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Macroalgal Community Structure on the Rocky Shores of Ongdo, Jusamdo, and Woejodo Islands of the Yellow Sea, Korea

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Abstract

The benthic algal community structures of the seaweed biomass, vertical distribution of dominant seaweeds, and species composition were examined on the rocky shores of Ongdo, Jusamdo, and Woejodo Islands, Korea, in August 2006. A total of 68 seaweeds were identified, comprising 5 green, 11 brown, and 52 red algae from the three study sites. The number of species at Ongdo (32 species) was less than that at Jusamdo (45 species) and Woejodo (44 species). Jusamdo exhibited the maximum seaweed biomass (73.99 g dry wt/m^2), while the minimum value was found at Woejodo (36.90 g dry wt/m^2). On the three islands, coarsely branched forms were the most dominant functional group in terms of species number and biomass among benthic algal species. The dominant species were *Gelidium amansii*, *Chondrus ocellatus*, and *Chrysymenia wrightii* at Ongdo, *Sargasum thunbergii*, *Ulva pertusa*, and *Sargassum fusiformis* at Jusamdo, and *U. pertusa*, *Undaria pinnatifida*, and *Corallina pilulifera* at Woejodo. Perennial seaweeds were abundant at Ongdo (*G. amansii* and *C. ocellatus*) and Jusamdo (*S. thunbergii* and *S. fusiformis*), whereas the sheet form of *U. pertusa* was relatively abundant at Woejodo Island.

Key words: Biomass, Community structure, Coverage, Functional form, Seaweed

Introduction

Marine seaweeds are a major source of primary production, providing habitat and food for associated invertebrates and fishes in marine coastal ecosystems (Terawaki et al., 2001; Bernecker and Wehrtmann, 2009). The pollution and disturbance of macroalgal habitats by human activities reduce species diversity and simplify its community structure (Díez et al., 1999; Kim et al., 2010). Biodiversity, which is high in stable habitats and unpolluted areas, can be used as a biological indicator responding environmental conditions (Piazzi et al., 2002; Arévalo et al., 2007). In addition, seaweed community structures in the intertidal and subtidal zones are influenced by a variety of biotic (grazing and competition) and environmental factors such as substrate characteristics, exposure, and tidal variation (Juul-Pedersen et al., 2008).

Seaweed community structures are generally analyzed by species composition, biomass, coverage, vertical distribution, and functional-form group, which are Parameters that respond to environment conditions (Murray and Littler, 1984; Prathep, 2005; Wells et al., 2007; Choi et al., 2008). The stability of a seaweed community does not always indicate a large seaweed biomass, because opportunistic algae account for substantial biomass in eutrophicated areas (Weston, 1990). In general, water pollution degrades macroalgae, resulting in the reduction of species richness (number), while the biomass of a few ephemeral species increases with high reproductive capability, tolerance to pollution, and simplified community structure (Gorostiaga and Díez, 1996). Thus, seaweed species composition is an ideal parameter for monitoring ecological status (Wells et al., 2007).

Seaweeds can be classified into six functional-form groups based on their morphology, physiology, internal structure, photosynthesis rate, and predation-tolerance strategy (Littler

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and Littler, 1984; Padilla and Allen, 2000). Thick-leathery and calcareous functional form seaweeds are dominant in stable environments, whereas green ephemeral algae of both sheet and filamentous forms are generally stress-tolerant species with high reproductive capability in polluted areas (Vásquez and Guerra, 1996; Schramm, 1999; Choi et al., 2008). Thus, the biomass and functional composition of seaweed communities are very important biological parameters that reflect overall environmental conditions (Hay, 1994; Phillips et al., 1997; Ballesteros et al., 2007).

To date, studies of seaweed community structure have been mainly conducted in coastal areas to examine the vertical distribution of dominant seaweeds, variation in seasonal biomass, and the species composition of intertidal rocky shores (Kim et al., 1995; Yoo et al., 2007; Choi and Huh, 2008). However, few studies of the subtidal seaweed assemblages surrounding islands in the Yellow Sea have been performed due to sampling difficulties and the high coasts of SCUBA and boating equipments (Baek et al., 2007; Choi et al., 2008; Wan et al., 2009; Kim et al., 2010). Therefore, the aim of the present study was to examine seaweed community structures using species compositions and functional groups as descriptors to contribute to the knowledge of intertidal and subtidal seaweed vegetation surrounding Ongdo, Jusamdo, and Woejodo Islands.

