Data on species composition and background concentrations of some elements in moss samples from Livingston Island (Antarctica)

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Abstract: GANEVA, A. & YURUKOVA, L. 2004. Data on species composition and background concentrations of some elements in moss samples from Livingston Island (Antarctica). – Herzogia **17**: 199–206.

During an expedition on Livingston Island at the end of 2001, 17 moss species were collected. Together with those collected in 1998/1999 23 moss species have been found so far around the Bulgarian Base Station. For the purposes of the biomonitoring, samples of *Sanionia georgico-uncinata* were collected from 8 sample plots. The concentrations of P, K, Ca, S, Na, Mg, Mn, Fe, Al, Zn, Cu, Pb, Cd, Co, Ni, Cr, As, and Se were analyzed using ICP-AES. The mean concentrations of Mn, Fe, Co, Ni, Cd and Pb accumulated in *Sanionia uncinata* used in a previous study were in the ranges of these metals found for *S. georgico-uncinata* in this study, whereas Zn was very close to the minimum value, and content of Cu (19 mg/kg) was 2-fold higher than the maximum value of *S. georgico-uncinata.* Using the current results for background concentrations of heavy metals and toxic elements in Europe it could be assumed that the region around the Bulgarian Base is not heavily polluted.

Zusammenfassung: GANEVA, A. & YURUKOVA, L. 2004. Ergebnisse zur Artenzusammensetzung und Grundkonzentrationen einiger Elemente in Moosproben von der Livingston Insel (Antarktis). – Herzogia **17**: 199–206.

Während der Expedition Ende 2001 auf der Insel Livingston (Antarktis) wurden 17 Moosarten gefunden. Gemeinsam mit den 1998/1999 gesammelten wurden 23 Arten in der Umgebung der bulgarischen Station festgestellt. Für ein Biomonitoring wurden Proben von *Sanionia georgico-uncinata* an acht Orten gesammelt. Die Konzentrationen von P, K, Ca, S, Na, Mg, Mn, Fe, Al, Zn, Cu, Pb, Cd, Co, Ni, Cr, As, und Se wurden durch ICP-AES ermittelt. Die Durchschnittskonzentrationen von Mn, Fe, Co, Ni, Cd und Pb in *S. uncinata*, die in einer früheren Untersuchung festgestellt wurden, sind auch für die jetzige Untersuchung von *S. georgico-uncinata* gültig. Der Gehalt an Zn liegt nahe dem Minimalwert und der Gehalt an Cu (19 mg/kg) ist doppelt so hoch wie der Maximalwert, verglichen mit entsprechenden Werten aus Europa. Die gemessenen Konzentrationen der Elemente zeigen, dass die Station nicht stark antropogen beeinflusst ist.

Key words: Mosses, bioaccumulation, biomonitoring.

Introduction

Bulgaria established a base on the Livingston Island in 1987 and since 1993 an Antarctic Biological Research Project has been carried out. Up to now, data on meteorological conditions, soil morphology, and soil microorganisms have been published (CHIPEV & VELTCHEV 1996, SOKOLOVSKA et al. 1996, ILIEVA & GROZEVA 1999, BOGOEV et al. 1999). The concentrations of the heavy metals and toxic elements Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd and Pb have been determined in feathers of molting Chinstrap penguins (*Pygoscelis antarctica* Bagshawe 1938*)*, from Livingston Island, Antarctica. The results show that this region of Antarctic Bulgarian Base is still an environment little affected by emissions. Moulting plumage accumulates these toxicants during one year of life, and it could be used successfully for biomonitoring purposes (METCHEVA & YURUKOVA 2002). Major essential (P, K, Ca and S) and trace elements (Mg, Fe, Mn, Al, Zn, Cu, Pb, Cd, Co, Ni, Cr, As, and Se) were measured by atomic emission spectrometry with the inductively coupled plasma (ICP-AES) method in muscle, liver, kidney, lung and heart of Gentoo penguin (*Pygoscelis papua* Murphy 1947; METCHEVA & YURUKOVA in press). CHIPEV & KOVACHEV (1999) and YURUKOVA (in preparation) focused their studies on the inorganic content of Antarctic lichens collected on Livingston Island.

