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Influence of microenvironment on the spatial distribution of *Himantormia lugubris* (Parmeliaceae) in ASPA No. 171, maritime Antarctic

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Abstract

This study analyzed how spatial distribution of *Himantormia lugubris* is affected by the microenvironment in the Antarctic Specially Protected Area (ASPA) No. 171 located in the Barton Peninsula of King George Island that belongs to the maritime Antarctic. In order to determine the population structure of *H. lugubris* growing in Baekje Hill within ASPA No. 171, we counted the individuals of different size groups after dividing the population into 5 growth stages according to mean diameter as follows: ≤ 1 cm, 1-3 cm, 3-5 cm, 5-10 cm, and ≥ 10 cm. The count of *H. lugubris* individuals in each growth stage was converted into its percentage with respect to the entire population, which yielded the finding that stages 1 through 5 accounted for 32.8%, 25.3%, 15.9%, 22.5%, and 3.5%, respectively. This suggests that the population of *H. lugubris* in ASPA No. 171 has a stable reverse J-shaped population structure, with the younger individuals outnumbering mature ones. The mean density of *H. lugubris* was 17.6/0.25 m^2, mean canopy cover 13.3%, and the mean dry weight 37.8 g/0.25 m^2. It began to produce spore in the sizes over 3 cm, and most individuals measuring 5-10 cm were adults with sexually mature apothecia. The spatial distribution of *H. lugubris* was highly heterogeneous. The major factors influencing its distribution and performance were found to be the period covered by snow, wind direction, moisture, size of the substrate, and canopy cover of *Usnea* spp. Based on these factors, we constructed a prediction model for estimating the spatial distribution of *H. lugubris*. Conclusively, the major factors for the spatial distribution of *H. lugubris* were snow, wind, substrate and the competition with *Usnea* spp. These results are important for understanding of the distribution in the maritime Antarctic and evolution of *H. lugubris* that claims a unique life history and ecological niche.

Key words: Antarctic, ASPA, *Himantormia lugubris*, niche, spatial distribution, *Usnea* spp.

INTRODUCTION

Lichens and bryophytes are major vegetation in Antarctica. They are remotely related phylogenetically, but share similar habitats withstanding long periods of dryness and extreme temperature (Schroeter et al. 1995). Maritime Antarctic that includes King George Island has relatively temperate climate and high precipitation compared to continental Antarctic areas and it has relatively high species diversity and abundant biomass (Lewis Smith 1982, Lewis Smith and Poncet 1985). *Himantormia lugubris* is an endemic lichen of the maritime Antarctic. It

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Fig. 1. Growth form of the *Himantormia lugubris* (left, drawn by Kim ES) and image of *H. lugubris* and *Usnea antarctica* (right) on the gravel.

is distributed in subantarctic islands, South Georgia and South Shetland islands of the Antarctic Peninsula (Kappen and Schroeter 2002, Sojo et al. 2003). *H. lugubris,* a black-coloured fruticose lichen, contains black pigment all over its body and woody branch shaped fronds developed (Fig. 1, Kappen et al. 1987). *H. lugubris* has great tolerance to being covered with snow for a long time and to wind (Kappen and Redon 1987). Accordingly, it prefers exposed bedrock where there is strong wind on the edges of perpetual snow areas. These edges of perpetual snow areas according to changes in snowfall every year showed continuous change of depth and area of snow piling. *H. lugubris* has very slow growth rate. Also, it is easy to identify because of black color bodies (Fig. 1). *H. lugubris* and *Usnea* spp. are most important species among fruticose lichen that attached to the rock matrix of the mountainous highlands of Maritime Antarctic (Korea's Ministry of Environment 2013). Therefore, understanding of their initial establishment mechanism and cause of spatial distribution is very important in figuring out the composition principle of the Antarctic ecosystem.

Due to recent climate changes, many researchers are concerned with the changes of Antarctic ecosystem (Favero-Longo et al. 2012). Areas of glacial retreat newly created due to rise in temperature are good place to explore the principles of ecosystem development. There needs to be ecological research such as population structure, cause of spatial distribution and phylogenetic research of the dominant species for the understanding of ecosystem development. However, there are only a few ecological researches about main lichens and bryophytes in the Antarctic.

This study analyzed the influences of microenvironments on spatial distribution of *H. lugubris* population in the ASPA No. 171 area, a core ecosystem of the Barton Peninsula. The objectives of the work on the Baekje Hill with ASPA No. 171 were to determine the population structure of *H. lugubris*, describe the major factors influencing its distribution and performance, and construct a prediction model for estimating the spatial distribution of *H. lugubris*.

MATERIALS AND METHODS

Survey area overview

This study was conducted in Baekje Hill in the ASPA No. 171 area which was designated as Antarctic Specially Protected Area (ASPA) in the Barton Peninsula of King George Island (Korea's Ministry of Environment 2013). The location of the survey site was 62˚13′41.3″ S, 58˚45′35.2″ W and the range of altitude was 177 m ~ 213 m (Fig. 2). Substrates and soils of the peninsula are subdivided into four suites based on bedrock type, namely those on granodiorite, basaltic andesite, lapilli tuff, and the Sejong formation (Lee et al. 2004). The survey site Baekje Hill is located on the starting point of watershed on the north end with the highest elevation. The dominant species of this survey site are *Usnea* spp. and *H. lugubris*. Mosses are partially dominant on the planes of the lower slope (Korea's Ministry of Environment 2013, Choi 2014).

