THE MACROPHYTOBENTHOS ON THE HARD UPPER MEDIOLITTORAL FROM TWO SITES OF SLOVENIAN COAST (NORTHERN ADRIATIC SEA)

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Izvleček

Prispevek obravnava rezultate raziskav flore bentoških makroalg v zgornjem mediolitoralu v zalivu Sv. Simona in na Debelem rtiču na slovenski obali (severni Jadran). Osnova raziskave je mesečno vzorčenje skozi vse leto na različnih substratih (fliš in apnenec). Iz nabranega materiala je bilo določenih 37 vrst makrobentoških alg: 21 *Rhodophyceae*, 3 *Phaeophyceae* and 13 *Chlorophyceae*. Prikazana je primerjava med floristično sestavo, sezonsko variabilnostjo in zonacija bentoške vegetacije makroalg iz obeh lokacij vzorčenja. Makrobentoška flora je analizirana tudi v smislu fitogeografske komponente.

Abstract

The results of the study on the benthic macroalgal flora in the upper mediolittoral of the St. Simon bay and Cape Debeli rtič on the Slovenian coast (Northern Adriatic) are presented. The study is based on monthly samples carried out throughout the year on different hard substrata (flysch and limestone). From the selected material 37 species of macrobenthic algae were identified: 21 *Rhodophyceae*, 3 *Phaeophyceae* and 13 *Chlorophyceae*. A comparison between the floristic composition, seasonal variations and the zonation of the benthic macroalgal vegetation in both investigated stations is presented. The macrobenthic flora is analysed in terms of its phytogeographical components too.

Ključne besede: makrobentoške morske alge, zgornji mediolitoral, floristična sestava, sezonske variacije, zonacija, seznam, slovensko obalno morje, severni Jadran

Key words: macrobenthic marine algae, upper mediolittoral, zonation, seasonal variations, check list, the Slovenian coast, the Northern Adriatic sea

1. INTRODUCTION

The Gulf of Trieste is a shallow, semi-enclosed, northernmost part of the Adriatic sea with a depth of cca. 25 m. The Slovenian coastal sea covers only the southern part of the Gulf of Trieste. The coastline is approximately 46 km long with two main bays: the bay of Koper - Capodistria and the bay of Piran - Pirano and two smaller bays: the bay of Izola - Isola and the bay of Strunjan - Strugnano. The coast is composed of Eocene flysch layers (Ogorelec & al. 1997); while in Izola - Isola (St. Simon bay - baia di S. Simone) the coast is formed by limestones with alveolines and nummulites (Pavlovec 1985).

The Gulf of Trieste is characterized by a patchy and discontinuous algal cover subjected to strong variations as a response to a wide variety of ever-changing abiotic and biotic conditions (Giaccone & Pignatti 1967; Pignatti & Giaccone 1967).

Most studies concerning the vegetation patterns, algal biomass and chemical composition of individual species of the Slovenian coastal sea,

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indicate that the benthic algal flora has changed as a result of increased pollution caused by sewage, agricultural drainage and industrial discharge (Vuković 1981, 1982, 1984; Munda 1988, 1991, 1993; Battelli 1997, 2000).

Over the last decades Slovenian coastal areas have suffered from many anthropogenic impacts. Many activities on the coast (urbanisation, farming, tourism and others) have drastically changed the natural shore line. Today, only 18 % of the coastline is still in its natural stage (Turk 1999).

The most frequently cited ecological factors controlling the composition and the distribution of the algal vegetation of the mediolittoral zone are: tidal rhythm (immersion/emersion and desiccating effect), the degree of wave action, light, temperature, type and orientation of the substratum. The response of animal and algae to this gradient, together with the effect of biological interactions between groups of organisms, such as grazing pressure, competition for space and food, lead to zonation. Zonation can be seen on hard substrata and is seen as the occurrence of different species of algae and animals at different levels on the coast (Ruitton 2000).

The task of the present study was:

- To examine the floristic qualitative composition, the seasonal variations and the zonation of the macrobenthic marine algal vegetation in the upper mediolittoral from the St. Simon bay and Cape Debeli rtič on different hard substratum type (limestone and flysch) of the Slovenian coast;
- To test the hypothesis that the seasons and the type of substratum cause variation in the patterns of distribution of the macrobenthic algal vegetation.

2. METHODS

Sampling was carried out on hard substrata monthly from October 2000 to September 2001 (Table 1). A total of 70 samples was collected with the direct method from three horizons in the upper mediolittoral, from the sea level (0 m) to high tide (+ 0,5 m) on each site, along transects perpendicular to the coast, where the species forms homogeneous settlements. The sampling areas were 100 cm^2 (10 cm x 10 cm) quadrats and were chosen on the basis of previous studies on qualitative minimal area, using the Pizzuto & Serio (1994) and Curiel & al. (1997) methods. The collected material was preserved in seawater-formalin (4 %) with borax buffer for later study in the laboratory. Voucher specimens are kept in the personal herbarium.