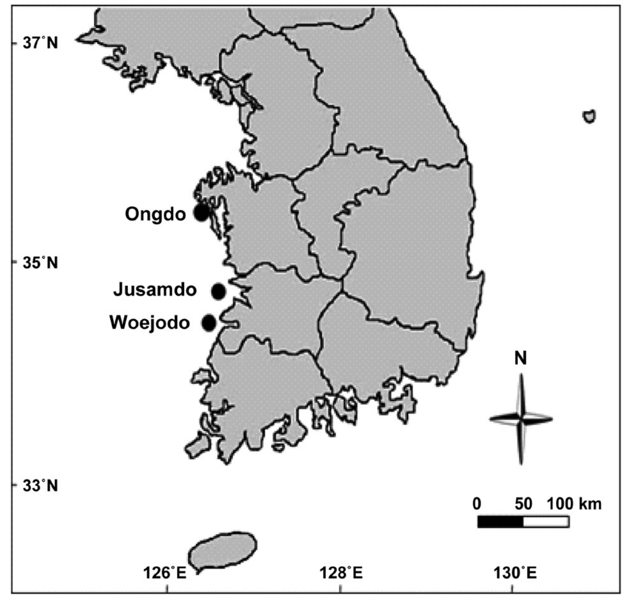

Fig. 1. A map of study sites and the location of Ongdo, Jusamdo and Woejodo Islands, Yellow Sea, Korea.

Materials and Methods

Seaweed community structures and their abundances were examined at intertidal and subtidal zones of Ongdo (36°38'N, 126°00'E), Jusamdo (35°48'N, 126°24'E), and Woejodo (35°35'N, 126°13'E) Islands, the Yellow Sea, Korea, in August 2006 (Fig. 1). Subtidal levels were established from the *Undaria pinnatifida* and *Sargassum fusiformis* zones as described previously (Kim et al., 2010). For quantitative data collection, five replicated quadrats (50 cm × 50 cm) were randomly placed within each intertidal zone (high, mid, and low) and subtidal shore (-1, -5, and -10 m depths from the *Undaria pinnatifida* zone) during low tide. Seaweeds were collected from the subtidal rocky shores by SCUBA diving. After recording the coverage and frequency, all seaweeds within each quadrat were destructively collected using a scraper following the methods of Saito and Atobe (1970), put into plastic bags, preserved in a 5-10% formalin:seawater solution, and transported to the laboratory. Qualitative sampling was also conducted to examine the macroalgal flora at the three study sites.

At the laboratory, seaweeds were rinsed with tap water and identified following the classification and nomenclature of Lee and Kang (2002). The seaweeds collected from each quadrat were measured for dry weight, and their biomass was calculated. Using the coverage and frequency data, the relative coverage (RC), relative frequency (RF), and importance value (IV) of each species was calculated. In addition, all seaweeds were divided into six functional-form groups based on thallus morphology and internal structure: sheet, filamentous, coarsely branched, thick-leathery, jointed-calcareous, and crustose forms (Littler and Littler, 1984; Steneck and Dethier, 1994; Padilla and Allen, 2000). The biomass of each group was calculated. The dominance index was calculated based on seaweed biomass using the method of McNaughton (1967). Diversity (H'), richness (R), and evenness (J') indices were assessed with biomass data of each species using the PRIMER statistical package (version 6.0). Similarities among the three study sites based on seaweed biomass (g dry wt/m^2) transformed data were calculated using a cluster analysis. The similarity profile test (SIMPROF) was used to examine the difference within each of the groups identified by the cluster analysis. K-dominance curves using seaweed biomass (g dry wt/m^2) data were also obtained using PRIMER to compare dominance patterns for the three study sites (Lambshead et al., 1983).

Results

A total of 68 species including 5 green, 11 brown, and 52 red algae were identified at the three islands (Table 1). However, the total number of species present was significantly lower at Ongdo Island than at Jusamdo and Woejodo. In total, 32 species (2 green, 4 brown, and 26 red) were found along the Ongdo rocky shore, whereas 45 seaweeds (4 green, 9 brown, and 32 red) and 44 species (2 green, 6 brown, and 36 red) were identified at Jusamdo and Woejodo, respectively. Red algae were the dominant taxon in term of species richness, ac-

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Table 1. Macroalgal lists, biomass (g dry wt/m^2) and functional (F) forms occurred at Ongdo, Jusamdo and Woejodo, the Yellow Sea, Korea in August 2006

