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Community Structure of Subtidal Macroalgae around Neobdo Island on the West-southern Coast of Korea

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Community structure of subtidal macroalgae was investigated at 3 sites of Neobdo Island in August 1994. In total, 66 taxa of red, 21 brown, 14 green, and 2 blue-green algae were identified. The number of species and biomass decreased with increasing depths. *Gelidium amansii, Ulva pertusa, Dictyota dichotoma, Sargassum thunbergii, Undaria pinnatifida, Ecklonia cava,* and *Sargassum horneri* had higher frequency and biomass. The vegetation of deeper zone was composed mainly of a few red algae. Substrate characteristic and light intensity were considered as environmental factors determining the underwater vegetation.

Keywords : community structure, macroalgae, biomass, frequency

Since about 1980, much valuable information on subtidal macroalgae has been obtained by a direct observation with SCUBA at several places around Korean waters. On the east coast, Koh (1983), Koh and Sung (1983), Koh and Ahn (1985), Koh *et al.* (1989), and Chung *et al.* (1991) carried out studies on the community structure or productivity of subtidal macroalgae. On the south coast, Sohn *et al.* (1983) investigated the subtidal algal community at Dolsan Island. Lee *et al.* (1991) reported the flora and vertical distribution of marine algae from intertidal to subtidal zone at Chongsando Island, located near the present study site, on the west-southern coast. However, knowledge of subtidal macrophytobenthos off Korean coasts is still very limited, compared to the floristic and monographic studies.

The intertidal flora of Neobdo Island was listed (Lee and Boo, 1982), but no detailed floristic information on subtidal algal communities was given. The purpose of the present study is to describe some of the subtidal algal communities at Neobdo Island. Particular emphasis has been placed on the vertical distribution of conspicuous macroscopic algae at the depths of below mean low water. SCUBA has been applied to investigate the subtidal vegetation.

Study Site Neobdo Island lies approximately 20 km west-south to the Yando harbor. Neobdo is a small island (approximately 5 km^2) with a narrow intertidal area. The island is isolated from the chain of a serial larger islands of Nowhado, Bogildo, and Soando. The surface sea water in this area is approximately temperature of 20-24℃ during summer months and has a salinity less than 33‰ (Anonymous, 1993). The tides are semi-diurnal with amplitude between 0.6-2.4 m at neap and 1.9-4.3 m at spring tide (Anonymous, 1994).

MATERIALS AND METHODS

The collection and observation of subtidal macroalgae were carried out at 3 sites chosen as representative areas that were accessible by boat and divers on 3-4 August, 1994 (Fig. 1). Site A is a sheltered rocky slope facing the sea of the northern side and descending steeply from intertidal to 7 m depth. Substrates consists of massive granitic rock. Below 7 m the substrates consists of pebbles, boulders, and larger rocks and decline gently. Site B and C are exposed rocky slope with substrates similar to Site A. They are faced on sea of the north-western side. The gradient of substrate is steep at these sites. Ro-

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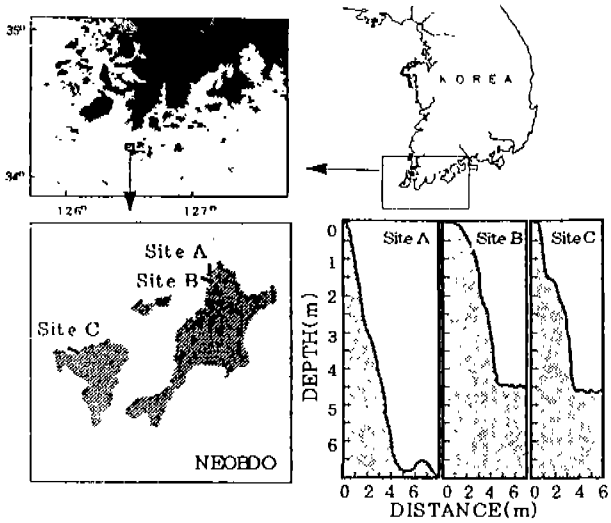

Fig. 1. Maps showing the study area and the vertical profiles of three line transects on subtidal zone (zero points show the mean low water).