Table 1. Sampling dates.
Tabela 1: Čas vzorčevanja.

Autumn	A1	October 2000
	A2	November 2000
	A3	December 2000
Winter	W1	January 2001
	W2	February 2001
	W3	March 2001
Spring	Sp1	April 2001
	Sp2	May 2001
	Sp3	June 2001
Summer	Su1	July 2001
	Su2	August 2001
	Su3	September 2001

The lists of the taxa, number and percentages for the main taxa (classes, orders, families and genera), phytogeographical elements and the monthly presence of species in both floras were made.

For categorization of higher taxonomic categories (classes, orders and families) the classifications by Ribera & al. (1992), Gallardo & al. (1993) and Silva & al. (1996) were used.

A schema for delineating phytogeographical regions of benthic algae is given. The following abbreviations are used: **A** = Atlantic, **Ab** = boreo-Atlantic, **Abt** = boreo-tropical Atlantic, **AP** = Atlanto-Pacific, **APct** = Atlanto-Pacific cold temperate, **At** = Atlantic tropical; **C** = Cosmopolite, **CB** = Circumboreal, **CBA** = Circumboreo-austral, **IA** = Indo-Atlantic, **IAt** = Indo-Atlantic tropical, **IAct** = Indo-Atlantic cold temperate, **IP** = Indo-Pacific, **M** = Mediterranean, **P** = Pantropical, **SC** = Subcosmopolitan (Furnari & al. 1999).

2.1 Terminology

Although the boundaries are often difficult to define properly, in this paper the investigated zones are defined according to the terminology of Bellan - Santini & al. (1994) and Giaccone & al., (1993), as follows:

- Mediolittoral - corresponds to the zone affected by the waves, subjected to sea level variations caused by wind, atmospheric pressure and tides.

- Upper mediolittoral - corresponds to the part of the mediolittoral situated above the sea-level. In the Mediterranean sea three horizons (upper, middle and lower) can be recognized. They correspond to the three belts of vegetation.
- Zonation means distribution of shore organisms in zones or belts on the shore.

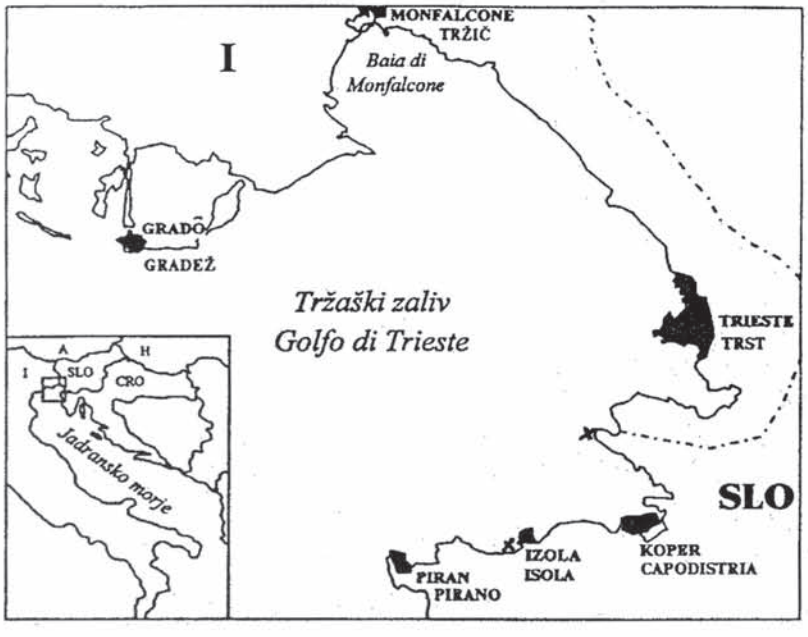
3. DESCRIPTION OF THE STUDY AREA

The study was restricted to hard substrata in the upper mediolittoral of two permanent sampling sites located on the northern (Cape Debeli rtič near Ankaran - Ancarano) and on the southern (St. Simon bay near Izola) part of the Slovenian coast. (Figure 1)

The station of the St. Simon bay is exposed to the north, strongly affected by waves generated by the bora wind which blows from the north-east; the slope is c.a. 80 degrees. The hard substratum type consists of limestones with alveolines and nummulites (Pavlovec 1985).

The site near Cape Debeli rtič is more exposed to the wind lebič, which blows from the south-west and the bora wind which blows from the north-east; the exposure of the site is from the south-west to the north-east. The hard substratum type is composed of Eocene flysch layers with alternating solid sandstone and soft marl (Ogorelec & al. 1997).

