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Species Composition and Biomass Distribution of Benthic Macroalgae in Maxwell Bay, King George Island, Antarctica

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ABSTRACT. Species composition and biomass distribution of benthic macroalgae were investigated during 92/93 austral summer in Maxwell Bay, King George Island, Antarctica. Systematic fieldworks at eleven sites, combined with the previous works, provided us opportunities to analyze the macroalgal assemblages quantitatively and qualitatively. A total of 42 species was collected and identified; 7 green, 1 golden-brown, 14 brown, and 20 red algae. The macroalgal biomass of Maxwell Bay was generally low (204.5 g wet w m^{-2} in average) due to discontinuity of the vegetation by mud deposition. It showed strong variation according to the substrate type; from 28 g wet w m^{-2} at muddy fjords to 364.8 g wet w m^{-2} at exposed rocky shores. The highest biomass (>8.7 kg wet w m^{-2}) was recorded on a vertical rock of exposed site. The littoral zonation was dominated by *Ulothrix australis* and *Porphyra endiviifolium* at supralittoral zone. In the center of tidepools at eulittoral zone, ephemeral species presented mainly at sublittoral fringe were observed. The sublittoral zonation was dominated by perennial brown algae of Desmarestiales, *Desmarestia* spp. (40%) and *Himantothallus grandifolius* (27%), which accounted for 67% of the macroalgal weight in total. In view of the vertical profile at the upper sublittoral zone which was affected by winterly sea-ice cover and abrasion by floating ice with wave action, various ephemeral species were observed. *Desmarestia* spp. were dominant from 5 to 15 m deep, and *H. grandifolius* was mainly distributed below 15 m. These zonations of the perennial brown algae assumed different aspects in relation to the inclination of substrate and the extent of mud deposition. More focus on *Desmarestia* spp. would be needed for the understanding of the nearshore ecosystem in the Antarctic Peninsula region.

Key Words: macroalgae, species composition, biomass, distribution, Maxwell Bay, King George Island, Antarctica

Introduction

Studies on the Antarctic macroalgae had been originated in the taxonomic accounts on the materials collected from the English and Swedish expedition teams (Montagne 1842; Foslie 1907; Gepp and Gepp 1907, 1912, 1917; Skottsberg 1907, 1921, 1923). Fieldworks in the cold water region had been restricted by methodology, resulting in limited reports on Antarctic littoral flora. Sublittoral materials had been depended on cast ashores (Gain 1912; Feldmann 1937; Skottsberg 1941; Zinova 1958). Since Neushul (1961, 1965, 1968), Delépine (1966), and Zaneveld (1966a, b, 1968) used scuba diving techniques as a turning point, the sublittoral vegetation had been appeared to our knowledge (DeLaca and Lipps 1976; Lamb and Zimmerman 1977; Richardson 1979; Zielinski 1981, 1990), and reconsideration of taxonomic accounts (Moe and Silva 1977a, b, 1989; Wynne 1982; Ricker 1987) had been carried out.

Many studies on the Antarctic macroalgal assemblages have been conducted mainly with

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using relative coverage method due to difficulty of direct observation in harsh environment (Amsler *et al.* 1990; Miller and Pearse 1991; Westermeier *et al.* 1992; Chung *et al.* 1994; Gambi *et al.* 1994; John *et al.* 1994). Only a few direct observations such as harvest method have been carried out (DeLaca and Lipps 1976; Richardson 1979; Amsler *et al.* 1995).

There are six year-round stations in Maxwell Bay from six countries. Under good conditions for logistic managements, however, the macroalgal studies in this area have not been conducted sufficiently. Except work by Klöser *et al.* (1996) which was investigated in entrance of Potter Cove, most of studies were limited in the littoral zone (Ramírez and Villouta 1984; Wu *et al.* 1989). Only a few sites were investigated on the sublittoral flora aboard a research vessel (Moe and DeLaca 1976; DeLaca and Lipps 1976).

The purpose of this study is to describe the vegetation and biomass distribution of benthic marine algae preliminarily in Maxwell Bay, King George Island, Antarctica.

Materials and Methods

Sites

Maxwell Bay is located between Nelson Island and King George Island in South Shetland Islands, which paralles Antarctic Peninsula. The bay is a glacially-eroded embayment, and is approximately 14 km long and 6 to 14 km wide with maximum depth of 520 m (Fig. 1). There are several fjords such as Collins Harbour, Marian Cove, and Potter Cove. The geological feature is a tertiary volcanic rock, and it is characterized by pebble-boulder layer in the shallow depth and thick mud layer in the lower depth. The detailed information on substrate was described in results with macroalgal vegetation.