The surfaces of Barton Peninsula can be classified into large rock formation exposure area, Boulder dominant area, cobble dominant area, and pebble dominant area. The substrate of ASPA No. 171 is widely covered by cobble-boulder, cobble and cobble-pebble (Korea's Ministry of Environment 2013). In Barton peninsula, meteoro-

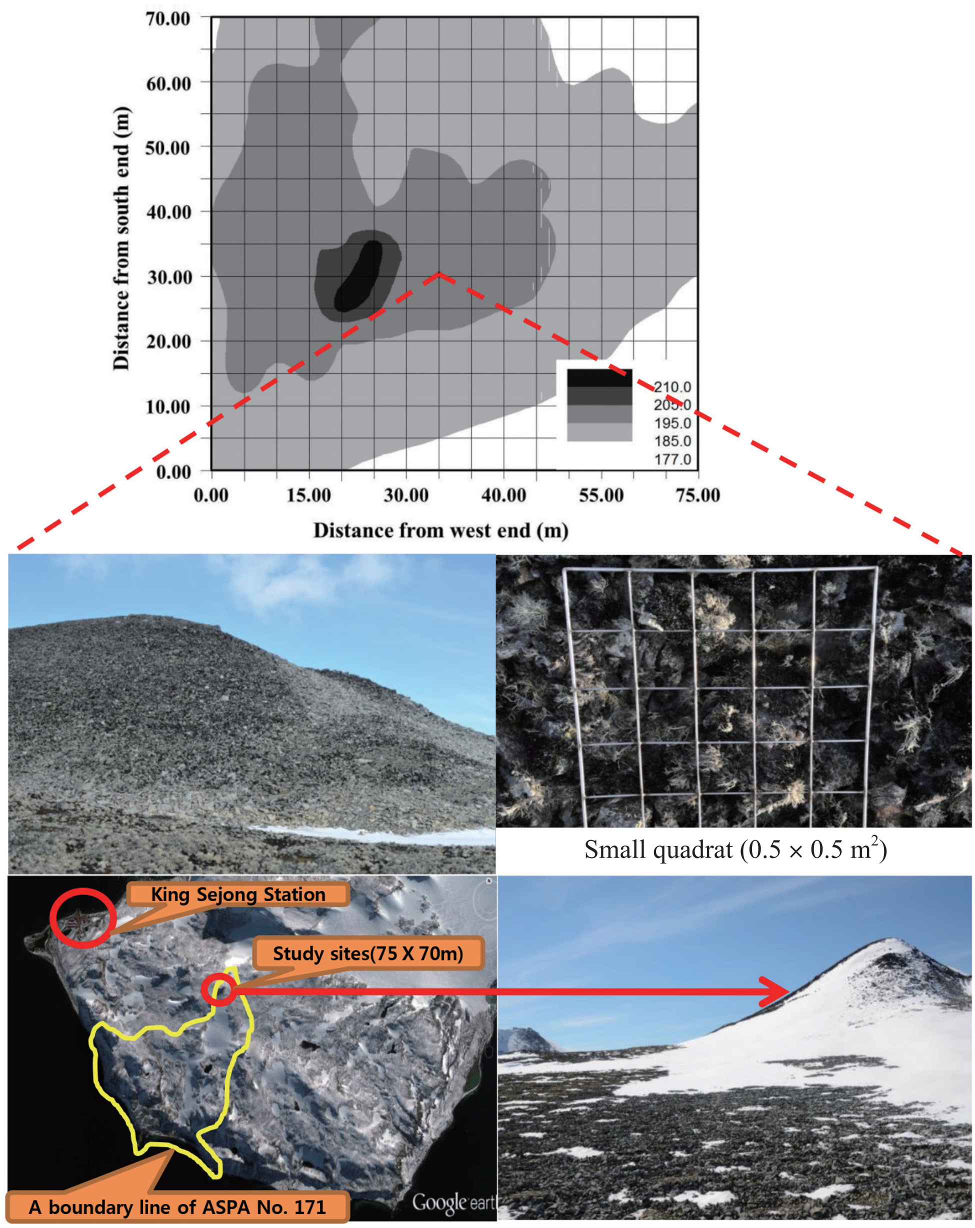

Fig. 2. Picture for locations of the permanent plot and mini-grids, landscape and survey grid in Baekje Hill located in the ASPA No. 171.

logical data have been collected from King Sejong Station since 1998. Annual mean temperature was 1.8˚C with an average summer temperature 1.6˚C (From December to February). The relative humidity and mean annual precipitation were 89% and 437 mm, respectively (Lee et al. 1997, Chung et al. 2004). From 1988 to 2013 the average temperatures of December, January, and February measured at the King Sejong Station were 0.9˚C, 2.0˚C, and 1.9˚C, respectively. In the same period the maximum average monthly temperature was 3.0˚C in January, 1997 and the minimum average monthly temperature was –0.7˚C in December, 2012 (Korea's Ministry of Environment 2013). In the analysis of the average wind speed by main direction of wind in January measured over three years from 2012 to 2014 at the King Sejong Station, the maximum wind speed in the Barton Peninsula was 26.9 m/s from southwest to northeast and the average wind speed from northwest to southeast was 7.4 m/s. The same period, the frequency of wind by main wind direction was the most frequent form southeast to northwest, northwest to southeast was the second most frequent, and south to north was the third most frequent (Choi 2014).

