyota dichotoma* which replaced *Cystoseira* species in the greater part of the investigated area.

INTRODUCTION

The biomass of the settlements of benthic algae was investigated in the vicinity of Rovinj in the years 1967 to 1970 (Munda, 1972 a, b, 1974 a, 1979). Biomass measurements were carried out on rocky slopes of the mainland and on some islands of the Rovinj archipelago. During this time the benthic algal vegetation of this area was still dominated by fucoids and biomass measurements mainly refer to their stands. During the last decade the vegetation of this area has changed under the influence of increased pollution by organic wastes. The fucoids deteriorated in most sites and were replaced by other algal associations. The vegetation of this area was newly investigated and a report of about its changes is given in the same volume. Simultaneously with vegetation analyses a survey of the algal biomass was repeated. Hence recent biomass measurements refer to other algal settlements than those of a decade ago.

Biomass data for algal stands in the vicinity of Rovinj are to be found also in the works of D. Zavodnik (1967 a, b) and N. Zavodnik (1977). There are, in general, few data for the algal biomass in the Adriatic Sea as well as in the Mediterranean as a whole. Adriatic *Cystoseira* settlements were studied quantitatively by Špan (1964, 1969). Further data for the algal biomass in the Adriatic were given by Giaccone and Pignatti (1967), Pignatti and Giaccone (1967) and Pignatti (1968). Mediterranean algal settlements were investigated by Bellan-Santini (1963, 1967) and new quantitative methods have been described by Boudouresque (1969, 1971).

MATERIAL AND METHODS

The algal biomass was determined along vertical transects at a total of 11 stations: Palu, Škaraba, Crveni otok (Red Island) Sturago, San Giovanni, Val di Lone, island of Sv. Katarina, vicinity of the Rovinj hospital, islands of Velika Figarola and Mala Figarola and the bay of Faborsa. These localities were described previously (Munda, 1972 b) and are shown on the map which appeared in the work dealing with vegetation changes (same volume).

The algal growth was harvested on rocky slopes and weighed from the area with a 1/4 m^2 frame. For small settlements in the eulittoral level and in rocky pools a 1/16 m^2 frame was used. The algal growth was separated into the dominant species and the biomass was expressed as fresh weight of seaweed per square meter of sea floor. The dry matter was determined after 12 h drying at 110°C; the ash content by combustion at 400°C; the total nitrogen by the Kjeldahl procedure and for the mannitol determinations the method of Cameron and al. was applied. The same methods were used during previous surveys in this area (Munda, 1962, 1972 a, b, 1979). All the compoundes within the biomass were calculated on a dry weight basis.

Biomass measurements refer to the spring aspect of the vegetation (April 1978).

ECOLOGICAL PARAMETERS

The seasonal changes of the water temperature, salinity, BOD_5 values and the total coliform bacteria for 1978/79 are presented in the paper dealing with vegetation changes and were kindly placed to my disposal by Mg. D. Fuks, center for Marine Research, Rovinj (personal communication). Average values of these parameters are presented here and include data for fecal coliforms separately.

Yearly average values for salinity were lowest at the control locality of Palu, due to influx of fresh water from the neighbouring marsh area. Negligible differences between yearly salinity averages were noted for the rest of the localities investigated here and the same was true of the yearly temperature averages. The highest average BOD_5 values were noted for the island of Sv. Katarina and the vicinity of the Rovinj hospital and next to it were Val di Lesso and Crveni otok (Red Island). The lowest values were found in the control localities of Faborsa and Palu. Bacterial pollution in terms of the total and fecal coliform bacteria was highest in Val di Lone and around the island of Sv. Katarina and negligible at Palu. Low average bacterial pollution was observed in the vicinity of the hospital. It was, however, of the same order of magnitude as in the bays of Škaraba and Faborsa.

Average values of ecological parameters for the period March 1978 to February 1979

localities	salinity ‰ Sal	temperature (°C)	BOD_5 (mg O_2/l)	total coliform bacteria (n/100 ml)	fecal coliform bacteria (n/100 ml)
PALU	35.36	17.26	0.82	1	0
ŠKARABA	36.03	17.42	0,98	12	8
CRVENI OTOK (RED ISLAND)	36.13	17.42	1.02	2	1
VAL DI LONE	36.00	17.51	0,96	247	287
SV. KATARINA	35.98	17.57	1.26	102	86
HOSPITAL	35.86	17.63	1.17	35	20
VAL DI LESSO	35.99	17.47	1.03	22	3
FABORSA	35.94	17.50	0.80	15	7

RESULTS OF FIELD OBSERVATIONS

A survey of the algal biomass and its constituents is given in Table 1 to 12. As mentioned, recent measurements refer to April 1978 and mainly deal with different algal stands than in the spring months of 1967 to 1969.

In the level of the LITTORAL FRINGE algal settlements were rarely encountered during recent surveys. In the control locality of Palu, however, *Rivularia atra* formed prolific and dense stands on flat rocky surfaces with an average biomass of 255 g/m^2. On the island of San Giovanni *Catenella caespitosa* covered rocky fissures with a relatively high biomass of 630 g/m^2 of fresh weight. Settlements of the same species were less prolific in the bay of Faborsa.

In terrestrial pools at this level rather dense stands of *Enteromorpha clathrata* were usual, exhibiting an average biomass of 588 g/m^2 of fresh weight. Such pools were found chiefly on the island of Velika Figarola.

Eulittoral zone

At the time of previous surveys (M u n d a, 1972 a, b) the rocky eulittoral was populated by *Fucus virsoides* in sheltered sites whereas under conditions of high exposure an uplift of the *Cystoseira* and *Corallina officinalis* populations was usual (M u n d a, 1977, 1979). Previously the eulittoral zone could be delimited in biological terms, the upper limit of this zone coinciding with the upper limit of the *Fucus virsoides* belts and the lower with the upper limit of the *Cystoseira* meadows. In exposed sites the delimitation of the zones was less clear.

Recently, however, the fucoids disappeared from most sites submitted to sewage impact and by this reason the delimitation of the littoral zone was obscured.

