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THE EFFECTS OF ORGANIC POLLUTION ON THE DISTRIBUTION OF FUCOID ALGAE FROM THE ISTRIAN COAST (VICINITY OF ROVINJ)

VPLIV ORGANSKE POLUCIJE NA RAZPOREDITEV FUKACEJSKIH ALG ISTRSKE OBALE (OKOLICE ROVINJA)

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Fucoid algae are rather susceptible to organic wastes and gradually disappear from polluted areas. During the last few years the impact by organic wastes increased drastically in the Istrian area, especially in the vicinity of the town of Rovinj. Marked changes in the general vegetation pattern were found. The distributional patterns of fucoids changed radically and reflect clearly the distribution of organic pollutants along the west coast of Istria. Individual species of fucoids exhibit different degrees of tolerance to environmental stresses. A scale was worked out reflecting the susceptibility of the previously dominant fucoids to organic pollution: *Sargassum* species, which disappeared from the area, are probably the most susceptible and *Fucus virsoides* which newly reappeared in some polluted sites, the least. The susceptibility of different *Cystoseira* species grades from *C. spicata* and *C. crinita* through *C. adriatica* to *C. barbata* and *C. compressa* which were found in tide pools of some polluted sites, first of all on nearshore islands.

INTRODUCTION

Fucoid algae exhibit a marked susceptibility to organic and industrial wastes. Field studies in different geographical areas have proved that fucoid species gradually disappear from polluted sites in accordance with their inherited physiological properties, particularly their resistance towards environmental stresses (e.g. Häyren 1937, Sundene 1953, Grenager 1957, Munda 1967, 1974, 1980 a, b, Golubić 1968, Burrows 1971, Edwards 1972, 1975, Rueness 1973, Murray and Littler 1976, 1978, Bokn and Lein 1978, Klavestad 1978).

The complex effects of organic pollutants are, however, combined woth those of other ecological parameters which act in undisturbed environments and are decisive for the distributional patterns of fucoids. Organic pollution influences the environment through a complex of factors, such as increased number of bacteria (especially coliforms), increased BOD, suspended and colloidally dispersed matter, enrichment with nutrient salts, increased turbidity, changes in pH and in O_2 content (which under extreme stresses leads to anaerobic conditions). In some cases, e.g. in polluted estuaries and in the vicinity of sewage outlets the diverse effects of organic pollution are combined with a decreased salinity.

In the Istrian area we dealt first of all with pollution by sewage. For ten years ago the benthic algal vegetation was dominated by fucoids, both in the eulittoral and sublittoral levels. They formed compact settlements and their associations have been described (M u n d a 1972 a, 1979). Even earlier data from this area have shown a high floristic diversity and prolific vegetation around Rovinj (V a t o v a 1928).

In undisturbed environments the distribution of individual fucoid species first of all depends of the degree of exposure and substratum configuration. In the Rovinj area salinity and temperature averages, as well as their seasonal variations were rather uniformly distributed (M u n d a 1972 b, 1980 a, b). Decreased salinities were only found in the innermost part of the Lim fjord (Limski kanal) (M u n d a 1977 a).