Sampling and Vegetation Analysis

Fieldwork was carried out from December 1992 to February 1993. At eleven sites in total, quadrat samplings of macroalgae were conducted with a transect line down to 30 m deep (Fig. 1). At site H,

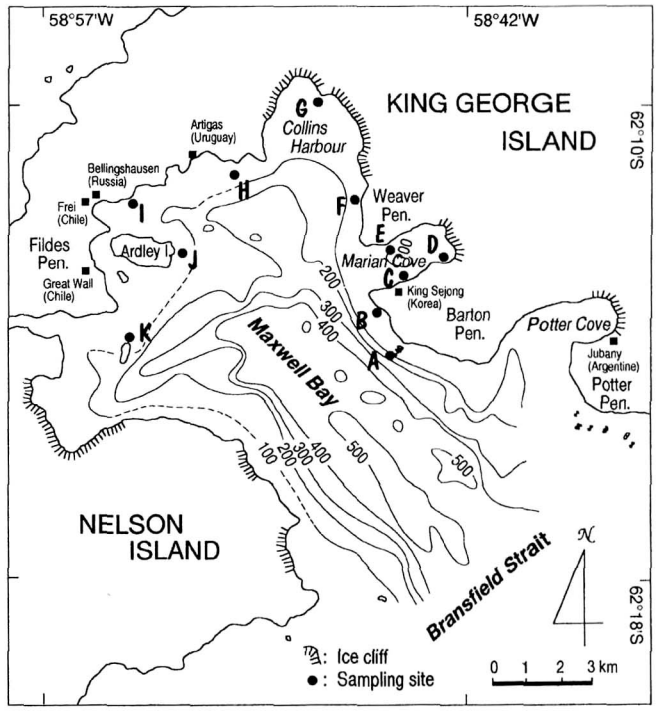

Fig. 1. A location map showing the sampling sites of macroalgae by harvest method during 1992/93 austral summer in Maxwell Bay, King George Island.

however, the quantitative samples of other species except giant brown algae were not obtained owing to continuous strong wind and wave. At sites B, I, and J formed gentle inclination, samples were collected down to 15 m, 10 m, and 10 m, respectively. Based on our previous work by coverage method in the same field (Chung *et al.*, 1994), different quadrat size was adapted at each depth, because vegetation of the flora was discrete and represented by giant brown algae. The size of quadrats were 1x1 m^2 (surface to 1 m), 2x2 m^2 (1-3, 3-5, 5-7 m), 3x3 m^2 (7-10 m), and 5x5 m^2 (10-15, 15-20, 20-25, 25-30 m). All the materials collected in the quadrats were transported to laboratory of the King Sejong Station. They were not preserved with formalin but stored in cold condition.

After identifying in laboratory, fresh weight of each population was measured with a chemical balance. The biomass data were recalculated from the data per unit area (m^2).

Results

Species Composition

A total of 42 species, 7 green, 1 golden-brown, 14 brown and 20 red algae, was collected and identified (Table 1). Giant brown algae *Desmarestia* spp. (mainly composed of *D. menziesii* and *D. anceps*) and *Himantothallus grandifolius* and thallic red algae *Palmaria decipiens*, *Gigartina skottsbergii*, *Plocamium cartilagineum* were most frequently observed.

Vegetation

The characteristics of macroalgal vegetation were as follows (Fig. 2).

Site A: As an islet at a distance of 50 m offshore of a penguin rookery in the center of Barton Peninsula, the vertical wall was steep and well developed down to 40 m deep.

At the steep supralittoral zone *Ulothrix australis* and *Urospora penicilliformis* (hereinafter referred to as *U. australis*, because *U. penicilliformis* was almost mixed together with it) were formed a mat, and *Porphyra endiviifolium* grew below the mat. The sublittoral fringe was only covered with crustous coralline algae. *Palmaria decipiens* and *Phaeurus antarcticus* were mixed together from 1 to 3 m deep, and the various red algae such as *Myriogramme manginii* were observed below them. On the flat rocky bottom between 5 and 7 m, *Desmarestia* spp. formed an algal mat with their bushy thalli. On the vertical wall below the mat, the flora was diverse and abundant, and many Gigartinales plants, *Gigartina skottsbergii* and *Curdiea racovitzae* were frequently observed with crustous sponges. At about 15 to 30 m, *Himantothallus grandifolius* hung curtains with their leathery thalli. The length of blades was over 10 m long. In this zone, *Cystosphaera jacquinotii* which had up-right thalli toward surface with their air-bladders was often observed, and also various red algae *Pantoneura plocamioides*, *Picconiella plumosa*, and *Plocamium cartilagineum* were observed frequently with thick layer of sponges.

Site B: With the nearby northern cape, the inclination was not moderate to the place at a distance of 200 m from the shore. The substrate was composed of well rounded pebbles and boulders owing to the severe wave action at the littoral zone and sublittoral fringe, and below about 3 m deep was replaced by boulders with sand.

Supralittoral zone was covered with filamentous green alga *Ulothrix australis*. *Porphyra endiviiforium* and *Enteromorpha bulbosa* were rarely observed. Crustous coralline algae were observed in tidepools. At about 1 to 3 m, *Desmarestia antarctica* and *Phaeurus antarcticus* were predominant with young *Adenocystis utricularis*. Below this zone *Ascoseira mirabilis* was commonly observed, and *Desmarestia menziesii* was very abundant on boulders. *Himantothallus grandifolius* found at about 10 m deep.