Sheltered shores

A — Shores subjected to sewage impact

On such shores, previously dominated by *Fucus virsoides,* the eulittoral algal growth was perturbed. Most of the rocky eulittoral was denuded and the average biomass notably decreased. Due to lack of competition with fucoids *Enteromorpha intestinalis* and *Cladophora dalmatica* populations which were previously inconspicuous were able to extend over wider surfaces.

VAL DI LONE (Table 6 a)

In this moderately exposed bay there were compact *Fucus* settlements a decade ago. The highest biomass for the area (2950 g/m^2) was observed during the spring of 1967 (Munda, 1972 b). Recently, the eulittoral zone was populated by patches of *Blidingia minima* and *Enteromorpha intestinalis,* the latter species covering small rocky pools and eulittoral depressions. Biomass measurements were carried out within the *E. intestinalis* populations, which had a limited extension. Relatively high average values of fresh weight per square meter were found (1808 and 1936 g/m^2 of fresh weight).

ISLAND OF SV. KATARINA (Table 7 a, b)

On this island two localities were studied. In the first a dense and prolific *Fucus virsoides* belt was developed previously, whereas in the second the *Fucus* belt was reduced and intermingled with green algae *(Ulva rigida, Enteromorpha multiramosa, E. ramulosa)* which contributed notably during spring to the total biomass of the eulittoral populations (Munda, 1972 a). During recent surveys only *Enteromorpha intestinalis* stands, occurring in patches, were noted in the eulitoral of both stations. In the second locality, which is situated nearer the Rovinj harbour and thus more polluted, the biomass of the *Enteromorpha* populations was about twice as great as in the first locality.

In VAL DI LESSO and the vicinity of the HOSPITAL (Table 8) a narrow *Fucus virsoides* belt was noted previously exhibiting considerable biomass values with a peak in summer (Munda, 1972 b). Recently the algal growth of the eulittoral level was destroyed in this area. Only negligible patches of *Enteromorpha intestinalis* remained. Biomass measurements were carried out on pebbles in a bay near the hospital, where the eulittoral vegetation was exceptionally prolific. *Enteromorpha intestinalis* occurred in a bigger growth form here and mingled at the lower limit of its zone with *Ceramium ciliatum* which tolerates a certain degree of organic pollution. The total biomass of thesse settlements was 2336 g/m^2 of fresh weight, corresponding to a production of 227 g/m^2 of dry weight and 22 g/m^2 of protein.

On the island of VELIKA FIGAROLA a wide and prolific *Fucus virsoides* belt was developed previously (Munda, 1972 a, b). It mingled at its lower limit with populations of *Ceramium diaphanum.* Recently the *Fucus* belts along with that of *Ceramium* deteriorated. Only single, dwarf *Fucus* plants were left. Biomass measurements at this level were carried out in mixed stands of *Enteromorpha intestinalis* and *Cladophora dalmatica* with single plants of *Fucus* occasionally intermingled (Table 9). On the seaward western banks of the island, where the pollution impact is less severe, scattered, compact *Fucus* stands were found, with an average biomass of 528 g/m^2 of fresh weight (Table 10).

On the island of MALA FIGAROLA, which is more exposed to surf, *Fucus* was previously present in narrow belts of dwarf plants, exhibiting low biomass values. Recently it was absent from the vegetation. Biomass measurements in the eulittoral level were carried out in mixed stands of *Ulva rigida* and *Ulvaria oxysperma* (Table 10).

In the bay of ŠKARABA prolific stands of *Cladophora dalmatica* were observed for a decade ago in spring as well as narrow *Fucus* belts with low biomass values. The reduction of the *Fucus* belt was due to a certain degree of exposure to wave action. At this site, where pollution effects were severe and grazing by sea urchins denuded considerable surfaces, no algal stands were found eulittorally during recent surveys.

B — Relatively undisturbed shores

The bay of FABORSA, distant from the outfall area, exhibited less pronounced changes in its vegetation pattern. In the eulittoral zone dense and prolific *Fucus virsoides* belts were found for a decade ago (Munda, 1972 a, b). Biomass measurements carried out recently in the same bay revealed higher values than previously (e. g. spring months 1967 and 1968). Exceptionally high biomass values were, however, found in March 1969 (Munda, 1972 b). The *Fucus* belts frequently overlap with *Ceramium diaphanum* stands, which cover the level of the eulittoral/sublittoral junction and the upper sublittoral. Recent measurements in the bay of Faborsa refer to mixed *Fucus-Ceramium* populations (Table 11).

Exposed shores

A — Shores subjected to sewage impact

As in the bay of Škaraba the algal growth along the open coast at ŠKARABA was severely influenced by sewage impact and grazing. On most sites *Mytilus* shells replaced algal belts. Some measurements were carried out in *Cladophora dalmatica* stands which occurred rather seldom and scattered in the eulittoral level (Table 2). Previously, mixed *Cystoseira* populations were found in the same level of this exposed area. They covered flat rocky terraces and were represented by *C. barbata* and *C. compressa* (= C. *abrotanifolia*) which exhibited an average biomass of 2961 g/m^2 of fresh weight (April 1967). Under conditions of high exposure *C. spicata* stands were found on steep slopes. It seems, however, that the destructive effects of sewage and grazing were most severe in the area around Škaraba, where *Mytilus* shells replaced algal stands on most sites.

On CRVENI OTOK (RED ISLAND) (Table 3) the eulittoral vegetation was impoverished. Biomass measurements were carried out in *Cladophora dalmatica* stands and in mixed populations of dendritic species, which covered rocky terraces previously populated by *Cystoseira* species. Such algal turfs exhibited relatively high biomass values and were observed on the same island also a decade ago, though with different dominants. Previously *Jania rubens, Corallina officinalis* and *Cladophora* species were predominant, whereas recently *Gelidium* and *Gelidiella* species prevailed.

STURAGO is the next island of the Rovinj archipelago. Due to the distance from the mainland its vegetation appeared less disturbed than on Crveni otok or in Škaraba. Previously only *Corallina officinalis* stands were measured on this island (M u n d a, 1972 b, 1977). *Corallina* formed dense populations in the eulittoral and upper sublittoral levels. They deteriorated recently and *Corallina* was only found in single specimens in between other algal populations. The eulittoral vegetation was represented by patches of *Cladophora dalmatica* and *Enteromorpha intestinalis,* with relatively low biomass values (Table 4). Mats of *Laurencia obtusa* were likewise found eulittorally and had rather high average biomass values (2320 g/m^2).