Installation of permanent plot

A permanent plot, sized 75 m × 70 m, was installed on Baekje Hill. It was sub-divided into 240 mini-grids of 5 m × 5 m size. The survey quadrats of 0.5 m × 0.5 m size were installed on the southern ends of each mini-grid. Height, coverage, density and size of each individual *H. lugubris* were investigated in the 0.5 m × 0.5 m quadrats. Phytological and environmental factors were also investigated in the same quadrats (Fig. 2).

Survey period

Phytological and environmental factors, and performance of *H. lugubris* were surveyed from 2013 December to 2014 February. Snow cover area to explain the snow melting period was drawn three times in December 2013, January 2014 and February 2014. All surveys were conducted on the field and images recorded with high resolution digital camera were utilized as complementary data.

Environmental factor

Environmental factors, such as elevation, aspect, slope inclination, topology, substrate and moisture gradient, were evaluated according to the standard methods described in Table 1 (Korea's Ministry of Environment 2013).

Phytological Factors

Height and coverage of vegetation and coverage of each lichens and bryophytes were surveyed in the 0.5 m × 0.5 m quadrats. Determination of species name was based on the morphological characteristics described by Ochyra (1998) for mosses (Bryopsida), and Øvstedal and Lewis Smith (2001) for lichens. Vegetation distribution patterns in quadrats were recorded using a high-resolution camera with over 12 mega pixels, and then the coverage of species was evaluated from the image.

To figure out the structure of *H. lugubris* population, using average width, it was classified into five size classes (class 1; under 1 cm, class 2; 1 cm-3 cm, class 3; 3 cm-5 cm, class 4; 5 cm-10 cm, class 5; over 10 cm). The structure of *H. lugubris* population was derived from composition ratio of size classes. Biomass of *H. lugubris* was calculated using the following allometric equation (Choi 2014).

$$\text{Dry weight (g)} = 0.0498\, e^{0.529x} \qquad \text{(Eq. 1)}$$

Here, x represents the average diameter of *H. lugubris* by each population size class.

By using size classes and density data in each quadrat, performance index and relative performance index of *H. lugubris* was calculated using the following equations (Eqs. 2 and 3).

$$\text{Performance index (PI)} = \sum (si \times d) \qquad \text{(Eq. 2)}$$

$$\text{Relative performance index} = \left(\frac{\text{PI}}{\text{PI (MAX)}}\right) \times 100 \qquad \text{(Eq. 3)}$$

Here, *si* represents size class, *d* represents density within quadrat, and PI(MAX) represents the maximum performance index.

Analysis and statistics

Descriptive statistics were calculated by using MS Excel 2010 (Microsoft, Raymond, WA, USA). Correlation and

Table 1. Classification into categories of the environmental variables

Environmental variables	Category									
	1	2	3	4	5	6	7	8	9	10
Altitude (m)	< 190	190-200	> 200	-	-	-	-	-	-	-
Aspect (dd)	270-360	0-90, 180-270	90-180	-	-	-	-	-	-	-
Inclination (dd)	0-5	5-10	10-15	15-20	20-25	25-30	30-35	> 35	-	-
Topology	summit	ridge	upper slope	middle slope	lower slope	arid valley	strem flow	pond or wet land	-	-
Substrate	rock	boulder	boulder-cobble	cobble	cobble-pebble	pebble	pebble-fine grain	coastal sand	fine grain	humus
Moisture	very arid	arid (moss cover; < 5%)	moderate (moss cover; 5-20%)	slightly wet (moss cover; 20-60%)	wet (moss cover; 60-80%)	very wet (moss cover; > 80%)	snow	-	-	-

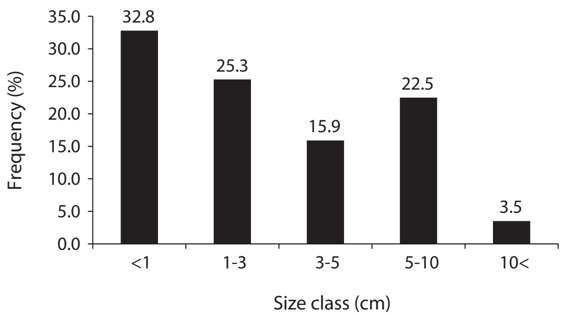

Fig. 3. Diagram for distribution ratio of size class of the *Himantormia lugubris* in the permanent plot located in the ASPA No. 171.

regression analysis were conducted using SYSTAT ver. 12.0 (SYSTAT Software Inc., San Jose, CA, USA). Spatial distribution chart was produced by using GS+ (Robertson 1998).