Species	Ongdo	Jusamdo	Woejodo	F-Form
Chlorophyta				
Ulva pertusa	1.75	4.24	3.71	S
Ulva sp.	+	+		S
Cladophora albida		+		F
C. stimpsonii			0.01	F
Bryopsis plumosa		0.11		F
Phaeophyta				
Desmarestia ligulata		1.41		CB
Leathesia difformis			+	S
Myelophycus simplex	0.67	0.01	1.75	CB
Sphacelaria furcigera			+	F
Undaria pinnatifida	5.53	0.01	8.59	TL
Dictyopteris divaricata		0.18	0.64	CB
D. undulata		+		CB
Sargassum fusiformis	+	8.15		CB
S. fulvellum		+		CB
S. thunbergii	0.03	49.14	2.78	CB
Sargassum sp.		0.46		CB
Rhodophyta				
Bangia atropurpurea			+	F
Auduinella codicola			+	CB
Gelidium amansii	27.00	0.03	2.61	CB
G. divaricatum		0.07	1.46	CB
G. elegans			0.87	CB
G. pacificum			0.18	CB
Gelidiella sp.		+		CB
Pterocladia capillacea	0.57		+	CB
Lithophyllum sp.	+	+	+	C
Amphiroa dilatata	+	0.16		JC
Bossiella cretacea	0.61			JC
Corallina officinalis		+		JC
C. pilulifera	0.16	4.17	7.23	JC
Carpopeltis affinis	0.32	2.55	0.04	CB
Grateloupia divaricata	0.04		0.00	CB
G. filicina		+		CB
G. prolongata		0.13	0.00	CB
G. sparsa	+			CB
G. turuturu	0.46	+	0.12	TL
G. elliptica	0.06	0.02	+	TL
Prionitis elata			0.02	CB
P. patens		+		CB
P. divaricata		+		CB
Gloiopeltis furcata	0.09			CB

Table 1. Continued

Species	Ongdo	Jusamdo	Woejodo	F-Form
G. tenax	0.02			CB
Callophyllis palmata		+		S
Kallymenia crassiuscula	6.43	0.02		S
Caulacanthus okamurae	0.40	0.22	1.38	CB
Gracilaria textorii	7.50	0.05	1.53	CB
Ahnfeltia plicata	+	+	+	CB
A. paradoxa	0.99	0.12	0.15	CB
Chondrus ocellatus	7.87	+		CB
Chondracanthus tenellus	0.38		+	CB
Chrysymenia wrightii	3.52	+	0.09	CB
Lomentaria catenata		+	+	CB
L. hakodatensis		0.02	+	CB
Champia parvula		0.42	0.07	F
Antithamnion nipponicum			+	F
Ceramium japonicum		0.01	0.04	F
C. boydenii			+	F
C. kondoi			+	F
Ceramium sp.	+		+	F
Acrosorium polyneurum	+	0.10	+	S
Marionella schmitziana			0.11	S
Polyneura japonica		+		S
Chondria crassicaulis	0.11	0.51	3.19	CB
Laurencia intermedia		0.03		CB
L. venusta	0.01			CB
Polysiphonia japonica			+	F
P. morrowii		0.08	0.13	F
Polysiphonia sp.			+	F
Symphyocladia latiuscula	0.57	1.57	0.20	CB
Total biomass	65.09	73.99	36.90	
No. of species	32	45	44	

S, Sheet form; F, Filamentous form; CB, Coarsely Branched form; TL, Thick Leathery form; JC, Jointed Calcareous form; +, present.

counting for an average of 76.47% (52 species) of the species at all three study sites, ranging from 71.11% (32 species) at Jusamdo to 81.82% (36 species) at Ongdo. A total of 1 green (*Ulva pertusa*), 3 brown (*Myelophycus simplex, Undaria pinnatifida*, *Sargassum thunbergii*), and 14 red algae were common along the rocky shores of all three islands (Table 1).

Biomass

The seaweed biomass was greatest at Jusamdo (73.99 g dry wt/m^2), followed by Ongdo (65.09 g dry wt/m^2) and Woejodo (36.90 g dry wt/m^2) (Table 2). The biomasses of the macroalgal taxon groups ranged from 1.75-57.11 g dry wt/m^2 (2.69-87.74%) at Ongdo to 3.72–19.42 g dry wt/m^2 (10.08-52.63%) at Woejodo. Red and green algae accounted for the highest and lowest biomasses at Ongdo and Woejodo Islands, respectively (Fig. 2). At Jusamdo, the seaweed biomasses were as follows: 4.35 g dry wt/m^2 (5.88%, green), 10.28 g dry wt/m^2 (13.89%, red), and 59.36 g dry wt/m^2 (80.23%, brown) (Fig. 2). Jusamdo Island was unique in that the brown seaweeds showed the highest biomass.