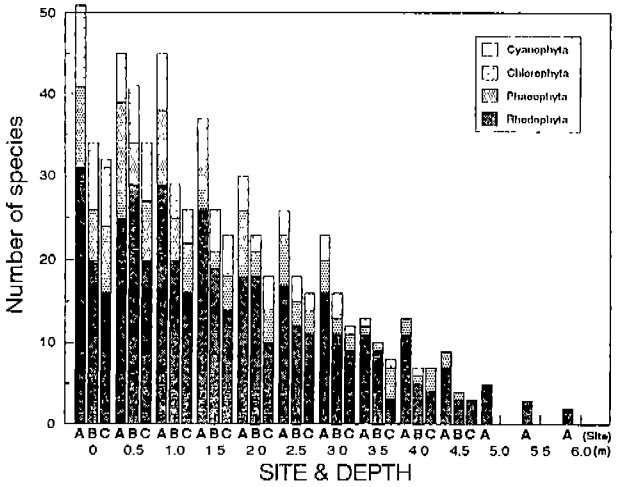

Fig. 2. The number of species of four major phyla with depth levels at 3 subtidal sites in Neobdo Island.

cky substrate in upper subtidal zone and silt-sand in the lowest depth (4-4.5 m) were found.

Samples of conspicuous algae were collected by SCUBA diving at depths from mean low water (M.L.W.) to lower distributional limits of benthic algae. Samples for community analyses were obtained from about 125 quadrats of 10 cm^2 at each depth (0.5 m interval) with 50 cm×50 cm wire quadrat. The following data were recorded for each quadrat: depth, frequency of occurrence of macroalgae, and time of collection to correct the tidal height. Algae (excluding crustose forms) were scraped out the substratum using a paint-scraper and placed in numbered fine-mesh bags. All samples were preserved in 5% formalin-seawater and transferred to the laboratory for identification. The classification of taxa was followed by Lee and Kang (1986). Algae in the quadrats were sorted in the laboratory and oven-dried at 65℃ for 72 h for dry weight determination. Specimens collected were preserved in the herbarium of the Department of Oceanography, Chonnam National University.

RESULTS

A total of 103 taxa was identified representing 66 taxa of Rhodophyta, 21 Phaeophyta, 14 Chlorophyta, and 2 Cyanophyta (Table 1). Seventy-two taxa were recorded at site A, and 63 and 59 taxa at site B and site C, respectively. The red algae contributed the greatest number of species at each site, while the brown and green algae consistently ranked the second and the third.

Twenty-four common species among 103 taxa recorded were present at all sites: *Ulva pertusa, Chaetomorpha aerea, Cladophora japonica, Bryopsis plumosa, Codium fragile, Myelophycus simplex, Undaria pinnatifida, Hizikia fusiformis, Sargassum thunbergii, Delisea fimbriata, Gelidium amansii, G. divaricatum, Corallina officinalis, C. pilulifera, Carpopeltis affinis, Caulacanthus okamurae, Hypnea saidana, Gymnogongrus flabelliformis, Champia parvula, Acrosorium uncinatum, Erythroglossum minimum, Chondria crassicaulis, Laurencia okamurae*, and *Symphyocladia latiuscula*. Twenty-one taxa were found only at one site: *Lyngbya aestuarii, Colpomenia sinuosa, Dictyota divaricata, Myagropsis myagroides, Pelvetia siliquosa, Erythrocladia carnea, Auduinella codicola, Amphiroa beauvoisii, Marginisporum aberrans, Pachymeniopsis lanceolata, Callophyllis adhaerens, Solieria mollis, Gracilaria textorii, Chondrus crispus, Lomentaria catenata, Ceramium paniculatum, Phycodrys fimbriata, Sorella repens, Heterosiphonia pulchra, Laurencia pinnata*, and *Polysiphonia morrowii*.

Fig. 2 illustrates a distributional pattern of species at 3 sites. A gradual decrease in species number was shown from the upper to lower subtidal zone. A total number of species showed also a gradual decrease with increasing depth; from 51 taxa in the

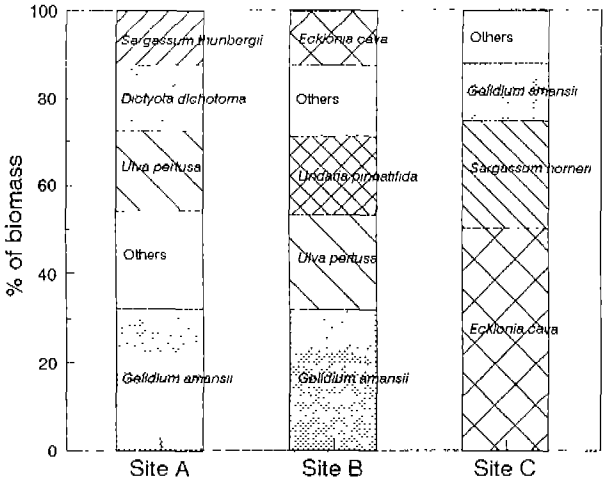

Fig. 3. The percentage composition of mean algal biomass at 3 subtidal sites in Neobdo Island.