Sites C, D and E: These sites were located in Marian Cove and had generally moderate inclination and thick mud layer. The floras were not diverse and abundant.

Ulothrix australis belt was observed on the rock of the supralittoral zone. *Palmaria decipiens* and *Monostroma hariotii* formed a mat sporadically on the pebble layer down to 10 m deep. At the deeper zone the perennial brown algae, *Desmarestia* spp. and *Himantothallus grandifolius* were sparsely found, especially on the naked pebbles or boulders in thick mud layer. It was remarkable that *P. decipiens* formed a mat just below Low Water Level at the northern coast (site E). Various epifauna such as amphipods, starfishs and sea-urchins were observed on the bushy thalli of *Desmarestia menziesii* at the mud layer (sites C and E). At site D in front of ice cliff covered with fine grained mud, populations of an acsidian *Cnemidocarpa verrucosa* were rich at the bottom.

Site F: In the western coast of Weaver Peninsula, the inclination was so steep that the mud deposition was not moderate down to the lower depth.

Ulothrix australis was commonly found on pebble layer of the littoral zone. However, any macroalgae were not observed on the unstable boulder zone of the sublittoral fringe. The dropped boulders were originated from the terrestrial rocky mountain nearby. At about 5 to 10 m, *Desmarestia* spp. formed a mat with various epiphytes of *Palmaria decipiens*,

Table 1. Occurrence of benthic marine algae collected in Maxwell Bay, Antarctica

Species \ Site No.	A	B	C	D	E	F	G	H	I	J	K
Chlorophyta											
Ulothrix australis Gain	+	+	+	+	+	+	+	+	+	+	
Monostroma hariotii Gain		+	+	+	+	+	+		+	+	+
Enteromorpha bulbosa (Suhr) Montagne		+								+	
Prasiola crispa (Lightfoot) Kützing subsp. *antarctica* (Kützing) Knebel	+	+	+								
Acrosiphonia pacifica (Montagne) J. Agardh *in* Hohenacker		+									
Urospora penicilliformis (Roth) Areschoug	+	+	+	+	+	+	+	+	+	+	
Lambia antarctica (Skottsberg) Delépine	+		+				+	+	+		+
Chrysophyta											
Antarctosaccion applanatum (Gain) Delépine	+	+	+			+	+	+	+	+	+
Phaeophyta											
Geminocarpus geminatus (Hooker et Harvey) Skottsberg	+						+			+	+
Elachista antarctica Skottsberg	+					+	+	+	+		+
Alethocladus corymbosus (Dickie) Sauvageau	+							+			
Desmarestia ancpes Montagne	+	+	+	+	+	+	+	+	+	+	+
D. antarctica Moe et Silva	+	+		+		+	+		+	+	+
D. cordalis Hooker et Harvey	+							+	+	+	+
D. menziesii J. Agardh	+	+	+	+	+	+	+	+	+	+	+
D. willii Reinsch	+							+	+	+	+
Himantothallus grandifolius (A. et E.S. Gepp) Moe et Silva	+	+	+	+	+	+	+	+	+	+	+
Phaeurus antarcticus Skottsberg	+	+					+	+	+	+	+
Adenocystis utricularis (Bory de Saint-Vincent) Skottsberg	+	+		+			+	+	+	+	+
Ascoseira mirabilis Skottsberg	+	+	+			+	+	+	+	+	+
Cystosphaera jacquinotii (Montagne) Skottsberg	+	+	+					+		+	
Lessonia flavicans Bory		+	+					+			+
Durvillea antarctica (Chamisso) Hariot	+							+		+	
Rhodophyta											
Bangia atropurpurea (Roth) C. Agardh							+	+	+		
Porphyra endiviifolium (A. et E.S. Gepp) Chamberlain	+	+					+	+	+	+	+
Rhodochorton concrescens Drew	+							+	+	+	
Synarthrophyton patena (J.D. Hooker et Harvey) Townsend	+								+	+	+
Callophyllis linguata Kylin et Skottsberg	+	+						+	+	+	
Kallymenia antarctica Hariot	+					+	+		+	+	
Plocamium cartilagineum (L.) Dixon	+	+	+	+		+	+	+	+	+	+
Plocamiocolax sp.	+							+	+		
Curdiea racovitzae Hariot	+	+		+					+	+	+
Phyllophora ahnfeltioides Skottsberg	+	+						+			+
Gigartina skottsbergii Setchell et Gardner	+	+	+	+	+	+	+	+	+	+	+
Iridaea cordata (Turner) Bory	+	+	+			+	+			+	+
Palmaria decipiens (Reinsch) Ricker	+	+	+	+	+	+	+	+	+	+	+
Antarcticothamnion polysporum Moe et Silva	+	+				+		+	+	+	+
Ballia callitricha (C. Agardh) Kützing	+	+						+	+	+	+
Georgiella confluens (Reinsch) Kylin	+	+	+	+			+	+	+	+	+
Delesseria lancifolia (J.D. Hooker et Harvey) J. Agardh	+	+				+		+	+	+	+
Myriogramme manginii (Gain) Skottsberg	+	+				+	+	+	+	+	
Pantoneura plocamioides Kylin	+	+						+	+	+	+
Picconiella plumosa (Kylin) De Toni	+							+	+	+	+

