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Community Dynamics of Benthic Marine Algae in the Intertidal and Subtidal Rocky Shore of Samyang, Jejudo Island

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Community structure and vertical distribution of benthic marine algae were investigated in the intertidal and subtidal rocky shore of Samyang, Jejudo Island. The total number of 62 algal species composed of 6 Cyanophyta, 6 Chlorophyta, 19 Phaeophyta, and 31 Rhodophyta were observed. The dominant species were melobesioidean algae, *Sargassum thunbergii*, *Hizikia fusiformis*, and *Ulva pertusa* in the intertidal zone and melobesioidean algae, *Ulva pertusa*, *Corallina* spp., and *Undaria pinnatifida* in the subtidal zone. The vertical algal distribution was represented by the melobesioidean algae in the whole rocky shore, *Caulacanthus ustulatus* in the upper intertidal zone, *Sargassum thunbergii* and *Hizikia fusiformis* in the middle and lower zone, *Ulva pertusa* in the lower zone and *Ulva pertusa*, *Corallina* spp., and *Undaria pinnatifida* in the subtidal zone. The composition of dominant species and pattern of the vertical distribution of algae in the present study were significantly different from the previous reports. Especially, distribution of crustose coralline algae was significantly extended.

Key Words: benthic marine algae, community structure, intertidal, Jejudo Island, subtidal, vertical distribution

INTRODUCTION

The study of the benthic marine algae of Jejudo Island started in earnest after Kang (1966a) reported 153 species of the summer algal flora. Kang (1966b) classified Korean algal flora into five sections such as Northern East Coast, Southern East Coast, South Coast, West Coast, and Jejudo Island Section based on the water temperature and other hydrological condition and recognized the unique algal distribution of Jejudo Island. Since Kang's study, the floral studies of the benthic marine algae have been conducted mainly in the intertidal zone (Lee 1974; Lee and Lee 1976, 1982; Kim 1983; Yoon 1985). Total of 541 species (22 Cyanophyta, 63 Chlorophyta, 110 Phaeophyta, 346 Rhodophyta) have been recorded from 64 sites inside Jejudo Island till now (Yoo 2003). Although the bioresource information acquisition on the biodiversity change has been recently raised as an international issue (Lee *et al.* 1994), there were not many studies on the benthic algal community of Jejudo Island in 1990s.

Till now, many studies have been conducted on the coastal benthic marine algae of many places in Korea (Kim 1983; Sohn 1987; Yoo and Kim 1990; Lee 1991; Yoo 2003b), but there have been few studies on the subtidal algal community (Chung *et al.* 1991; Lee *et al.* 1991; Kang *et al.* 1993; Kim *et al.* 1998). Because it is difficult to collect the subtidal benthic algae and they can be collected only through SCUBA diving. It is necessary to get the information on the subtidal algal community, because the subtidal algal community may occupy relatively larger habitat with more complex community structure than the intertidal community and benthic marine algae are basic components of the submarine forest (Terawaki *et al.* 1998; Yoo 2003a).

There has not been any study on the benthic algal ecology of Samyang, Jejudo Island. Lee (1989) reported only 2 unrecorded species, *Galaxaura hystrix* and *Halichrysis micans*. This study was focused on describing the characteristics of the algal community in the intertidal and subtidal zone of Samyang coast, Jejudo Island. The problems of melobesioidean algae that radically have increased on the coast of Jejudo Island were also discussed.