Figure 1. Research area with sampling stations.
Slika 1: Raziskovalno območje z vzorčevalnimi postajami



Both stations are influenced by the wind mistral, which blows from the north-west.

During the investigation, the overall temperature range in the surface water layer was between 10,7 and 25,5 ° C in both stations. The tidal range was about 150 cm.

In the algal vegetation of the investigated sites, which at low tide remain partly on dry land, the degree of humidity decreases considerably during the high summer temperatures. Considerable variations in the temperature and salinity take place during the day (e. g. the salinity during rainfall decreases considerably). Besides this, the settlements are exposed to maximum light intensity. This allows the settlement of various scyaphile algal elements.

4. RESULTS AND DISCUSSION

4.1 Qualitative composition of the macrobenthic flora

In the investigated sites 37 species of benthic macroalgae were identified. They belong to three basic sytematic classes of algae: *Rhodophyceae*, *Phaeophyceae* and *Chlorophyceae*, with a total of 13 orders, 15 families and 24 genera. The flora is mostly represented by the *Rhodophyceae* (*Bangiophycidae* and *Florideophycidae*), namely 21 species or 56,76 % share of determined taxa. The *Bangiophycidae* included 7 taxa divided in 2 orders, 2 families and 3 genera. The *Florideophycidae* comprised 31 taxa divided in 6 orders, 7 families and 12 genera. The order *Ceramiales* was characterized by the largest number of taxa (2 families, 4 genera and 8 species).

Phaeophyceae are represented by a small number of taxa, only 3, with the percentage of 8,33 % of determined taxa including 2 orders, 3 families and 3 species with 1 endemic species for the Adriatic sea (*Fucus virsoides*).

Chlorophyceae are represented by 13 taxa or 35,13 % of determined taxa including 3 orders, 3 families and 6 genera with 13 species. The most numerous genus was *Enteromorpha* with 5 species (Table 2 and 3).

This inventory is not com-

***Tab. 2**: Floristic list of macrobenthic marine algae in the upper mediolittoral zone of the St. Simon bay and Cape Debeli rtič with signs of their phytogeographic elements*
***Tab. 2**: Seznam makrobentoških morskih alg zgornjega mediolitorala pri Sv. Simonu in pri Debelem rtiču s fitogeografskimi elementi*

TAXA	Phyt. el.	St. Simon bay	Cape Debeli rtič
RHODOPHYCEAE		20	19
BANGIOPHYCIDAE			
Porphyridiales			
Porphyridiaceae			
Stylonema alsidii (Zanardini) K. M. Drew	C	+	+
Bangiales			
Bangiaceae			
Bangia atropurpurea (Roth) C. Agardh	C	+	-
Porphyra leucosticta Thuret	A	+	+
FLORIDEOPHYCIDAE			
Nemaliales			
Liagoraceae			
Nemalion helminthoides (Velley) Batters	SC	+	+
Gelidiales			
Gelidiaceae			
Gelidium minusculum (Weber Bosse) R.E. Norris	C	+	+
Gelidium pusillum (Stackhouse) Le Jolis	C	+	+
Gelidium spathulatum (Kützing) Bornet	Ab	+	+
Corallinales			
Corallinaceae			
Hydrolithon farinosum (J. V. Lamouroux) Penrose & Y. M. Chamberlain var. *farinosum*	C	+	+
Lithophyllum pustulatum (J. V. Lamouroux) Foslie	IA	+	+
Neogoniolithon brassica-florida (Harvey) Setchel &L.R. Mason	IA	+	+
Pneophyllum fragile Kützing	C	+	+
Gigartinales			
Caulacanthaceae			
Catenella caespitosa (Withering) L. M. Irvine	SC	+	-
Hildenbrandiales			
Hildenbrandiaceae			
Hildenbrandia rubra (Sommerfelt) Meneghini	SC	+	+
Ceramiales			
Ceramiaceae			
Callithamnion corymbosum (J. E. Smith) Lyngbye	Abt	-	+
Ceramium ciliatum (J. Ellis) Ducluzeau var *robustum* (J. Agardh) Feldmann-Mazoyer	M	+	+
Ceramium comptum Břrgesen	IA	+	+
Ceramium diaphanum (Lightfoot) Rooth	SC	+	+
Ceramium tenerrimum (G. Martens) Okamura	SC	+	+
Rhodomelaceae			
Lophosiphonia obscura (C. Agardh) Falkenberg	SC	+	+
Polysiphonia opaca (C. Agardh) Moris & De Notaris	Ab	+	+
Polysiphonia sertularioides (Grateloup) J. Agardh	IA	+	+
PHAEOPHYCEAE		3	1
Ectocarpales			
Ectocarpaceae			
Ectocarpus siliculosus Dillwyn	C	+	-
Ralfsiaceae			
Ralfsia verrucosa (Arescough) Arescough	SC	+	+
Fucales			
Fucaceae			
Fucus virsoides J. Agardh	M	+	-