RESULTS

The spatial distribution of *Himantormia lugubris* population

The population structure of *H. lugubris* was evaluated at Baekjae Hill in the Antarctic Specially Protected Area (ASPA No. 171). By measuring the diameter of all individuals appearing in the permanent quadrats, composition ratio according to size classes was calculated. The size classes were classified into five types according to width. Relative abundances of class 1 through class5 were 32.8%, 25.3%, 15.9%, 22.5%, and 3.5%, respectively (Fig. 3). Individuals belonged to small size class were the most frequent and it showed a stable reverse J shaped population structure where the ratio decreases gradually with increase of size classes (Fig. 3). Apothecia were hardly observed in class 1 and class 2 individulas, but it is produced on class3 (3-5 cm wide) and bigger lichen thalli. Most of the class 5 (> 10 cm wide) *H. lugubris* contained apothecia.

Spatial distribution characteristics, such as coverage, density according to size class, biomass and relative performance index, were summarized in Table 2. Coverage of *H. lugubris* ranged between 0 and 89%, average coverage was 13.3% and coefficient of variation was 139.7%. Density of *H. lugubris* ranged between 0 and 102 individuals per 0.25 m². Average density was 17.6 individuals per 0.25 m² and showed very high spatial variation. Density of *H. lugubris* that corresponded to class 1 had range of 0~62 No./0.25 m², those that corresponded to class 2 had range of 0~48 No./0.25 m², those that corresponded to class 3 had range of 0~22 No./0.25 m², those that corresponded to class 4 had range of 0~27 No./0.25 m², and those that corresponded to class 5 had range of 0~14 No./0.25 m². The mean density that belonged to class 1, class 2, class 3, class 4 and class 5 were 5.8, 4.5, 2.8, 4.0, and 0.6 No./0.25m², respectively. Mean density of class 5 were 10.3% of mean density of class 1. Spatial distribution of class 1, class 2, and class 5 showed relatively large variation. The largest spatial variation was showed in class 5. Relative performance index of *H. lugubris* showed range of 0~100% and there was very large spatial variation. The dry weight of *H. lugubris* by unit area was on average 37.8g/0.25 m². Density of *H. lugubris* that belonged to class 5 also showed very large skewness and kurtosis. This represents that *H. lugubris* individual of large size biased to one side showing intensive distribution (Table 2). The isopleths of the major growth properties of the

Table 2. Statistics of population characteristic of *Himantormia lugubris*

Property	Units	Mean	SD	CV (%)	Skewness	Kurtosis	*N*
Coverage	%	13.3	18.6	139.7	2.27	1.58	240.0
Density	No / 0.25 m^2	17.6	22.7	129.0	2.08	1.45	240.0
1 class of size	cm, No / 0.25 m^2	5.8	10.3	178.8	9.24	2.77	240.0
2 class of size	cm, No / 0.25 m^2	4.5	7.3	162.4	8.58	2.55	240.0
3 class of size	cm, No / 0.25 m^2	2.8	4.2	151.5	2.86	1.77	240.0
4 class of size	cm, No / 0.25 m^2	4.0	5.5	139.3	1.15	1.34	240.0
5 class of size	cm, No / 0.25 m^2	0.6	1.5	249.2	27.96	4.35	240.0
Relative performance index	%	21.0	25.4	120.6	-0.30	0.93	240.0
Dry weight	g / 0.25 m^2	37.8	4.8	12.6	3.56	19.00	240.0

All values were untransformed and calculated based on *N* sample locations.
SD, standard deviation; CV, coefficient of variation.