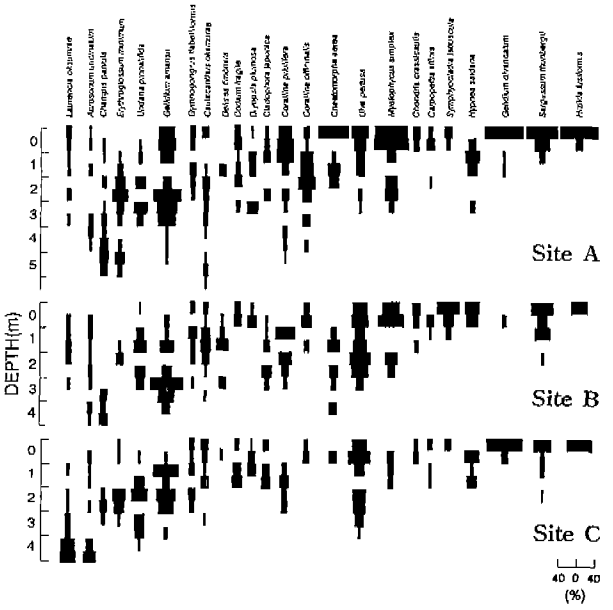

Fig. 4. The vertical distribution of % frequency of occurrence for 24 common species at 3 subtidal sites in Neobdo Island.

upper-most (0 m) to 2 taxa in the lowest (6 m) at Site A, from 41 taxa at 0.5 m depth to 4 taxa in the lowest (4.5 m) at Site B, and from 34 taxa at 0.5 m depth to 3 taxa in the lowest depth (4.5 m) at Site C. Most of the algal phyla showed also their highest species numbers in the upper subtidal zone (0-1 m depth). The red and brown algae occurred continuously from the upper to lower subtidal zone, while green and blue-green algae grew in mid subtidal and upper-most zone, respectively.

Species occurred at every depth are listed in Table 1. About 60% of the species showed a continuous vertical distribution from upper to mid or lower subtidal zones. Among the rest, 3 green algae (*Ulva pertusa, Chaetomorpha aerea*, and *Caulerpa okamurae*), 3 brown algae (*Undaria pinnatifida, Dictyopteris divaricata*, and *Sargassum micracanthum*) and 11 Rhodophyta (*Gelidium amansii, Corallina officinalis, C. pilulifera, Caulacanthus okamurae, Gracilaria textorii, Gigartina tenella, Rhodymenia intricata, Acrosorium uncinatum, Erythroglossum minimum, Dasya sessilis*, and *Laurencia okamurae*) showed broad subtidal distributions, extending from 0-3.5 m depth or deeper.

Dominant species are shown as a percentage of the mean algal biomass at each site (Fig. 3). Plants belonging to the crustose Corallinaceae were excluded. The values of mean biomass at Site A (350.6± 112.3 $g \cdot m^{-2}$) and Site C (368.7± 55.4 $g \cdot m^{-2}$) were similar, and at Site B showed 461.9± 77.2 $g \cdot m^{-2}$. At Site A, *Gelidium amansii* dominated the biomass (32.4%), followed by *Ulva pertusa* (18.6%), *Dictyota dichotoma* (15.0%), and *Sargassum thunbergii* (12.1%). The dominant species for biomass at Site B were *Gelidium amansii* (32.2%), *Ulva pertusa* (21.2%), *Undaria pinnatifida* (16.3%), and *Ecklonia cava* (12.0%), while these at Site C were *Ecklonia cava* (50.3%), *Sargassum horneri* (24.9%), and *Gelidium amansii* (13.2%). The biomass differed among the tidal levels at all sites, and the values abruptly decreased with increasing subtidal depth. The biomass ranged from 825.5 $g \cdot m^{-2}$ to 15.5 $g \cdot m^{-2}$. The highest value was obtained at 0 m depth and the lowest at 6 m depth of Site A. *Ulva pertusa, Undaria pinnatifida, Hizikia fusiformis, Sargassum thunbergii*, and *Gelidium amansii* dominated the biomass in upper subtidal zone.

