Composition and distribution of moss formations in the ice-free areas adjoining the Arctowski region, Admiralty Bay, King George Island, Antarctica[1]

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ABSTRACT – The phytosociology of moss vegetation in the ice-free areas adjoining Polish Antarctic Station Henrik Arctowski, located at Admiralty Bay, inside the King George Island, was investigated during the 2002/2003 and 2003/2004 summer season. The most representative families had been *Bryaceae*, *Polytrichaceae*, *Andreaeaceae* and *Pottiaceae*. The most frequent species had been *Sanionia uncinata* (Hedw.) Loeske and *Polytrichum juniperinum* Hedw. Was possible to describe the associations of mosses in the region of Arctowski, being evidenced the occurrences of seven main formations, which it have been recognized and described twelve associations between the frequent and abundant species in the area. Here they are described along with their distribution in the area, their species richness and the diversity index for each formation found during this study.

Key words: Antarctic plant communities; Bryophyta. Phytosociology.

RESUMO – **Composição e distribuição das formações de musgos nas áreas de degelo adjacentes a região de Arctowski, Baía do Almirantado, Ilha Rei George, Antártica**. Durante os verões austrais 2002/2003 e 2003/2004 foram realizados estudos fitossociológicos nas áreas de degelo adjacentes a Estação Polonesa Henrik Arctowski, localizada na Baía do Almirantado, no interior da Ilha Rei George. As famílias mais representativas foram *Bryaceae*, *Polytrichaceae*, *Andreaeaceae* e *Pottiaceae.* As espécies mais freqüentes foram *Sanionia uncinata* (Hedw.) Loeske e *Polytrichum juniperinum* Hedw. Foi possível descrever as associações de musgos na região de Arctowski, constatando a ocorrências de sete formações principais. Dentro destas formações foram reconhecidas e descritas doze associações entre as espécies mais freqüentes e abundantes da amostragem.

Palavras-chave: Comunidades vegetais antárticas; briófitas; fitossociologia.

INTRODUCTION

King George Island (61º50'S, 62º15'W) is located in the South Shetlands archipelago (Maritime Antarctica). The Admiralty Bay is situated on its southeastern side, a sheltered region with a very distinct micro-climate compared to other parts of the island, especially in relation to winds (Pereira & Putzke 1994). The Antarctic Specially Managed Area (ASMA) of Admiralty Bay was created (Fig. 1) with the intention of minimizing the impact of human disturbance on its environment and biota (Simões *et al.* 2001).

The ice-free areas adjoining the Polish Antarctic station Henrikk Arctowski, on the west coast of Admiralty Bay, cover a large altitude range, varying from sea level (beaches) up to 500 a.s.l. (Jardine Peaks). The beaches of Arctowski are mainly formed by rocks and volcanic sediment, and are littered with whale skeletons remnants of the whale oil industry, active during the nineteenth and early twentieth centuries (Cardot 1910, Holdgate 1964, Hooker 1847). During summer, especially, Admiralty Bay is inhabited by a large numbers of seals, penguins, and other sea birds. The mosses and lichens are exposed in summer, after the snow from the winter has melted (Putzke *et al.*