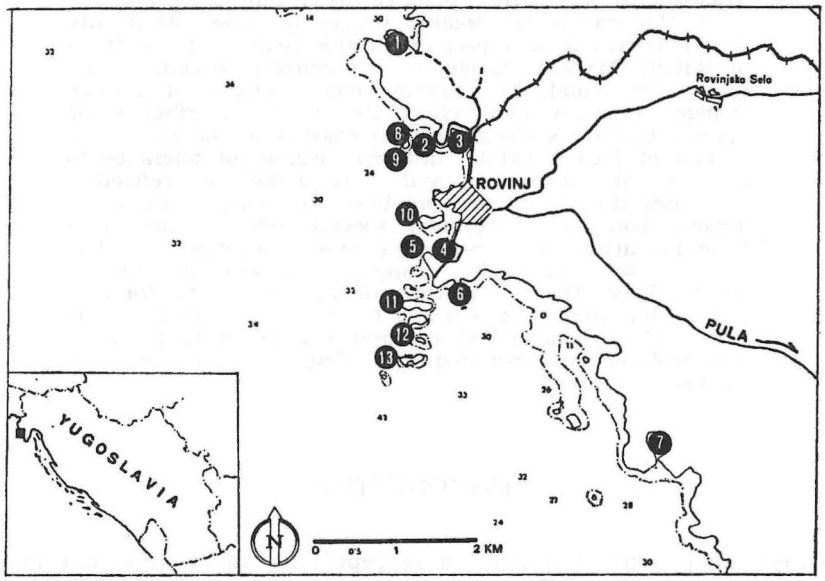

Figure 1. Map of the Rovinj area with the investigated localities.

During the last few years the impact organic wastes increased drastically due to urbanization and tourism. Marked changes in the general vegetation pattern were found (M u n d a 1974, 1980 a, b) and were first of all visible in a changed distribution and local disappearence of fucoids. The present

distribution of fucoid species in this area is primarily dependent on the amount of organic pollutants; their concentration gradients along the shore and inbetween the islands, and the localization of sewage outlets.

Hence, a brief survey of the recent distribution of the previously dominant fucoids is of special interest for a comparison with past and future conditions.

RESULTS AND DISCUSSION

Results of field studies carried out during the spring months of 1978, 1979 and 1980 indicate a gradient in susceptibility to pollution by sewage in fucoids, which for ten years ago dominated the eulittoral and sublittoral vegetation. It is noteworthy that grazing by sea urchins and molluscs is a secondary effect to the deteriorating influence of sewage. Locally the coastal slopes were totally denuded and only the crustouse undervegetation remained.

Fucus virsoides (Don.) J. Ag.

Fucus virsoides is an eulittoral species which was widely distributed around Rovinj and along the Istrian coast as a whole. In undisturbed environments it prefers moderately sloping rocky surfaces and conditions of medium exposure (Munda 1972 a). Ten years ago it formed prolific and continuous belts both, in rather sheltered bays (e.g. Faborsa, Škaraba, Val di Lone) and on some nearshore islands (St. Catarina, V. Figarola). Under conditions of high exposure it was found in narrow belts or in patches behind the shelter of protruding rocks (e.g. Val di Lesso, islands of M. Figarola, San Giovanni, Crveni otok (Red Island). Hence its distributional pattern was meerely related to substratum configuration and the degree of exposure.

During recent studies in the same localities (spring 1978, 1979, 1980) deteriorations of its settlements were observed in most sites near the town, where the degree of organic pollution was considerable (Val di Lone, Škaraba, islands of St. Catarina and V. Figarola). In all these sites it previously formed conspicuous belts and ecologically and seasonally conditioned variations in its association have been described (M u n d a 1972 a). In the bay of Faborsa, distant from the town, *Fucus virsoides* belts were still prolific and the same was true for the vicinity of Palu. On exposed offshore islands (Crveni otok, San Giovanni) patches of its settlements remained.

As described (M u n d a 1974, in 1980 a) the previously compact *Fucus* settlements were not replaced by belts of other algae when the effect of organic pollution became prevalent. Only patches of several green algae (representetatives of the genera *Cladophora, Enteromorpha* and *Blidingia)* were found in small pools and eulittoral depressions, whereas the greater part of the rocky slopes was denuded. Locally (Škaraba, parts of the island of St. Catarina) belts of *Mytilus* shells formed a compact population in the level previously occupied by *Fucus.* In 1980 a partial restitution of *Fucus virsoides* settlements was observed in some rather pollutes sites (Val di Lone, Val di Lesso, islands of St. Catarina and V. Figarola). These settlements were scattered and are not comparable with the compact belts which dominated the eulittoral vegetation for ten years ago. This restitution might indicate an increased

resistance or gradual adaptation of this species to environmental impacts rather than a decrease in the amount of organic pollutants. In the distant bays of Faborsa and Palu, *Fucus* settlements were still prolific and patches of its populations were found, as previosly, on offshore islands. *Fucus virsoides* settlements were found even on mud-covered rocks in the bay of Saline, outside Limski kanal.