The vertical distribution of seaweed biomasses showed clearly different patterns at the three study sites (Fig. 3). At Ongdo Island, the macroalgal biomass was distributed from the high intertidal zone to the -10 m subtidal zone and ranged from 10.39 g dry wt/m^2 to 134.00 g dry wt/m^2 at -10 m at these locations, respectively (range: 6 to 10 species). At Jusamdo, seaweeds were present within the high intertidal zone to -5 m depth, with biomasses ranging from 10.50 g dry wt/m^2 at -5 m depth to 136.48 g dry wt/m^2 in the high intertidal zone (species richness, 6-19 species). The distribution of seaweeds was narrow from the mid intertidal zone to the -5 m depth zone with

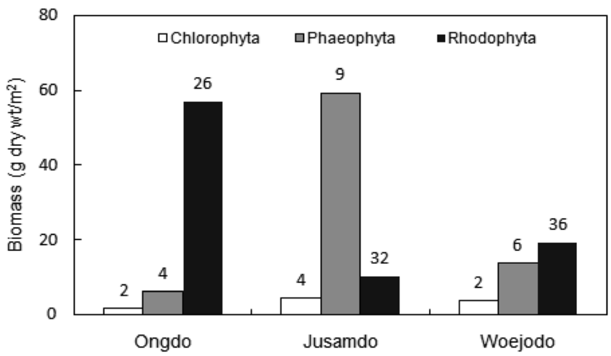

Fig. 2. Seaweed biomass (g dry wt/m^2) and species richness of each taxon group occurred at Ongdo, Jusamdo and Woejodo Islands, the Yellow Sea, Korea.

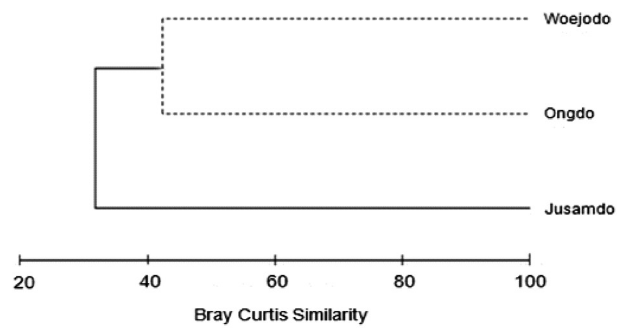

Fig. 4. Results of cluster analysis performed on Bray Curtis Similarity using seaweed biomass (g dry wt/m^2) at the three study sites, Yellow Sea, Korea in August 2006. The dotted lines indicate no significant difference in similarity between the study sites (SIMPROF test).

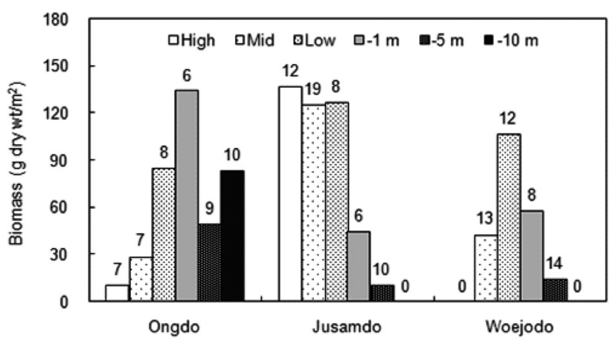

Fig. 3. Vertical variations of seaweed biomass (g dry wt/m^2, n = 5 replicates) and species number occurred on each shore levels of Ongdo, Jusamdo and Woejodo Islands, the Yellow Sea, Korea.

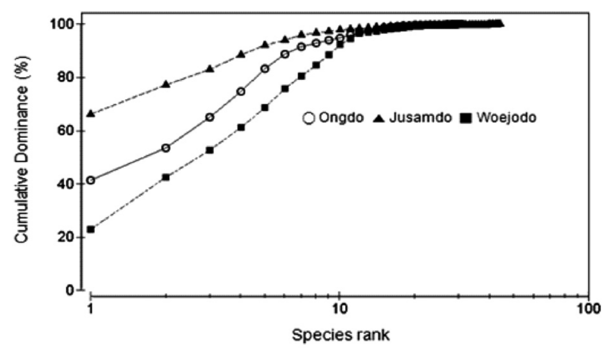

Fig. 5. K-Dominance curves (x-axis logged) for average biomass (g dry wt/m^2) of seaweeds at Ongdo, Jusamdo, and Woejodo Islands, the Yellow Sea, Korea.