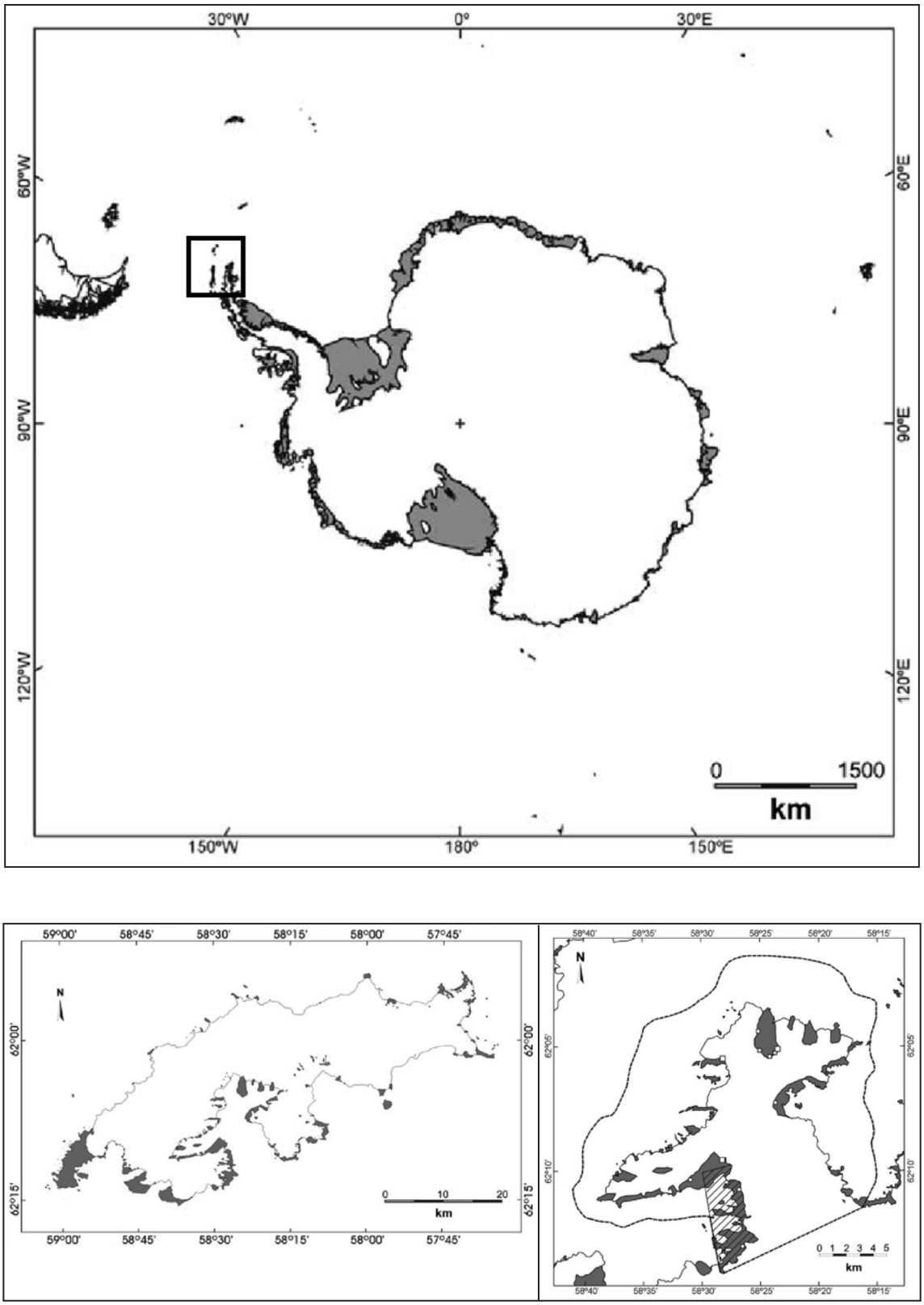

Fig. 1. Location of the study area. Above: the Antarctic continent, showing the South Shetlands (black square). Left below: King George Island and right: Admiralty Bay, showing the perimeter of the Antarctic Special Managed Area (hatched line) and the limits of the Special Scientific Interest Area (parallel lines) (Adapted from Simões *et al*., 2004).

1995). According to Rakusa-Suszczewski (2002), the annual mean temperature is around 0°C, but the region has a wide daytime temperature range (Cygan 1981). In the summer it varies from -5°C to 13°C, falling as low as -30°C in winter. According to Kovalski (1985), the winds and the humidity may significantly decrease chill temperature.

Studies of plant communities in Antarctica have a very relatively short history, if compared to other parts of the world particularly tropical and temperate regions. However, there are areas of the Maritime Antarctic region with excellent descriptions of the vegetation, such as the South Shetlands Islands (Lindsay, 1971, Furmanczy & Ochyra, 1982, Hu 1998), Signy Islands (Lewis-Smith, 1972), Nelson Island (Putzke *et al.,* 1995), and Elephant Island (Allison & Lewis-Smith, 1973, Pereira & Putzke, 1994) among others. Furmanczy & Ochyra (1982) provide maps of plant community distribution for the Arctowski.

According to Furmanczy & Ochyra (1982) and Kanda (1986), the plant communities of the ice-free areas of Antarctica have physiognomic characteristics of fairly easy identification, where the dominant species stands out either for their life form or even for their color. Examples are carpets of *Sanionia uncinata* (Hedw.) Loeske, which has an extensive distribution over Admiralty Bay, or tufts of *Polytrichastrum alpinum* (Hedw.) G.Sm. which are easily recognized in the marine terraces of the Arctowski region (Ochyra 1998).

However, we found that the vegetation associations and their recognition are more complex.

Some sites may have species that, at first sight, do not seem to be present in the sample, or that hide important associations. Two or more moss species with similar color patterns may co-exist. Community structure can therefore only be identified through detailed sampling methods.

The aim of this work is to describe and discuss the formations of dominant mosses and their respective associations in the ice-free areas of the Arctowski region, based on quantitative data from detailed phytosociological surveys.

MATERIALS AND METHODS

During the austral summer of 2003/2004, members of the XXII Antarctic Expedition of the Brazilian Antarctic Program (PROANTAR), studied the cryptogamic communities, with emphasis on bryophyte communities, adjoining the Polish H. Arctowski Station and the beach close to the Ecology Glacier (Fig. 2).