B — Relatively undisturbed shores

The island of SAN GIOVANNI is situated even farther out and receives negligible amounts of pollutants. Its algal vegetation was more prolific than a decade ago, though with same changes in the dominant associations. In contrast to Sturago, *Corallina officinalis* populations were prolific here, forming contiuous stands with high biomass values (3680 and 5760 g/m^2). Behind the shelter of protruding rocks fragmentary belts of *Fucus virsoides* were found, whereas exposed sites of this island were occupied by *Cladopora dalmatica* and *Corallina officinalis* (Table 5 a).

PALU (Table 1) is a reference locality which has not been observed previously. Here the sewage impact is negligible and the bacterial pollution near zero. In the eulittoral level *Cladophora dalmatica* formed patches with high biomass values whereas the *Fucus* belt was badly developed and fragmentary (average biomass of 670 g/m^2).

Upper sublittoral zone

The upper sublittoral vegetation of the area around Rovinj was previously dominated by stands of diverse *Cystoseira* species Locally, *Sargassum* species were also represented. The recent state of the vegetation may be characterised by the disappearence of these populations. Changes which took place in the sublittoral zone seem even more severe than those which were observed eulittorally.

Sheltered shores

A — Shores subjected to sewage impact

Sheltered shores were occupied manly by *Cystoseira barbata* and *C. compressa* populations in the upper sublittoral zone. During spring prolific belts of *Ceramium diaphanum* were usually interimposed between the *Fucus virsoides* and *Cystoseira* belts, protruding into the sublittoral level.

In VAL DI LONE the upper sublittoral vegetation was previously dominated by *Cystoseira barbata.* A broad belt of seasonal species, during spring dominated by *Ceramium diaphanum* was usually found above it. Previous biomass measurements in Val di Lone mainly refer to this belt (M u n d a, 1972 b). As mentioned in the recent vegetation study (same volume) diverse algal stands replaced the *Ceramium* and *Cystoseira* populations during the spring aspect of the vegetation. A mixed population of diverse filamentous algae, accompanied by *Ulva rigida* was characteristic for the subtidal of this bay as did populations of *Ulva rigida* and *Scytosiphon lomentaria;* all of them exhibiting high biomass values in terms of fresh weight per unit area though the dry matter production was relatively low (Table 6 a). Further characteristic sublittoral populations were those of *Halopteris scoparia*, of *Dictyota dichotoma* and of *Colpomenia sinuosa*, the latter exhibiting high biomass values (5056 g/m^2 fresh weight) (Table 6 b). Seasonal red algae and fucoids have totally disappeared from the sublittoral zone of this bay.

On the island of SV. KATARINA a complete zonation of fucoids was found a decade ago, with belts of *Cystoseira species* (dominant *C. barbata* and *C. compressa*), *Sargassum hornschouchii* and *Sargassum acinarium* following eachother in a vertical sequence. Recently the sublittoral vegetation was impoverished in terms of biomass and degree of covering. Locally sublittoral slopes were totally denuded. *Halopteris scoparia* and *Dictyota dichotoma* were the dominant subtidal populations during recent surveys. In some sites *Cystoseira compressa* and *C. spicata* were intermingled in minor quantities (Table 7 a, b). whereas *Sargassum* stands completely disappeared from the vegetation. In the second locality on this island *Cystoseira* populations were lacking already a decade ago, being replaced by *Halopteris scoparia* and mats of diverse dendritic species. Recently extremely prolific stands of both *Ulva rigida* and *Scytosiphon lomentaria* were found here. They exhibited high biomass values in terms of fresh weight, though the production of dry weight per unit area was rather low (Table 7 b).

On the island of Sv. Katarina, however, small residuals of *Cystoseira* stands were still present in spite of the radical chanoes which took place in the subtidal vegetation.

VAL DI LESSO and the vicinity of the HOSPITAL (Table 8)

The subtidal of Val di Lesso was previously occupied by prolific *Cystoseira* stands among which *C. adriatica* was the dominant and considerable quantities of *Jania rubens* were intermingled (M u n d a, 1972 b, 1979). The algal vegetation observed recently in the vicinity of the hospital was totally devoid of fucoids. In spring, *Scytosiphon lomentaria* and *Ulva rigida* were extremely prolific. Biomass measurements revealed the highest values observed recently in the area around Rovinj (7232 g/m^2 of fresh weight corresponding to a production of 748 g/m^2 of dry weight and 83 g/m^2 of protein). Biomass measurements were likewise carried out in mixed populations of diverse seasonal species (*Punctaria latifolia, Ectocarpus siliculosus, Cladophora* sp.)

On the island of VELIKA FIGAROLA dense *Cystoseira* populations were likewise found during previous surveys *(C. barbata, C. compressa, C. spicata, C. adriatica).* In a separate study the vertical distribution of biomass was carried out for this island, revealing the maximum biomass in a depth of 5 m within *C. adriatica* stands (9500 g/m^2) (M u n d a, 1974 a). This vegetation disappeared completely from the sublittoral slopes and was replaced by populations of *Dictyota dichotoma* and *Halopteris scoparia* (Table 9). Most of the subtidal rocky surfaces were denuded. Turfs of diverse *Gelidium* and *Gelidiella* species, interwoven into shell sand, were found around the eulittoral/sublittoral junction and in the uppermost sublittoral, revealing rather high biomass values.

Around the bay of ŠKARABA dense meadows of codominant *Cystoseira compressa* and *C. spicata* were found previously (spring biomass 5080 g/m^2). In this site the sublittoral slopes were totally denuded of algae due to pollution effects and grazing. *Mytilus* belts protruded into the sublittoral.

B — Relatively undisturbed shores

FABORSA

The eulittoral vegetation of this bay was almost undisturbed but that of the sublittoral appeared strongly reduced. *Cystoseira* stands which were previously compact, were fragmentary and wide rocky slopes were denuded or occupied by populations of *Dictyota dichotoma* and *Halopteris scoparia*. It seems likely that organic pollution exerts a disturbing effect on the benthic vegetation over wide distances.

