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Ecophysiological characteristic of plants communities under the bird rookery of West Spitsbergen

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Abstract. In the Arctic nature carries out its unique experiments, an example of which is the vegetation of bird colonies, where life is determined by the organic matter, which is taken out from the sea birds and is used only under the bird colonies. The absorption of nitrogen in the Arctic is limited by abiotic factors: low temperature and humidity, the slow erosion of rocks, low transpiration and the presence of permafrost. The data on the content of total nitrogen and chlorophyll in plants and lichens in communities located beneath bird colonies in the West Svalbard. The study showed that plant communities of rookeries, where the effect of one of the limiting factors of the Arctic (poor soil horizon) is reduced, give some idea of the "Green Arctic", where the current climate change is guiding it.

Keywords: *West Spitsbergen, plants, lichens, ornitogenic communities, pigments of plastid, total nitrogen, the "Green Arctic"*

Low nitrogen content limits the growth of plants at high latitudes [1]. Absorption of nitrogen in the Arctic is limited by abiotic factors: the low temperature and humidity, the slow erosion of the rocks, low transpiration and the presence of the permafrost. The slow speed of the natural decomposition of organic matter and a long term ice cover lead to a reduction of vegetation period up to 6-8 weeks.In nature, there are various ways that improve plant nutrition for these poor soils. Under these conditions, free nitrogen-fixing microorganisms, ericoids, work and exsiccosis symbioses that utilize available soil nitrogen goes on. Some species consume ammonia. Against the background of the poor nutrogen areas, rich with organic matter places exist and they are related to bird colonies and formed

ornithocophilous community. Ornithogenic soil associated with the places of seasonal replenishment of organic matter; on top of the rookery its maximum is reached and its amount is gradually reduced to its base. This territory usually has nitrogen content. Communities along the nitrogen concentration gradient are a natural model system that allows analysis of the reaction of certain plants to additive nitrogen. Purpose is to study the content of plastid pigments and total nitrogen in plants and lichens, as a reaction to the changing conditions on the transect on the slope under the rookery.

Materials and methods

The research was carried out in July 2011, at Cape Starostin, based on the fragments of rock ridge (78° 04'44 "N, 13° 50'16" E). Rookery was about 150 meters along the rock of about 400 m. The height of the rock to the rookery area is about 12 meters. The mountains are composed of limestone, dolomite, conglomerate-breccias Carboniferous-Permian. The area was inhabited by a colony of fulmars (Fulmarus glacialis), a small numbered one [2]. The rookery is of the southern orientation, so it has a light for about 11 hours a day. The territory on the way to the rookery represents a community of the upland tundra with numerous lakes and marshy places. Mountain foothills were intensely colored with a red-brown color, the height is 300—400 m, snow tongues are 150—200 m. Transect[1] was laid down on top of the high rock, where there is a waterfall and a snowfield departs. In period between the 19th of April and 24th of August this latitudes enjoy the polar day and a stable temperature transition through 0°C to positive values takes place between the 5th of June; to negative — on the 18th of September. The most warm month is July with an average temperature of 8.0°C. The average for the annual precipitation is 563 mm, with most of the falls in winter [3, p. 10—12].

Composition of the ornithocophilous vegetation near the rookeries is quite specific [4, 2004], and it includes oligomers, monodominant meadows, dominated by Trisetum spicatum (L.) K. Richt., *Poa arctica* R. Br. var. vivipara, *Poa alpina* L. var. vivipara, *Poa alpigena* (Fr.) Lindm, there are herbaceous plants: *Cochlearia groenlandica* L., *Cerastium alpinum* L., *Bistorta vivipara* (L.) F. Gray, *Saxifraga cernua* L., *Arabis alpina* L., *Chrysosplenium tetrandrum* (N.Lund) Th. Fr. Participation of species typical for the zonal tundra and mountain tundra is small: *Salix polaris Walenb*. L., *Saxifraga oppositifolia* L., S. *cespitosa* L., a significant part of species and their diversity falls on moss and lichen synusia. Indices of species diversity of communities constitute 5—13 species per society.

Species of plants and lichens were identified by the PABSI staff: vascular — V.A. Kostina, mosses — O.A. Belkin, lichens — L.A. Konoreva. Latin names are given by the following sources: for vascular plants [5]; moss [6]; lichens [7].

[1] Transcent (from. Latin words *trans* — through, across, and *sectio* — section) — narrow and long platform used to study the quantitative characteristics of the species and their changes.