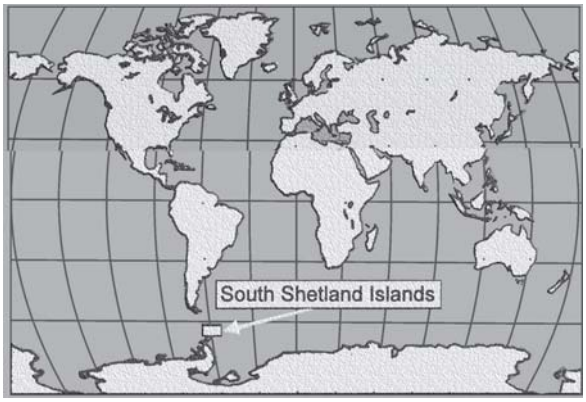

Fig. 1: Location of Livingston Island in the Southern Hemisphere.

Preliminary data on floristic composition and bioaccumulative characteristics of mosses for 8 heavy metals near St. Kliment Ohridski Antarctic Base Station were published after the Bulgarian expedition in the Antarctic summers 1993/1994 and 1998/1999 (YURUKOVA & GANEVA 1999). During the expedition in December 2001 samples were collected in order to assess the bryophyte diversity on the territory around the Bulgarian Base Station and to obtain more data on background concentrations of 19 macro- and microelements.

Study area

Livingston Island together with King George Island are the largest islands of the South Shetland Island Group (fig.1). The largest summer ice-free areas on Livingston Island are on Bayers Peninsula and on Hurd Peninsula, facing the South Bay where Bulgarian Base is located (62°38'29"S and 60°24'53"W) (fig. 2). The mean annual temperature for Livingston Island is minus 4 °C. Most of the time in summer the weather is cloudy and air temperature remains between 0–2 °C. Relative humidity during Antarctic summers 1993–1996 is above 65 % (CHIPEV & VELTCHEV 1996). The average temperature during the 3 summer seasons (1993–1994, 1994–1995 and 1995–1996) around Bulgarian Base was 1.98 °C (max 7.7 and min –2.9 °C), humidity of the air was above 43 %, atmospheric pressure was between 954.17 and 1018.1 hPa, and prevailing winds N–S with maximum speed 28–30 m/s (VELTCHEV et al. 1998).

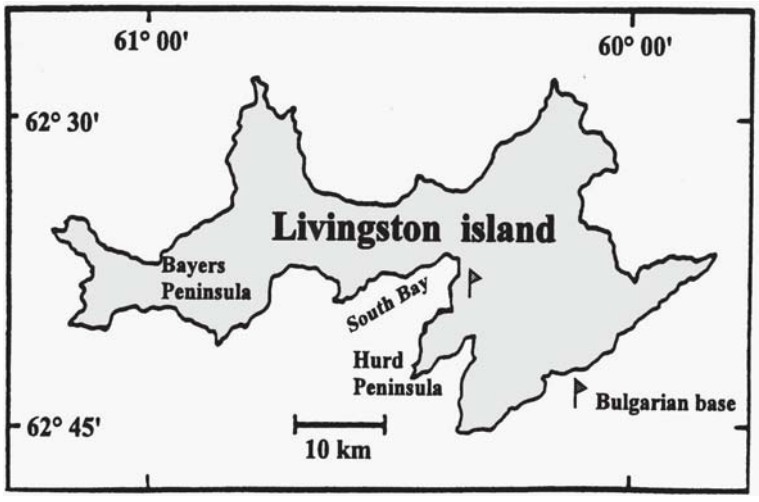

Fig. 2: Location of Bulgarian Antarctic Base on Livingston Island.

Materials and Methods

To estimate species composition moss samples were collected in the area near the Bulgarian Base Station (fig. 2). Nomenclature follows OCHYRA (1998).

For the purpose of chemical analysis samples of *Sanionia georgico-uncinata* were collected at eight sample-plots (tab. 1). Moss samples were taken using polyethylene bags and frozen during their transport to Bulgaria. In laboratory the samples were mechanically cleaned to remove adhering substratum. The green and green-brown parts of shoots were selected for analytical determination. About 2 g of the powered and dried (at 80 °C for 48 h) material was treated with 10 ml nitric acid overnight. The wet-ashed procedure was continued with heating on a water bath, following addition of hydrogen peroxide (5 ml in portion) till full digestion. The filtrate was diluted with double distilled water to 50 ml and stored in plastic flasks. Analysis was done by atomic emission spectrometry (AES) with the inductively coupled plasma (ICP). The elements P, K, Ca, S, Na, Mg, Mn, Fe, Al, Zn, Cu, Pb, Cd, Co, Ni, Cr, As, and Se were analyzed using SPECTROFLAME (Germany). Each sample was digested 3 times, and each digested sample was measured 3 times. Analytical precision was checked by blanks, standard solutions, plant reference material CRM 281 (ryegrass) and 3 moss standard interlaboratory materials used in the European moss survey in 1995/1996. Total nitrogen was determined by the Kjeldahl method. The concentrations were expressed in mg/kg on dry basis. The results were statistically processed (average, standard deviation, median, correlation analysis, Student's t-test) using statistical functions (Excel 2000).