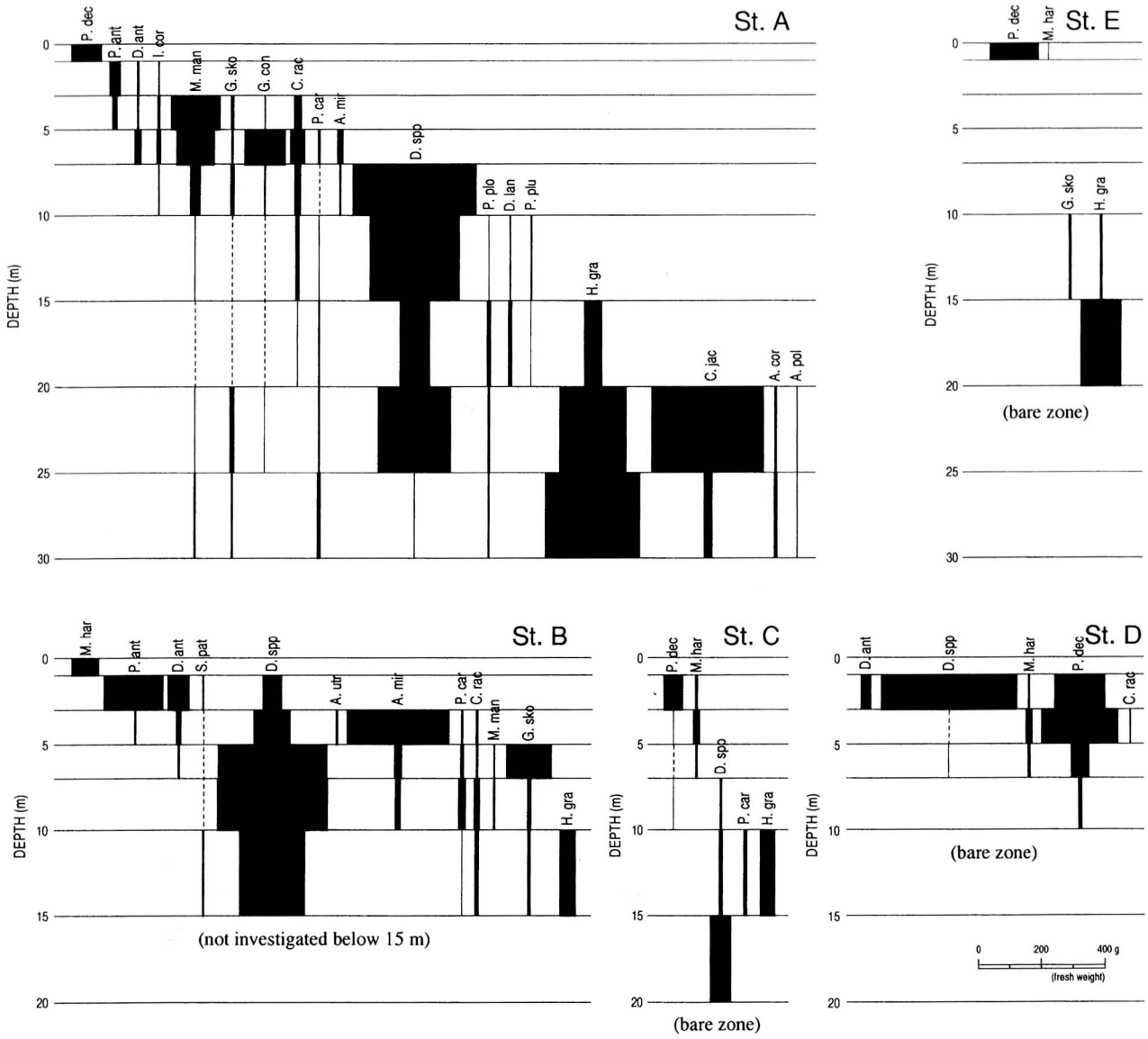

Fig. 2. Vertical distribution patterns of macroalgal biomass in Maxwell Bay. Only giant brown algae were investigated at site H (A.utr, *Adenocystis utricularis*; A.cor, *Alethocladus corymbosus*; A.pol, *Antarcticothamnion polysporum*; A.mir, *Ascoseira mirabilis*; C.rac, *Curdiea racovitzae*; C.jac, *Cystosphaera jacquinotii*; D.lan, *Delesseria lancifolia*; D.ant, *Desmarestia antarctica*; D.spp, *Desmarestia* spp.; G.con, *Georgiella confluens*; G.sko, *Gigartina skottsbergii*; H.gra, *Himantothallus grandifolius*; I.cor, *Iridaea cordata*; K.ant, *Kallymenia antarctica*; M.har, *Monostroma hariotii*; M.man, *Myriogramme manginii*; P.dec, *Palmaria decipiens*; P.plo, *Pantoneura plocamioides*; P.ant, *Phaeurus antarcticus*; P.plu, *Picconiella plumosa*; P.car, *Plocamium cartilagineum*; P.ahn, *Phyllophora ahnfeltioides*; S.pat, *Synathrophyton patena*).