The content of plastid pigments was determined in alcohol extracts using spectrum-photometr UV-1800 (“Shimadzu”, Japan) by optical density at the absorption maxima of chlorophyll a and b, carotenoids [8; 9]. Samples for the determination of total nitrogen content were collected at once, dried at 60°C and analyzed by the Kjeldahl method [10, 1970].

Results and discussion. Description of the community under the rookery

A transect with the release of 7 sample plots per an area of 1 m^2 was laid under rookeries in the plant community from top to bottom. Description of species and cover types (CP) of plants and lichens ispresented in Table 1.

Table 1

Species and spread (%)of plants and lichen of the ornithocophilous community

Type	Trial area of transect (up-down)						
	1	2	3	4	5	6	7
Oxyria digyna (L.) Hill	40	-	-	-	-	-	+
Puccinella phryganoides (Trin.) Scribn. & Merr.	20	20	10	20	-	-	-
Cerastium alpinum L.	+	1	+	-	+	-	-
Saxifraga cespitosa L.	+	10	5	-	+	-	+
S. oppositifolia L.	+	1	20	-	20	1	+
S. nivalis L.	+	1	+	-	5	-	-
S. cernua L.	+	+	+	1	-	+	+
Salix polaris Walenb. L.	-	-	+	-	-	-	-
Bistorta vivipara (L.) F. Gray	-	-	30	-	-	-	-
Luzula confusa Lindeb.	-	-	-	10	1	2	2
Cochlearia groenlandica L.	-	+	-	-	-	-	+
Dupontia pelligera (Rupr.) A. Løve & Ritchie	-	+	-	-	-	10	2
Alopecurus borealis Trin.	-	-	-	20	+	5	5
Ranunculus sulphureus Soland.	-	-	-	-	-	+	+
R. pygmaeus Wahlenb.	+	-	-	-	-	+	+
Total higher vascular plants (amount of species)	**8**	**8**	**8**	4	6	7	**10**
Sanionia uncinata (Hedw.) Loeske	80	50	-	-	20	90	20
Hylocomium splendens (Hedw.) B. S. G.	10	50	50	50	20	15	20
Aulacomnium palustre (Hedw.) Schwaegr.	10	50	50	50	20	10	25
Dicranum angustum Lindb.	+	+	+	1	+	+	+
Dicranum spadiceum Zett.	+	+	+	1	+	+	+
Polytrichastrum alpinum (Hedw.) G. L. Sm.	-	-	+	+	-	+	+
Paludella squarrosa (Hedw.) Brid.	-	-	-	-	+	+	+
Total bryophytes (amount of species)	5	5	5	5	**6**	**7**	**7**
Peltigera rufescens (Weiss.) Humb.	21	25	3	2	2	2	-
Peltigera leucophlebia (Nyl.) Gyeln.	-	-	5	5	-	-	-
*Peltigera malacea (*Ach.) Funck	-	-	-	5	-	-	-
Peltigera aphthosa (L.) Willd.	-	+	1	-	+	1	-
Xanthoria elegans (Link.) Th Fr.	20	-	-	-	-	-	-
Total lichens (amount of species)	2	2	**3**	**3**	2	2	0

In total, in the chosen transect we have studied: 27 species, including 15 species of height vascular plants, 7 mosses and 5 lichens.

Pl 1. Located below the rookery between a rock and snowfields (3 meters of snow on the language), near a waterfall, which provides its hydration. *Oxyria digyna* dominates with the active

participation *Puccinella phryganoides* on the background of the continuous moss cover, a great contribution is made by epilithic lichen *Xanthoria elegans* and *Peltigera rufescens* estimated coverage on rocky outcrops up to 20%.

Pl 2. Located on transect 3 meters below. It has a rich moss cover (100%). Dominating species: *Puccinella phryganoides*, different species of the *Saxifraga* with huge leaves and peduncles, which are not typical for the normal habitat. Among lichens the *Peltigera rufescens* is dominating.

Pl 3. Loacated at a distance of 5 meters below the previous one, along the rock, 15 meters from the snow cover. The moss cover is complete (100%). In a community with a large CP there are *Bistorta vivipara* and *Saxifraga oppositifolia* and lichens *Peltigera leucophlebia*, *Peltigera rufescens, Peltigera aphthosa*.

Pl 4. Located at a distance of 40 meters from the rookery, 20m lower than the previous. The moss cover is complete (100%) with the present of marked PP cereals: *Puccinella phryganoides* and *Alopecurus borealis*. Lichens are represented by the species p. Peltigera (*Peltigera rufescens, Peltigera leucophlebia, Peltigera malacea*).