TAXA	Phyt. el.	St. Simon bay	Cape Debeli rtič
CHLOROPHYCEAE		13	8
Ulotrichales			
Ulotrichaceae			
Ulothrix flacca (Dillwyn) Thuret	SC	+	-
Ulothrix subflaccida Wille	IP	+	-
Ulvales			
Ulvaceae			

***Tab. 3**: Numbers (N) and percentages (%) of main taxa (classes and orders) for floras of St. Simon bay and Cape Debeli rtič*
***Tab. 3**: Število (N) in odstotek (%) višjih taksonov (razredov in redov) flor pri Sv. Simonu in Debelem rtiču*

Area	Cape Debeli rtič		St. Simon bay	
Taxa	N	%	N	%
RHODOPHYCEAE	19	67.8	20	55.6
Porphyridiales	1	3.6	1	2.8
Bangiales	1	3.6	2	5.6
Nemaliales	1	3.6	1	2.8
Gelidiales	3	10.7	3	8.3
Corallinales	4	14.3	4	11.1
Hildenbrandiales	1	3.6	1	2.8
Ceramiales	8	20.6	7	19.4
Gigartinales	-	-	1	2.8
PHAEOPHYCEAE	1	3.6	3	8.3
Ectocarpales	1	3.6	2	5.5
Fucales	-	-	1	2.8
CHLOROPHYCEAE	8	20.6	13	36.1
Ulotrichales	-	-	2	5.5
Ulvales	4	14.3	6	16.7
Cladophorales	4	14.3	5	13.9
TOTAL	28	100	36	100

plete since some genera, such as *Gelidium*, *Polysiphonia* (*Rhodophyceae*), *Enteromorpha* and *Cladophora* (*Chlorophyceae*) have not yet been completely determined.

The analysis of floristic composition of the macrophytobenthos of the St. Simon bay shows that *Rhodophyceae* dominated with 20 species (54,05 %), whereas *Phaeophyceae* were represented with only 3 species (8,10 %) and *Chlorophyceae* by 13 species (35,13 %). To be noted is the presence of the red algae *Catenella caespitosa*, a characteristic species from shady and wet fissures of limestone rocks of the upper mediolittoral. The other characteristic species of this station was the brown algae *Fucus virsoides* with two epiphytes: the brown *Ectocarpus siliculosus* and the green *Enteromorpha flexuosa* subsp. *flexuosa*.

The flora of Cape Debeli rtič was mostly represented by the *Rhodophyceae* with 19 species (51,35 %), whereas *Phaeophyceae* were represented with only one species (*Ralfsia verrucosa*) and *Chlorophyceae* with 8 (21,62 %) species.

The comparison of the macrobenthic flora in the upper mediolittoral of Cape Debeli rtič with the flora of the St. Simon bay showed that the flora of Cape Debeli rtič is poorer (28 taxa) in the total number of algal taxa than the flora of the St. Simon bay (36 taxa). It is to be noted (Table 4) that while the number of *Rhodophyceae* in both floras is quite similar (20 for the St. Simon bay and 19 for the Cape Debeli rtič), there are some differences in their share; a small increase is present from 51,35 % for the Cape Debeli rtič to 54,05 % for the St. Simon bay. The comparison based on percent values shows decreasing values of *Phaeophyceae* from the St. Simon bay (8,10 %) to the Cape Debeli rtič (2,70 %) and *Chlorophyceae* from the St. Simon bay (35,13 %) to the Cape Debeli rtič (21,62 %).

4.2 Zonation and seasonal variations

As mentioned above, the study of macrophytobenthos was based on collections made along depth transects perpendicular to the coast. This allowed us to distinguish three different horizons in the upper mediolittoral of both sampling stations. They were named: upper, middle and lower horizon. In both stations they reached about 10-15 cm in height.

The floristic substrate of the upper mediolittoral of both investigated stations presented some significant differences in the zonation and seasonal variations.

The upper horizon of the Cape Debeli rtič was characterized by the presence of the green algae *Cladophora sp., Chaetomorpha linum, Enteromorpha compressa, E. muscoides* and the red algae *Polysiphonia sertularioides*, which varied slightly during the seasons in relation to their biological cycle, while the number of these species remained the same (Table 4).

The middle horizon was colonized by the green algae of the genera *Cladophora, Chaetomorpha, Ulva* and *Enteromorpha*. These algae occured throughout the year in succeeding generations and were most luxuriant in spring. Beside these the most diffuse were crostose perennial red algae *Hildenbrandia rubra, Neogoniolithon brassica-florida* and the brown algae *Ralfsia verrucosa*. This horizon was, in the winter and spring time, characterized by the presence of the red species *Porphyra leucosticta* (from November to May) and *Nemalion helminthoides* (from December to February) (Table 4).