Monostroma hariotii, *Desmarestia antarctica*, and juveniles of *Himantothallus grandifolius*. Below 15 m deep *H. grandifolius* hung the leathery curtains of 5 to 8 m in length.

Site G: It is rocky shore at a distance of 200 m from the ice cliff of Collins Harbour. The littoral zone was well developed with tidepools, but the sublittoral zone was affected by mud deposition below 10 m deep.

At the supralittoral zone *Ulothrix australis* formed the distinct belt. In tidepools, *Palmaria decipiens* was dominant, but other algae such as *Monostroma hariotii*, *Adenocystis utricularis*, *Kallymenia antarctica* were also observed together. The upper sublittoral had a diverse flora with *P. decipiens*, *Gigartina skottsbergii*, *A. utricularis*, *Desmarestia antarctica*, *K. antarctica*, and *Georgiella confluens*, but the biomass was not so much. At about 5 to 10 m deep, *Desmarestia* spp. showed a dense canopy with their bushy thalli. *Himantothallus grandifolius* commonly

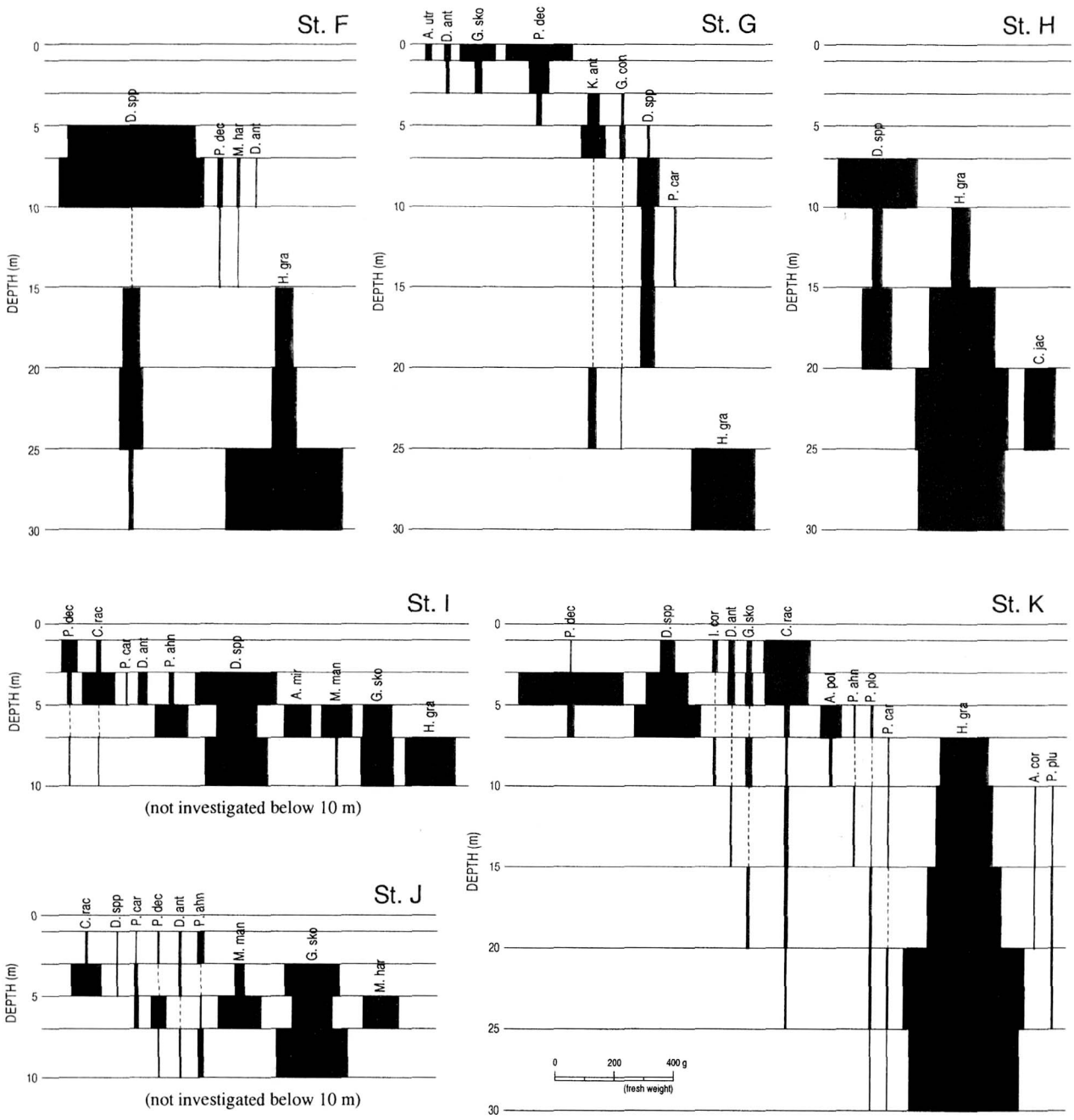

Fig. 2. continued

grew at 25 m on the pebbles in mud layer with steep inclination.

