B070

The Relationship between Microenvironmental Features and Distribution of Lichen *Cladonia* in Antarctica

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ABSTRACT

The Barton Peninsula of King George Island, Antarctica, is a small area but their topographical features including a variety of slopes, aspect, and elevation result in a various microclimate and diverse vegetation such as lichens, mosses, liverworts, and vascular plants. Among terrestrial vegetation, lichens are sensitively affected nearby environmental condition because the whole body of a lichen is directly exposed to external environments. However, the environmental factors that largely determine the distribution of lichen in Antarctica have been poorly understood across the Barton peninsula. To investigate the distribution pattern of lichens *Cladonia squamosa* and *C.gracilis* complex that are widely distributed in Barton Peninsula and the factor that influences their distribution, a total of 177 *Cladonia* samples were collected in 11 different sites and frequency of distribution of vegetation, microclimatic and topographic data were obtained at each site. There were several sites, which were observed to inhabit only one species of *Cladonia*. Correlation analyses between the distribution of *Cladonia* species and environmental data revealed that distribution of moss *Chorisodintium aciphyllum*, the periode of snow accumulation, and moisture were closely related to a distribution of *Cladonia* species. These results imply that various geographical features and microclimate conditions can affect the distribution of lichen and environmental shift may cause a change in a distribution of vegetation.

MATERIALS and METHODS

Cladonia squamosa and *C.gracilis*

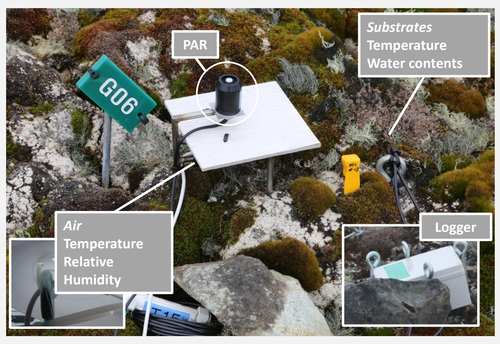
The Genus Cladonia is one of the most morphologically diverse lichen taxa in Antarctica and widespread on Barton Peninsula. C. squamosa and C. gracilis have similar features those are absent of scyphi or if present, not wider than podetical stalk and have a brownish color and slender thalli shaped. It usually grows on mosses and liverwarts and usually forms colonies composed of many slender thalli. It is difficult to distinguish directly from the field. Total 177 Cladonia samples belonged to C.squamosa and C.gracilis were collected in 11 different sites in Barton Peninsula.

Nuclear LSU rRNA gene sequence analysis for microbial community

DNA extraction	Whole genome
PCR	Nuclear LSU rRNA gene Bacterial 16S rRNA gene
Sequencing	454 GS-FLX Titanium PacBio RSII
Trimming	PyroTrimmer (Oh et al., 2012)
Clustering	Clustom (Hwang et al., 2013)
Chimera check	UCHIME (Edgar et al., 2011)
Taxonomic assignment	MycoDE and RDP (nucLSU)
Statistical analyses	Primer6 & PERMANOVA+

Microclimate mornitoring

Data logger and sensors installed KGL sites in Barton Peninsula. The data logger sets consist of PAR, air temperature, relative humidity, water contents and temperatere of substrates.