MATERIALS AND METHODS

Three stations that represented the local flora of the benthic marine algae of Samyang, Jejudo Island were

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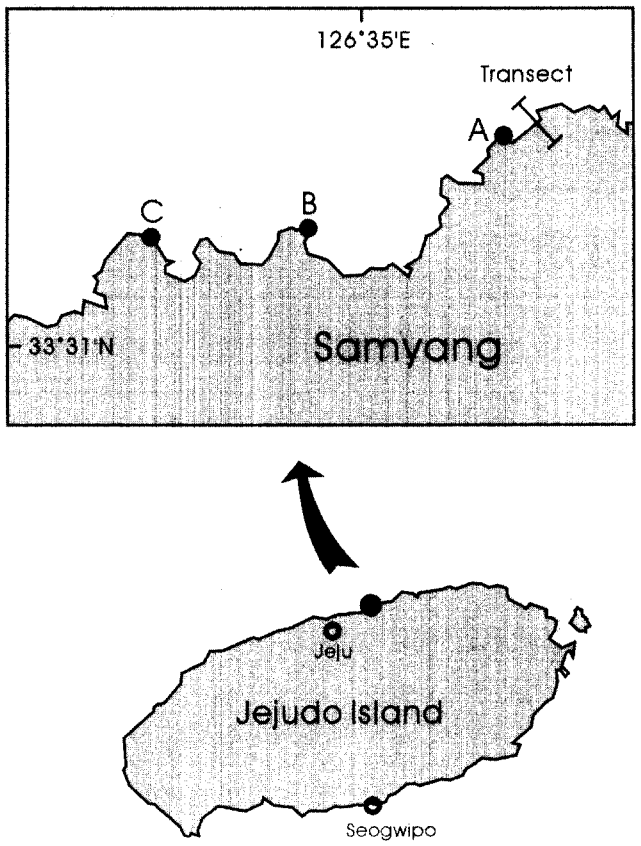

Fig. 1. Map showing the sampling sites at Samyang of Jejudo Island.

investigated in February, May and August of 2002 (Fig. 1). Five quadrats were placed on the upper, middle and lower intertidal zone of each station and the coverage and frequency data were measured to get the information of the algal flora and community structure. The station A was selected for the vertical distribution of the algal community in the intertidal and subtidal zone. The vertical transect line was set and the quadrats were placed at interval of 1 m, in which the coverage of all marine algal species was measured (Yoo 2003a).

The frequency and coverage of dominant species by random quadrat method from field survey were measured, and the average of total relative frequency and relative coverage calculated from field data was represented as an importance value (IV) (Yoo 2003a).

All benthic algal plants present within the quadrat were collected for the further ecological study. The collected samples were fixed in 10% formalin-seawater and transported to the laboratory. The samples were identified under a stereoscopic zoom microscope (Nikon SMZ800) and biological research microscope (Nikon E600) based on Lee and Kang (2001)'s algal catalogue.

Table 1. The number of benthic marine algal species observed in quadrats at three stations of Samyang in Jejudo Island

Division	Month	Sampling station			Sum
		St. A	St. B	St. C	
Cyanophyta	Feb.	-	-	-	-
	May	1	1	3	5
	Aug.	2	-	-	2
Chlorophyta	Feb.	5	3	4	5
	May	2	4	4	6
	Aug.	2	2	2	3
Phaeophyta	Feb.	7	4	10	10
	May	11	9	7	13
	Aug.	7	8	7	8
Rhodophyta	Feb.	16	12	16	17
	May	22	16	23	25
	Aug.	21	13	26	26
Total	Feb.	28	19	30	48
	May	36	30	37	48
	Aug.	32	24	36	49
	Cum*	48	39	51	62

*Cum: Cumulative number of species.

RESULTS

Algal flora

Total of 62 benthic marine species were identified in this study area, including 6 Cyanophyta, 6 Chlorophyta, 19 Phaeophyta and 31 Rhodophyta (Table 1). There were 48 species in station A (2 Cyanophyta, 5 Chlorophyta, 14 Phaeophyta and 27 Rhodophyta), 39 in station B (1 Cyanophyta, 6 Chlorophyta, 15 Phaeophyta and 57 Rhodophyta), and 51 in station C (3 Cyanophyta, 5 Chlorophyta, 15 Phaeophyta and 28 Rhodophyta). Generally the number of observed algal species in stations A and C were slightly larger than that of station B (Appendix 1).