Tab. 1: Location of the sample plots where *Sanionia georgico-uncinata* samples were collected

Sample plot	Geographic coordinates	Altitude, m	Collection date
1	S 62°38'14" W 60°21'37"	6	26.12.2001
2	S 62°38'36" W 60°22'14"	56	27.12.2001
3	S 62°38'24" W 60°21'08"	57	27.12.2001
4	S 62°38'12" W 60°21'26"	36	27.12.2001
5	S 62°38'04" W 60°20'55"	4	28.12.2001
6	S 62°38'07" W 60°21'03"	5	28.12.2001
7	S 62°38'07" W 60°21'22"	9	28.12.2001
8	S 62°38'09" W 60°21'29"	2	28.12.2001

Results

Species composition

At the end of 2001, 17 moss species were collected, listed below in alphabetical order:

Andreaea gainii
A. regularis
Bartramia patens
Brachythecium austrosalebrosum
Bryum pallescens
Ceratodon purpureus
Dicranoweisia crispula
Distichium capillaceum
Hennediella heimii
Polytrichastrum alpinum
Polytrichum juniperinum
Racomitrium sudeticum
Sanionia georgico-uncinata
Schistidium occultum
Syntrichia filaris
S. princeps
Warnstorfia sarmentosa.

Together with *Ditrichum hyalinum*, *Sanionia uncinata*, *Schistidium antarctici*, *Pohlia cruda*, *Bryum urbanskyi* and *B. pseudotriquetrum* collected in 1998/1999 (YURUKOVA & GANEVA 1999), 23 moss species have been found so far around the Bulgarian Base. These include bipolar *Polytrichastrum alpinum*, *Pohlia cruda*, *Sanionia uncinata*, *Bryum pseudotriquetrum*, antarctic endemics *Andreaea gainii*, *Schistidium antarctici*, amphiatlantic South-Temperate, amphipacific South-Temperate, and amphiatlantic Subantarctic elements. The most abundant species are *Sanionia georgico-uncinata*, *Polytrichastrum alpinum*, *Syntrichia princeps*, *S. filaris* and *Bryum pseudotriquetrum* which form patches and "moss meadows" on some places. The mosses grow in dry to wet habitats on rocky ground, in sheltered to exposed places, thus showing considerable variation in microhabitats.

Element concentrations

The highest concentrations of P (3622 mg/kg), K (7686 mg/kg), S (1823 mg/kg), Na (1702 mg/kg), Zn (33 mg/kg) and the lowest contents of Mn (36 mg/kg), Fe (1220 mg/kg), Al (698 mg/kg), Pb (2.1 mg/kg), Co (0.8 mg/kg) were found in the samples from sample plot 8. The highest concentration of Cu (10 mg/kg) was recorded in the moss samples from plots 1, 6 and 8. The maximum content of Co (2.5 mg/kg) was found in the samples from plots 1, 3 and 4. The concentrations of As and Se in all samples were under the detection limits: 0.6 mg/kg for both elements (tab. 2). The minimum, maximum and mean concentrations are shown on fig. 3.

The following orders of decreasing concentration of the elements were found in the moss samples from the sample plots:

plot 1: N>Fe>Ca>Mg>K>Al>P>Na>S>Mn>Zn>Cu>Pb>Ni>Co>Cr>Cd
plot 2: N>Mg>Ca>Fe>K>Al>Na>P>S>Mn>Zn>Pb>Cu>Ni>Co>Cr>Cd
plot 3: Ca>N>Fe>K>Mg>Al>S>P>Na>Mn>Zn>Pb>Cu>Ni>Co>Cr>Cd
plot 4: N>Ca>Fe>K>Mg>Al>S>P>Na>Mn>Zn>Pb>Cu>Ni>Co>Cr>Cd
plot 5: N>Ca>K>Fe>Mg>Al>P>S>Na>Mn>Zn>Cu>Pb>Ni>Co>Cr>Cd