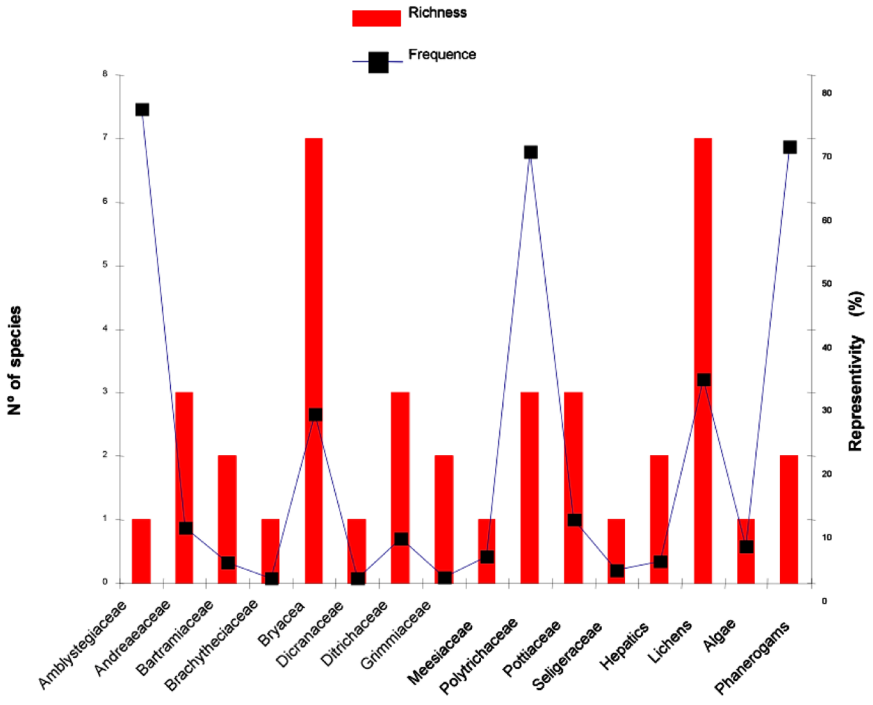

Fig. 2. Richness and frequency of families in the quadrats sampled at Arctowski region, Admiralty Bay, Kind George Island, Antarctica.

Phytosociological surveys were made over an altitude ranging from 0 to 250 a.s.l., following the Braun-Blanquet (1932) sampling method, adapted to Antarctic conditions. Quadrats of 25 × 25 cm were subdivided in 100 smaller squares of 2.5 × 2.5 cm. These quadrats were placed at 10 m intervals along a transect 100 m long randomly placed within the study area. A total of 20 transects with 200 sample quadrats were surveyed. In areas of smaller plant biomass or in small patches of vegetation, where it was not possible to use transects, quadrats were place subjectively on the vegetated areas. Coverage percentages and frequency of occurrence of the moss species in the sampled quadrats were determined. Estimates of coverage followed the method of Kanda (1986) and for frequency, Putzke *et al.* (1995). The Hu (1998) characterization scheme was also adopted determining the community type, mainly because of its associated use as the basic unity for community classification, which differs from other researchers who use life forms (physiognomy). Concomitantly with the phytosociologic sampling, some mosses found in each quadrat were collected for laboratory studies and for taxon identification up to the specific level.

The identification of the bryophytes was based on Putzke & Pereira (1990, 2001), Ochyra (1998), and Bednarek-Ochyra *et al.* (2000).

Statistical analyses were applied, using the software EstimateS 5.0 to get the index of phytosociologic parameters (Chao, 2004; Colwell, 2004). The Shannon index was applied to estimate diversity and its index of equability in order to compare our results with those of Hu (1998).

In order to illustrate the importance of the species in the total sampling, the index of ecological importance was applied (Lara & Mazimpaka, 1998), which combines the parameters of abundance (coverage and frequency), being described as:

$$\mathbf{IIE = F(1+C)}$$

where:

F is the relative frequency of the species in the area or habitat (generated by the number of occurrences (x) divided by the total number of samples considered (n): $\mathbf{F = 100x/n}$).

C is the average coverage of the specie in the samples: $\mathbf{C = \Sigma(c_i)/x}$; where c_i is the cover class and x, the number of sampling points in which the species occur.

The names of the places presented in this work follow the official nomenclature according to Simões *et al*. (2004).

RESULTS

A total of 30 species of bryophytes (28 mosses, 2 hepatics), 2 angiosperms, 1 alga, and 7 species of lichenized fungi were recorded in the analyses. *Sanionia uncinata*, the most important frequent moss species in the total analyzed samples (present in 240 quadrats), showed the highest index of ecological importance (Table 1).

TABLE 1 – Most important species in the phytosociological analyses made in Arctowski region. Nº quadrats = number of quadrats in which the species was observed; Qdominant = number of quadrats in which species was found with dominant cover; F = species frequency in 240 sampled quadrats; IEI = species index of ecological importance in the total sampling.