Community structure

Dominant species: The dominant species of the algal community in each station had changed along the vertical transect as shown in Table 2. First of all, the dominant species of station A were melobesioidean algae, *Hizikia fusiformis*, *Ulva pertusa*, and *Sargassum thunbergii* in the intertidal zone and *Ulva pertusa*, *Hizikia fusiformis* and *Undaria pinnatifida* in the subtidal zone in February. Melobesioidean algae and the crustose coralline algae were dominant in the subtidal zone below

Table 2. Important value of benthic marine algae for each station at the rocky shore of Samyang, Jejudo Island (Species which had a total important value of less than 0.5 were not listed)

Tidal level / Station / Species	Intertidal zone				Subtidal zone	Sum
	St. A	St. B	St. C	Aver		
Melobesioidean algae	34.5	14.9	24.1	24.5	28.1	52.6
Ulva pertusa	10.7	11.3	10.4	10.8	16.0	26.8
Sargassum thunbergii	17.8	25.3	11.9	18.4	6.0	24.4
Corallina spp.	-	6.9	9.2	5.4	15.3	20.7
Hizikia fusiformis	15.1	22.6	11.2	16.3	4.3	20.6
Undaria pinnatifida	-	-	0.1	-	9.9	9.9
Gelidium amansii	-	-	1.1	0.4	6.3	6.7
Lithophyllum okamurae	0.1	0.2	2.4	0.9	5.4	6.3
Carpopeltis affinis	4.6	3.9	6.1	4.9		4.9
Lomentaria hakodatensis	-			-	3.7	3.7
Caulacanthus ustulatus	4.8	3.0	1.4	3.1		3.1
Spatoglossum pacificum	-			-	2.4	2.4
Ahnfeltiopsis flabeliformis	2.6	0.2	4.0	2.3		2.3
Colpomenia sinuosa	0.1	-	2.4	0.8	1.2	2.0
Gelidium divaricatum	1.9	3.0	0.9	2.0		2.0
Chondracanthus intermedia	4.0	-	0.8	1.6		1.6
Chondria crassicaulis	1.5	2.1	1.0	1.5		1.5
Ishige sinicola		1.8	1.5	1.1		1.1
Ecklonia cava	-			-	1.0	1.0
Grateloupia lanceolata	-	0.6	2.0	0.8		0.8
Punctaria latifolia	0.4	1.2	1.0	0.8		0.8
Grateloupia filicina	-	-	2.2	0.7		0.7
Scytosiphon lomentaria	0.1		2.0	0.7		0.7
Myelophycus simplex	0.6	1.2	-	0.6		0.6
Cladophora sp.	-	-	0.4	0.1	0.4	0.5
Ralfsia verrucosa	0.1	0.4	1.0	0.5		0.5

5 m depth. This zone was also dominated by same species in May and the important values were similar among them. That is, melobesioidean algae were most dominant group and followed by *Sargassum thunbergii, Ulva pertusa* and *Hizikia fusiformis* in May. In August, the dominant species were melobesioidean algae, *Hizikia fusiformis* and *Corallina* spp.

Generally, the most dominant species in station A was melobesioidean algae, and followed by *Sargassum thunbergii, Hizikia fusiformis* and *Ulva pertusa*. The coverage and vertical distribution of *Hizikia fusiformis* decreased in summer season. That is, *Corallina* spp. tended to expand its distribution relatively wider in August. These dominant species accounted for 78.1% of the important value of total species in station A.

The dominant species of station B were *Sargassum thunbergii, Hizikia fusiformis,* and melobesioidean algae that accounted for 61% of the entire important value in February; *Hizikia fusiformis, Ulva pertusa* and *Sargassum thunbergii*, 74% in May; *Corallina* spp., melobesioidean algae, *Sargassum thunbergii, Ulva pertusa* and *Hizikia fusiformis*, 81% in August. These dominant species accounted for 74.1% of the important value in station B.

The dominant species of station C were melobesioidean algae, *Hizikia fusiformis* and *Carpopeltis affinis* in February; *Sargassum thunbergii,* melobesioidean algae, *Ulva pertusa* and *Corallina* spp. in May; and melobesioidean algae, *Ulva pertusa* and *Corallina* spp. in August. These dominant species accounted for 72.9% of the important value in station C.