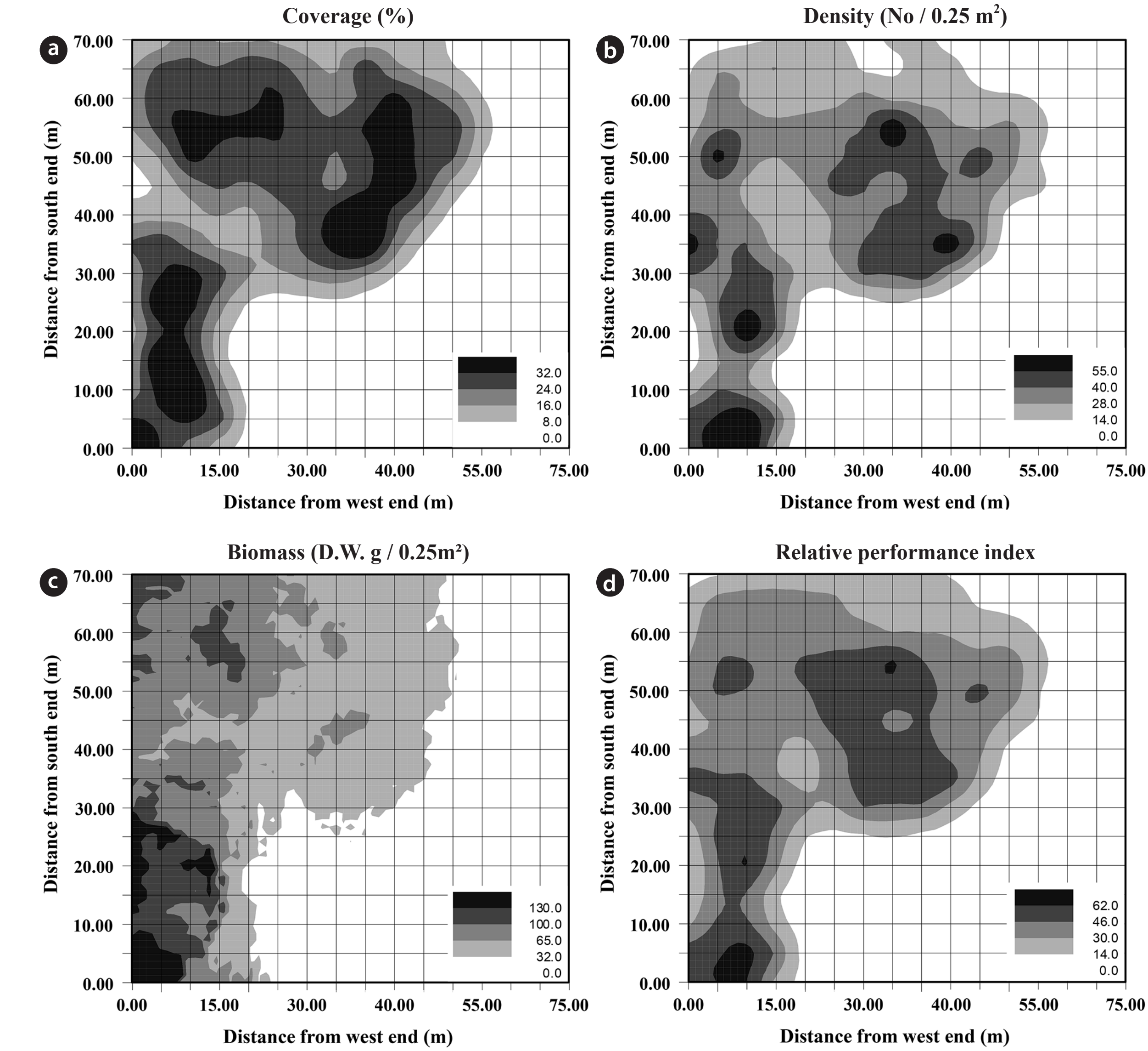

Fig. 4. Isopleths of growth state of *Himantormia lugubris* in the permanent plot located in the ASPA No. 171.

H. lugubris population were represented in Fig. 4. The highest coverage of *H. lugubris* was observed in northern and southwestern surface parts of Baekjae Hill (Fig. 4a). Density distribution was similar to coverage distribution pattern. There were five highly dense sites in northern and southwestern surface parts (Fig. 4b). Biomass was higher in western part than eastern parts and the highest biomass was observed in southwestern parts (Fig. 4c). Relative performance index, which was calculated based on size class and density was relatively high in the upper slope of the northern slope and southern parts. Relative performance index was high in areas with high coverage and density (Fig. 4d).

The spatial distribution of the main environmental factors

Average values of the major environmental site factors, standard deviation, and coefficient of variation were summarized in Table 3. In the survey area, elevation ranged between 177 and 213 m, slope inclination ranged between 0 and 57°, topology rating ranged between class 1 and class 5, substrate rating ranged between class 3 and class 6, moisture rating ranged between class 2 and class 7, and coverage of snow ranged between 0 and 100%. Among environmental factors, substrate, moisture, and coverage of snow showed relatively large spatial variation within the