Tab. 2: Concentrations (mg/kg dry weight ± SD) of macro- and microelements in samples of *Sanionia georgico-uncinata.*

Element	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
N	9300 ± 1116	8200 ± 984	5600 ± 672	10400 ± 1248	9400 ± 1128	12300 ± 1476	17400 ± 2088	20900 ± 2508
P	1238 ± 17	981 ± 13	579 ± 8	802 ± 11	1752 ± 24	2270 ± 31	2511 ± 34	3622 ± 49
K	2542 ± 29	2029 ± 23	3120 ± 35	3582 ± 40	4472 ± 51	3223 ± 36	5525 ± 62	7686 ± 87
Ca	4914 ± 57	3298 ± 38	7274 ± 84	10212 ± 118	6941 ± 81	4330 ± 50	5174 ± 60	4854 ± 56
S	963 ± 12	756 ± 9	805 ± 10	929 ± 12	1031 ± 13	951 ± 12	1540 ± 19	1823 ± 23
Na	1167 ± 17	1225 ± 18	475 ± 7	357 ± 5	580 ± 9	718 ± 11	793 ± 12	1702 ± 25
Mg	3891 ± 49	3622 ± 46	3060 ± 39	3452 ± 43	3197 ± 40	3240 ± 41	3398 ± 43	3821 ± 48
Mn	76 ± 0.4	56 ± 0.3	108 ± 1	141 ± 1	85 ± 0.5	59 ± 0.3	43 ± 0.2	36 ± 0.2
Fe	5016 ± 54	2852 ± 31	4100 ± 44	5649 ± 61	3866 ± 42	3318 ± 36	1570 ± 17	1220 ± 13
Al	2431 ± 26	1557 ± 16	2318 ± 24	3434 ± 36	1870 ± 20	1566 ± 16	841 ± 9	698 ± 7
Zn	23 ± 0.3	21 ± 0.3	21 ± 0.3	28 ± 0.3	21 ± 0.3	22 ± 0.3	19 ± 0.2	33 ± 0.4
Cu	10 ± 0.5	2.0 ± 0.1	5.2 ± 0.3	7.5 ± 0.4	4.8 ± 0.3	10 ± 0.5	8.9 ± 0.5	10 ± 0.5
Pb	4.0 ± 1.0	2.9 ± 0.7	6.0 ± 1.0	8.0 ± 2.0	4.4 ± 1.0	2.6 ± 0.6	3.0 ± 0.7	2.1 ± 0.5
Cd	0.14 ± 0.03	0.18 ± 0.04	0.40 ± 0.09	0.38 ± 0.09	0.20 ± 0.05	0.35 ± 0.08	0.09 ± 0.02	0.05 ± 0.01
Co	2.5 ± 0.4	1.5 ± 0.2	2.5 ± 0.4	2.5 ± 0.4	2.1 ± 0.3	1.6 ± 0.3	0.9 ± 0.1	0.8 ± 0.1
Ni	3.0 ± 0.4	1.6 ± 0.2	2.9 ± 0.4	3.3 ± 0.5	2.8 ± 0.4	3.6 ± 0.5	2.9 ± 0.4	1.9 ± 0.3
Cr	1.8 ± 0.4	0.8 ± 0.2	1.3 ± 0.3	2.2 ± 0.5	1.3 ± 0.3	1.4 ± 0.3	0.5 ± 0.1	0.5 ± 0.1
As	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Se	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6