Generally the dominant species of intertidal zone were melobesioidean algae, *Sargassum thunbergii, Hizikia fusiformis* and *Ulva pertusa,* whereas melobesioidean algae, *Ulva pertusa, Corallina* spp. and *Undaria pinnatifida* in the subtidal zone. It is noteworthy that wide distribution of crustose coralline algae was common in this area.

Table 3 shows the dominant species of the upper,

Table 3. Important value of benthic marine algae for each layer of intertidal zone at each station of Samyang in Jejudo Island (U, upper layer; M, middle layer; L, lower layer)

Station	Station A			Station B			Station C		
Intertidal zone / Species	U	M	L	U	M	L	U	M	L
Melobesioidean algae	36.8	27.4	27.4	28.5	7.1	12.8	36.3	21.1	15.5
Sargassum thunbergii	23.8	20.0	16.4	23.7	26.7	24.6	-	20.2	15.9
Hizikia fusiformis	5.0	11.2	30.2	2.2	6.8	44.0	-	1.4	29.4
Ulva pertusa	10.6	16.9	9.8	11.9	8.7	12.0	13.0	14.6	4.8
Corallina spp.	0.1	-	-	-	27.8	-	7.2	-	19.6
Carpopeltis affinis	4.5	0.2	4.2	-	11.9	0.4	-	18.1	-
Caulacanthus ustulatus	1.3	7.2	3.2	8.9	1.2	-	-	4.6	-
Ahnfeltiopsis flabeliformis	7.8	1.8	-	0.6	-	-	7.0	6.0	-
Gelidium divaricatum	1.6	0.3	3.5	13.0	-	-	-	3.0	-
Chondracanthus intermedia	3.6	11.6	0.9	-	-	-	-	0.9	1.4
Chondria crassicaulis	3.2	0.4	1.8	0.6	-	3.6	1.1	1.9	-
Ishige sinicola				7.6	-	-	4.7	-	-
Lithophyllum okamurae	-	-	0.3	1.0	-	-	7.6	-	-
Grateloupia sp.	-	-	-	-	2.3	-	5.8	-	-
Colpomenia sinuosa	0.3	0.2	-	-	-	-	-	0.7	6.2
Punctaria latifolia	0.4	0.3	0.5	0.9	2.1	0.4	-	0.9	1.7
Grateloupia filicina	-	-	-	-	-	-	6.5	-	-
Myelophycus simplex	-	-	1.9	-	2.4	0.8	-	-	-
Laurensia intermedia	-	-	-	-	1.8	-	2.9	-	-
Scytosiphon lomentaria	0.4	-	-	-	-	-	-	3.0	1.3
Ralfsia verrucosa	-	0.2	-	-	-	1.2	-	2.3	0.5
Polysiphonia sp.	0.1	0.1	-	-	-	-	1.8	1.2	-

middle and lower intertidal zone of each station. The dominant species of station A were Melobesioidean algae and *Sargassum thunbergii* in the entire intertidal zone; *Ulva pertusa* in the upper zone; *Ulva pertusa, Hizikia fusiformis* and *Chondracanthus intermedia* in the middle zone. *Chondracanthus intermedia* that was dominant in the middle zone was not dominant in the lower zone.

The dominant species of station B were *Sargassum thunbergii* in the entire intertidal zone; melobesioidean algae, *Gelidium divaricatum,* and *Ulva pertusa* in the upper zone; *Corallina* spp. and *Carpopeltis affinis* in the middle zone; and *Hizikia fusiformis,* melobesioidean algae and *Ulva conglovata* in the lower zone.

The dominant species of station C were melobesioidean algae in the entire intertidal zone; *Ulva pertusa* in the upper intertidal zone; *Sargassum thunbergii, Caulacanthus ustulatus,* and *Ulva pertusa* in the middle zone; and *Hizikia fusiformis, Corallina* spp., and *Sargassum thunbergii* in the lower zone.