Floral distribution survey

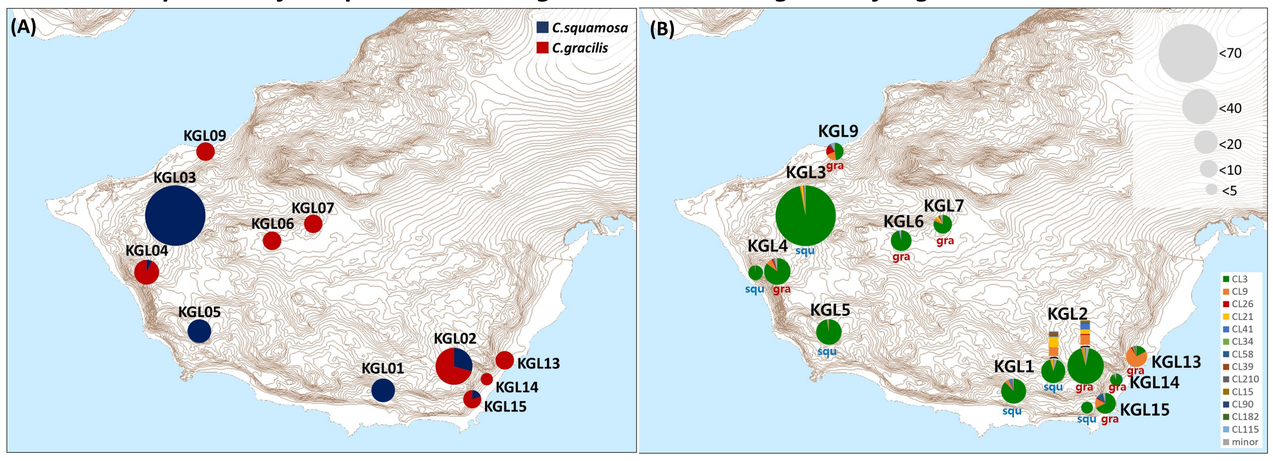
Total 154 research sites for identifying distribution of vegetation were investigated with quadrat of 50 x 50 size consisted of 5 x 5 cell. High-resolution images up to 9 were obtained on a site and we counted their frequencies for 11 lichens, 15 mosses, and 2 plants

Geographic data

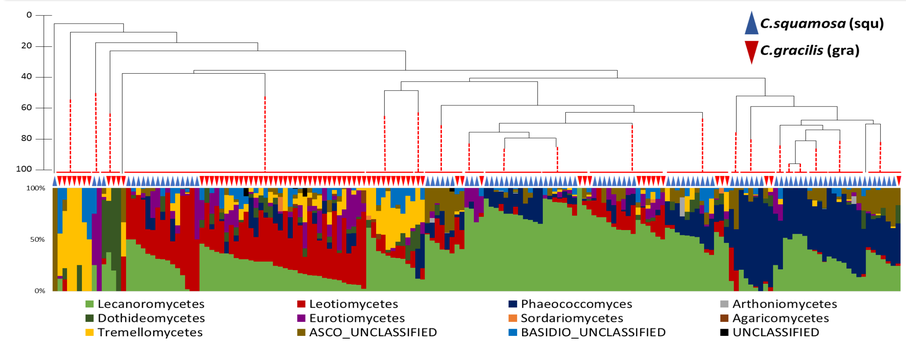
Five resolution digital elevation model (DEM) included elevation of each 5m x 5m area was rasterized on the ArcGIS Pro (ESRI).

RESULTS

Distribution pattern of C. squamosa and C.gracilis and their algal and fungal communities



▲ **Distribution pattern (A) and Algal communieis (B) of *C.squamosa* and *C.gracilis* in Barton Peninsula (A) Two morphologically similar species, *C.squamosa* and c.graciis inhabited different sites in Barton Peninsula. While middle altitude area, KGL01, KGL03, and KGL05 only detected *C.squamosa*, *C.gracilis* were only detected in near by shore or high altitude areas.**
(B) Symbiotic algal communities in *C.squamosa* and *C.gracilis* appeared different pattern. The algal community in *C.gracilis* inhabiting near by shore were the most diversed. In the presence of both species in the same area, the algal diversity of Cladonia gracilis (CL2) was higher than *C.squamosa*



◀ **The group averaging cluster analysis of LAF communities based on Bray-Curtis similarity of OTU abundance.**
The black lines indicate significantly supported clusters by the SIMPROF test (P<0.05) and the dashed lines indicate clusters those were not. In case of LAF, *Lecanoromycetes* and *Phaeococcomyces* were dominant in C.squamosa and *Leotiomycetes* and *Tremellomycetes* were dominant in *C.gracilis*.