Species	Nº Quadrats	Qdominant	F (%)	IEI
Mosses				
Sanionia uncinata	177	76	74	215.20
Polytrichastrum alpinum	146	29	60	153.54
Syntrichia princeps	21	6	8.75	22.96
Bryum pseudotriquetrum	55	18	22.51	52.4
Andreaea gainii	18	5	7.5	24.54
Ditrichum hyalinum	13	1	5.4	11.1
Polytrichum juniperinum	12	4	5.4	10.8
Bartramia patens	6	1	2.5	1.625
Others				
Deschampsia antarctica	190	55	79.17	245.8
Usnea antarctica	66	25	27.5	77.29
Usnea aurantiaco-atra	16	5	6.66	15
Cephaloziella varians	8	0	3.33	7.05

The family with highest richness was *Bryaceae,* with seven species, followed by *Andreaeaceae, Polytrichaceae*, and *Pottiaceae* with three species each (Fig. 2). The genus *Bryum* had the highest number of sampled species (4), followed by *Andreaea* and *Pohlia*, with three species each, and *Polytrichum* and *Syntrichia* with two species each in the samples. The families and their respective most frequent species were *Amblystegieaceae* (*Sanionia uncinata*), *Polytrichaceae* (*Polytrichastrum alpinum*)*, Bryaceae* (*Bryum pseudotriquetrum*), *Pottiaceae* (*Syntrichia princeps*), and *Andreaceae* (*Andreaea gainii*) as the most frequently encountered species.

List of species found in ice-free areas of the Arctowski region

Bryophyta

Amblystegiaceae
Sanionia uncinata (Hedw.) Loeske

Andreaeaceae
Andreaea depressinervis Cardot
Andreaea gainii Cardot
Andreaea regularis Müll. Hal.

Bartramiaceae
Bartramia patens Brid.
Conostomum magellanicum Sull.

Brachytheciaceae
Brachythecium austrosalebrosum (Müll. Hal.) Kindb.

Bryaceae
Bryum amblyodon Müll. Hal.
Bryum orbiculatifolium Cardot & Broth.
Bryum pallescens Schelich. *ex* Schwägr.
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey. & Scherb.
Pohlia cruda (Hedw.) Lindb.
Pohlia drummondii (Müll. Hal.) A.L. Andrews
Pohlia nutans (Hedw.) Lindb.

Dicranaceae
Chorisodontium aciphyllum (Hook. f. & Wilson) Broth.

Ditrichaceae
Ceratodon purpureus (Hedw.) Brid.
Ditrichum hyalinum (Mitt.) Kuntze
Ditrichum lewis-smithii Ochyra

Grimmiaceae
Racomitrium sudeticum (Funck) Bruch & Schimp.
Schistidium falcatum (Hook. f. & Wilson) B. Bremer

Meesiaceae
Meesia uliginosa Hedw.

Polytrichaceae
Politrichastrum alpinum (Hedw.) G.L. Sm.
Polytrichum juniperinum Hedw.
Polytrichum piliferum Hedw.

Pottiaceae
Hennediella heimii (Hedw.) R.H. Zander
Syntrichia princeps (De Not.) Mitt
Syntrichia saxicola (Cardot) R.H. Zander

Seligeraceae
Dicranoweisia brevipes (Müll. Hal.) Card.

Marchantiophyta

Cephaloziellaceae
Cephaloziella varians (Gottsche) Steph.

Lophoziaceae
Lophozia excisa (Dicks.) Dumort.

Algae

Prasiola crispa (Lightfoot) Menegh.

Phanerogams

Colobanthus quitensis (Kunth) Bartl
Deschampsia antarctica Desv.

Lichens

Caloplaca sp.
Cladonia sp.
Cornicularia sp.
Leptogium sp.
Rizocarpum geographicum (L.) DC
Usnea antarctica Du Rietz
Usnea aurantiaco-atra (Jacq.) Bory

Sampling showed eleven species as dominants in one or two times (Table 1) and 10 species were observed showing low frequency and abundance, representing species only rarely encountered in the communities with cover values often lower than 1% (Table 2). The remaining species occurred with higher frequency, but low coverage and with the exception of *Colobanthus quitensis*, none of those showed dominance in the sampled quadrats. Mosses were the dominant species in 75% of the quadrats laid in the study. In the other samples, lichens or the grass *Deschampsia antarctica* had dominant coverage. *Polytrichastrum alpinum*, *Sanionia uncinata*, and *Deschampsia antarctica* occurred more than once as co-dominant species in the same sample. The moss *Polytyrichum juniperinum* was the other commom

Polytrichaceae species in the samples. Ochyra (1998) recorded that *P. juniperinum* was found more frequently than *Polytrichastrum alpinum* in the Admiralty Bay area.

Moss formation types observed in the Arctowski region

In the studied region five moss formations were identified (Table 3), four of those occurring in well drained and rocky areas (Antarctic tundra). Only one formation was observed in flooded areas (Antarctic swamp), as follows:

***Sanionia uncinata* formation**

Sanionia uncinata is the highest biomass species found on the King George Island, occurring over a wide habitat and altitude gradient, from the tops of uplands and their slopes down to the beaches. In the Arctowski region, this species forms extensive carpets on the beach adjoining the Polish station (Fig. 3-I). The formation only occurs in areas with a stable substrate, and includes 24 taxa (E=0.75203; H'=2.39). The following seven associations in this formation:

***Sanionia uncinata-Deschampsia antarctica* association**

This association has a wide distribution, occurring from sea level up to 120 a.s.l., especially next to Penguin Ridge and Skua Cliff, around colonies of skuas (*Catharacta* maccormicki) and Adelié penguins (*Pygoscelis adeliae*). It is well represented in the limits of the tundra and the Antarctic swamp.