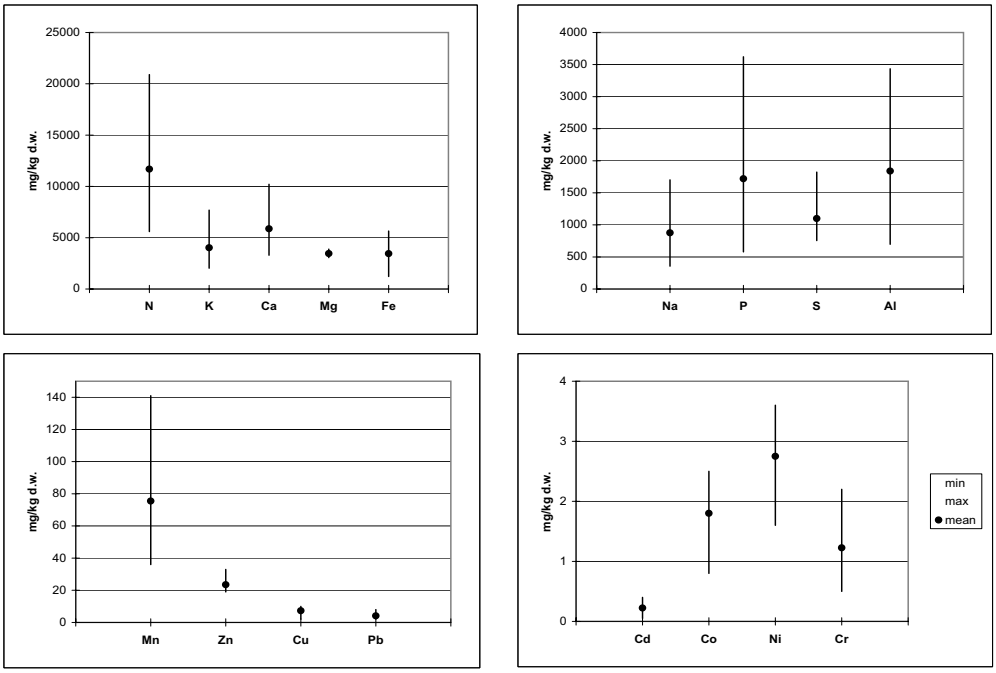

Fig. 3: Maximum, minimum and mean of macro- and microelements (mg/kg dry weight) in *Sanionia georgico-uncinata* during summer 2001/2002, based on samples from the eight plots.

plot 6: N>Ca>Fe>Mg>K>P>Al>S>Na>Mn>Zn>Cu>Ni>Pb>Co>Cr>Cd
plot 7: N>K>Ca>Mg>P>Fe>S>Al>Na>Mn>Zn>Cu>Pb>Ni>Co>Cr>Cd
plot 8: N>K>Ca>Mg>P>S>Na>Fe>Al>Mn>Zn>Cu>Pb>Ni>Co>Cr>Cd

The median values of elements in the mosses for the area around the Bulgarian Antarctic Base were as follows: N (9900) > Ca (5044) > Fe (3592) > Mg (3425) > K (3403) > Al (1718) > P (1495) > S (957) > Na (756) > Mn (68) > Zn (22) > Cu (8.2) > Pb (3.5) > Ni (2.9) > Co (1.8) > Cr (1.3) > Cd (0.19 mg/kg).

There was considerable variation between plots in the order of concentration shown by the elements occurring at the higher concentrations. However, most of the plots fell into two groups as regards the order of concentrations shown by the less abundant elements (Mn-Cd), i.e. lower altitude plots (1, 5, 7, 8) and higher altitude plots (2, 3, 4).

The results from correlation analysis of elements in *Sanionia georgico-uncinata* samples from different plots are presented in tab. 3. There were 58 significant correlations. Positive correlation with high statistical reliability ($p < 0.001$) was found between 20 pairs of elements, and high negative correlation between 2 pairs. The elements Zn and Cu do not show any statistically significant correlations with other elements.

Student's t-test showed a statistically significant difference ($p = 0.05$) between lower (2, 3, 4) and higher altitude, (1, 5, 6, 7, 8) plots only for P. The location of moss species near the see (plot 1, 2, 7, 8) was statistically significant ($p = 0.05$) only for magnesium and sodium.

Tab. 3: Correlation coefficients for elements in *Sanionia georgico-uncinata* samples.