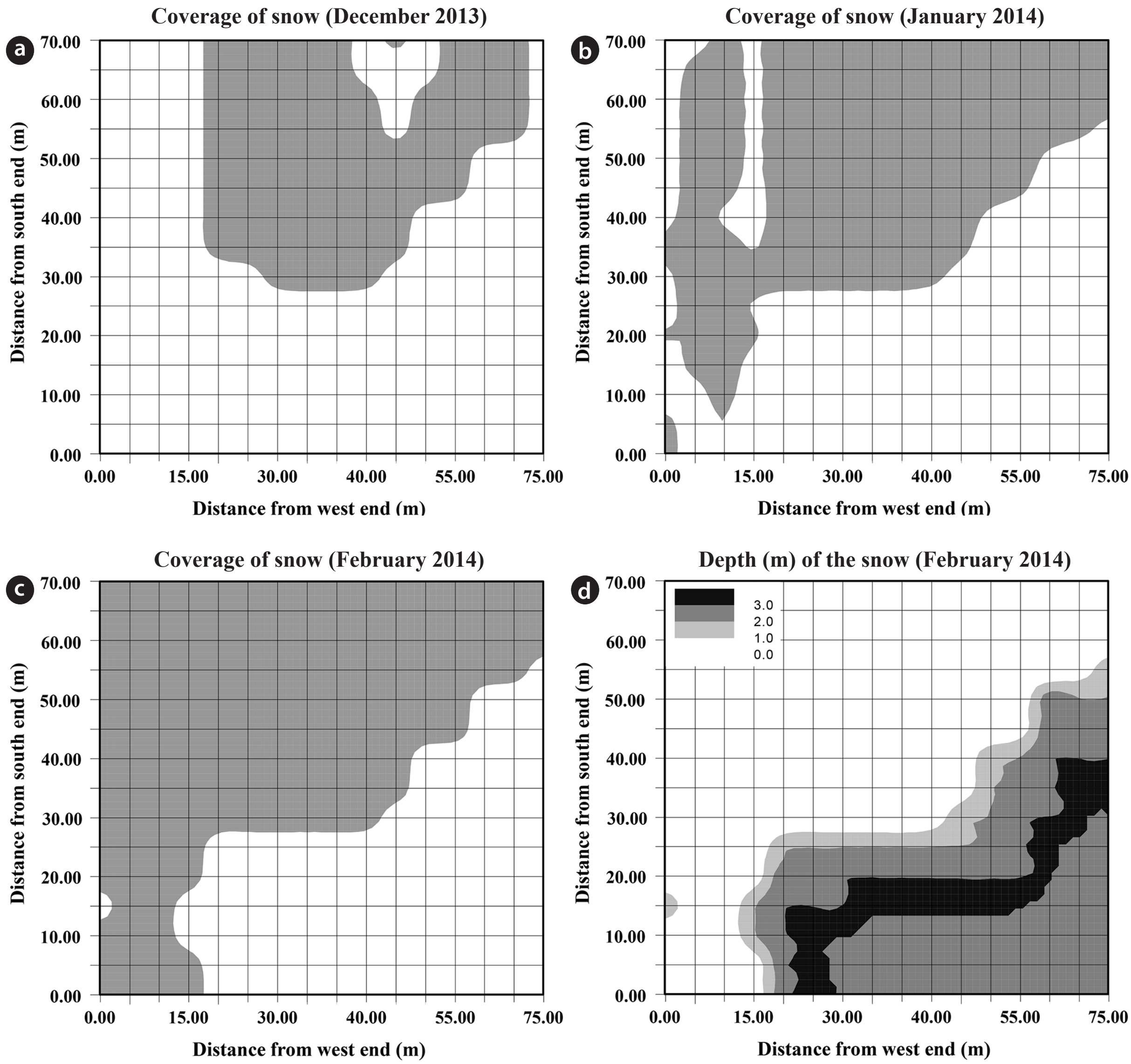

Fig. 5. Spatial distribution of coverage and depth of the snow in the permanent plot located in the ASPA No. 171. White area is covered by snow.

Table 3. The values of environmental factors in the permanent plot located in the ASPA No. 171

Property	Units	Mean	SD	CV (%)	Skewness	Kurtosis	*N*
Altitude	m	191.1	7.3	3.8	-0.13	0.50	240
Slope aspect	°	188.3	101.6	53.9	-0.64	0.20	240
Slope degree	°	21.4	8.9	41.8	1.25	-0.17	240
Topology		3.1	0.8	24.5	3.89	0.28	240
Substrate		2.9	2.6	89.3	-0.73	0.18	240
Soil moisture		4.3	2.4	55.2	0.26	-1.85	240
Coverage of snow	%	40.6	49.0	120.7	-1.87	0.38	240
Coverage of *Usnea*	%	16.8	23.2	138.0	1.33	0.77	240

All values are untransformed and calculated on the basis of *N* sample locations.
SD, standard deviation; CV, coefficient of variation.

permanent quadrat (Table 3). The isopleths that represents elevation well represents the topography of Baekjae Hill (Fig. 2). The point of highest elevation is 30 m from the south and 25 m from the west and the lowest area was the southeastern area of the permanent quadrat (Fig. 2). For slope, near the southeast face and northwest face of the top were more steeper than other parts. For substrate boulder-cobble, cobble, and cobble-pebble were widely distributed, and cobble was dominant overall. For moisture supply, apart from the southeastern slope that was covered with snow, the northeast was relatively humid compared to other sites. The snow started melting from the area of the northwest slope that was most strongly influenced by wind. Therefore the area near the southeast slope that was least influenced by wind was always covered in snow. The area that was continually covered with snow was the southeast parts (Fig. 5).

H. lugubris and *Usnea* spp. are widely distributed in areas of the survey site where snow had melted. The average coverage of *Usnea* spp. was 16.8% which was relatively higher than that of *H. lugubris*. Coefficient of variation of coverage of *Usnea* spp. was very large with 138% (Table 3). Whereas the relative performance index of *H. lugubris* being high on the upper middle areas of the slope, the coverage of *Usnea* spp. was high in the lowland planes of the northern parts.