Belts of *Ceramium diaphanum* and *Polysiphonia* spp. were prolific but their biomass was relatively low (Table 11). *Ceramium* belts frequently overlapped with the *Fucus* populations. Biomass measurements were carried out in *Cystoseira* stands which were scattered and limited to the uppermost sublittoral level. Relatively high average biomass values were found (2068 and 3584 g/m^2) and the dominance of *C. barbata* was less pronounced than during previous surveys. In the middle of the bay the biomass of the *Cystoseira* stands was of the same order of magnitude as previously and *Alsidium corallinum* contributed a notable part to the total fresh weight per unit area (Table 12).

Exposed shores

A — Shores subjected to sewage impact

Along the open coast of ŠKARABA diverse *Cystoseira* stands were present during previous studies, the species composition being dependent on the local degree of exposure. On steep, highly exposed slopes *C. spicata* was dominant, with high biomass values, whereas where there were flat rocky terraces *C. barbata* and *C. compressa* were usual. This rich subtidal vegetation was destroyed by pollution and grazing. Around the eulittoral/sublittoral junction and the uppermost sublittoral *Gelidium* carpets covered limited surfaces and exhibited high biomass values of 2408 g/m^2 on the average. Scattered stands of *Halopteris scoparia* and of *Dictyota dichotoma* represented the sublittoral vegetation and showed relatively high biomass values (Table 2).

The greater part of the sublittoral slopes was denuded whereas in the upper sublittoral *Mytilus* shells locally dominated.

CRVENI OTOK (RED ISLAND)

The sublittoral vegetation of the banks of Crveni otok was dominated by *Cystoseira* species a decade ago. *C. crinita* was outstanding here and high biomass values were found within its stands (Munda, 1972 b). Recently the subtidal vegetation of this island became extremely reduced though somewhat less than around Škaraba. *Gelidium* carpets covered wide surfaces and below these turfs *Halopteris scoparia* and *Dictyota dichotoma* populations occurred in patches (Table 3). In contrast to Škaraba residuals of *Cystoseira* populations were fonud, e. g. *C. spicata* intermingled in the *Halopteris* stands.

STURAGO

Pollution effects on the subtidal vegetation were even less pronounced around this little island. Prolific and dense stands of *Cystoseira spicata* were found in the uppermost sublittoral (average biomass of 6080 g/m^2). The greater part of the sublittoral slopes was still occupied by *Halopteris scoparia* and *Dictyota dichotoma* populations and the eulittoral/sublittoral junction by *Gelidium* spp. carpets (average biomass 4010 g/m^2).

B — Relatively undisturbed shores

SAN GIOVANNI

In spite of the distance from the mainland the sublittoral vegetation of this island was not dominated by *Cystoseira* species. Due to the high exposure of its banks the vegetation was poorly developed already a decade ago. Recently, patches of *Cystoseira* stands were observed with *C. spicata* as dominant (Table 5 b). *Dictyota dichotoma* and *Halopteris scoparia* populations were dominant here as in the rest of the investigated area. Contrary to the neighbouring island, dense stands of *Ceramium diaphanum* and of *Lomentaria clavellosa* were fonud here.

At PALU, which is the least polluted, *Cystoseira barbata* was locally dominant in the upper sublittoral whereas lower down *Dictyota dichotoma* was prevalent. *Ceramium diaphanum* and *Laurencia obtusa* formed prolific settlements on flat rocky surfaces (Table 1). In spite of the distance from the outfall area the sublittoral vegetation was scattered and *Cystoseira* species were subordinate in the vegetation.

Tide pools

Overall in the investigated area small rocky pools inhabited by *Cladophora dalmatica* and *Enteromorpha* species were found.

On the island of Sv. Katarina where the subtidal vegetation was disturbed, residual *Cystoseira* stands were found in rock pools and were quite prolific (Table 7). Similar conditions were observed. on some islands, e. g. on Mala Figarola (Table 10), where *Cystoseira* populations inhabited tide pools but were absent from the sublittoral slopes. In the bay of Faborsa *Cystoseira barbata* dominated in flat rocky pools as a decade ago. On some islands as well as in the bay of Faborsa and in Palu, rock pools were likewise inhabited by *Ceramium diaphanum, Laurencia obtusa* and *Polysiphonia* species. Hence minor changes in the algal cover took place in rock pools as on sublittoral slopes.

DISCUSSION AND CONCLUSIONS

From this descriptive survey, carried out in spring 1978, changes in the benthic algal vegetation around Rovinj became obvious, both in term of biomass and floristic composition. These changes seem to be causally connected with the increased organic pollution of this area during the last decade.

The outfall areas, however, represent unstable stress environments and favour rapid colonizers with simple thalli and high surface to volume ratio (Littler and Murray, 1974, 1975, Murray and Littler, 1978). Usually the immediate surroundings of the outfalls are colonized by sheets of blue greeen algae (Golubić, 1970, Munda, 1974 b, Murray and

Littler, 1974). During recent surveys, however, blue greens have not been observed in the vicinity of heavily polluted sites around Rovinj. A general feature of outfall areas here was a reduction of the fucoid vegetation. In the eulittoral *Fucus virsoides* populations deteriorated and only scattered stands of green algae remained (*Enteromorpha* and *Cladophora* species). In the sublittoral a reduction or disappearence of *Cystoseira* populations was observed and a total disappearence of representatives of the genus *Sargassum*. The general perturbation of the subtidal vegetation of this area resulted in the dominance of *Halopteris scoparia* and *Dictyota dichotoma* which obviously succeded the *Cystoseira* vegetation. A notable denudation of the rocky slopes in the subtidal was observed. A characteristic assemblage found throughout the area was carpets of diverse *Gelidium* and *Gelidiella* species, interwoven into shell sand. Usually they covered rocky surfaces around the eulittoral/sublittoral junction. All these populations were characterised by relatively high biomass values and a reduction in degree of covering, stratification and diversity if compared with the previous *Cystoseira* and *Sargassum* stands (Munda, 1979).