In the lower horizon the floristic substrate was

Tab. 4: List of the species present in the station of Cape Debeli rtič during the sampling
Tab. 4: Seznam vrst, prisotnih na postaji Debeli rtič v času vzorčevanja

Month Species	Nov	Dec	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Presence
Enteromorpha compressa	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	12
Enteromorpha intestinalis	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Chaetomorpha linum	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	12
Cladophora albida	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Cladophora dalmatica	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Cladophora laetevirens	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Ulva laetevirens	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	12
Gelidium minusculum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Gelidium spathulatum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Gelidium pusillum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Stylonema alsidii	l	l	l	l	l	l	l	l	l	l	l	l	12
Ralfsia verrucosa	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Hydrolithon farinosum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Neogoniolithon brassica-florida	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Pneophyllum fragile	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Litophyllum pustulatum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Hildenbrandia rubra	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Polysiphonia sertularioides	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	12
Lophosiphonia obscura	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	11
Polysiphonia opaca	m,l	m,l	m,l	m,l	m,l	m,l	-	-	m,l	m,l	m,l	m,l	10
Porphyra leucosticta	m	m	m	m	m	m	m	-	-	-	-	-	7
Nemalion helminthoides	-	m	m	m	-	-	-	-	-	-	-	-	3
Enteromorpha muscoides	u,m,l	u,m,l	-	u,m,l	-	-	-	-	-	-	-	-	3
Ceramium ciliatum	m,l	m,l	-	-	-	-	m,l	-	-	-	-	-	3
Ceramium tenerrimum	m,l	-	-	-	-	m,l	-	-	m,l	-	-	-	3
Ceramium diaphanum	-	-	-	-	-	m,l	-	-	m,l		-	-	2
Ceramium comptum	-	m,l	-	-	-	-	-	-	-	-	-	-	1
Callithamnion corymbosum	-	l	-	-	-	-	-	-	-	-	-	-	1
Total	24	26	22	23	21	23	21	19	22	20	19	20	

Legend: u = upper; m = medium; l = lower horizon.
Legenda: u = zgornji; m = srednji; l = spodnji horizont.

represented by the crostose perennial elements (e.g. red algae *Hydrolithon farinosum, Pneophyllum fragile, Lithophyllum pustulatum, Hildenbrandia rubra, Neogoniolithon brassica-florida*). Many macroalgae occured in scattered stands or as single specimens and rarely formed continuous populations which varied slightly during the seasons. The most diffuse of these were: the red algae *Gelidium pusillum, G. spathulatum, G. minusculum, Ceramium* species, *Polysiphonia opaca, Lophosiphonia obscura* and the green algae *Ulva laetevirens, Enteromorpha compressa, E. intestinalis, Cladophora* species. It should be noted that in this horizon the *Ceramium* species were present only occasionally during the year. (Table 4)

In the upper horizon the macrophytobenthos of the St. Simon bay was prevalently characterized by the presence of the red algae *Bangia atropurpurea* and the green algae *Ulothrix flacca* and *U. subflaccida.* These algae formed a dense red-green belt only in winter and early spring and then disappeared. The green algae *Enteromorpha compressa, E. muscoides,*

Tab.5: List of the species present in the station St. Simon bay during the sampling
Tab. 5: Seznam vrst, prisotnih na postaji Sv. Simon v času vzorčevanja

MONTH /SPECIES	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	presence
Fucus virsoides	l	l	l	l	l	l	l	l	l	l	l	l	12
Catenella caespitosa	u	u	u	u	u	u	u	u	u	u	u	u	12
Ralfsia verrucosa	m,l	m,l	m,l	m,l	m,l	M,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Hildenbrandia rubra	m,l	m,l	m,l	m,l	m,l	M,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Enteromorpha compressa	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	12
Enteromorpha flexuosa	l	l	l	l	l	l	l	l	l	l	l	l	12
Enteromorpha muscoides	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	12
Chaetomorpha linum	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	12
Cladophora albida	m,l	m,l	m,l	m,l	m,l	M,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Cladophora dalmatica	m,l	m,l	m,l	m,l	m,l	M,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Cladophora laetevirens	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Polysiphonia sertularioides	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	12
Polysiphonia opaca	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Lophosiphonia obscura	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Ulva laetevirens	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	u,m,l	12
Gelidium minusculum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Gelidium spatulatum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Gelidium pusillum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Stylonema alsidii	l	l	l	l	l	l	l	l	l	l	l	l	12
Litophyllum pustulatum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Hydrolithon farinosum	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Neogoniolithon brassica-florida	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Pneophyllum fragile	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Enteromorpha prolifera subsp. *Prolifera*	l	l	l	l	l	l	l	l	l	l	l	l	12
Enteromorpha intestinalis var. Intestinalis	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	12
Porphyra leucosticta	m,l	m,l	m,l	m,l	m,l	m,l	m,l	m,l	-	-	-	m,l	9
Ectocarpus siliculosus	l	l	l	l	l	l	l	l	-	-	-	l	8
Bangia atropurpurea	u	u	u	u	u	u	u	-	-	-	-	-	7
Ceramium ciliatum	-	-	-	-	-	-	m,l	m,l	m,l	m,l	m,l	-	5
Ulothrix flaccida	-	u	u	u	u	-	-	-	-	-	-	-	4
Ulothrix subflaccida	-	u	u	u	u	-	-	-	-	-	-	-	4
Nemalion helminthoides	-	m	m	m	-	-	-	-	-	-	-	-	3
Ceramium diaphanum	-	-	-	-	-	-	m,l	m,l	-	-	-	-	2
Ceramium comptum	-	-	-	-	-	-	m,l	m,l	-	-	-	-	2
Ceramium tenerrimum	-	-	-	-	-	-	-	-	-	-	m,l	-	1
Rhizoclonium tortuosum	-	-	-	-	-	l	-	-	-	-	-	-	1
TOTAL	28	31	31	31	30	29	31	30	26	26	27	26	