Vertical distribution: The vertical distribution patterns of algal groups in the intertidal and subtidal rocky shore are as shown in Fig. 2. In February green algae showed high coverage in the lower part of the middle intertidal zone and upper subtidal zone. Generally, brown algae showed high coverage in all rocky shore except for the lower subtidal zone. Red algae covered all throughout the intertidal zone. Furthermore, their coverage below the middle intertidal and the subtidal zone were high. In August, the coverage of green algae was low in the middle intertidal zone and that of brown algae also decreased from the lower intertidal to the middle subtidal zone, whereas red algae showed relatively higher coverage in all rocky shores. The vertical distribution pattern of major benthic algal species is shown in Fig. 3. *Hizikia fusiformis* showed high coverage from the middle intertidal to the upper subtidal zone in February, whereas its distribution range was reduced down to only the lower intertidal zone in August. *Sargassum thunbergii* showed high coverage in the lower part of the middle intertidal zone and the upper subtidal zone in February. In August, this species showed similar vertical distribution as in May with low coverage except for the upper subtidal zone. Melobesioidean algae were dominant in the highest intertidal zone, lower middle intertidal zone and lower subtidal zone in February. This species showed relatively higher coverage on all the rocky shore than the others in August. *Ulva pertusa* showed lower coverage in every

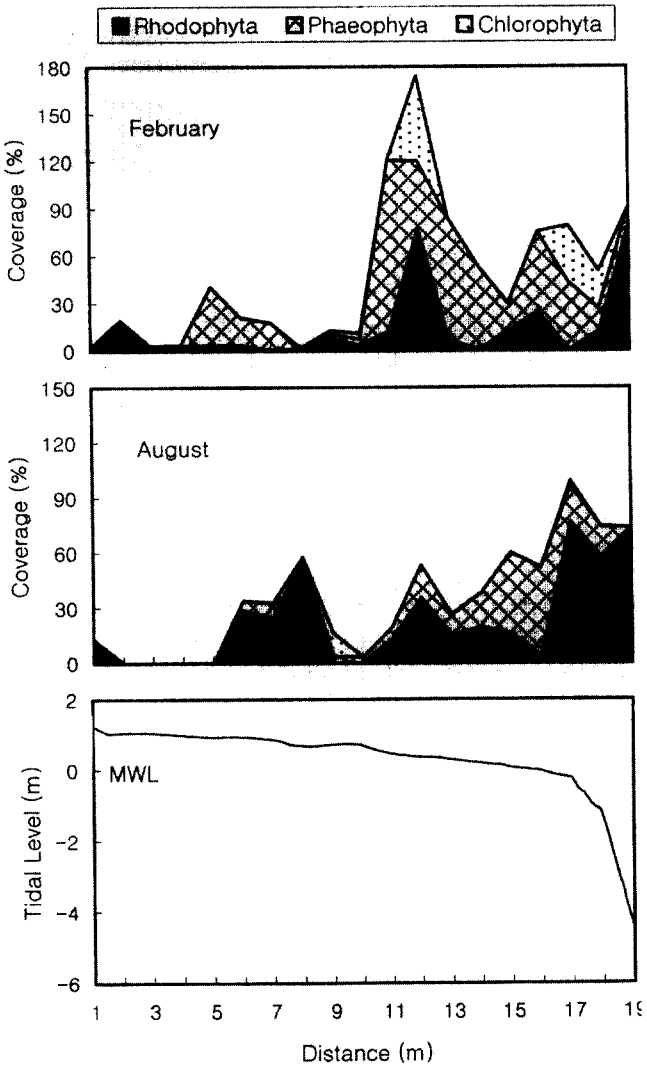

Fig. 2. Distribution patterns of each division of benthic marine algae along the transect line in Samyang, Jejudo Island.