Table 2. Average biomass (g dry wt/m^2), percent coverage (%) and various community indices for seaweed biomass at Ongdo, Jusamdo and Woejodo Islands, the Yellow Sea, Korea

Community indices	Ongdo	Jusamdo	Woejodo
Biomass (g dry wt/m^2)	65.09	73.99	36.90
Coverage (%)	15.41	12.09	11.23
Dominance index (DI)	0.54	0.77	0.43
Diversity index (H')	1.99	1.35	2.39
Richness index (R)	7.42	10.22	11.90
Evenness index (J')	0.57	0.35	0.63

seaweed biomass ranging from 14.41 g dry wt/m^2 to 106.69 g dry wt/m^2 at the low intertidal shore (from 8 to 14 species). The largest seaweed biomass was found at the -1 m depth zone (Ongdo), in the high intertidal zone of Jusamdo, and at the low intertidal zone of Woejodo (Fig. 3). In terms of vertical distribution, there was no clear relationship between species richness and biomass, and the species richness was highest in the -10 m subtidal zone off of the Ongdo shore as well as in the mid-intertidal zone (Jusamdo and Woejodo). Macroalgal biomass was greater in the intertidal zone than in the subtidal zone at both Jusamdo and Woejodo, whereas the opposite pattern was observed at Ongdo. The average biomass of intertidal seaweeds ranged from 41.40 g dry wt/m^2 (Ongdo) to 129.56 g dry wt/m^2 (Jusamdo), while that of the subtidal zone was between 27.67 g dry wt/m^2 (Jusamdo) and 91.70 g dry wt/m^2 (Ongdo) calculated from depths of -1 m to -5 m.

The similarity analysis using seaweed biomass data at the three study sites clustered the data into the Jusamdo group and the Ongdo-Woejodo group (Fig. 4). The similarity between these groups was 32.04%, which was significantly different in terms of seaweed biomass (SIMPROF test, P < 0.05). However, the similarity between Ongdo and Woejodo was 42.71%, which was not significantly different.

The K-Dominance curves based on seaweed biomass were slightly different between the three study sites in terms of species evenness (Fig. 5). On the rocky shore of Jusamdo Island, the dominant seaweeds *Sargassum thunbergii* (49.14 g dry wt/m^2, species rank 1), *Sargassum fusiformis* (8.15 g dry wt/m^2, rank 2), and *Ulva pertusa* (4.24 g dry wt/m^2, rank 3) occupied more than 83.16% of the total biomass (Fig. 5). At Ongdo, the shape of the curve suggested substantial dominance by three species: *Gelidium amansii* (27.00 g dry wt/m^2, species rank 1), *Chondrus ocellatus* (7.87 g dry wt/m^2, rank 2), and *Gracilaria textorii* (7.50 g dry wt/m^2, rank 3), which made up 65.09% of the total algal biomass in August 2006. At Woejodo, *Undaria pinnatifida* (8.59 g dry wt/m^2, species rank 1), *Corallina pilulifera* (7.23 g dry wt/m^2, rank 2), and *Ulva pertusa* (3.71 g dry wt/m^2, rank 3) accounted for 52.93% of the total algal biomass. The dominance indices (DI) based on biomass data were 0.43 for Woejodo, 0.54 for Ongdo, and 0.77 for Jusamdo. At Jusamdo, in terms of biomass, the first and second most dominant species were *Sargassum thunbergii* and *S. fusiformis*, respectively, occupying approximately 77% of the total biomass. Evenness indices were negatively correlated with DI and ranged from 0.35 at Jusamdo to 0.63 at Woejodo. The diversity (H') and richness (R) indices, which are calculated based on species number and evenness of seaweed biomass, respectively, were greatest at Woejodo (Table 2). The diversity index ranged from 1.35 to 2.39 while the richness index was 7.42 at Ongdo and 11.90 along the Woejodo shore (Table 2).

Coverage

The seaweed coverage was greatest at Ongdo (16.61%), followed by Jusamdo (14.51%) and Woejodo (13.48%). The average seaweed coverage along the Ongdo rocky shore was 16.61% from the high intertidal zone to the -5 m zone (we excluded the -10 m coverage to enable comparisons with the other islands), and varied vertically from 3.60% to 30.86%. The total seaweed coverage was 14.51% (from 2.70 at -5 m depth to 23.55% at the mid intertidal zone) at Jusamdo and 13.48% on the Woejodo rocky shore (from 0.00% in the high intertidal zone to 25.99% in the low intertidal zone). The seaweed coverage at Ongdo was greater in the subtidal zone (22.01%) than in the intertidal zone (13.00%). Conversely, the algal coverage at both Jusamdo (21.73% in the intertidal zone, 3.68% in the subtidal zone) and Woejodo (14.06%, 12.60%) were highest in the intertidal zones.