	N	P	K	Ca	S	Na	Mg	Mn	Fe	Al	Zn	Cu	Pb	Cd	Co	Ni	Cr
N		0.93***	0.88***	–0.25	0.95***	0.55	0.41	–0.64*	–0.74**	–0.69*	0.52	0.62	–0.54	–0.66*	–0.84***	–0.20	–0.58
P			0.85***	–0.41	0.90***	0.59	0.30	–0.76**	–0.79**	–0.81**	0.43	0.58	–0.71*	–0.65*	–0.84***	–0.20	–0.64*
K				0.01	0.95***	0.40	0.18	–0.43	–0.67*	–0.60	0.57	0.45	–0.33	–0.55	–0.67*	–0.23	–0.56
Ca					–0.18	–0.70*	–0.37	0.89***	0.62	0.74**	0.23	–0.04	0.93***	0.56	0.59	0.47	0.64*
S						0.54	0.37	–0.59	–0.74**	–0.69*	0.50	0.56	–0.48	–0.71*	–0.77**	–0.26	–0.62
Na							0.80**	–0.75**	–0.60	–0.63*	0.46	0.22	–0.73**	–0.78**	–0.60	–0.72*	–0.58
Mg								–0.37	–0.14	–0.16	0.52	0.33	–0.34	–0.67*	–0.25	–0.47	–0.11
Mn									0.87***	0.94***	0.03	–0.24	0.98***	–0.77**	0.86***	0.47	0.84***
Fe										0.97***	–0.09	–0.12	0.80**	0.66*	0.96***	0.54	0.97***
Al											0.01	–0.16	0.90***	0.70*	0.92***	0.48	0.94***
Zn												0.39	0.05	–0.17	–0.18	–0.24	0.05
Cu													–0.22	–0.22	–0.22	0.47	0.08
Pb														0.69*	0.78**	0.43	0.76**
Cd															0.67*	0.59	0.66*
Co																0.47	0.88***
Ni																	0.65*
Cr																	

* – $p \leq 0.05$
** – $p \leq 0.01$
*** – $p \leq 0.001$

Discussion

During the floristic and ecological study on bryophytes of Livingston Island, SCHULTZ (1993) found 42 species, so the 23 species collected in the area of Bulgarian station are about a half of all the species so far known. Further collections on a larger territory could increase this number.

In 1998/1999 samples of *Sanionia uncinata* were collected and analyzed, together with some other species (YURUKOVA & GANEVA 1999). *S. uncinata* is taxonomically and ecologically closely related to *S. georgico-uncinata*, so some comparisons could be made. The mean concentrations of Mn, Fe, Co, Ni, Cd and Pb accumulated in *S. uncinata* were in the ranges of these metals found for *S. georgico-uncinata* in this study, whereas the concentration of Zn was very close to the minimum value, and content of Cu (19 mg/kg) was 2-fold higher than the maximum value found in *S. georgico-uncinata*.

BARGAGLI et al. (1998) wrote that Antarctic mosses show very low Pb concentrations but according to BOURTON & PATTERSON (1987) there are data showing lead contamination caused by Antarctic scientific stations. Lead concentration in moss samples from Parangalitza Biosphere Reserve, Rila Mt (Bulgaria) was found to be 31 mg/kg, much higher than in Livingston samples (GANEVA 1998). The results of the first and second moss surveys in whole Bulgaria done in 1995 and 2000 showed average values of lead 33 and 38 mg/kg, respectively (YURUKOVA 2000, YURUKOVA in press). From the last two European moss surveys (1995/1996 and 2000/2001) of wet and dry atmospheric deposition of heavy metals using some carpet-forming moss species as *Hylocomium splendens*, *Pleurozium scheberi* (RÜHLING & STEINNES 1998, UNECE ICP VEGETATION 2003) could be pointed out the following values of medians for the Europe: Cd – 0.40 and 0.27, Cr – 2.03 and 2.76, Cu – 7.51 and 7.47, Fe – 666 and 844, Ni – 3.06 and 2.32, Pb – 9.03 and 8.01, Zn – 37.3 and 37.7 mg/kg. As compared with these European medians of heavy metals the medians of Cu and Ni of the mosses studied around Bulgarian Antarctic Base were similar, of Cd and Zn were slightly lower, Cr and Pb up to 2 times less and Fe 5–6 times higher. *Sanionia georgico-uncinata* forming mats on rocky soil differs in growth-form from *Hylocomium splendens* and *Pleurozium schreberi* and this could explain the soil particle input and higher Fe content. In the study mentioned above, BARGAGLI et al. (1998) found increased concentration of both Cd and total P in mosses on ornithogenic soils. In this study the sample plots 5, 6, 7 and 8 were in the region of gull nests. The phosphorous concentrations in moss samples from these plots were high, but cadmium did not show such a trend. The opposite, a slight negative correlation ($p < 0.05$) was found between concentrations of these elements (tab. 3).

The lack of similar studies on mosses in the region prevents more comprehensive comparison of element concentrations. Using the current results for background concentrations of elements it could be assumed that the region is not heavily influenced anthropogenically. The scientific studies on Livingston Island continue. Monitoring using different biological objects on comparatively small territory, as well as soils and rocks, will be of scientific importance for environmental assessments together with revealing the advantages of animals and plants in long-term biomonitoring.

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