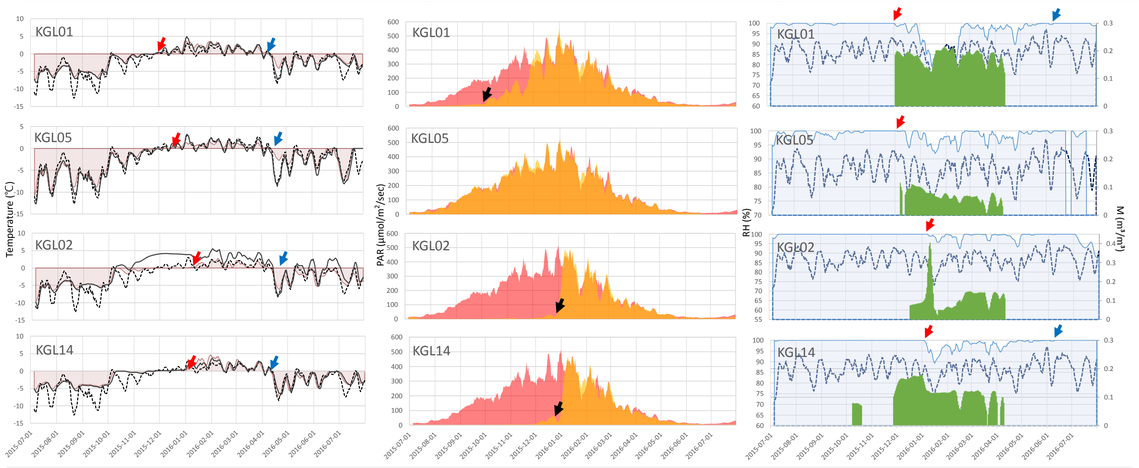
Mycobiont	Chlorophyta						Lichen-associated fungi					
	richnessS		Shannon (H')		Equitability (J')		richnessS		Shannon (H')		Equitability (J')	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	aver	sd
C.squamosa	2.67	1.46	0.22	0.27	0.23	0.18	9.71	5.52	1.67	0.69	0.82	0.15
C.gracilis	4.07	3.15	0.62	0.48	0.53	0.24	13.23	6.77	2.05	0.74	0.87	0.11

◀ **Diversity indices of algae belonged to Chlorophyta and Lichen-associated fungal communities according to mycobiont type. Diversity indices of each group were presented at mean and standard deviation (sd).**
Chlorophyta and LAF communities of *C.gracilis* showed higher diversity indices than those of *C.squamosa*

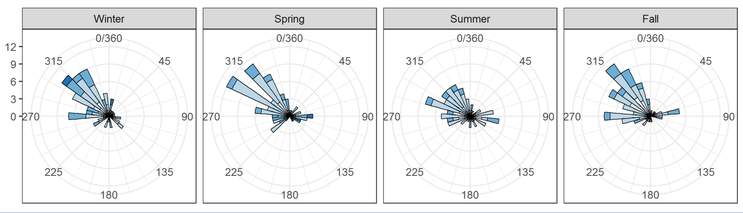
Microclimate patterns

▼ **Site information of KGL site in Barton Peninsula** Average (max/min)