Abundant species (IV > 10) were *Gelidium amansii*, *Chondrus ocellatus*, and *Chrysymenia wrightii* at Ongdo Island, and *Sargassum thunbergii*, *Ulva pertusa*, and *S. fusiformis* at Jusamdo. *Ulva pertusa*, *Gracilaria textorii*, and *Corallina pilulifera* dominated the rocky shore of Woejodo Island (Table 3), while *Gelidium amansii* was dominant at the Ongdo and Woejodo shores. *Sargassum thunbergii*, *U. pertusa*, and *C. pilulifera* were abundant along both the Jusamdo and Woejodo shores.

Vertical distribution

The vertical distributions of the dominant seaweed species based on IV are provided in Table 4. The dominant seaweeds (IV>20) of each shore level at Ongdo Island were *Caulacanthus okamurae*, *Myelophycus simplex*, *Gelidium amansii*, *Ahnfeltiopsis paradoxa*, *Chondrus ocellatus*, and *Undaria pinnatifida* from the upper to lower intertidal zones, and *G. amansii*, *Chrysymenia wrightii*, *Gracilaria textorii*, and *Kallymenia crassiuscula* in the subtidal zone. At the Jusamdo shore, *Sargassum thunbergii* was dominant from the high to -1 m subtidal zones and *S. fusiformis* was abundant near the subtidal zone. No seaweed species were recorded in the -10 m depth regions of the Jusamdo and Woejodo rocky shores. At Woejodo, the dominant species (IV > 20) were *M. simplex*, *C. okamurae*, *U. pertusa*, *Corallina pilulifera*, *Undaria pinnatifida*, *G. amansii*, and *G. textorii* from the mid intertidal zone to the -5 m subtidal zone (Table 4).

Functional-form groups

The same six functional-form groups (*i.e.,* sheet, filamentous, coarsely branched, thick-leathery, jointed-calcareous, and crustose forms) were found at all three study sites. The coarsely-branched form was the most dominant group in terms of species number and biomass at all three study sites. The percentage of coarsely-branched form seaweeds ranged from 52.27-60.00% in species number and 45.77-87.37% of the total biomass (Fig. 6). On the rocky shores of Ongdo and Judsamdo Islands, the sheet form was the sub-dominant

Table 3. Average coverage (C), frequency (F), relative coverage (RC), relative frequency (RF), and importance value (IV) of seaweeds occurred on the rocky shores of Ongdo, Jusamdo and Woejodo Islands, the Yellow Sea, Korea

Site/Species	C	F	RC(%)	RF(%)	IV*
Ongdo					
Gelidium amansii	5.53	24.00	35.85	26.20	31.02
Chondrus ocellatus	3.36	13.47	21.78	14.70	18.24
Chrysymenia wrightii	1.39	13.87	9.00	15.14	12.07
Gracilaria textorii	1.19	8.40	7.75	9.17	8.46
Undaria pinnatifida	1.00	4.00	6.49	4.37	5.43
Jusamdo					
Sargassum thunbergii	7.08	24.93	58.53	37.40	47.97
Ulva pertusa	1.53	9.60	12.67	14.40	13.53
Sargassum fusiformis	1.33	9.33	11.01	14.00	12.51
Carpopeltis affinis	0.47	4.27	3.88	6.40	5.14
Corallina pilulifera	0.33	4.93	2.74	7.40	5.07
Woejodo					
Ulva pertusa	1.73	13.33	15.36	18.15	16.75
Undaria pinnatifida	1.67	9.33	14.86	12.70	13.78
Corallina pilulifera	1.05	7.87	9.35	10.71	10.03
Gelidium amansii	1.20	6.53	10.68	8.89	9.79
Gracilaria textorii	0.83	6.13	7.35	8.35	7.85
Sargassum thunbergii	0.89	4.40	7.90	5.99	6.95
Myelophycus simplex	0.83	2.93	7.40	3.99	5.70
Caulacanthus okamurae	0.56	3.73	5.01	5.08	5.05

*IV > 5.

group, accounting for 12.57% and 5.90% of the total biomass, respectively. However, at Woejodo, the thick-leathery form (second group, 23.61%) and jointed-calcareous form (third group, 19.57%) had very similar biomasses (Fig. 6). As shown in Table 3, *Gelidium amansii*, *Chondrus ocellatus*, *Chrysymenia wrightii*, and *Gracilaria textorii* were all in the coarsely-branched form at Ongdo. Also, the functional form seaweeds, *Sargassum thunbergii*, *S. fusiformis*, and *Carpopeltis affinis* were dominant on the Jusamdo rocky shore. However, at Woejodo, the abundant seaweeds (IV > 10) were *U. pertusa* (sheet), *Undaria pinnatifida* (thick-leathery), and *Corallina pilulifera* (jointed-calcareous).