It is the most frequent association of the studied area, with a wide distribution, except in rocky outcrops. It occurs in relatively wet environments, close to drainage lines that fill small lakes and pools, where the species develop. *Sanionia uncinata* showed 70% coverage in the quadrats, while *Deschampsia antarctica* varies from 20 to 30%. Fruticulose lichens like *Usnea antarctica* and *U. aurantiaco-atra* are not of rare occurrence, especially next to the slopes. However, the coverage of those lichens does not exceed 15%. Cushions of *Syntrichia princeps* and tufts of *Polytrichum juniperinum* and *P. piliferum* are also found with coverage near 15%, often in samples near birds' nests, and some individuals of *Brachythecium austrosalebroum* and *Ditrichum hyalinum,* are both found with coverage less than 5%.

TABLE 2 – Additional species found in the sampling. Nº quadrats = number of quadrats in which species was observed; Cr = Species cover in the sampled quadrats; F = species frequency in the sampling; IEI = species index of ecological importance in the total sampling.

Species	Nº Quadrats	Cr (%)	F(%)	IIE
Andreaea depressinervis	1	15	0.41	1.25
Bryum amblyodon	1	5	0.41	0.83
Cladonia aff *metacularifera*	1	3	0.41	0.83
Cornicularia sp.	1	4	0.41	0.83
Lophozia excisa	1	2	0.41	0.83
Pohlia drumondii	1	2	0.41	0.83
Schistidium falcatum	1	2	0.41	0.83
Brachythecium austrosalebrosum	2	5-10	0.83	1.66
Chorisodontium aciphyllum	2	10-25	0.83	2.03
Dicranoweisia brevipes	2	10-25	0.83	2.03
Pohlia cruda	2	5-10	0.83	1.66

TABLE 3 – Number of species (R), equability (E) and specific diversity (H') for the moss formations found in the Arctowski region.

Formation	R	E	H'
Sanionia uncinata	24	0.75203	2.39
Sanionia uncinata-Deschampsia antarctica-Polytrichum juniperinum	18	0.73001	2.11
Polytrichum juniperinum	21	0.79487	2.42
Syntrichia princeps-Deschampsia antarctica-Sanionia uncinta	8	0.88004	1.83
Bryum pseudotriquetrum	11	0.62554	1.50

***Sanionia uncinata-Polytrichastrum alpinum* association**

Mainly distributed around the slopes of Skua Cliff, it is characteristically found near the Skua's nests of the region. It occurs on rocky substrates on many outcrops, but also with some stable and well drained soils. The cover of *S. uncinata'*s is around 50%, covering the soil between the rocks, while *P. alpinum* covers 25%, mainly on rocks adjoining carpets of *S. uncinata.* It is also commonly found between tufts of *P. alpinum*, with *Chorisodontium acyphyllum*, *Polutrychum juniperinum*, and *Cephaloziella varians*, always associated, with approximately 20% cover of the quadrat. This is a typically ornithocoprophilous association, as it occurs next to the Skua's nests, but it may also occur in small isolated patches on the beach, next to the *Sanionia unicnata-Deschampsia antarctica* association.

***Sanionia uncinata-Usnea antarctica* association**

This is the least frequent association in the formation, being limited to the highest parts of the cliffs next to the beach (aprox. 70 a.s.l.), mainly on the face of Skua Cliff facing the H. Arctowski station. *Sanionia uncinata* occurs in smaller frequency in relation to the previous associations, with around 35% coverage. Yet, *Usnea antarctica* occurs on rocks surrounding moss carpets, covering 15%. Other lichens may occur, such as *Rhizocarpum geographicum* and *Usnea aurantiaco-atra*, but rarely covering above 5%.

***Sanionia uncinata-Andreaea gainii* association**

This association occurred only in the Ornithologists Creek (5/40) area next to the beach, and next to skua's nests. Some muscicolous lichens occur associated with these two dominant moss species, most importantly *Usnea antarctica* and *Caloplaca* sp. *Andreaea gainii* occurs between the carpet of *S. uncinata,* on small rock fragments. This same association was recorded in formations of *Sanionia uncinata* on Nelson's Island, neighboring King George Island (Putzke *et al.*, 1995).

***Sanionia uncinata-Colobanthus quitensis* association**

Found only in three sampled sites, the cover of the moss is aprox. 30%, while *C. quitensis* may be 25%. In this association *S. uncinata* frequently occurs in tufts, with tufts of *P. piliferum* found between the two species, but in a very low cover, aprox. 1%.