Chaetomorpha and *Cladophora sp.* and the red algae *Polysiphonia sertularioides*, on the other hand, were present all year round (Table 5).

In the shady and wet fissures of the rocks was a well developed settlement of the red algae *Catenella caespitosa* that occured throughout the year.

In the middle horizon a belt of the red algae *Porphyra leucosticta* appeared in November and was present until early June. In the winter time young thalli of green algae *Enteromorpha compressa*, *E. intestinalis*, *Chaetomorpha linum* and *Ulva laetevirens* were present, too. During the summer the algae *E. compressa* decayed. The green species that survived longer, after the summer, were *E. intestinalis*, *Chaetomorpha linum* and *Ulva laetevirens*. The brown algae *Ralfsia verrucosa*, the red algae *Hildebrandia rubra* and *Neogoniolithon brassica-florida* were present on the rocks throughout the year (Table 5). It is to be noted that, especially on barnacles (*Chthamalus stellatus*) young thalli of the *Fucus virsoides* appeared in winter time.

The main charateristic feature of the lower horizon was the settlement of the species *Fucus virsoides*. This species grows all year round, is endemic of the Adriatic sea and represents the characteristic species of the association *Fucetum virsoidis* Pignatti. This settlement was located partly in the upper mediolittoral and partly in the lower mediolittoral, forming a belt of 30 - 40 cm.

In the undergrowth of this horizon, which varies slightly during the seasons, crostose perennial red algae, such as *Hildenbrandia rubra*, *Hydrolithon farinosum*, *Neogoniolithon brassica-florida*, *Pneophyllum fragile* and *Lithophyllum pustulatum*, and the brown *Ralfsia verrucosa* were present. The most diffuse red algae that formed turf-like mats were *Gelidium pusillum* in company with *G. spathulatum*, *G. minusculum* and *Polysiphonia sertularioides*, *P. opaca* and *Lophosiphonia obscura*. The number of these species appeared more or less constantly during the seasons (Table 5). The brown algae *Ectocarpus siliculosus*, the species of the genus *Ceramium*, *Porphyra leucosticta* and the green algae *Enteromorpha flexuosa* subsp. *flexuosa*, *E. muscoides*, *E. compressa*, *Cladophora* sp. and *Chaetomorpha linum* were present as epiphytes on the species *Fucus virsoides* all year round, except the *E. siliculosus* and *P. leucosticta* which are both seasonal species; they were absent in the summer months (Table 5).

It is to be noted, however, that the seasonal red species of the genus *Ceramium* were present in this horizon only occasionally in the summer months.

As stated above, the response of algae to the abiotic factors, together with the effect of biological interactions between groups of organisms, such as grazing, competition for space and food, lead to zonation. It should be noted that most of the herbivorous animals such as *Patella caerulea*, *Monodonta* spp., *Littorina neritoides* were abundant in both of the investigated areas. As a result there were large surfaces completely denudated by grazing, especially in the middle horizon of both stations. So we can say that one of the biotic factors involved in the composition, zonation and seasonal variations of macrobenthic algal vegetation in both investigated areas is grazing.

Figure 2. Seasonal variation of the number of the species during the investigation in the S.Simon bay.
Slika 2. Sezonske variacije vrst prisotnih v času raziskave na postaji sv. Simona.