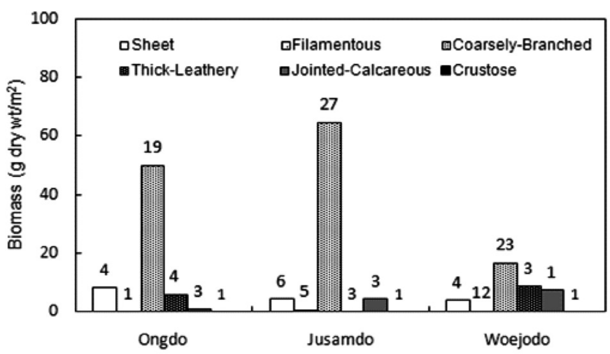

Fig. 6. Average biomass (g dry wt/m^2) of five functional-form seaweeds on the rocky shore of Ongdo, Jusamdo, and Woejodo Islands, the Yellow Sea, Korea. The number presented species number of each functional form group.

Discussion

Seaweed species richness is a basic tool showing the conditions of coastal marine ecosystems because it responses sensitively to environmental changes of seaweed habitats (Wells et al., 2007). During summer, seaweed species richness has been reported to vary from 14 species at Oshikto (Park and Kim, 1990) to 16 species at 10 Islands (from Deokjegdo to Seungbongdo Islands) of the Gyonggiman islets (Lee et al., 1997) and 70 species at Sapsido (Yoon and Boo, 1991) in the Yellow Sea, Korea. In the present study, 32, 45, and 44 species were identified at Ongdo, Jusamdo, and Woejodo Islands, respectively, during the summer. These data suggest that the environmental conditions at the three study sites are better than many other island areas in terms of algal species richness.

Seaweed biomass determines the amount of primary production in marine ecosystems because macroalgae are used as food sources of many marine animals (Terawaki et al., 2001; Eklöf et al., 2005). Thus, seaweed biomass is a common indi-

Table 4. Vertical distribution of dominant seaweeds based on importance value (IV > 10) at the three study sites of Yellow Sea, Korea

Levels		Ongdo	Jusamdo	Woejodo
Intertidal Zone	High	*Caulacanthus okamurae* (34.10)	*Sargassum thunbergii* (68.87)	
		Myelophycus simplex (32.29)		
		Chondrus ocellatus (13.89)		
		Gloiopeltis furcata (10.52)		
	Mid	*Gelidium amansii* (52.07)	*Sargassum thunbergii* (42.59)	*Myelophycus simplex* (24.26)
		Ahnfeltiopsis paradoxa (20.73)	*Ulva pertusa* (29.13)	*Caulacanthus okamurae* (21.19)
		Pterocladia capillacea (14.21)		*Gelidium divaricatum* (17.79)
	Low	*Chondrus ocellatus* (49.20)	*Sargassum thunbergii* (42.21)	*Ulva pertusa* (32.94)
		Undaria pinnatifida (21.52)	*Sargassum fusiformis* (25.76)	*Corallina pilulifera* (22.36)
				Sargassum thunbergii (12.96)
				Chondria crassicaulis (12.94)
Subtidal Zone	-1 m	*Gelidium amansii* (58.24)	*Sargassum thunbergii* (46.42)	*Undaria pinnatifida* (42.92)
		Chrysymenia wrightii (27.17)	*Sargassum fusiformis* (42.94)	*Gelidium amansii* (22.01)
		Chondrus ocellatus (11.50)		*Gracilaria textorii* (10.76)
				Ulva pertusa (10.32)
	-5 m	*Gelidium amansii* (29.58)	*Desmarestia ligulata* (49.54)	*Gracilaria textorii* (36.10)
		Chrysymenia wrightii (23.82)	*Gracilaria textorii* (21.76)	*Gelidium amansii* (15.31)
		Gracilaria textorii (22.46)	*Ulva pertusa* (10.88)	*Undaria pinnatifida* (10.71)
		Chondracanthus tenellus (10.08)		*Gelidium elegans* (10.55)
	-10 m	*Gracilaria textorii* (43.61)		
		Kallymenia crassiuscula (28.61)		

cator of the health of marine ecosystems. In the island areas of the Yellow Sea, the average seaweed biomass of the intertidal zone is 89.25 g dry wt/m^2 and varies from 23.78 g dry wt/m^2 at Oshikto Island (Park and Kim, 1990) to 176.68 g dry wt/m^2 at Nachido Island in the summer. At our study sites, the macroalgal biomasses of intertidal rocky shores ranged from 41.40 g dry wt/m^2 (Ongdo) and 49.83 g dry wt/m^2 (Woejodo) to 129.56 g dry wt/m^2 (Jusamdo) in August 2006. Thus, the conditions along the Woejodo and Ongdo shores appeared relatively poor, whereas Jusamdo was in better condition.