***Sanionia uncinata-Deschampsia antarctica-Cladonia* association**

Limited to the border of the outcrops, on small rock fragments. Usually the carpets of *S. uncinata* are on the rocks and the turfs of *D. antarctica* on the organic layer formed by dead mosses. The fruticolous lichen *Cladonia* sp. is associated with moss carpets, but grows attached to the rock below. *Sanionia uncinata* has the largest cover value of the association, around 60%, occurring sometimes in an equal frequency to the maximum found for *Cladonia* sp., around 30%. *Deschampsia antarctica* appears in showy turfs, that might give the false impression of dominance in this association, but with cover varying from 15% to 20%.

***Bartramia patens-Deschampsia Antarctica* association**

This association occurred in one single quadrat, with both species co-dominant and covering 25%. *Polytrichastrum alpinum*, *Polytrichum juniperinum*, *P. piliferum*, *Sanionia uncinata*, *Syntrichia princeps*, *Messia uliginosa* also occurred, all covering no greater than 5%. Two lichen species occurred in this sample, *Leptogium* sp. and *Cladonia* sp., with the same coverage as the non-dominant moss species in this association. The hepatic *Lophozia excisa* is found in blackish compact masses between the tufts of *Bartramia patens,* always with coverage less than 1%.

***Sanionia uncinata-Deschampsia antartica-Polytrichum juniperinum* formation**

This formation is typically found from Rakusa Point and Ornithologists Creek (Fig. 3-II). Due to the more stable substrate of the areas closer to the beach, *S. uncinata* and *D. antarctica* are best developed there, utilizing the rich ornithogenic substrate. *Polytrichum juniperinum* occurs between turfs of *D. antarctica*, in sandy to gravel soil. A total of 18 species were observed (E = 0.73001; H' = 2.11), but only three species were regularly associated, as described below.

***Sanionia uncinata-Deschampsia antarctica-Polytrichum juniperinum* association**

This is well represented in all formation, with the same physiognomic characteristics above, and is also found in limited distribution between the slopes of Rakusa Point and Ornithologist Creek. *Sanionia uncinata*, *D. antarctica*, and *P. juniperinum* have similar cover values, varying from 25 to 30% for

each species. Cushions of *Syntrichia princeps* and *Hennediela antarctica* are also common, but they both never exceed 5% coverage. Lichens are rare, but *Cladonia* sp. growing on *S. uncinata* may occur, usually killing the moss.

***Polytrichastrum alpinum* formation**

This formation is limited to higher areas of Skua Cliff, aprox. 100 a.s.l. (Fig. 3-III). It occurs on well drained sites, with rocky substrate and on some accumulated soil found in cracks of rocks. In this formation, 21 species were observed (E = 0.79487; H' = 2.42), with two distinct associations.

***Polytrichastrum alpinum* association**

Formed by tufts of *P. alpinum*, having a cover of about 40%. Usually several lichens occur, covering less than 1% and they are usually found growing on fragments of rocks next to tufts of the moss. Small tufts of *Sanionia uncinata* and *Bartramia patens* may occasionally occur, but never covering above 5%. *Cephaloziella varians* also occurs with cover value equal to the other mosses of the association. With the exception of *P. alpinum*, usually the other species occur on rocky soil or directly on the rocks, since soil is quite scarce.

***Polytrichastrum alpinum-Sanionia uncinata-Usnea antarctica* association**

This association is found more frequently and occurs on well drained sites with rocky substrates and also on accumulated soil found in cracks of rocks. It is easily observed, since the relatively tall tufts of *P. alpinum* are obvious, as opposed to the short lichens, forming a color gradient from green to gray. *Sanionia uncinata* occurs in tufts, side by side with *P. alpinum* and the *Usnea antarctica* that covers the exposed rocks. *P. juniperinum* has aprox. 25% cover, while *Sanionia uncinata* and *Usnea antarctica* never occur with more than 20% cover *Andreaea gainii* may occur in this association, usually on the rocks next to the stipes of *Usnea antarctica*, and its cover varies from 5% to 25%. Although rare the lichen *Rizhocarpum geographicum* and the cushion-forming angiosperm *Colobanthus quitensis* may occur with cover values of 1% to 5% respectively.

***Syntrichia princeps-Deschampsia antarctica-Prasiola crispa* formation**

It is formed mainly by cushions of *Syntrychia princeps*, next to the colonies of Adelié penguins of Rakusa Point (Fig. 3-IV). A small formation including only eight species (E = 0.88004; H' = 1.83), with five of these species occurring eventually in the quadrats. It is common in Rakusa Point, where one of the largest Adelié penguin colonies of the region is located. Only the association between *Syntrichia princeps* had 20% coverage, while *Deschampsia antarctica* had 15%, and *Prasiola crispa* aprox. 10%.

***Bryum pseudotriquetrum* formation**

This formation was found in flooded areas and within melted water drainage lines of the Arctowski region. It is distributed throughout the whole south face of this area, at altitudes below 30 a.s.l., occurring mainly on the beaches adjoining the Ecology Glacier (Fig. 3-V). The substrate of these beaches is predominantly rocky, mainly due to the scarcity of plants that tend to accumulate organic matter, such as *Colobanthus quitensis*, *Deschampsia antarctica*, and *Sanionia uncianta*, with vegetative cover less than 1%. The diversity of this formation is low compared to that of tundra communities found at the same altitude (E = 0.62554; H' = 1.50). Eleven species were observed growing usually around the drainage lines. The dominant species of this formation is *Bryum pseudotriquetrum* and it is found along and adjacent to the drainage lines, with coverage values between 40 and 60%.