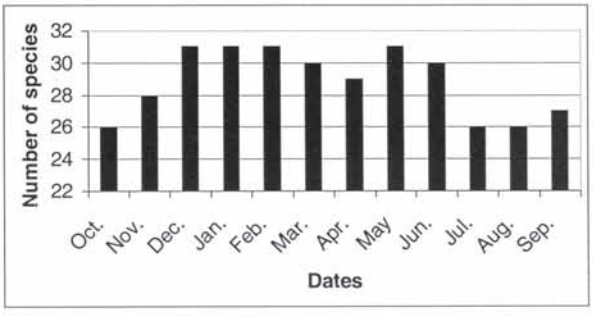
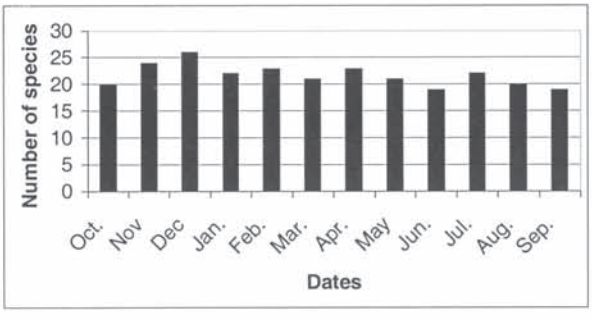


Figure 3. Seasonal variation of the number of the species during the investigation in the Cape Debeli rtič.
Slika 3. Sezonske variacije vrst prisotnih v času raziskave na postaji Debelaga rtiča.



4.3 Phytogeographic composition

Although the phytogeographical analysis is not very significant for such small investigated areas, it should be noted that the macrobenthic marine flora of the investigated stations is composed of floristic

Tab. 6: Numbers (N) and percentages (%) of members of different phytogeographic elements in the macrobenthic floras of St. Simon bay and Cape Debeli rtič
Tab. 6: Število (N) in odstotek (%) fitogeografskih elementov makrobentoške flore pri Sv. Simonu in Debelem rtiču

Phyt. El.	Division / Station	Rhodophyceae N	Rhodophyceae %	Phaeophyceae N	Phaeophyceae %	Chlorophyceae N	Chlorophyceae %	Total N	Total %
M	St. Simon bay	1	5.00	1	33.33	-	-	2	5.55
M	Cape Debeli rtič	1	5.26	-	-	-	-	1	3.57
A	St. Simon bay	1	5.00	-	-	-	-	1	2.78
A	Cape Debeli rtič	1	5.26	-	-	-	-	1	3.57
Ab	St. Simon bay	2	10.00	-	-	-	-	2	5.55
Ab	Cape Debeli rtič	2	10.53	-	-	-	-	2	7.14
IA	St. Simon bay	4	20.00	-	-	2	15.38	6	16.67
IA	Cape Debeli rtič	4	21.05	-	-	2	25.00	6	21.43
IP	St. Simon bay	-	-	-	-	1	7.69	1	2.78
IP	Cape Debeli rtič	-	-	-	-	-	-	-	-
C	St. Simon bay	6	30.00	1	33.33	5	38.46	12	33.33
C	Cape Debeli rtič	5	25.31			4	50.00	9	32.14
SC	St. Simon bay	6	30.00	1	33.33	5	38.46	12	33.33
SC	Cape Debeli rtič	5	26.31	1	100	2	25.00	8	28.57
Abt	St. Simon bay	-	-	-	-	-	-	-	-
Abt	Cape Debeli rtič	1	5.26	-	-	-	-	1	3.57
TOTAL	St. Simon bay	20	100	3	100	13	100	36	100
TOTAL	Cape Debeli rtič	19	100	1	100	8	100	28	100

elements from different phytogeographical regions (Tab. 6). The most frequent floristic elements are Cosmopolitan (C) and Subcosmopolitan (SC) with 12 taxa or 32,43 %; followed by Indo-Atlantic (IA) with 6 taxa or 16,22 %. Mediterranean (M) and Atlantic-boreal (Ab) elements are represented by 2 taxa or 5,40 % and by 1 taxon or 2,70 % Atlantic (A), Indo-Pacific (IP) and Atlantic boreo-tropical (Abt) elements.

The comparison of chorological spectra of the two macrobenthic floras shows that the most frequent phytogeographical elements in the St. Simon bay were Cosmopolitan and Subcosmopolitan with 12 taxa respectively; followed by Indo-Atlantic elements with 6 taxa. Mediterranean elements were present with only 2 species.

In the Cape Debeli rtič area Cosmopolitan and Subcosmopolitan elements dominated with 9 and 8 species respectively; followed by Indo-Atlantic elements.

It is our opinion that Cosmopolitan phytogeographical elements dominated in both stations, because the abiotic ecological factors of the upper mediolittoral are extreme and only these species with wide ecological tolerance can survive in this zone.

In conclusion, the floristic composition, seasonal variations and the zonation of the benthic macroalgae in the upper mediolittoral of the investigated stations are related to the substratum type and seasons.