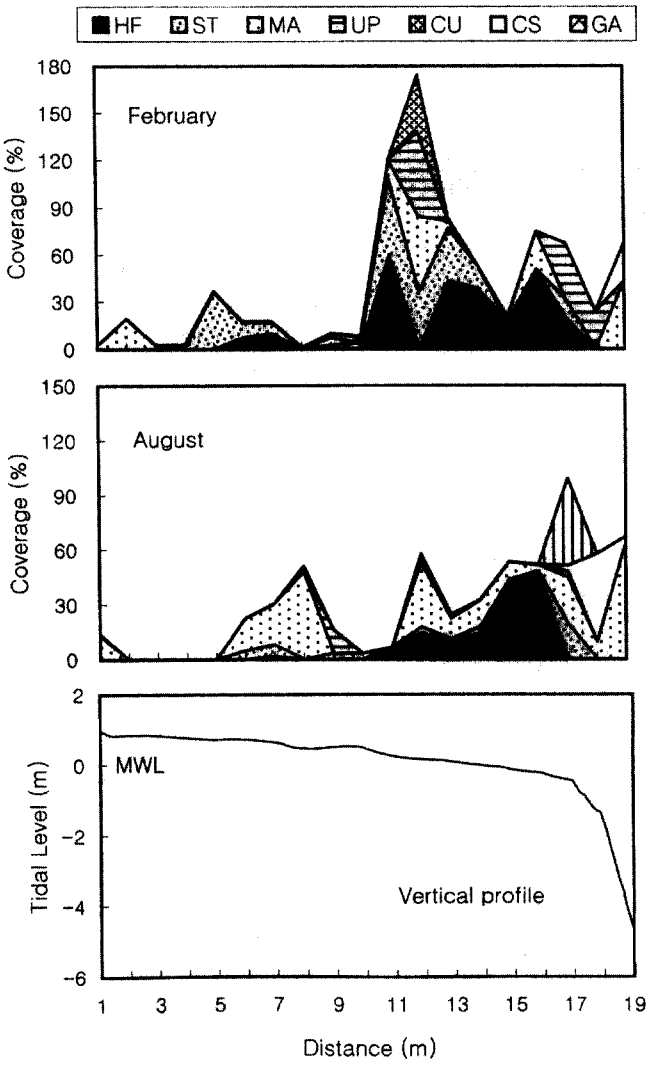

Fig. 3. Vertical distribution patterns of algal community by major species based on the coverage along the transect line in Samyang, Jejudo Island (CS, *Corallina* spp.; CU, *Caulacanthus ustulaths*; GA, *Gelidium amansii*; HF, *Hizikia fusiformis*; MA, melobesioidean algae; ST, *Sargassum thurbergii*; UP, *Ulva pertusa*).

intertidal zone except for the lower middle zone in February, whereas it showed higher coverage in the upper and middle subtidal zone. In August, it showed low coverage in the middle and lower intertidal zone. *Caulacanthus ustulatus* was present in the upper and the lower part of the middle intertidal zone in every investigation. *Corallina* spp. showed higher coverage in the zone under the water not deeper than 5 m in February, whereas it showed higher coverage in the whole subtidal zone in August. *Gelidium amansii* showed higher coverage in the upper subtidal zone in August.

DISCUSSION

The numbers of the benthic marine algal species have been reported 205 by Kang (1966b), 212 by Lee (1974, 1976), 221 by Lee and Lee (1982), 189 by Yoon (1985) in Jejudo Island since Kang (1966a) listed 153 taxa. The present study recognized that the number of benthic algal species of Jejudo Island was 541 (22 Cyanophyta, 63 Chlorophyta, 110 Phaeophyta, and 346 Rhodophyta), accounting for 72% of Korean algal checklist. So the number of species in Jejudo Island and the South Coast are very high (Lee and Kang 2001; Yoo 2003).

The benthic marine algae of Jejudo Island that showed such abundant algal vegetation have been studied mainly focusing on the analysis of the characteristics of algal flora and community structure of the intertidal zone (Lee 1974; Lee and Lee 1976, 1982; Kim 1983).