In the area under discussion, control localities distant from the outfalls were still colonized by rather prolific *Fucus virsoides* stands in the eulittoral level, their biomass being dependent on the local degree of exposure. Red algae (representatives of the genera *Ceramium* and *Polysiphonia* as well as *Lomentaria clavellosa* and *Laurencia obtusa*) were likewise prolific in spring. It is, however, a general phenomenon that the dominant species in relatively unpolluted areas are more long-lived and structurally complex (Littler and Murray, 1975). Contrary to conditions in the eulittoral level, the sublittoral vegetation of the Rovinj area vas changed also in the control localities, distant from the oufalls. A general phenomenon on this tidal level was a reduction of the *Cystoseira* populations and the local dominance of *Halopteris scoparia* and *Dictyota dichotoma*. The degree of covering was reduced.

In most sites, submitted to sewage impact, fucoids were absent from the subtidal vegetation. With the increasing distance from the outfall regions, the admixture of *Cystoseira* species increased. In this regard, a pronounced gradient was found on the line Škaraba — Crveni otok — Sturago — San Giovanni. On the mainland (Škaraba) the *Cystoseira* component was absent, whereas on the island of Crveni otok single specimens were found. On the island of Sturago which is situated farther out compact *Cystoseira* populations were found locally and they were even more extensive on the offshore island San Giovanni. Hence, the amount of the *Cystoseira* component in the vegetation is a rather reliable indicator for the degree of pollution impact.

In the vicinity of the outfalls an extreme perturbation of the subtidal vegetation was observed, with seasonal stands of *Scytosiphon lomentaria*, *Ulva rigida* and *Enteromorpha* species along with other filamentous algae. They exhibited extremely high biomass values in term of fresh weight (over 7000 g/m^2). The immediate vicinity of the outfalls, however, represents an envrionment rich in nutrient salts which is favourable for the development of rapidly growing seasonal species. A similar phenomenon was observed in a polluted area in western Norway (Munda, 1967, 1974 b) where the maximum biomass was found in *Enteromorpha* stands at a certain distance from the outfalls whereas in their immediate vicinity the biomass was decreased. Farther from the pollution sources the amount of nutrient salts is again decreased. Frequently the greater part of the rocky surfaces was denuded and algal vegetation replaced by belts of *Mytilus minimus* and *M. galloprovincialis*. A similar phenomenon was mentioned by Murray and Littler (1977).

The pollution effects in the area under discussion could be thus better defined in terms of vegetation structure and biomass than with merely ecological parameters, which are extremely unstable in sewage impacted areas. As pointed out by several authors a reduction of species diversity and degree of covering is a characteristic feature of outfall regions (e. g. Goodwin, 1975, Andrews, 1976, Borowitzka, 1972, Edwards, 1972, Littler and Murray, 1974, 1975). These phenomena are followed by a reduction of stratification in the eulittoral and sublittoral communities and changes in biomass (Murray and Littler, 1974, 1976, 1978).

The long — term pollution impact caused, however, different chategories of changes in the benthic vegetation:

EULITTORAL ZONE

outfall areas:

1 — disappearence of *Fucus virsoides* and red algae
2 — dominance of green algae which occur in patches (*Cladophora* and *Enteromorpha* species)
3 — decreased degree of covering but relatively high biomass values in term of fresh weight within green algae stands

control areas:

1 — presence of *Fucus virsoides* and red algae
2 — relatively high biomass values, also in term of dry weight

SUBLITTORAL ZONE

outfall areas:

A — strong pollution:

1 — absence of fucoids
2 — dominance of seasonal stands of *Scytosiphon lomentaria, Ulva rigida* and *Enteromorpha* species
3 — high biomass values

B — distant from the outfalls:

1 — denuded rocky surfaces
2 — minimum cover of macrophytes and negligible biomass (green algae)
3 — dominance of macroinvertebrates (*Mytilus* shells)

C — medium pollution:

1 — reduction or absence of *Cystoseira* stands
2 — total disappearence of *Sargassum* species
3 — reduction in biomass and degree of covering
4 — dominance of *Halopteris scoparia* and *Dictyota dichotoma*
5 — low carpets of *Gelidium* and *Gelidiella* species
6 — the amount or absence of *Cystoseira* species as measure for the degree of the pollution impact

control areas:

1 — reduction of *Cystoseira* populations in terms of degree of covering and biomass
2 — disappearence of *Sargassum* species
3 — local dominance of *Halopteris scoparia* and *Dictyota dichotoma* populations

TIDE POOLS: relatively unchanged vegetation both in medium polluted and control areas

Annual changes of average biomass values are given in Fig. 1 and 2. They refer to the first observation period from 1967 to 1969 and to the second in 1978. Only spring aspects of the vegetation are considered. In the eulittoral level (Fig. 1) a decrease in biomass of the *Fucus virsoides* settlements became obvious already during the first observation period in sites where the pollution impact was the most severe later (Val di Lone, island of Katarina, Val di Lesso — hospital). In the vicinity of the hospital *Fucus* stands were already in 1969 replaced by *Enteromorpha.* A decade later relatively high biomass values were found within *Enteromorpha* populations of the same site. In highly exposed localities, such as the island of Crveni otok and the