***Bryum pseudotriquetrum* association**

This association occurs mainly adjacent to the small drainage lines or around lakes that originated from melting ice, on the south face of the Polish station, at altitudes below 30 m a.s.l. (Fig. 3-V). The dominant *Bryum pseudotriquetrum* often covering above 50%, is often associated with the mosses *Bryum pallescens* and *Syntrichia princeps* and the alga *Prasiola crispa*. Tufts of *B. pseudotriquetrum* were observed only within the drainage lines.

***Bryum pseudotriquetrum-Sanionia uncinata* association**

It is a common association in the drainage lines located more to the southeast, in the part of the beach closer to the Ecology Glacier. In this area, the vegetation is assorted in widely spaced fragments of low diversity, often in groups formed by three associated species. Usually the mosses, *Bryum pseudotriquetrum* and *Sanionia uncinata*, are observed associated, with cover value for each not exceeding 25%, together with *Deschampsia antarctica* or *Pohlia nutans* or yet

Colobanthus quitensis, with cover values equal to or less than 1% each, but they both are rarely found in the same sample.

***Bryum pseudotriquetrum-Cephaloziella varians* association**

A rare association. The moss *Bryum pseudotriquetrum* and the hepatic *Cephaloziella varians* were observed in only two quadrats located on the swamp that is in the beach next to the Ecology Glacier. It was developed inside a small lake, between the beach line rich in pebbles and other rocks and the *Bryum pseudotriquetrum-Sanionia uncinata* association, described above. Around 40% of the sample is composed by the moss, while the hepatic covers between 10 to 25% of the sampled quadrats.

***Conostomum magellanicum – Sanionia uncinata* association**

An association that is present on the beach between Ornithologist Creek and Ecology Glacier, in a rocky region with little drainage. *Conostomum magellanicum* occurs with cover value about 50%, surrounded by carpets of *Sanionia uncinata*. *S. uncinata* occurs with a coverage of about 25%, the largest cover value of this moss that was sampled in a flooded area. The substrate where these two moss species are found is formed by rocks and gravels that are probably derived from nearby e.g., Skua Cliff. Usually the substrate is easily removed together with the moss when it is collected, showing its importance in aggregating and stabilizing small substrate particles. In a small layer of soil between the rocks, blackish tufts of *Cephaloziella varians* are found, whose small size and dark color make it easy to overlook. Because of its color, they can be easily mistaken by soil or the rocks around.

***Pohlia drummondii-Cephaloziella varians-Sanionia uncianta* association**

This association was found in a single quadrat, at the border of a drainage line between Skua Cliff and the moraines to the north of Ecology Glacier, in an isolated fragment of vegetation. Tufts of *Pohlia drummondii* were overlaying about 75% of the quadrat, while the other species of the association covered 25%. *Cephaloziella varians* occurred in loose tufts between the mosses, opposite to the other sites where it was observed. The substrate is composed of soil and large fragments of rocks, with higher drainage when compared to the sites of other associations found in flooded areas.