Table 4. *A comparison of vertical distribution patterns of dominant algal species in the intertidal zone at previous study in Jejudo* Island. (Bang atr, *Bangia atropurpurea;* Caul ust, *Caulacantus ustulatus;* Colp sin, *Colpomenia sinuosa;* Cora pil, *Corallina pilulifera;* Cora spp, *Corallina* spp.; Eckl cav, *Ecklonia cava;* Gloi fur, *Gloiopeltis furcata;* Gloi spp, *Gloiopeltis* spp.; Hizi fus, *Hizikia fusiformis;* Ishi spp, *Ishige* spp.; Melo alg, melobesioidean algae; Porp spp, *Porphyra* spp.; Porp sub, *Porphyra suborbiculata;* Sarg con, *Sargassum confusum;* Sarg cor, *Sargassum coreanum;* Sarg hem, *Sargassum hemiphyllum;* Sarg spp, *Sargassum* spp.; Sarg thu, *Sargssum thunbergii;* Ulva per, *Ulva pertusa;* Unda pin, *Undaria pinnatifida*)

Sites	Intertidal zone			Subtidal Zone	Source
	Upper	Middle	Lower		
Seoguipo	Porp spp Gloi spp	Ishi spp Hizi fus	Sarg spp Cora spp	-	(Lee 1974), Coverage
Hadori, Hwabuk, Moeupo, Kangjeong	Porp sub Bang atr Gloi fuc	Ishi spp Hizi fus Cora pil Sarg thu	Sarg cor Sarg con	-	(Lee and Lee 1982), IV*
Seongsan, Hwabuk, Kosan, Beobhwan	Ishi spp Hizi fus Sarg thu Caul ust	Ulva per Colp sin Cora pil	Sarg spp Eckl cav	-	(Lee and Lee 1982), IV*
Hwabuk	Porp sub Bang atr Gloi fuc	Hizi fus Ishi spp Sarg thu Cora pil	Sarg con Colp sin Sarg hem	-	(Kim 1983), Coverage
Samyang	Melo alg Caul ust	Melo alg Sarg thu Hizi fus	Melo alga Sarg thu Hizi fus Ulva per	Melo alga Ulva per Cora spp Unda pin	This Study, IV*

*: Importance value (IV).

According to the previous reports, the dominant species can be grouped by their distribution in the intertidal zone. *Porphyra* spp., *Gloiopeltis* spp., *Bangia atropurpurea,* and *Caulacanthus ustulatus* are dominant in the upper layer zone; *Ishige* spp., *Hizikia fusiformis, Sargassum thunbergii,* and *Corallina pilulifera* in the middle layer zone; and *Sargassum* spp., *Ecklonia cava* and *Colpomenia sinuosa* in the lower layer zone (Kim 1991).

There are several differences between this study and the previous reports. First of all, melobesioidean algae and the crustose coralline algae were most dominant species in all intertidal and subtidal zones that were not observed in the previous reports. *Hizikia fusiformis* was dominantly distributed in the middle intertidal zone in the previous reports and had extended its distribution to the lower intertidal zone in this study. *Sargassum* spp. was dominantly distributed in the lower intertidal zone in the previous reports and had extended its distribution to the middle intertidal zone in this study. Laminarian algae and *Colpomenia sinuosa* that were dominant in the lower intertidal zone in the previous studies, but they were not observed in this study.

On the other hand, the dominant algal species of the subtidal zone in this study were *Ulva pertusa, Corallina* spp. and *Undaria pinnatifida* (Table 4). That is, the results of this study differed from the results of the previous reports. It is very important to identify whether such change of community structure was due to the difference of sampling sites or the temporal gap of 20 years between this study and the previous reports in understanding the algal species composition and community structure of Jejudo Island.

It is noteworthy that crustose coralline algae were dominant on all rocky shore (Chung *et al.* 1998). This result has never been reported before this study and could be interpreted that the algal community of Jejudo Island has been drastically changed. For last 20 years, there have been few data about how the algal communities have succeeded and how the community structure and dominant species have changed. Therefore, how the crustose coralline algae have become new dominant species on the rocky shore of Jejudo Island is

not clear.