Site H: As an islet at a distance of 200 m offshore of the Artigas Station, the substrate was mainly composed of rocks and was not affected by mud deposition down to 30 m.

On the vertical rock, *Ulothrix australis* grew at supralittoral zone, and just below it *Bangia atropurpurea* and *Porphyra endiviifolium* formed a mixing belt. At the sublittoral the species diversity was greater than in other areas. The dominant species were *Palmaria decipiens*, *Kallymenia antarctica*, *Plocamium cartilagineum*, and *Gigartina skottsbergii*. Below 7 m deep, the dominance of perennial brown algae was apparently observed. *Desmarestia* spp. and *Himantothallus grandifolius* had their heavy assemblages at 8 to 20 m and 10 and 30 m, respectively. Perennial brown alga *Cystosphaera jacquinotii* (>3 m in length) grew toward surface with their air-bladders at 24 m deep. It was remarkable

that various plants of Gigartinaceae, Ceramiaceae, and Delesseriaceae were abundant at the lower depth of this site.

Sites I and J: Site I was located in front of the fuel tanks of Bellingshausen Station. Site J was an islet at a distance of 20 m offshore of Ardley Island. Two sites had generally clear waters with rocks with sand. The substrates were very steep from the surface, but just below 10 m deep were changed to flat bottom.

Vegetations of the supralittoral zone were similar with site H. In tidepools *Kallymenia antarctica* and *Palmaria decipiens* (site I) and *Enteromorpha bulbosa* (site J) were very abundant. Sublittoral fringes were covered with crustous coralline algae. At about 1 to 7 m deep, the floras were diverse and abundant. The representative species were composed of thallic red algae *P. decipiens*, *Curdiea racovitzae*, *Gigartina skottsbergii*, and *Iridaea cordata*. Other algae such as *Ascoseira mirabilis*, *Myriogramme manginii*, and *Phyllophora ahnfeltioides* were frequently observed. On the other hand, at site I perennial brown algae *Desmarestia* spp. had an assemblage below 3 m deep, but at site J they were not observed commonly.

Site K: As an islet offshore of the Fildes Peninsula, the substrate had an inclination of about 45° and was mainly composed of frequently exposed boulders in mud layer.

On the littoral rock *Porphyra endiviifolium* was only observed. There was no vegetation at pebble beach of the sublittoral fringe. At about 1 to 7 m, various flora was observed on the boulder layer of which inclination was less moderate. The representative species were composed of thallic red algae *Curdiea racovitzae*, *Palmaria decipiens*, *Gigartina skottsbergii*, and *Iridaea cordata*; and brown alga *Desmarestia menziesii* and *Desmarestia antarctica*. Below the depth *Himantothallus grandifolius* formed a great assemblage down to at least 40 m deep. In this area it is remarkable that the filamentous red alga *Antarcticothamnion polysporum*, *Pantoneura plocamioides*, *Picconiella plumosa*, and *Plocamium cartilagineum* were abundant at the lower depth.

Biomass and Dominant Species

Macroalgal biomass in Maxwell Bay was 204.5 g wet w m^{-2} in average. Higher biomass was recorded at some rocky shore like site A. The value was 8.7 kg m^{-2} of *Cystosphaera jacquinotii* or 7.1 kg m^{-2} of *Desmarestia menziesii*. However, the mean value was estimated low due to discontinuity of the vegetation.

Considering the biomass values by each site (Table 2), they were generally higher at the exposed sites of which substrates were composed of rock and boulder. The highest biomass of 364.8 g m^{-2} was recorded at site A where the perennial brown algae *Desmarestia* spp., *Himantothallus grandifolius*, and *Cystosphaera jacquinotii* were dominant. Whereas at the sites in fjords lower biomass (28.2 g m^{-2} in minimum) was observed.

Considering the biomass by each species (Table 2), Desmarestiales plants such as *Desmarestia* spp. (40.0%) and *Himantothallus grandifolius* (26.8%) occupied 66.8% in total biomass and played an important role for the macroalgal vegetation. Otherwise, thallic red algae *Gigartina skottsbergii*, *Palmaria decipiens*, *Curdiea racovitzae* and brown algae *Ascoseira mirabilis*, *Cystosphaera jacquinotii*, were also predominant although they were not comparable with the Desmarestiales.

Zonation

In summary, the distribution patterns of macroalgal vegetation in Maxwell Bay were as follows.

Littoral zonation was characterized by *Ulothrix australis* and *Urospora penicilliformis* at the supralittoral zone and *Porphyra endiviiforium* just below the zone. In the eulittoral zone where gentle slope was formed, various macroalgae of green algae *Enteromorpha bulbosa*, *Monostroma hariotii*, brown algae *Adenocystis utricularis*, *Phaeurus antarcticus*, and thallic red algae *Palmaria decipiens*, *Kallymenia antarctica*, *Iridaea cordata* were observed.

Sublittoral vegetation can be divided into three groups as follows.