The dominant seaweed taxon and seaweed biomass are always tightly correlated (Littler and Littler 1980). Brown algae dominate the island areas of the Yellow Sea, with *Sargassum thunbergii* being abundant along the shores of Nachido, Wonsando, Kodoedo, Odo, Hodo, and Changgodo Islands (Kim et al., 1995). Red algae were the second most abundant, with *Neorhodomela aculeata* at Bagryoungdo (Baek et al., 2007) and *Corallina pilulifera* at Gyounggiman islets (Lee et al., 1997). Green seaweeds tend to only dominate the rocky shores of a few islands. For example, green seaweeds accounted for 38.1% of the total biomass at Oshikto Island (Park and Kim, 1990). In the present study, red algae (*Gelidium amansii*, *Chondrus ocellatus*, and *Chrysymenia wrightii*) accounted for 58.96% of the total biomass at Ongdo, while *S. thunbergii* (brown algae) made up 66.40% of the total biomass at Jusamdo. On the Woejodo shore, 64.12% of the total seaweed biomass was composed of *Ulva pertusa* (green), *Undaria pinnatifida* (brown), and *C. pilulifera*, *G. amansii*, and *Gracilaria textorii* (red). Generally, brown algae exhibit larger biomasses than red seaweeds due to their larger size, whereas red algae are mostly small or filamentous in form (Johnston, 1969). These taxon differences may explain why the seaweed biomass was greatest at Jusamdo Island, which is dominated by *S. thunbergii*, compared to Woejodo and Ongdo, which are dominated by green and red seaweeds, respectively.

Functional form composition in seaweed community is another important indicator of environmental conditions (Choi et al., 2008). During the summer, coarsely-branched seaweeds are the major group in terms of species number, making up 33.33% to 78.95% of the seaweed forms (from Shimwon to Nachido) in the island areas of the Yellow Sea (Hwang et al., 1996; Lee et al., 2007; Yoo et al., 2007). Sheet and filamentous groups exhibit relatively high proportions, ranging from 5.26% (at Nachido) to 45.45% (at Hyanghado, Maseom) due to the high water turbidity during the summer (Hwang et al., 1996; Lee et al., 2007; Yoo et al., 2007). Generally, sheet-like and filamentous seaweeds, such as *Ulva* sp. and *Cladophora* sp., are dominant in unstable or polluted habitats, whereas late successional, thick-leathery and calcareous seaweeds thrive in stable environmental conditions (Littler and Littler, 1984; Choi et al., 2008; Kim et al., 2010). In addition, coarsely-branched seaweeds typically occur in moderate environments (Littler and Littler, 1984). In the present study, we observed that the coarsely-branched form was qualitatively most dominant, accounting for 52.27% (at Woejodo), 59.38% (at Ongdo), and 60.00% (at Jusamdo) of all species. Conversely, the sheet-like and filamentous forms made up 15.63%, 24.44%, and 36.36% of all species at Ongdo, Jusamdo, and Woejodo, respectively. The dominant species (*Ulva pertusa*) of the sheet form was most abundant from mid intertidal zone to -5 m depth at Jusamdo and Woejodo, while the desiccation-tolerant species *Corallina pilulifera*, which is of the jointed-calcareous form, was also abundant in summer at Jusamdo and Woejodo (Choi et al., 2008).

In conclusion, a total of 68 species, including 5 green, 11 brown, and 52 red algae, were identified at three study sites in August 2006. Seaweed biomass was highest at Jusamdo (74.01 g dry wt/m^2) and lowest at Woejodo (36.92 g dry wt/m^2). The dominant seaweed species included *Gelidium amansii*, *Chondrus ocellatus*, and *Chrysymenia wrightii* at Ongdo, *Sargassum thumbergii*, *Ulva pertusa*, and *Sargassum fusiformis* at Jusamdo, and *U. pertusa*, *Undaria pinnatifida*, and *Corallina piluifera* at Woejodo. Abundant perennial seaweeds (*G. amansii* and *C. ocellatus* at Ongdo, *S. thunbergii* and *S. fusiformis* at Jusamdo) were present in stable environments, whereas sheet algae such as *U. pertusa* thrived in disturbed habitats, such as that at Woejodo Island. On the basis of biomass, IV, and functional form composition of seaweed communities, we conclude that the Jusamdo shore is in the best condition, whereas Woejodo is in the poorest condition in terms of seaweed habitats among the three islands.

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