Factors that influence spatial distribution of *H. lugubris* population

Coverage, density, mean size, biomass, and relative performance index of *H. lugubris* population showed positive correlation with elevation and showed strong negative correlation with aspect, moisture conditions,

Table 4. Pearson correlation coefficients between environmental factors and distribution of population of the *Himantormia lugubris* in the permanent plot

Property	Altitude	Aspect	Slope	Topology	Substrate	Moisture	Period of snow cover	Coverage of snow	Coverage of *Usnea*
Coverage(%)	0.36***	-0.47***	-0.02	-0.14*	-0.13*	-0.64***	-0.55***	-0.59***	0.28***
Density (No. / 0.25m^2)	0.45***	-0.53***	0.01	-0.24***	-0.41***	-0.70***	-0.56***	-0.64***	0.15*
Mean width Size (cm)	0.28***	-0.51***	-0.21**	0.14*	0.09	-0.71***	-0.64***	-0.73***	0.60***
Density of size class 1 (No. / 0.25m^2)	0.34***	-0.36***	0.02	-0.19**	-0.34***	-0.51***	-0.38***	-0.46***	-0.02
Density of size class 2 (No. / 0.25m^2)	0.31***	-0.45***	0.01	-0.20**	-0.33***	-0.56***	-0.46***	-0.51***	0.14*
Density of size class 3 (No. / 0.25m^2)	0.44***	-0.46***	0.06	-0.20**	-0.05	-0.60***	-0.48***	-0.55***	0.16*
Density of size class 4 (No. / 0.25m^2)	0.42***	-0.47***	-0.07	-0.18**	-0.05	-0.65***	-0.55***	-0.60***	0.30***
Density of size class 5 (No. / 0.25m^2)	0.24***	-0.33***	0.05	-0.11	-0.03	-0.36***	-0.25***	-0.32***	0.10
Biomass (g D.W. / 0.25m^2)	0.31***	-0.40***	0.03	-0.13*	-0.04	-046***	-0.34***	-0.42***	0.15*
Relative performance Index (%)	0.49***	-0.57***	-0.00	-0.24***	-0.20**	-0.75***	-0.61***	-0.68***	0.22***

$^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

Table 5. Comparison of coverage, density, relative performance index and biomass of the *Himantormia lugubris* among period covered by snow located in the permanent plot located in the ASPA No. 171

Variables of *H. luguburis*	Months covered by snow during summer season			
	0	1	2	3
Coverage (%)	22.2 ± 19.0^{ab}	27.9 ± 22.5^{a}	14.9 ± 14.0^{b}	0.2 ± 1.6^{c}
Density (No./0.25m^2)	28.6 ± 21.2^{a}	32.9 ± 25.7^{a}	27.6 ± 22.8^{a}	0.2 ± 1.5^{b}
Mean width (cm)	3.6 ± 2.1^{a}	4.4 ± 2.3^{a}	3.4 ± 2.1^{a}	0.1 ± 0.6^{b}
Relative performance index (%)	34.2 ± 23.6^{a}	40.6 ± 25.9^{a}	31.1 ± 22.1^{a}	0.2 ± 1.4^{b}
Biomass (g D.W./0.25m^2)	45.8 ± 54.1^{a}	108.1 ± 131.0^{b}	43.0 ± 47.5^{a}	0.9 ± 9.1^{c}

According to Tukey's test, columns are statistically different where they do not share any letter ($P < 0.05$).

substrate, cumulative period of being covered in snow, and coverage of snow (Table 4). The relative performance index of *H. lugubris* was relatively high in areas of high elevation, northern slope, areas with relatively large sized substrate, and humid areas where snow melted well (Table 4). Also, relative performance index of *H. lugubris* population showed positive correlation with coverage of *Usnea* spp. Especially mean size and density of class 4 of *H. lugubris* showed high positive correlation with coverage of *Usnea* spp.. This means that although *H. lugubris* of large-size prefers site conditions similar to *Usnea* spp., *H. lugubris* of small size established in different site conditions (Table 4). In addition, the establishment of the small size individuals of *H. lugubris* was strongly influenced by substrate (Table 4). Table 5 is a comparison of major properties of *H. lugubris*, according to the period covered by snow in summer. In areas where there is no snow or covered for about one month during the summer, the major property values of *H. lugubris* was larger than for areas that were covered in snow for long-term. However, the biomass of *H. lugubris* was larger in areas that were covered in snow for one month compared to areas without snow. Although statistical differences were not confirmed in other properties, the average values showed the higher in areas that were covered in snow for one month than those of areas without snow.

Table 6 is a multiple regression model to explain the spatial distribution of relative performance index of *H. lugubris* in the survey area. The tolerance values to explain multicollinearity among independent variables ranged between 0.574 and 0.954. The relative performance index of *H. lugubris* can be 66.2% explained of its total variation with four factors moisture, topology, coverage of *Usnea*, and slope. The most important factor among these is the moisture conditions and with this one factor, 56.4% of the total variation can be explained. With the three factors moisture, topology, and coverage of *Usnea*, 65.4% of spatial distribution variation of relative performance index of *H. lugubris* can be explained.