Pl 5. Located 60 meters below from the previous one, there is no snowfield, 20 meters from the stones, on the left. The moss cover is thin (90%), there are rocks, wasteland, *Saxifraga oppositifolia* and *Alopecurus borealis* with the CP of 20%; the species composition of lichen and PP decreases.

Pl 6. Located at the base of the slope, runoff goes to the right in the valley, at 120-130 meters below the previous site. Smooth area, continuous moss cover with domination of *Sanionia uncinata*. Among cereals: *Dupontia pelligera*, *Alopecurus borealis*, also one of lichens, with a small CP — *Peltigera rufescens, Peltigera aphthosa*.

Pl 7. Located 200 meters lower than the previous site, along the flow (stream with snowfields and a rookery) with access to the upland area with the set of streams. Solid moss cover, grains with a small estimated coverage and lichens do not exist there.

A species distribution analysis on the transect showed that the number of species and the projection lichen cover is reduced along the slope, and is absent on the upland areas. The moss cover is rich in all the test areas, but the variety of species increases on the lower sited. The species composition of vascular plants is larger on the upper and lower parts of the transect. The projected coverage is decreasing along the slope. All transect has: two species of mosses (*Sanionia uncinata, Aulacomnium palustre*); such species are not presented among the vascular plants, which indicates the differential demands of this taksonomic group for growth conditions in the study area.

The content of plastid pigments

Comparative analysis of the content of chlorophyll in species growing near the rookery and the natural conditions of the Arctic tundra has shown an increase in pigments under ornithocophilous communities (25-100%) of the following species of vascular plants: *Luzula confusa* (the family Juncaceae.), *Puccinella phryganoides, Alopecurus borealis* (the family Poaceae.) and almost 2 times in mosses: *Sanionia uncinata, Aulacomnium palustre, Hylocomium splendens*. In lichen community pigment content changes have not been identified compare to natural conditions (*Table* 2).

Individuals *S.oppositifolia* on pl. 2 had different size, large and long shoots, but they had shown the lowest values of chlorophyll content of 0.46 mg/g. Smaller plants within the test area (pl. 5) had higher values of chlorophyll content — 0.73 mg/g, which corresponded to this plant growing in natural communities. Reduction of chlorophyll content in rich soils are related, to the change of osmotic potential due to the absorption of nitrogen and consequently a higher water content in these plants. Large examples of *S. oppositifolia* have a larger vegetative mass, but almost do not bloom, which is also a negative reaction to the conditions of increased wealth of soil.

Table 2

The content of chlorophyll and total nitrogen in plants in natural and ornithocophilous areas

Type	*Chlorophyll (a+b), mg/g of raw mass*		*Total Nitrogen, %*	
	1	2	1	2
Oxyria digyna	0.76	0.61	4.7	4.4
Bistorta vivipara	1.32	1.17	3.3	3.5
Saxifraga cespitosa	0.39	0.37	1.5	2.1
S. oppositifolia	0.66	0.58	1.5	2.5
S. nivalis	0.98	1.10	2.5	2.8
Salix polaris	1.23	1.22	2.6	2.6
Luzula confusa	1.12	1.68	-	2.4
Puccinella phryganoides	0.78	1.81	2.1	3.2
Dupontia pelligera	1.38	1.38	1.7	3.3
Alopecurus borealis	1.28	1.56	2.0	-
Sanionia uncinata	0.18	0.42	1.0	1.2
Hylocomium splendens	0.14	0.30	-	0.8
Aulacomnium palustre	0.19	0.42	0.8	0.9

Note. 1 — natural conditions, 2 — anemophilous conditions. Dash — the lack of data.

Sanionia uncinata is the most common type of moss in all of the test areas with large estimated coverage. The content of chlorophyll changed in a transect from top to bottom: 0.25 (PL2), 0.27 (Pl4); 0.72 (Pl6) and 0.42 (Pl7) mg/g of the wet weight. A similar pattern was observed for *Aulacomnium palustre*, whose chlorophyll content increases to the bottom of the slope: 0.29 (PL2), 0.49 (Pl4) and 0.47 (Pl7) mg/g of the wet weight. The content of chlorophyll in *Peltigera rufescens* varies by transect as follows: 0.35 (PL1), 0.15 (PL2), 0.23 (Pl3) mg/g of the wet weight.