The frequency of occurrence (%) of 24 common species occurring all the investigated sites is shown in Fig. 4. Seven species among them (*Hizikia fusiformis, Sargassum thunbergii, Gelidium divaricatum, Carpopeltis affinis, Hypnea saidana, Chondria crassicaulis*, and *Symphyocladia latiuscula*) occurred with highest frequency at upper part of subtidal zone. The highest frequency of *Hizikia fusiformis, Sargassum thunbergii, Gelidium divaricatum*, and *Symphyocladia latiuscula* was recorded at 0 m depth at all sites. The maximum frequency was 80% at Site A, 64% at Site A, 80% at Site A, and 45% at Site B, respectively. Three species (*Champia parvula, Acrosorium uncinatum*, and

Table 1. List of benthic marine algae from 3 subtidal sites in Neobdo Island. Values in columns are depths or depth ranges of species occurring at each site and summation of 3 sites (total)

Species	A	B	C	Total	Species	A	B	C	Total
Lyngbya aestuarii			0-0.5	0-0.5	*Grateloupia okamurae*		0-1	0.5-2.5	0-2.5
Microcoleus chthonoplastes	0	0		0	*G. turuturu*	1-4	0.5-1		0.5-4
Ulothrix implexa	0	0		0	*Pachymeniopsis elliptica*	2.5-3	0.5-2		0.5-3
Capsosiphon fulvescens	0-1		0	0-1	*P. lanceolata*			1-3	1-3
Monostroma arcticum	0.5	0-0.5		0-0.5	*Prionitis patens*	1.5-6	0.5-2.5		0.5-6
Enteromorpha clathrata		0	0-0.5	0-0.5	*Gloiosiphonia capillaris*	0-0.5	0-1		0-1
E. linza	0.5-2	0-2		0-2	*Gloiopeltis furcata*	0	0-0.5		0-0.5
Ulva pertusa	0-3	0-3	0-3.5	0-3.5	*G. tenax*	0-0.5	0	0-0.5	0-0.5
Chaetomorpha aerea	0-2	1-4	0.5	0-4	*Callophyllis adhaerens*	1			1
Cladophora japonica	0-2.5	0.5-3	0-1.5	0-3	*C. crispata*		2-3.5	1-3	1-3.5
C. wrightiana		0.5	0-2	0-2	*Schizymenia dubyi*	2-4	1.5-2.5		1.5-4
Bryopsis plumosa	0-3	0-0.5	0-1	0-3	*Solieria mollis*		0.5-2		0.5-2
Caulerpa okamurae	0-3.5		1.5-2.5	0-3.5	*Caulacanthus okamurae*	0-6	0-3.5	0-3	0-6
Codium adhaerens	0	1		0-1	*Plocamium telfairiae*	0-2.5	0.5		0-2.5
C. fragile	0-3	0-0.5	0-1.5	0-3	*Hypnea charoides*	10.5-3		1-1.5	1-1.5
Derbesia marina		1.5	0.5-2	0.5-2	*H. saidana*	0-3.5	0-0.5	0.5-1.5	0-3
Ectocarpus arctus		0-1	1.5	0-1.5	*Gracilaria textorii*				0-3.5
Ralfsia verrucosa	0-2		0	0-2	*Ahnfeltia plicata*		0.5-2	0.5-4.5	0.5-4.5
Ishige okamurae	0-0.5		0	0-0.5	var. *tobuchiensis*				
I. sinicola	0-1	0		0-1	*Gymnogongrus flabelliformis*	0-2.5	0-3	0-2.5	0-3
Colpomenia bullosa		0.5	0	0-0.5	*Chondrus crispus*			0.5-1.5	0.5-1.5
C. sinuosa	0-0.5			0-0.5	*C. ocellatus*	0-3	0-2		0-3
Petalonia fascia	0.5-2	0.5		0.5-2	*Gigartina intermedia*	0-1.5	0-0.5		0-1.5
Scytosiphon lomentaria	0-2.5		0-1	0-2.5	*G. tenella*	0-4	1.5-3.5		0-4
Myelophycus simplex	0-3	0-2.5	0.5-1.5	0-3	*Chrysymenia wrightii*	0-0.5		0.5-2.5	0-2.5
Undaria pinnatifida	0.5-3.5	0-3	0.5-4	0-4	*Rhodymenia intricata*	0	1-4		0-4
Sphacelaria radiata	0.5-3		0.5-1.5	0.5-3	*Binghamia californica*	1.5-2	1.5-4		1.5-4
Ecklonia cava		2.5-4.5	1-4	1-4.5	*Lomentaria catenata*	0-1.5			0-1.5
Dictyopteris divaricata	0-1		0.5-3.5	0-3.5	*L. hakodatensis*	0-1.5		0-0.5	0-1.5
Dictyota dichotoma	0.5-4.5	0.5-1.5		0.5-4.5	*Champia parvula*	0.5-5.5	3.5-4.5	2-3	0.5-5.5