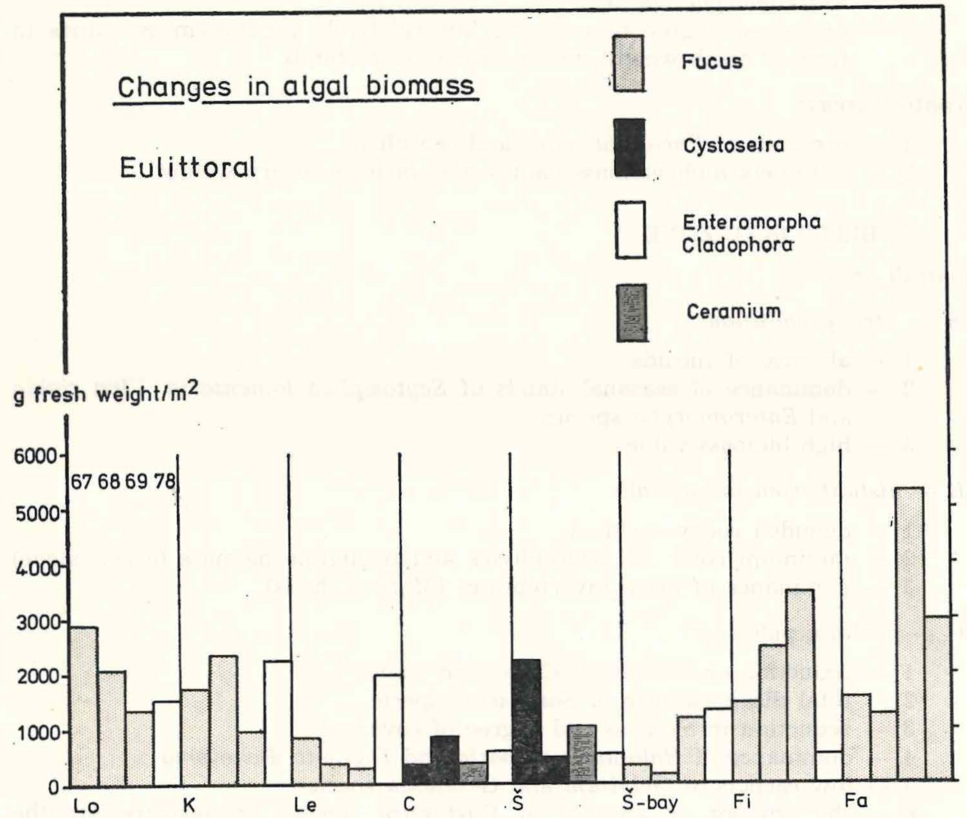

Fig. 1

open coast at Škaraba, *Cystoseira* stands were found eulittorally in 1967 and 1968. In 1969 they were replaced by red algae populations (dominance of *Ceramium* species) and a decade later by *Enteromorpha* stands with a relatively low biomass. In the neighbouring bay of Škaraba the exposure is less severe and thus *Fucus* stands were found during the first observation period. Their relatively low biomass was related to the exposure factor. In 1978 they were replaced by *Enteromorpha,* stands which exhibited biomass values of the same order of magnitude as the previous *Fucus* populations. It is, however, noteworthy that the greater part of the eulittoral slopes was denuded in 1978 whereas previously it was rather uniformly populated by fucoids.

In some localities as e.g. the island of Velika Figarola and the bay of Faborsa, the biomass of the *Fucus* stands was increased in 1969. On this island, which is submitted to pollution impact, the prolific *Fucus* stands deteriorated. Only patches of *Cladophora* and *Enteromorpha* remained in 1978. In the bay of Faborsa, which represents a relatively unpolluted control locality, there were still prolific *Fucus* stands in 1978, mingled with *Ceramium* and *Polysiphonia* species.

In the sublittoral level another pattern of changes was observed (Fig. 2). In the three most polluted localities an increase in biomass was found in the