1) Mixed assemblage of ephemeral species (surface to 5 m deep): As the upper sublittoral zone which was affected by winter sea-ice and abrasion by

Table 2. Mean biomass of representative species in Maxwell Bay. *, mixed of *Desmarestia anceps* and *D. menziesii*; RV, relative value

Species \ Site No.	Mean biomass (g wet w m^{-2})											RV
	A	B	C	D	E	F	G	I	J	K	Mean	(%)
Desmarestia spp.*	139.57	205.38	13.26	28.69		101.85	22.11	144.66	135.95	27.35	81.88	40.0
Himantothallus grandifolius	93.59	15.93	7.87		22.03	88.61	35.16	49.84	24.03	210.20	54.73	26.8
Gigartina skottsbergii	4.66	24.07	0.07	0.08	1.05		5.25	51.67	34.90	6.00	12.78	6.3
Palmaria decipiens	6.15	0.27	3.95	31.09	5.15	2.12	12.76	14.32	9.48	25.04	11.03	5.4
Curdiea racovitzae	8.02	8.02		0.13				25.32	3.64	26.24	7.14	3.5
Ascoseira mirabilis	1.53	48.69						17.90			6.81	3.3
Cystosphaera jacquinotii	62.13										6.21	3.0
Phaeurus antarcticus	2.57	24.41						0.01	21.53	0.04	4.86	2.4
Myriogramme manginii	21.96	0.88						22.26	5.09		5.02	2.5
Desmarestia antarctica	1.87	11.37		2.06		0.24	1.23	6.12	11.93	3.22	3.80	1.9
Phyllophora antarctica	0.21							25.31	0.01		2.55	1.2
Plocamium cartilagineum	3.04	6.44	1.56				0.98	0.67	0.01	1.38	1.41	0.7
Kallymenia antarctica							12.56		0.01		1.26	0.6
Georgiella confluens	8.98	0.00	0.18				1.74	0.01			1.09	0.5
Monostroma hariotii		5.71	1.82	2.11	0.01	0.98		0.01	0.02		1.07	0.5
Pantoneura plocamioides	3.36									3.16	0.65	0.3
Antarcticothamnion polysporum	0.36							0.01		5.37	0.57	0.3
Iridaea cordata	1.45	0.65							0.85	1.59	0.45	0.2
Others	5.36	2.25					0.69		0.01	3.49	1.18	0.6
Total	364.81	354.07	28.71	64.16	28.24	193.80	92.48	358.11	247.46	313.08	204.49	100.0

floating ice with wave action, ephemeral species were mainly dominant in austral summer. The representative species were composed of thallic red algae *Palmaria decipiens*, *Gigartina skottsbergii* and *Curdiea racovitzae*. In clear and sandy rocky beaches, *Ascoseira mirabilis*, *Phaeurus antarcticus*, and *Myriogramme manginii* were frequently observed.

2) *Desmarestia* spp. assemblage (from 5 to 15 m): This zone free from the frequent ice abrasion was composed of the most representative assemblages in Maxwell Bay and also the various epifauna and epiflora. In the areas which were not severely affected by mud deposition, the zonation was expanded more downward.

3) *Himantothallus grandifolius* assemblage (below 15 m): This assemblage formed the hung curtains with their leathery blades down to 40 m deep. The zonation assumed different aspects in relation to the inclination of substrate and the extent of mud deposition and was occasionally expanded upward to 7 m.

Discussion

Littoral Zone

In the Antarctic Peninsula region including this study area, the littoral vegetation and perennial macroalgal assemblages are not developed well due to the periodic ice cover and abrasion by drift ice, while green algae *Urospora*, *Ulothrix*, *Enteromorpha*, *Spongomorpha*, and *Monostroma*; brown alga *Adenocystis*; red alga *Porphyra* are recorded as dominant species (Lamb and Zimmermann 1977; Picken 1985; KORDI 1988; Lüning 1990).

Since we observed the macroalgal assemblages in Maxwell Bay from 1988 (KORDI 1988; Chung *et al.* 1994; the present study), some algae *Enteromorpha*,

Cladophora, and *Spongomorpha* which were easily observed around the western coast of Barton Peninsula have been disappeared. Instead *Ulothrix australis* appeared as dominant species in the whole area, suggesting the changes of environment. It is a subject which should be solved through the continuous and detailed investigations to understand whether the changes were triggered by temporal and gradual changes or by local environmental changes.

On the littoral zonation in Maxwell Bay, Wu *et al.* (1989) reported that *Porphyra endiviifolium* at supralittoral zone and *Ulothrix australis* at littoral fringe were representative around Fildes Peninsula with gentle inclination. In the present study which was carried out mostly on the vertical rocks the results were contrary to theirs. Chung *et al.* (1994) observed similar reversal pattern at a flat rocky shore, and they found the same results in the rest of other sites with us. Vertical zonation of macroalgae showed clear vertical stratification distinctly on the steep rock with *U. australis* as the uppermost species rather than *P. endiviifolium*, although *U. australis* was frequently observed on the flectional rock of eulittoral zone.