The present distributional pattern of *Fucus virsoides* in the polluted area around Rovinj, however, indicates a certain degree of tolerance towards the complexity of factors, associated with pollution by organic wastes.

Among the previously dominant fucoid species from this area *Fucus* is likely to be the most resistant. This is in accordance with its tolerance for lowered salinities, proved both in the laboratory and in the field (Munda 1977 a, b) as well as with the fact that it grows eulittorally and hence tolerates wider fluctuations in environmental parameters than the constantly submersed *Cystoseira* and *Sargassum* species.

Transplantation experiments, carried out in 1979 by transferring adult plants from the bay of Faborsa to differently polluted localities (V. Figarola, St. Catarina, Val di Lone and vicinity of the hospital) gave negative results. No adult plants, which were transplanted to polluted sites, survived.

Cystoseira species

The distributional pattern of the diverse *Cystoseira* species in this area differed in accordance with their genetically conditioned properties and were determined by exposure and substratum configuration. Their distribution and ecologically conditioned variations in the Adriatic as a whole were thoroughly studied by Ercegović (1952) and later also by Giaccone and Bruni (1972, 1973).

Ten years ago representatives of this genus still dominated the upper-sublittoral vegetation of the area around Rovinj and formed conspicuous associations (Munda 1979). In exposed habitats, particularly on offshore islands, an uplift of *Cystoseira* stands into the eulittoral level was obvious (e.g. on Crveni otok, Maskin, San Giovanni, Pirozi and in Škaraba). During field studies from 1967 to 1969 *Cystoseira* stands exhibited considerable biomass values (Munda 1972 b) and were floristically rich. A high species diversity was found both among the companion species and in the epiphytic cover during spring.

The present state of the sublittoral vegetation around Rovinj is markedly changed. Observations carried out in spring 1978, 1979 and 1980 revealed a total deterioration of *Cystoseira* beds in the vicinity of the town as well as a reduction of the stands in distant bays and on offshore islands.

Within this genus, however, a certain gradient in susceptibility towards organic pollutants was noted and is reflected in the distributional patterns of the individual species in this area.

In general, the susceptibility of *Cystoseira* species to environmental stresses exceeds that of *Fucus virsoides*. They are adapted to more stable sublittoral environments than the latter eulittoral species and were seldom found under conditions of lowered salinities.

On the basis of the present distributional pattern of *Cystoseira* species in the Rovinj area a susceptibility scale was worked out (Fig. 2). It seems likely, however, that species adapted to deeper water layers (e.g. *Cystoseira fucoides, C. discors*) are more susceptible to organic pollution than those growing near the surface.

Cystoseira barbata (Good. et Woodw.) J. Ag. and *C. compressa* (Esper) Gerloff et Nizamuddin (*C. fimbriata* /Desf./ Bory)

Ten years ago *C. barbata* was the most common and widespread among the *Cystoseira* species in this area. It was found in broad belts, 2 to 3 m in width, on moderately sloping rocky surfaces in inlets and bays as well as on nearshore islands (V. Figarola, St. Catarina). The ecologically and seasonally conditioned variations in the floristic composition and biomass of its association have been described (Munda 1972 b, 1978).

Cystoseira compressa was similarly well represented in the Roviny area and occurred in widely different habitats regarding depth and exposure conditions. One variant of its association was found sublittorally in sheltered sites, which were slightly polluted even ten years ago. The second variant of the same association was found eulittorally under conditions of high exposure, mostly on offshore islands. Under such conditions the species occurred in reduced growth forms.