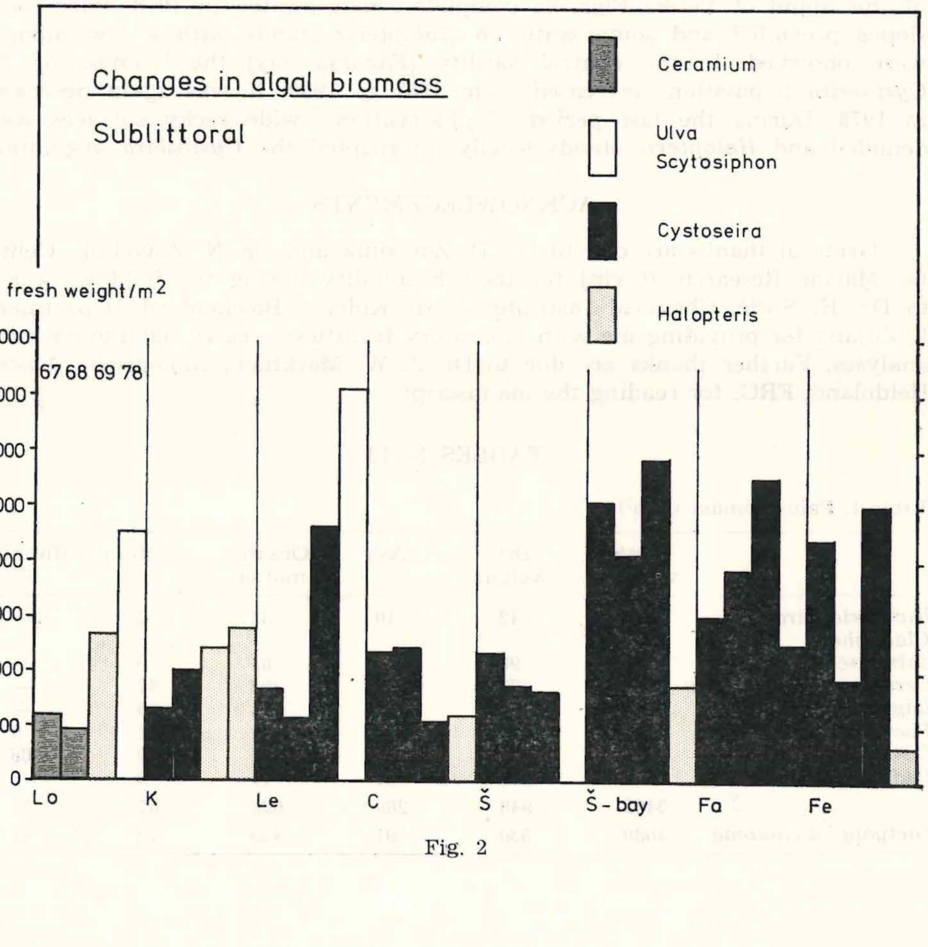

Fig. 2

vernal vegetation of 1978. This refers first of all to the *Ulva-Scytosiphon* association. In Val di Lone first biomass measurements in the subtidal refered to *Ceramium* stands. Already in 1969 a dominance of *Halopteris scoparia* was noted and hence the biomass was increased. On the island of Katarina subtidal *Cystoseira* stands were replaced by *Halopteris*. In 1978 *Scytosiphon — Ulva* stands with high biomass values were locally found on the same island but the greater part of the subtidal rocky slopes was totally denuded. In Val di Lesso, like in most sheltered bays of this area, the biomass of *Cystoseira* populations increased prominently during the spring 1969. These associations disappeared completely and were replaced by seasonal associations of *Scytosiphon — Ulva* with extremely high biomass values. In general, the degree of covering by macrophytes was decreased. In the bay of Škaraba the prolific *Cystoseira* growth deteriorated and was replaced by scatered *Halopteris scoparia* stands with a considerably lower average biomass. During the first observation period the density of the *Cystoseira* stands was lower in exposed localities, such as e.g. Crveni otok and the open coast at Škaraba. At Crveni otok they were replaced by scattered *Halopteris* stands, which exhibited biomass values of the same order of magnitude as the previous *Cystoseira* populations. Along the open coast of Škaraba the greater part of the subtidal rocky slopes was denuded in 1978. The prolific and dense *Cystoseira* meadows of the island of Velika Figarola completely deteriorated in 1978. Bare rocky slopes prevailed and some scattered *Halopteris* stands with a low biomass were observed. In the control locality (Faborsa bay) the biomass of the *Cystoseira* populations increased from 1967 to 1969. It was again decreased in 1978. During the last period of observations, wide rocky surfaces were denuded and *Halopteris* stands locally interrupted the *Cystoseira* vegetation.

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TABLES 1—12

Table 1. Palu-biomass (g/m²)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Rivularia atra	255	42	10	32	3	—
Cladophora dalmatica	1200	98	17	81	9	—
Ceramium diaphanum	3140	379	76	303	47	—
Laurencia obtusa	2800	221	43	178	26	—
Fucus virsoides	870	130	65	65	13	9
Cystoseira barbata	4575	796	199	597	79	66
Padina pavonia	890	152	81	71	8	6
Σ	5465	948	280	668	87	72
Dictyota dichotoma	4080	530	91	439	72	41

Table 2. Škaraba-biomass (g/m^2)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Cladophora dalmatica	1360	72	13	59	6	—
Gelidium spp. carpet:	2408	433	151	282	24	—
Halopteris scoparia	3120	405	202	203	45	23
Halopteris scoparia	1500	198	99	99	22	12
Dictyota dichotoma	1920	204	35	169	27	15

In the eulittoral and upper sublittoral level *Mytilus galloprovincialis* and *M. mimimus* dominated.

Table 3. Crveni otoka (Red Island) — biomass (g/m^2)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Gelidium spp. carpet:	3368	606	216	390	34	—
Cladophora dalmatica	592	48	8	40	4	—
Mixed population (dendritic species)	1184	260	95	165	16	—
Dictyota dichotoma	3680	448	77	271	62	35
Halopteris scoparia	2880	372	74	298	37	22
Halopteris scoparia	560	83	32	51	9	5
Cystoseira spicata	320	64	17	47	5	4
Σ	880	147	49	98	14	9

Table 4. Sturago — biomass (g/m^2)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Enteromorpha intestinalis	820	71	16	55	9	—
Low covering: *Laurencia obtusa*	2320	302	151	151	31	—
Rock-pool: *Laurencia obtusa*	512	62	12	50	7	—
Low covering: *Cladophora dalmatica*	1288	109	43	66	9	—
Rock-pool: *Cladophora dalmatica*	630	52	9	43	6	—
Cystoseira spicata	6080	930	140	790	75	60
Dictyota dichotoma	3360	568	58	510	78	44
Halopteris scoparia	2880	405	51	354	46	24
Gelidium spp. carpet:	4010	722	311	411	40	—

Table 5 a. San Giovanni — biomass (g/m^2)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Catenella caespitosa	630	81	13	68	17	—
Carolina officinalis	3680	1251	824	426	116	—
Corallina officinalis	5760	1987	1290	697	184	—
Halopteris scoparia	4320	639	144	395	64	38
Lomentaria clavellosa	1563	95	47	48	9	—
Dictyota dichotoma	368	48	8	40	7	4
Σ	1936	143	55	88	16	4
Ceramium diaphanum	576	58	12	46	7	—
Laurencia obtusa	64	45	8	37	5	—
Σ	640	103	20	83	12	—
Fucus virsoides	390	66	25	41	7	5
Rock-pool:						
Cladophora dalmatica	480	39	15	24	3	—

Table 5. b. San Giovanni — biomass (g/m^2)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Halopteris scoparia	880	130	50	80	15	7
Cystoseira compressa	112	21	5	16	2	2
Σ	992	151	55	96	17	9
Sublittoral:						
Cystoseira spicata	1280	320	125	195	26	21
Cystoseira compressa	384	72	18	54	7	6
Padina pavonia	352	56	29	27	3	2
Σ	2016	448	172	276	36	29
Dictyota dichotoma	1500	195	33	162	26	15

Table 6 a. Val di Lone — biomass (g/m^2)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Rock-pools:						
Enteromorpha intestinalis	1808	112	26	86	3	—
Enteromorpha intestinalis	800	80	18	62	2	—
Enteromorpha intestinalis	1936	176	40	136	37	—
Ulva rigida	2880	252	42	210	23	—
Scytosiphon lomentaria	2080	316	32	284	49	10
Σ	4980	568	74	494	72	10
Scytosiphon lomentaria	1600	243	24	219	37	8
Stictyosiphon adriaticus	560	56	9	47	5	3
Cutleria multifida	320	35	6	29	3	4
Dictyota dichotoma	640	67	12	55	9	5
Ulva rigida	800	72	12	60	7	—
Halopteris scoparia	320	42	16	26	5	2
Σ	4240	515	79	436	66	22

Table 6 b. Val di Lone — biomass (g/m²)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Sublittoral:						
Dictyota dichotoma	2400	254	44	210	35	20
Cutleria multifida	820	94	15	79	9	4
Ulva rigida	960	96	10	86	8	—
Halopteris scoparia	300	33	13	20	4	2
Σ	4420	477	82	395	56	26
Colpomenia sinuosa	5056	404	58	346	25	22
Dictyota dichotoma	3770	377	64	313	51	29