At the eulittoral zone with gentle inclination various ephemeral species were patched mainly in tidepools. Most of them except *Enteromorpha bulbosa* were the species observed at the upper sublittoral zone, and it is recognized that the flora may be migrated from the sublittoral by tide and surge.

From in-door culture experiments on *Enteromorpha bulbosa*, Wiencke and Dieck (1990) reported it had an extended growth range from 20 to 25°C and could survive at the highest temperature among the experimented 14 Antarctic species. In the present study *E. bulbosa* was abundant in shallow tidepools with higher water temperature during the austral summer.

Sublittoral Zone

It is a characteristic trait of the Antarctic sublittoral macroalgal vegetation that the Laminariales are absent and the dominating canopy algae have been taken over by the Desmarestiales (Neushul 1965; Michanek 1979; Moe and Silva 1989; Lüning 1990). Comaring with the continental coast represented by *Phyllophora antarctica* (Zaneveld 1966b; Kirkwood and Burton 1988; Miller and Pearse 1991), especially the Antarctic Peninsula region shows marked dominance of the Desmarestiales (DeLaca and Lipps 1976; Richardson 1979; Zielinski 1981). Thus *Himantothallus* with fronds up to 10 m long grows beneath 5 m depth together with species of *Desmarestia* (mainly *D. menziesii* and *D. anceps*).

Most studies on the Antarctic macroalgae were carried out by relative coverage method due to the severe natural environment and the accompanying problem of logistics (Amsler *et al.* 1990, 1995; Miller and Pearse 1991; Westermeier *et al.* 1992; Chung *et al.* 1994; Gambi *et al.* 1994; John *et al.* 1994; Klöser *et al.* 1994). As the results it has been recognized that *Himantothallus grandifolius* is similar or higher in coverage than *Desmarestia* spp. among the above mentioned Desmarestiales. However, the results by harvest method are contrary to each other (DeLaca and Lipps 1976; the present study). Thus *Desmarestia* spp. of 40% is much higher in biomass than *H. grandifolius* of 27%. Because the coverage method is simply based on the covered substrate (Mueller-Dombois and Ellenberg 1974), the difference may be caused by that biomass of thallic *H. grandifolius* may be overestimated while the bushy *Desmarestia* spp. is underestimated. It is estimated that the dominance of *Desmarestia* spp. is particulary important in consideration of its role for the various epifauna and epiflora on the thalli.

On the other hand, small quadrats within one meter-square have been used on the sublittoral works in Antarctic Peninsula region recently (DeLaca and Lipps 1976; Richardson 1979; Amsler *et al.* 1990; Westermeier *et al.* 1992). Because of properties of the dominant species mentioned above, the small size can be overestimated in the standing stock. In the present study the larger one of which size was different each other in depth (see Materials and Methods) although a test for the minimal sample area was not carried out.

As the result of it macroalgal biomass appeared to be 204 g wet w m^{-2} average in total, indicating that

the overall biomass in Maxwell Bay is not so abundant. Also the variation among sampling sites was obviously from 28.7 g wet w m^{-2} (muddy and protected area) to 364.8 g wet w m^{-2} (rocky and exposed area). Unfortunately, except Richardson (1979) investigated at several localities in Signy Island, there has been no available data to compare with our data in the peninsula region. He estimated it at average 980 g wet w m^{-2} and maximum 2.1 kg wet w m^{-2}. Of course, we also observed some huge populations of perennial brown algae. But these partial standing stocks cannot illuminate the overall vegetation. Because the macroalgal assemblages are discontinuously patched in the center of naked rocky subsurface. In all bays of the peninsula region, a variable bottom sediment can not be fully utilized by macroalgae, resulting in unstable condition for the colonization due to physical factors such as a terrigenous mud deposition and ice formation (Richardson 1979; Griffith and Anderson 1989; Chung *et al.* 1994).

Various zonation arrangements have been mentioned by workers investigating the Antarctic Peninsula region (Neushul 1965; DeLaca and Lipps 1976; Richardson 1979; Zielinski 1981; Klöser *et al.* 1994, 1996). As a result of the present study three zones are recognized in Maxwell Bay. The zones could be grouped by 1) ephemeral species down to 5 m deep; 2) *Desmarestia* spp. from 5 to 15 m; and 3) *Himantothallus grandifolius* below 15 m. The array coincides with the previous results from other works, but the boundary depth is somewhat different each other. On the other hand, *Ascoseira mirabilis* has been shown up as an representative species with *Desmarestia* spp. in the middle zone (Richardson 1979; Zielinski 1981; Chung *et al.* 1994; Klöser *et al.* 1996). In the present study, they attain a lower level of 3.3% among the total weight. Considering them in detail, they make assemblages mainly at the areas (sites A, B, and I) of which transparency are relatively higher. Also they are observed in entrances of Admiralty Bay (Zielinski 1981) and Maxwell Bay (Klöser *et al.* 1996). It is finally estimated from the distribution patterns that they are dominant at rocky shore of clear waters.

Based on the analysis of macroalgal vegetation in the present study, the distribution patterns of major assemblages will be discussed later in relation to physical environmental factors around the micro-habitat.

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