Jejudo Island is a suitable place for the algal study because there are 85 endemic species (1 Cyanophyta, 22 Chlorophyta, 13 Phaeophyta and 60 Rhodophyta) and her algal vegetation covers 72% of Korean algal species (Yoo 2003). It is necessary to conduct studies on the algal distribution and community structure of Jejudo Island to manage the biodiversity and coastal environments.

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Appendix 1. Checklist of benthic algal species observed in quadrats at Samyang of Jejudo Island

Stations / Month / Species	St. A			St. B			St. C		
	Feb.	May	Aug.	Feb.	May	Aug.	Feb.	May	Aug.
Cyanophyta									
Anacystis aeruginosa								+	
Entophysalis conferta			+						
Microcystis sp.								+	
Lynbya lutea					+				
Oscillatoria sp1.								+	
Oscillatoria sp2.		+	+						
Chlorophyta									
Enteromorpha compressa	+			+	+		+		
Ulva conglobata					+				
Ulva pertusa	+	+	+	+	+	+	+	+	+
Cladophora conchopheria	+	+			+		+	+	
Cladophora sp.	+		+	+				+	
Codium flagile	+					+	+	+	+
Phaeophyta									
Ralfsia verrucosa	+					+	+		+
Dictyota dicotoma	+	+						+	
Dilophus okamurae		+						+	
Spatoglossum pacificum			+			+			
Ishige sinicola			+			+			+
Leathesia difformis		+	+			+		+	+
Myelophycus simplex	+	+	+	+	+		+		
Punctaria latifolia	+	+		+	+		+		
Colpomenia sinuosa	+	+	+		+		+	+	+
Colpomenia bullosa							+		
Scytosiphon lomentaria		+			+		+	+	
Undaria pinnatifida		+				+	+		
Ecklonia cava					+	+			
Ecklonia stolonifera							+		
Hizikia fusiformis	+	+	+	+	+	+	+	+	+
Sargassum fulvellum					+				
Sargassum horneri		+			+				
Sargassum thunbergii	+	+	+	+	+	+	+	+	+
Sargassum sp.						+			
Rhodophyta									
Styronema alsidii		+	+		+	+		+	+
Porphyra sp.					+				
Amphiroa pusilla			+						+
Corallina officinalis	+	+	+	+	+	+	+	+	+
Corallina pilulifera	+	+	+	+	+	+	+	+	+
Lithophyllum okamurae	+	+	+	+	+	+	+	+	+
Pneophyllum zostericola	+	+	+	+	+	+	+	+	+
Titanoderma canescens	+	+	+	+	+	+	+	+	+
Gelidium amansii	+	+	+	+	+	+	+	+	+
Gelidium divaricatum	+	+	+	+	+	+	+	+	+
Pterocladia capillacea			+						+
Caulacanthus ustulatus	+	+	+	+	+	+		+	+
Gloiopeltis furcata	+	+		+	+		+	+	
Chondracnathus intermedia	+	+	+				+	+	+
Chondrus ocellatus			+				+	+	+
Hypnea charoides									+

(Continued)

Appendix 1. (Continued)

Stations / Month / Species	St. A			St. B			St. C		
	Feb.	May	Aug.	Feb.	May	Aug.	Feb.	May	Aug.
Ahnfeltiopsis flabelliformis	+	+	+	+	+	+	+	+	+
Carpopeltis affinis	+	+	+		+	+	+	+	+
Grateloupia lanceolata		+				+		+	+
Grateloupia turuturu		+						+	
Grateloupia filicina	+	+	+				+	+	+
Grateloupia sp.								+	
Halymenia acuminata			+						+
Gracilaria verrucosa		+			+				
Champia parvula								+	+
Ceracium sp.		+	+					+	+
Chondria crassicaulis	+	+		+	+		+	+	+
Laurencia intermedia	+	+	+				+	+	+
Laurencia pinnata			+						
Laurencia sp.		+						+	+
Polysiphonia morrowii	+	+	+	+	+	+	+	+	+