In spite of considerable differences between the tested ecological factors (substratum type and seasons), a similarity of the macrobenthic algal flora between the two investigated stations is evident. Qualitative differences between the individual studied localities were not substantial and these are mainly the result of the effect of different substratum type (limestone and flysch) (Figure 2 and 3).

In spite of the fact that the main aim of the study was to describe the floristic qualitative composition, seasonal variations and the zonation of the macrophytobenthos in the upper mediolittoral of different substratum type, it is our opinion that the results can contribute to a better understanding of the general situation of the macrophytobenthos not only for the Slovenian coastal sea but also for the similar areas of the Mediterranean sea.

5. POVZETEK

Morski makrofitobentos trdne podlage zgornjega mediolitorala na dveh postajah slovenske obale (severni Jadran)

Morski makrofitobentos trdne podlage zgornjega mediolitorala na dveh postajah slovenske obale (severni Jadran)

Slovenska obala v floristicnem in fitocenoloskem pogledu ni enotna. Zaradi razlicnega posrednega in neposrednega delovanja ekoloških dejavnikov, kot so: razlicna geoloska podlaga (apnenec in flis), zmanjšana prozornost vode zaradi povecane koliCine lebdecih delcev, velike spremembe temperature in slanosti, gibanje morske vode in onesnaženost, je tudi razširjenost, razporejenost, število in sestava makrobentoške flore alg razlicna.

Prispevek obravnava floristicno in fitogeografsko sestavo, sezonske variacije in zonacijo makro-bentoške morske vegetacije alg zgornjega mediolitorala na dveh postajah slovenske obale (severni Jadran).

Namen raziskave je bil testirati hipotezo, da vrsta podlage in letni cas vplivata na floristicno sestavo, sezonsko variacijo in zonacijo makrobentoških alg zgornjega mediolitorala.

Raziskava je potekala na dveh stalnih vzorcevalnih postajah, in sicer: ena na naravni apnenCasti podlagi, umeščena v Izoli - Isola pri Sv. Simonu - baia di S. Simone in druga na naravni flišni podlagi, umeščena v Ankaranu - Ancarano pri Debelem rticu - Punta Grossa.

Doloceni je bilo 37 vrst. Rdecih alg je bilo 21, rjavih 3, zelenih pa 13. Število vrst rdecih alg je v obeh florah približno enako (20 za Sv. Simon in 19 za Debeli rtic), razlika v odstotkih je 54,05 % za Sv. Simon in 51,35 % za Debeli rtic; odstotek rjavih alg za Sv. Simon je 8,10 %, za Debeli rtic pa 2,70 %; kloroficeje so v Sv. Simonu zastopane s 35,13 %, na Debelem rticu pa z 21,62 %.

Na splošno lahko delimo zgornji mediolitoral trdne podlage na obeh postajah na tri horizonte, in sicer: zgornji, srednji in spodnji.

V zgornjem horizontu se na obeh postajah pojavljajo predstavnice zelenih makrobentoških alg, med katerimi prevladujejo: *Enteromorpha compressa, E. muscoides, Chaetomorpha linum.* V zimskem in zgodnjem spomladanskem casu se pojavlja rdeca alga *Porphyra leucosticta.* V bolj senCnatih mestih, zlasti v razpokah skal, se rdeca alga *Catenella caespitosa* pojavlja le v Sv. Simonu. Alge *Bangia atropurpurea, Ulothrix flacca* in *Ulothrix subflaccida* se pojavljajo samo v Sv. Simonu.

Na obeh postajah se v srednjem horizontu pojavljajo predstavnice zelenih alg rodov *Enteromorpha, Chaetomorpha, Cladophora* in *Ulva.*

V spodnjem horizontu so na obeh postajah pogoste naslednje vrste: *Gelidium pusillum, G. spathulatum, G. minusculum, Enteromorpha compressa, E. intestinalis, Polysiphonia opaca, P. sertularioides* in *Lophosiphonia obscura.*

V Sv. Simonu se pojavlja jadranska endemska vrsta *Fucus virsoides* kot znacilna vrsta asociacije *Fucetum virsoidis.* Poleg navedenih vrst se tu kot epifita na fukusu pojavljata še *Ectocarpus siliculosus* in *Enteromorpha flexuosa* subsp. *flexuosa.*

Makrobentoško floro alg raziskovanega območja sestavljajo razlicni fitogeografski elementi. Najvec je kozmopolitskih (C) in subkozmopolitskih (SC) elementov z 12 vrstami ali 32,43 %; sledijo indo-atlantski (IA) s 6 vrstami ali 16,22 %. Mediteranski (M) in atlantsko-borealni (Ab) elementi pa so prisotni le z 2 vrstama ali 5,40 %. Z 1 vrsto (2,70 %) so prisotni naslednji elementi: atlantski (A), indo-pacifiški (IP) in atlantsko borealno-tropski (Abt).

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