Site	Latitude	Longitude	Elevation (m)	Annual mean air temerature (AT, ℃)	Annual mean relative humidity (RH,%)	Annual mean photosynthetic active radiation (PAR,μmol/m²/sec)	Annual mean substrate temperature (ST, ℃)	Annual mean water content in substrate (M,m³/m³)	Site description
KGL01	62, 14' 25.819" S	58, 44' 32.341" W	31.935	-1.67 (2.3/-6.03)	98.2 (100/92.57)	119.46 (361.99/1.59)	-1.37 (2.51/-5.46)	0.1 (0.19/0.04)	Gradual slope nearby lake
KGL02	62, 14' 17.032" S	58, 43' 46.447" W	74.964	-0.63 (4.16/-6.7)	99.61 (100/98.58)	76.38 (369.34/1.22)	-1.69 (2.24/-6.35)	0.07 (0.2/0.01)	Slope near by wetland
KGL03	62, 13' 29.932" S	58, 46' 40.236" W	84.916	-2.35 (1.61/-7.33)		131.54 (358.77/8.09)	-2.1 (2.46/-7.59)	-0.03 (0.02/-0.11)	Slope with rocks covered with moss and lichen
KGL04	62, 13' 47.772" S	58, 46' 54.163" W	93.015	-2.36 (1.6/-7.17)	99.32 (100/97.02)	107.06 (350.04/2.15)	-1.86 (2.29/-6.18)	0.03 (0.11/-0.01)	Gradual slope nearby Giant Pattrol habitats
KGL05	62, 14' 4.2577" S	58, 46' 20.369" W	87.34	-2.72 (1.51/-7.95)	98.41 (100/96.99)	162.92 (380.23/7.92)	-2.26 (1.34/-7.37)	0.03 (0.1/-0.03)	Hill on the Penguin habitats
KGL06	62, 13' 39.635" S	58, 45' 33.534" W	186.912			151.4 (407.22/6.69)	-2.55 (2/-7.94)	0.12 (0.25/0.04)	High altitude area under the Silla hill
KGL07	62, 13' 35.516" S	58, 45' 12.543" W	186.921	-3.06 (1.55/-7.83)	98.74 (100/95.87)	99.44 (276.36/3.31)	-2.64 (2.14/-7.1)	0.08 (0.18/-0.03)	High altitude area under the Backje hill
KGL09	62, 13' 13.312" S	58, 46' 18.929" W	9.963	-1.26 (2.6/-6.43)	97.18 (100/89.32)	114.4 (382.11/2.85)	-0.7 (3.56/-5.55)	0.08 (0.15/0.03)	mixed habitat nearby Marian cove
KGL13	62, 14' 15.904" S	58, 43' 17.305" W	13.052	-1.51 (2.9/-6.71)	97.4 (99.99/92.42)	123.59 (353.6/3.25)	-0.99 (3.54/-5.7)	0.02 (0.08/-0.04)	mixed habitat very close to Potter cove
KGL14	62, 14' 21.123" S	58, 43' 29.213" W	15.918	-1.31 (2.99/-5.66)	98.66 (100/95.64)	68.02 (288.61/1.48)	-0.98 (3.93/-5.2)	0.03 (0.17/-0.03)	flat habitat covered with moss nearby potter cove
KGL15	62, 14' 26.692" S	58, 43' 34.247" W	14.271	-0.97 (2.95/-4.14)	98.48 (100/94.58)	65.71 (277.45/1.23)	-0.52 (3.61/-3.47)	0.05 (0.14/-0.01)	flat habitat under the steep slope nearby potter cove

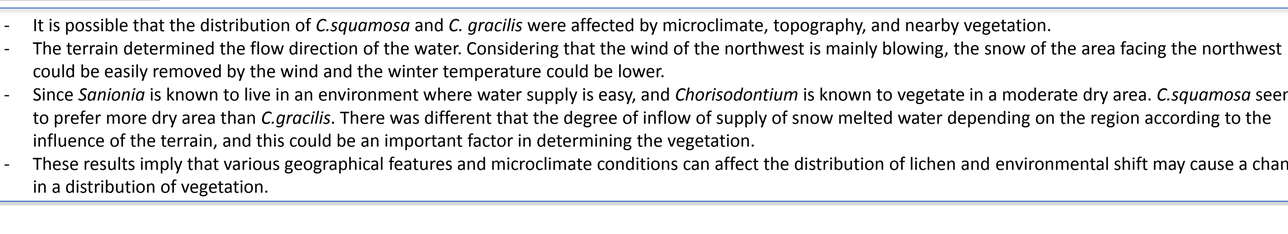


▲ **Microclimate data in 2015-2016, The sites of KGL01 and KGL05 only existed *C.squamosa* and the sites of KGL14 and KGL02 only existed C.gracilis. The *C.squamosa* site does not accumulate snow deeper enough to illuminate nearby vegetation around October, and then slowly begins to melt. In early December, the snow melted completely, the relative humidity was lowered. And the temperature rose up to zero. On the other hand, the snow of *C.gracilis* sites melted rapidly from the end of December, and snow completely melted by early January. And the temperature goes up to zero. The relative humidity became similar to the atmospheric environment.**



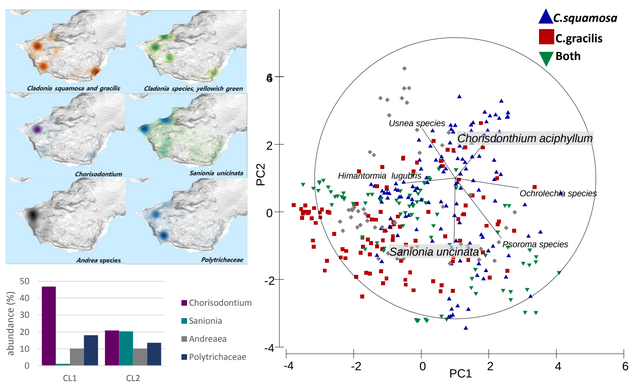
◀ **Wind direction and speed in Barton Peninsular in 2015-2016**
The Baton Peninsula was mainly a northwest wind blowing all four seasons, but sometimes an east wind blowing.