D. divaricata	0.5-2.5			0.5-2.5	*Antithamnion sparsum*	1-4	1-3.5		1-4
Myagropsis myagroides	0.5			0.5	*Callithamnion callophyllidicola*	0.5-2		1-1.5	0.5-2
Pelvetia siliquosa			0-0.5	0-0.5	*Ceramiopsis japonica*	0		0-1.5	0-1.5
Hizikia fusiformis	0-0.5	0	0	0-0.5	*Ceramium kondoi*	0-2	0-3		0-3
Sargassum horneri	1.5-2.5		0.5-4	0.5-4	*C. paniculatum*	0.5-2.5			0.5-2.5
S. micracanthum	0-4.5	1-3.5		0-4.5	*Herpochondria elegans*		0.5-2	0.5-3	0.5-3
S. thunbergii	0-1	0-2	0-2	0-2	*Platythamnion yezoense*	0.5-1	2		0.5-2
Erythrocladia carnea	1-2			1-2	*Wrangelia tayloriana*	1.5-4	1.5		1.5-4
Auduinella codicola	0			0	*Acrosorium uncinatum*	0-4.5	0.5-4.5	0.5-4.5	0-4.5
Nemalion vermiculare	0	0		0	*Erythroglossum minimum*	1-5.5	1.5-2	0-3	0-5.5
Bonnemaisonia hamifera	0.5-2.5	0-2		0-2.5	*Phycodrys fimbriata*			0	0
Delisea fimbriata	1	0-2.5	0	0-2.5	*Sorella repens*		2.5-4.5		2.5-4.5
Gelidium amansii	0-5	0.5-4	0.5-3.5	0-5	*Dasya sessilis*		0.5-3.5	0-0.5	0-3.5
G. divaricatum	0-1.5	0.5	0-0.5	0-1.5	*Heterosiphonia japonica*	0-3	0-0.5		0-3
G. pacificum	1-1.5		3-4	1-4	*H. pulchra*		0.5-1.5		0.5-1.5
Dumontia simplex		0	0	0	*Chondria crassicaulis*	0-0.5	0-1.5	0-0.5	0-1.5
Hyalosiphonia caespitosa	0-0.5	0.5		0-0.5	*Laurencia intermedia*	0-1	0-0.5		0-1
Amphiroa beauvoisii			0.5	0.5	*L. okamurae*	0-3.5	0.5-3	1-4.5	0-4.5
Corallina officinalis	0-4.5	0-1.5	0-0.5	0-4.5	*L. pinnata*			1	1
C. pilulifera	0-5	1-3	1-2.5	0-5	*Polysiphonia japonica*	0-2.5	0-0.5		0-2.5
Marginisporum aberrans		1		1	*P. morrowii*			0-1	0-1
Carpopeltis affinis	0-2	0.5-1	0-1.5	0-2	*Symphyocladia latiuscula*	0-0.5	0-1	0	0-1

Laurencia okamurae) had the highest frequency in the deeper zone, while the other 3 (*Undaria pinnatifida, Gelidium amansii*, and *Erythroglossum minimum*) had the highest frequency in mid subtidal zone.

Among individual species *Undaria pinnatifida* inhabited in the upper to mid or lower subtidal zones, and its frequency at Site C was higher than at Site A and B, and the high frequency of occurrence was recorded in mid subtidal, 2-3.5 m depths. The maximum value was 32% at 2 m depth of Site C. *Gelidium amansii* and *Erythroglossum minimum* occurred in the upper and middle zones and were clumpy in distribution. These species occurred with *Delisea fimbriata, Caulacanthus okamurae*, and *Gymnogongrus flabelliformis*. The frequency of *Gelidium amansii* and *Erythroglossum minimum* was higher at Site A than at other study sites. Their maximum frequency was 65% at 2.5 m depth of Site B and 30% at 2.5 m depth of Site A, respectively. Higher frequency of *Laurencia okamurae* and *Acrosorium uncinatum* was recorded at 3.5-4.5 m depth of Site C. Their highest frequency was recorded at 4.5 m depth with a frequency of 28% and 25%, respectively, while it was recorded in the subtidal zone at Site A and B with a frequency less than 10%. The frequency values for the rest species were generally high in the upper to mid subtidal, although the main habitat of the population occurred in very wide vertical range.