DISCUSSION

H.imanantormia lugubris that is dominant in Baekjae Hill in the Antarctic Specially Protected Area 171, a core ecosystem of Barton Peninsula. It is a representative fruticose lichen that appears in maritime Antarctic. *H. lugubris* is an endemic species of these areas. Thus climate conditions of these areas can exert selection pressure about specific adaptation of *H. lugubris*. The structure of population of *H. lugubris* in Baekjae Hill in the Antarctic Specially Protected Area 171 was analysed. It showed stable reverse J shape population structure. Also, because the population size was very large and the establishment of young individuals on the newly exposed substrate in the slopes with high winds was very active, it is determined that it also has high sustainability (Fig. 3 and Table 2). Generally, individuals over the size of 3 cm start to form apothecium and more than 80% of individuals over the size of 5 cm formed apothecium. This means that ample number of spores for new population settlement of *H. lugubris* is created in this area. There are very few studies about population ecology focusing on Antarctic vegetation. Kim and Chung (2004) had figured out population structure in 7 coverage classes on *Deschampsia antarctica* where its influence is becoming larger due to recent climate warming. This study used average diameter size to classify into five stages of *H. lugubris*. To evaluate appropriate population structure and sustainability for the conservation of maritime Antarctic, there needs to be more population ecological researches such as population size, population structure and key of classification of life stages of the major lichens, mosses, and flowering plants.

The factors that influence spatial distribution of *H. lugubris* at Baekjae Hill in the Antarctic Specially Protected Area 171 were elevation, aspect, topology, substrate, moisture, duration of snow cover, and *Usnea* spp. (Fig. 4 and Tables 4-6) (Choi 2014, Shin et al. 2014). The most important factor among these is the moisture conditions of the ground surface (Table 6). Apart from spatial dis-

Table 6. Multiple regression for spatial distribution of relative performance index of *Himantormia lugubris* in the permanent plot

Variables	Regression coefficients	Partial R^2	Cumulative R^2	Tolerance	P
Constant	78.809				0.000
Moisture	-9.441	0.564	0.564	0.655	0.000
Topology	-6.756	0.066	0.630	0.856	0.000
Coverage of *Usnea*	-0.203	0.024	0.654	0.574	0.000
Slope	1.384	0.008	0.662	0.954	0.021

tribution of *H. lugubris*, the thing that most importantly applies to distribution of other vegetation is moisture gradient of the ground surface (Shin et al. 2014). Therefore, the most primarily important factor that explains the distribution of vegetation in the survey area is the causality between environmental factors that can decide exposure and moisture conditions of the ground surface. Also, important factor is the ecological niche differentiation between species that have similar ecological niche (Choi 2014). In this survey area, *H. lugubris* and *Usnea* spp. are strong competitors that prefer similar ecological niche (Choi 2014). However while *Usnea* spp. showed high coverage where there was no snow for long-term, *H. lugubris* showed the highest performance in areas where it was covered in snow for one month during the summer and there was highest distribution of biomass in that area (Table 5). Also, spatial distribution of young *H. lugubris* of small size had no relation with spatial distribution of *Usnea* spp.. The new establishment of young individuals is the site with strong winds and the primary snow area with course substrate where it is difficult for *Usnea* spp. to establish (Table 4). This means that ecologic niche is differentiated between *H. lugubris* and *Usnea* spp. in this survey area. While *Usnea* spp. prefers cobble-pebble areas with relatively fine substrate in a lowland with low influence of wind, *H. lugubris* prefers boulder-cobble areas with relatively course substrate in a high land upper slope with high influence of wind (Choi 2014). However, because the scale of this survey area was small, research about niche breadth and differentiation of the two species should be conducted in larger scale where the survey area is larger. Because the survey area was located on the highest elevation point in the Antarctic Specially Protected Area 171, This area was exposed to strong winds. The main source of moisture in this area is snow. Accordingly spatial and temporal distribution variation of snow can have a very important influence on the vegetation in this area (Lee and Cho 2000a, 2000b, Lee et al. 2002, Chung et al. 2004). There is very active relocation of snow due to winds in this area and these changes according to elevation, topology, irregularities of ground surface, and substrate. Then wind direction, wind speed, and frequency can have large influences on spatial distribution of *H. lugubris* (Choi 2014). Exposure and moisture conditions of ground surface caused by different distribution and duration of snow had influence on growth and habitat scale of plants (Lee and Cho 2000a, 2000b). Hence, it is proposed that *H. lugubris* grows slowly after establishment on the mounds, rock and gravel with adequate moisture from melting snow (Green et al. 1999).

In conclusion, because *H. lugubris* copes with very harsh environments and lives for a long time with very slow growth rate, it is proposed that it has clear K strategy and stress tolerance strategy (Sojo et al. 2003, Sancho et al. 2007, Kappen 2000). *H. lugubris* initially establish in an area where there is nearly melted snow with strong winds and it has slow growth rate. Therefore, it is determined that *H. lugubris* is a species that very sensitively response to spatial and temporal distribution of snow due to climate fluctuation and retreat of glaciers following climate change. *H. lugubris* that shows diverse responses according to changes in time and space and microenvironment has high utilization value as a biological indicator for long-term ecological research. This study elucidated the distribution causes of *H. lugubris* in a limited space and time scale. Consequently, to understand the distribution, adaptation, and evolution of *H. lugubris*, there needs to be research for long-term responses in a multi space scale.

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