Topography



▲ **Topography in Barton Peninsula (A) Aspect of slope. East and south areas faced to east to north side, and west and north areas faced to west to north. This may be related to water flow, which can be an important factor in determining vegetation.**
(B) A hillshade in Barton peninsular, that is a grayscale 3D representation of the surface,with the sun's relative position taken into account for shading the image. Sites in the southeastern region are less exposed to the sun than in the northwest. (C) Altitude of Barton Peninsular. The Barton Peninsula tended to become higher inland as the altitude increased.

Floral distribution



Correlation

variable	Posively correlated variables	Negatively correlated variables
Cladonia squamosa (CL1)	AICL3(0.43)*, Lecanoromycetes(0.46)*	Aspect.sin E.W.(-0.48)*, CL2(-1.0)**, Leotiomycetes(-0.46)*
Cladonia gracilis (CL2)	Aspect.sin E.W.(0.48)*, Leotiomycetes(0.46)*	AICL3(-0.42)*, CL1(-1.0)**, Lecanoromycetes(-0.47)*
AICL3	CL1(0.43)*, Elevation(0.45)*, HillShade(0.51)*	AICL58(-0.43)*, Aspect.sin E.W.(-0.44)*, CL2(-0.42)*
Lecanoromycetes	CL1(0.46)*	CL2(-0.47)*,C.bor(-0.44)*, Sanionia.uncinata(-0.45)*, Leotiomycetes(-0.43)*
Leotiomycetes	AICL41(0.74)**, CL2(0.46)*	CL1(-0.46)*, Lecanoromycetes(-0.43)*
Elevation	AICL3(0.45)*, Aspect.cos N.S.(0.49)*	Cladonia species, yellowish green cup(-0.44)*
Aspect.sin E.W.	AICL15(0.42)*, CL2(0.48)*	AICL3(-0.44)*, CL1(-0.48)*, TWI(-0.46)*
Aspect.cos N.S.	Elevation(0.49)*, HillShade(0.79)**	Longitude(-0.47)*
HillShade	AICL3(0.51)*, Aspect.cos N.S.(0.79)**	Sanionia.uncinata(-0.51)*
TWI		Aspect.sin E.W.(-0.46)*, slope(-0.45)*
Cladonia squamosa and gracilis complex (C.squ&gra)	Chorisdontium.aciphyllum(0.43)*	Sanionia.uncinata(-0.48)*
Cladonia-yellowish green cup (C.bor)		Elevation(-0.44)*, Lecanoromycetes(-0.44)*
Chorisdontium.aciphyllum	C.squ&gra (0.43)*	
Sanionia.uncinata		Andreaea(-0.47)*,C.squ&gra(-0.48)*, HillShade(-0.51)*, Lecanoromycetes(-0.45)*

▲ **Distribution of Cladonia and related moss**
***C.squamosa* was inhabited in an environment similar to those of *Chorisodontium* and showed a negative correlation with *Sanionia*. *C.gracilis* was inhabited in an environment similar to those of Sanionia and also lived together with *Chorisodontium*. *Chorisodontium* was found in 46% and *Sanionia* in 1% at the *C.squamosa* existing sites. *Chorisodontium* and *Sanionia* were found in a similar frequency in the sites of *C.gracilis* existed.**

Conclusion

- It is possible that the distribution of *C.squamosa* and *C. gracilis* were affected by microclimate, topography, and nearby vegetation.
- The terrain determined the flow direction of the water. Considering that the wind of the northwest is mainly blowing, the snow of the area facing the northwest could be easily removed by the wind and the winter temperature could be lower.
- Since *Sanionia* is known to live in an environment where water supply is easy, and *Chorisodontium* is known to vegetate in a moderate dry area. *C.squamosa* seems to prefer more dry area than *C.gracilis*. There was different that the degree of inflow of supply of snow melted water depending on the region according to the influence of the terrain, and this could be an important factor in determining the vegetation.
- These results imply that various geographical features and microclimate conditions can affect the distribution of lichen and environmental shift may cause a change in a distribution of vegetation.