DISCUSSION

In the present study, emphasis has been laid on the evaluation of the quality and quantity of the conspicuous macroscopic algae in the subtidal zone around Neobdo Island. The number of species and ratios of Chlorophyta/Rhodophyta decreased with increasing depths. The subtidal vegetation is dominated by Rhodophyta. Similar vegetational patterns have also been reporded by Lee *et al.* (1991) in Chongsando of the west-southern coast of Korea. The shallow vegetation at Site B and C are probably substrate limited rather than light, because a discontinuity of rock to silt-sand occurs at approximately 4.5 m depth. In contrast, distribution limit at Site A is probably light dependent, for massive granitic outcrops being present below at 6 m depth.

Species of occurrence in the subtidal zone of the study area are also common in intertidal of the west-southern coast of Korea, *e.g.*, many of the species mentioned as to occur in the intertidal zone by Lee and Boo (1992) are observed on relatively deeper zone in this study. The fact that most species are found over a wide depth range suggests that changes in vegetation with depth are continuous in the study area.

The floristic observations at several localities on the west-southern coast of Korea suggest that *Sargassum thunbergii, Corallina pilulifera, Ulva pertusa, Myelophycus simplex*, and *Hizikia fusiformis* dominate the lower intertidal zone, and extend into the subtidal fringe (Kang *et al.*, 1980; Lee and Boo, 1982; Lee *et al.*, 1983; Boo and Choi, 1989; Choi *et al.*, 1989; Lee *et al.*, 1991). However, since lack of information precludes comparisons with other areas in the west-southern subtidal of Korea, we cannot determine whether communities described here are typical of this region.

In contrast to a relatively simple vegetation on the east coast of Korea (Koh and Sung, 1983; Chung *et al.*, 1991), the subtidal vegetation of this study area, the west-southern coast, has a greater number of species and higher algal biomass. The biomass figures among the investigated sites reflect conditions of substrate supporting algal vegetation, and the mean biomass value abruptly decreases with subtidal depth. Low algal biomass in deeper zone indicates that phytobenthos are light-limited.

In the present observations, 7 species (*Ulva pertusa, Dictyota dichotoma, Sargassum thunbergii, Undaria pinnatifida, Ecklonia cava, Sargassum horneri*, and *Gelidium amansii*) are representative of biomass, although they do not form distinct communities regularly. Particularly, many of the deepest subtidal species are fleshy forms, which seem to favor low light conditions (Mathieson and Norall, 1975, Lobban *et al.*, 1985). Although this study did not measure the biomass of encrusting coralline algae, the biomass for this group is nearly as high as that of all other algae at certain depths, particularly where the bottom is covered with cobbles and stones.

Although we could not study precisely in the present investigation, the roles of light, substrate, animal grazing, spore dispersal and seasonality in determining the quality and quantity of the subtidal vegetation should be further evaluated for adequate doc-

ument on the ecology of subtidal algae.

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西南海 넙島 조하대 海藻類의 群集構造

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적 요

한국 서남해 넙도의 조하대에 생육하는 해조류의 군집구조를 파악하였다. 채집, 동정된 해조류는 총 103종류였으며, 이들은 66종류의 홍조류, 21종의 갈조류, 14종의 녹조류 그리고 2종의 남조류로 구성되었다. 출현종수와 생물량은 깊이의 증가에 따라 감소하였다. *Gelidium amansii, Ulva pertusa, Dictyota dichotoma, Sargassum thunbergii, Undaria pinnatifida, Ecklonia cava, Sargassum horneri*는 높은 출현빈도와 생물량을 보였다. 하부조하대의 식생은 일부 홍조류로 구성되었으며, 기질의 특성이나 광조건은 조하대 식생의 유형을 결정하는 중요한 요인들로 판단되었다.

주요어 : 군집구조, 해조류, 생물량, 빈도

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