Table 7 a. Sv. Katarina I. — biomass (g/m²)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Enteromorpha intestinalis	2320	202	47	155	28	—
Rock pool:						
Cystoseira compresa	928	122	19	103	7	9
Cystoseira spicata	1248	275	42	233	22	22
Dictyota dichotoma	32	3	1	2	—	
Σ	2208	400	62	338	29	31
Sublittoral:						
Cystoseira compresa	976	142	36	106	13	13
Cystoseira spicata	560	82	18	64	11	5
Ulva rigida	240	24	4	20	2	—
Halopteris scoparia	320	36	14	22	4	2
Dictyota dichotoma	480	50	9	41	7	4
Σ	2570	334	81	253	37	24

Table 7 b. Sv. Katarina I. and II. — biomass (g/m²)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Sublittoral:						
SV. KATARINA I.						
Dictyota dichotoma	1360	144	25	119	19	11
Dictyopteris membranacea	384	199	61	138	57	18
Ulva rigida	160	44	24	20	15	—
Halopteris scoparia	944	108	42	66	12	7
Σ	2848	485	152	343	101	36
SV. KATARINA II.						
Enteromorpha intestinalis	4080	355	97	258	18	—
Scytosiphon lomentaria	4256	642	80	562	100	22

Table 8. Hospital — biomass (g/m²)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Ulva rigida	2432	182	36	146	17	—
Scytosiphon lomentaria	4800	566	70	496	71	34
Σ	7232	748	106	642	88	34
Punctaria latifolia	1840	128	13	115	13	12
Ectocarpus siliculosus	560	40	6	34	5	5
Cladophora sp.	1760	239	37	202	54	—
Σ	4160	407	56	351	72	17
Enteromorpha intestinalis	2080	191	83	108	19	—
Ceramium ciliatum	256	36	10	26	3	—
Σ	2336	227	93	134	22	—
Gelidium spinulosum cf.	336	39	5	34	3	—

Table 9. Velika Figarola — biomass (g/m²)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Terrestrial pool:						
Enteromorpha clathrata	588	28	8	20	1	—
Fucus virsoides	46	11	6	5	1	1
Enteromorpha sp. and *Cladophora dalmatica*	720	59	23	36	3	—
Σ	766	99	37	39	4	1
Enteromorpha intestinalis	1600	139	32	107	19	—
Cladophora dalmatica	890	56	10	46	5	—
Σ	2490	195	42	153	24	—
Dictyota dichotoma	1320	187	32	155	25	14
Dictyota dichotoma	560	79	14	65	11	6
Halopteris scoparia	75	90	34	56	10	5
Σ	635	169	48	121	22	11

Table 10. Velika Figarola and Mala Figarola — biomass (g/m²)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
VELIKA FIGAROLA						
West side:						
Gelidium spp. carpet	1839	294	68	226	16	—
Enteromorpha sp. and *Cladophora dalmatica*	240	13	5	8	1	—
Fucus virsoides	528	88	44	44	9	6
MALA FIGAROLA						
Ulva rigida and Ulvaria oxysperma	1380	124	21	103	11	—
Rock pool:						
Cystoseira spicata	672	91	20	71	7	7
Cystoseira compresa	1040	130	21	109	11	10
Σ	1732	221	41	180	18	17

Table 11. Faborsa I. — biomass (g/m²)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Fucus virsoides	3024	454	91	363	42	32
Ceramium diaphanum	448	53	11	42	6	—
Σ	3472	507	102	405	48	32
Fucus virsoides	2800	420	84	336	39	29
Ceramium diaphanum	272	33	6	27	4	—
Σ	3072	453	90	363	43	29
Polysiphonia furcellata	256	55	7	28	4	—
Ceramium diaphanum	144	17	3	14	2	—
Σ	400	52	10	42	6	—
Sublittoral:						
Cystoseira compresa	800	144	36	108	14	14
Cystoseira spicata	244	48	10	38	5	5
Cystoseira barbata	544	104	37	67	10	9
Σ	2068	296	83	213	29	28

Table 12. Faborsa II. — biomass (g/m²)

	Fresh weight	Dry weight	Ash	Organic matter	Protein	Mannitol
Catenella caespitosa	160	21	3	18	4	—
Cladophora dalmatica	512	27	5	22	2	—
Rock-pool:						
Cystoseira barbata	1152	200	50	150	20	16
Cystoseira compresa	408	67	17	50	4	7
Padina pavonia	40	8	4	4	1	—
Σ	1600	275	71	204	25	23
Sublittoral:						
Cystoseira spicata	1120	224	88	136	31	22
Cystoseira barbata	2256	393	98	295	39	33
Alsidium corallinum	208	40	5	35	6	—
Σ	3584	657	191	466	76	55
Halopteris scoparia	2755	324	62	262	53	21
Dictyota dichotoma	1900	198	40	158	36	14

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PREGLED BIOMASE ALG POLUIRANEGA PODROČJA OKOLICE ROVINJA (ISTRSKA OBALA, SEVERNI JADRAN)

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POVZETEK

1 — Podan je pregled biomase naselij bentoških alg okolice Rovinja (istrska obala). Meritve biomase so bile izvedene na obali od Zaliva Faborsa do zaliva Škaraba ter na nekaterih otokih rovinjskega arhipelaga.

2 — Opravljene so bile meritve mokre teže alg na enoto površine morskega dna in analizirane tudi nekatere sestavine biomase alg (suha teža, pepel, manitol, proteinske komponente).

3 — Sedanje stanje je primerjano s stanjem pred 10 leti (Munda, 1972 a, b), ko so fukaceje prevladovale v nivojih eulitorala in zgornjega sublitorala. Novejše meritve biomase so pokazale spremembe, ki jih je pripisati naraščajočemu vplivu organske polucije na tem področju.

4 — Sedanje meritve so pokazale v splošnem znižanje biomase naselij alg eulitoralnega nivoja. V zgornjem sublitoralu je bila biomasa relativno visoka v bližini virov organskih odplak, a v določeni oddaljenosti od kloak pa je bila biomasa minimalna in prevladovali so makroinvertebrati (školjke rodu *Mytilus*).

5 — V okolici Rovinja so fukaceje izginile iz nivojev eulitorala in zgornjega sublitorala poluiranih lokalitet. Nadomestila so jih v glavnem naselja vrst *Halopteris scoparia* in *Dictyota dichotoma* s poprečno nižjo biomaso. Naselja vrst rodu *Cystoseira* so bila reudcirana celo v manj poluiranih kontrolnih lokalitetah.