During the last few years the dense settlements of both species deteriorated in the vicinity of the town. On the basis of their present distributional pattern in the investigated area we might assume that they are, nevertheless, the most resistant to organic pollution among representatives of this genus. They were found in tide pools of polluted sites, where they were absent from the littoral slopes. (e.g. on the islands of St. Catarina, M. Figarola, V. Figarola and in Val di Lesso). In the rather distant bay of Faborsa they were still present in the upper sublittoral, though that their belts were notably reduced. A progressing reduction of their settlements was observed in spring 1980. On offshore islands, such as Maskin and San Giovanni both *Cystoseira* associations were still found, though reduced. Only the surf adapted variant of the *Cystoseira compressa* association was still well represented.

Both species disappeared totally from Val di Lone, Škaraba and the vicinity of the Rovinj hospital. In contrast to the eulittoral level, *Cystoseria* stands from the upper sublittoral were replaced by other algal associations after the deteriorating effects of organic pollutants (Munda 1974, 1980 a, b). Most commonly *Halopteris scoparia* and *Dictyota dichotoma* occurred on sublittoral slopes, previously covered by *Cystoseira* beds. Around the eulittoral/sublittoral junction low carpets of diverse *Gelidium* and *Gelidiella* species succeeded *Cystoseira* species, whereas during spring, associations of *Scytosiphon lomentaria* and *Ulva rigida* were usual in highly polluted sites. In habitats where grazing followed the deteriorating effects of sewage, rocky slopes were denuded of macrophytes and coated only by a diatom layer.

Cystoseira adriatica Grev.

The association of this species exhibited a rather limited distributional pattern around Rovinj, but it had a wide range of vertical extension. In

accordance with its present distribution we might assume a higher susceptibility towards organic pollutants than in the two species, named above. It occurred mostly in patches in sites where, ten years ago, it formed dense beds (e. g. island of V. Figarola, Val di Lesso). There sublittoral slopes were mostly denuded of macrophytes.

Cystoseira spicata Erc. *(C. stricta* Sauv. v. *spicata* (Erc.) Giacone et Bruni).

This species was previously widely distributed in the Istrian area, mostly on exposed rocky slopes (M u n d a 1979). Its present distribution around Rovinj revealed a high susceptibility to organic pollution. Continuous stands were only found on distant islands (e.g. on San Giovanni) and in Palu; patches in the bay of Faborsa and tide-pool stands on most islands. Its tide--pool populations were, however, dense and prolific on the islands of Maskin and Crveni otok (Red Island).

Cystoseira crinita (Desf) Bory.

This species was relatively rare in the area ten years ago, though it was asssociation-forming in the upper eulittoral of exposed sites. Its present distribution in the Rovinj area indicates a high susuceptibility to organic pollution since it was fund in patches only in Palu and on offshore ialands.

Cystoseira discors (L.) J. Ag. emend. Sauv.
(C. ercegovichii Giaccone) and *C. fucoides* Erc. *(C. dubia* Valiante emend. Erc.)

These two species are limited to lower sublittoral levels. They obviously exibit the highest susceptibility towards organic pollutants since they totally disappeared from the vicinity of Rovinj. Only single specimens could be found in the dredged material from offshore localities.

Sargassum species.

previously represented by *S. acinarium* (L.) C. Ag. and *S. hornschouchii* C. Ag. disappeared from the area indicating a high degree of susceptibility to organic wastes.

Hence, the most striking feature of the present state of the benthic algal vegetation of the vicinity of Rovinj was the disappearence or extreme reduction of the *Cystoseira* stands, which were, in contrast to *Fucus,* replaced by other associations; and the disappearence of representatives of the genus *Sargassum.* Observations revealed that deep-water species exhibit the highest degree of susceptibility towards organic pollutants since they disappeared from the area.

Within the genus *Cystoseira,* however, a certain gradient in susceptibility towards organic pollutants was noted.

The previously dominant *Cystoseira* species could be, however, placed in the following susceptibility scale in accordance with their distribution in the area:

1 — deep-water species *Cystoseira discors* and *C. fucoides*
2 — *C. crinita*
3 — *C. spicata*
4 — *C. adriatica*
5 — *C. barbata* and *C. compressa*

Field observations should, however, be proved by experiments in vitro to find out the effects of single pollutants on the assimilation/respiration ratio of species which disappear from sewage-impacted areas.