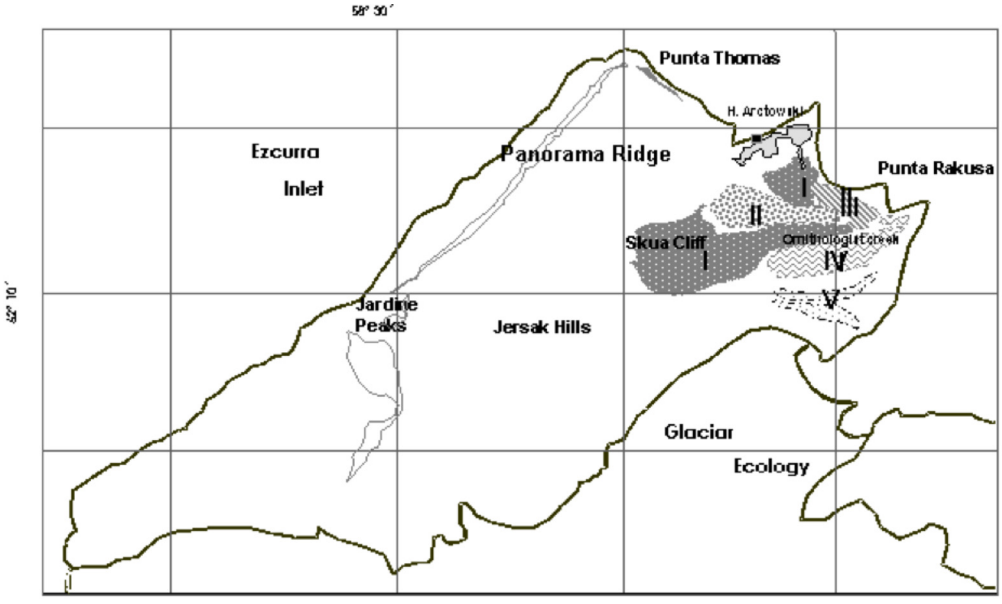

Fig. 3. Southwest area of Admiralty Bay, indicating distribution of moss formations of Arctowski region. I. *Sanionia uncinata* formation. II. *Polytrichastrum alpinum* formation. III. *Sanionia uncinata-Deschampsia antarctica-Polytrichum juniperinum* formation. IV. *Syntrichia princeps- Deschampsia antarctica-Sanionia uncinata* formation. V. *Bryum pseudotriquetrum* formation.

DISCUSSION

The bryophyte flora of the Admiralty Bay is well known (Putzke & Pereira, 1990, 2001; Ochyra, 1998). Some 58 species of mosses have being recorded for the region. Of these, 28 species were observed in this phytosociological survey, with 240 sampled quadrats, outlining the difference between the floristic and the phytosociologic approaches. It was expected that the largest number of species found would be from the families Andreaeaceae, Bryaceae, Polytrichaceae, and Pottiaceae, since they are the richest families in the Maritime Antarctic (Allison & Lewis-Smith, 1973, Ochyra *et al.*, 2008). The family Grimmiaceae has 11 known species for the South Shetlands, but only two species were found. This might be related to the higher occurrence of this family, principally the genus *Schistidium*, in areas of rocky substrate above 250 a.s.l. (Ochyra, 1998), that were not sampled in this study. *Sanionia uncinata* and *Polytrichum juniperinum* were the most frequent moss species in the samples. This was to be expected, as *S. uncinata* is the species of highest biomass in the Maritime Antarctic (Putzke & Pereira, 2001) and *P. juniperinum* has its largest population in the Admiralty Bay (Ochyra, 1998).

From the moss formations found, two occur in other already studied areas of the Antarctic Peninsula. The *Sanionia uncinata* formation was observed by Putzke *et al.* (1995) on Nelson Island (as *Sanionia uncinata* "sociation") and by Hu (1998) in the Fieldes Peninsula (King George Island). The *Bryum pseudotriquetrum* formation was observed by Kanda (1986), as the *Bryum pseudotriquetrum "*sociation".

Furmanczy & Ochyra (1982) studied the vegetation of Jasnorzewski Gardens, concentrating their efforts in the beach adjacent to the Polish station, describing the vegetation of this area as something similar to *Sanionia uncinata-Deschampsia antarctica-Polytrichum juniperinum* formation, but quantitative data are not presented. These authors also recognized three plant associations, (1) *Deschampsia antarctica-Colobanthus quitensis,* (2) *Polytrichastrum alpinum*, (3) *Caliergon austro-stramineum-Caliergon sarmentosum,* distinguished and described in a single sample area. The absence of phytosociological indices in the work of Furmanczy & Ochyra (1982) preludes a direct assessment of the similarity of their associations to the *Sanionia unicinata* formation observed in this study.

The other formations and their respective associations are different from those described in studies of this sort.

The formations distributed in hilly areas, with a predominance of rocky substrates, showed high species richness, equability and diversity indices. Those found close to sea level, although more vigorous, had lower indexes (Table 3). This is easily demonstrated by comparing the diversity indexes of the *Sanionia uncinata* and *Polytrichastrum alpinum* formations. The first has a larger distribution, from Skua Cliff to the proximities of the Polish station, with 24 observed species (H'=2.39), while *Polytrichastrum alpinum* formation is limited to the slopes of Skua Cliff, with 21 observed species (H'=2.42).

Hu (1998) obtained similar results with the distribution of moss communities of the Fieldes Península, also on the King George Island, but with higher similarity of dominant species in the tundra and the swamps. This is not the situation for the Arctowski region.

For the formations next to penguin colonies and the drainage lines, the diversity and richness were clearly lower than in drier areas or in areas with no active bird colonies. In those areas the diversity is usually smaller because of the substrate. Next to bird colonies the soil is nitrate and ammonia rich, due to the concentration of guano. Only few ornithocoprophilous (nutrient-tolerant) species develop in these areas. The formations of the swampy areas, like Skua Cliff and Ornithologist Creek, are restricted to the beaches adjoining the Ecology Glacier and occur in narrow drainage lines that receive water from melting ice of nearby slopes and platforms. In these sites, water is a limiting factor for diversity, since in this kind of substrate only species that can survive submerged for long periods in water can prevail. According to Kanda *et al.* (1991), the colonization of this habitat requires a series of morphological adaptations. Thus, only the species that have such attributes may develop, for example *Bryum pseudotriquetrum.*

Our studies has provided critical baseline information necessary for monitoring the ASMA of Admiralty Bay. Detailed maps of plant communities in this region will help with the management of human activities in the region, thereby minimizing the risks of unnecessary environmental impact on the sensitive vegetation communities.

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