DISTRIBUTION OF FUCOIDS AROUND ROVINJ (1978 to 1980)

	mainland							nearshore islands			offshore islands		
localities	❶	❷	❸	❹	❺	❻	❼	❽	❾	❿	⓫	⓬	⓭
yearly averages:	FABORSA	VAL DI LESSO	HOSPITAL	VAL DI LOŠE	PUNTA CORRENTE	ŠKARABA	PALU	V.FIGAROLA	M.FIGAROLA	ST.CATARINA	CRVENI OTOK	MASKIN	ST.GIOVANI
total coliform bacteria (n/1ooml)	15	22	2o	247	-	12	1	-	-	1o2	2	-	-
BOD_5	o,8o	1,o3	1,17	o,96	-	o,98	o,82	-	-	1,26	1,o2	-	-
FUCUS VIRSOIDES	▬	—		—	—		▬	—		—	—		▬
CYSTOSEIRA BARBATA	▬				—		▬					—	▬
C. COMPRESSA	▬				—		▬					—	▬
C. ADRIATICA	—	—			—		—						
C. SPICATA	—				—		▬	—		—			▬
C. CRINITA							—				—	—	
C. DISCORS													
C. FUCOIDES													
SARGASSUM SPP.													

▬ compact settlements — patches — only in tide pools

Figure 2. Distribution of fucoids around Rovinj (1978—1980).

SUMMARY

1 — The distributional patterns of several fucoid species were studied in the vicinty of Rovinj during spring months of 1978, 1979 and 1980.

2 — The present state of the benthic algal vegetation and particularly the distributional pattern of fucoids was compared with conditions for ten years ago (1967 to 1969).

3 — On the basis of their distributional patterns in the polluted area a susceptibility scale was worked out for previously dominant fucoids. *Fucus virsoides* being the most resistant and *Sargassum* species the least. A certain gradient in susceptibility towards organic pollutants was found within representatives of the genus *Cystoseira; C. barbata* and *C. compressa* having the widest distribution since they were found in pools of polluted sites. (Figs. 1 and 2).

4 — It seems, however, likely that susceptibility increases in accordance with the vertical distribution of species. Those which normally thrive in the eulittoral or upper sublittoral are the most resistant, whereas species adapted to stable environments in the deeper water layers exert the highest degree of susceptibility to environmental impacts involved in pollution by sewage.

5 — Observations revealed a partial restitution of *Fusus* stands in some polluted sites, whereas

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POVZETEK

Fukaceje kažejo precejšnjo občutljivot do organskih odplakov in postopoma izginjajo iz poluiranih področij. Tekom zadnjih let je onesnaženje istrske obale, zlasti okolice mesta Rovinja, drastično narastlo. Opaziti je globoke spremembe v splošni vegetacijski sliki tega področja. Razporeditev fukacej v tem obalnem področju se je radikalno spremenila in jasno odraža razporeditev organskih polutantov na zahodno istrski obali. Posamezne vrste fukacej kažejo različno stopnjo tolerance do okolnih stresov. Izdelana je bila skala ki kaže stopnjo občutljivosti posameznih, prej dominantnih vrst, do organske polucije. Vrste rodu *Sargassum* ki so izginile iz tega področja so očitno najbolj občutljive, *Fucus virsoides*, ki se je v zadnjem času znova pojavil v nekaterih poluiranih lokalitetah, pa najmanj. Občutljivost vrst rodu *Cystoseira* kaže naslednjo lestvico: *Cystoseira spicata* in *C. crinita*, sledi *C. adriatica*, medtem ko sta vrsi *C. barbata* in *C. compressa* najbolj rezistentni. Pojavljata se namreč v »tide-pools« poluiranih lokalitet, zlasti na priobalnih otokih.