Total nitrogen content

Humidity is the major factor involved in the labeling of ornitophilous vegetation and in processing of organics. The disintegration of organic matter determines ornithocophilous community and the state of vegetation, which is a food for many soil organisms. All the freed mineral substances, especially nitrogen, are an important and the most informative exponents of the soil wealth and status of the plants. Determination of total nitrogen as a measure of functional activity of the plant organism demonstrated one general rule: the lower amount of nitrogen was observed in the test areas in the upper parts of cones of weathering, closer to the rookery, and the maximum consentration of nitrogen was observed at the lowest test area — close to the foot of the slope.

According to the content of total nitrogen, two groups could be distinguished among the vascular plants. The first group includes species whith the unchanges nitrogen content in comparison with the natural conditions (*Oxyria digyna, Bistorta vivipara, Cerastium alpinum, Salix polaris*). However *Oxyria digyna* and *Cochlearia groenlandica* under anthropogenic communities (about cattle-breeding complex in Barentsburg) have several times more bio-mass, compared to plants of the natural habitat. For Cerastium alpinum it was also noted an increase in the total nitrogen content, but it was also found that another type of *C. arcticum* had a very high constitutive activity of nitrate reductase [11]. Its active work, could be explained by the genetic differences of the different species of the same family and the populations of the same species. This argument can explain a number of differences between the data obtained in this study and some literature [12].

The second group consists of species with the increased total nitrogen content. Thus, the species of *Saxifraga* (*Saxifraga cespitosa, Saxifraga oppositifolia, Saxifraga nivalis*) have an increase of 15-70%. The maximum values were observed in *Saxifraga oppositifolia*. It is known that *Saxifraga oppositifolia* is an ectomycorrhizal type, but in terms of Svalbard this is not implemented. [11] We can assume that, natural increase of nitrogen content in species of *Saxifraga* under ornithocophilous communities may be associated with the induction of this process in this ecotope of Spitsbergen only. In monocotyledonous plant (*Puccinella phryganoides, Dupontia pelligera, Luzula confusa*) the increase in total nitrogen was 50—100%. The reaction of these species may be associated with their ability to master the ruderal ecotopes. The response of mosses and lichens is less noticeable and the increase in the total nitrogen content amounted to 30—40% only in species such as *Aulacomnium palustre* and *Sanionia uncinata, Peltigera rufescens*.

The effect of increased nitrogen and warming is widely studied [13]. Studies have shown that only an increase in temperature has less impact on the projective cover (PC) of various types, and more, and as a rule, the negative effect is achieved with the addition of nitrogen or nitrogen in

combination with higher temperatures. In the context of the rookery the impact is happening in the system of soft experiment, where each type can find a “micro-niche” containing orgaic materials relevant to their needs. In this experiment, the shrubs (species of Salicaceae) reduced density of coverage in all variants of experience with the addition of nitrogen and increasing the temperature; in a rookery this type was rare and had a slight cover. Among the herbaceous species the greatest effect in the experiment was observed for *Cerastium alpinum*, its projective cover increased up to 90% in the form of nitrogen supplements. Great effect of stimulation growth of *Cerastium alpinum* was archieved as a response to the addition of nitrogen and warming; it was observed in other studies as well [14]. In our study, *Cerastium alpinum* presented along the transect, but its projective covering was insignificant. *Saxifraga oppositifolia* increases its cover with the addition of nitrogen, but decreases — in the variant with nitrogen temperature. In our study, this species increased the projective cover up to 20% at the bottom of the transect.

Reaction of moss

The response of mosses in all variants of the field experiment was negative and most of the species disappear from the grounds by the third year (*p. Dicranum*). A similar reaction got the other groups of organisms (representatives of liverworts and lichens partially disappear or drastically reduce their abundance). In our study, we noted a sharp increase in the moss cover, throughout the transect, the formation of large moss meadows. It is known that 3-6 year increase in temperature led to a change in community composition (it became poorer), according to research carried out on 17 alpine and arctic areas [15]. Small plants that have a low potential to increase biomass, such kinds of *p. Saxifraga*, including *S. oppositifolia* reduce their projective cover [12; 16] with a long-term effect of high temperature due to the emergence of competition. This factor plays an important role in the disappearance of moss, which can not compete and make the shading with a strong impact of higher vascular plants [17].

Thus, grasses, mosses and lichens constitutively react to the warming and/or an increase in nitrogen, and the reaction depends on the type and function of habitat type [18, 2002]. However, this study shows a fairly mixed picture in the reaction of certain types belonging to the same functional type [13].

Ecosystem functions of plant communities of rookeries

Ornithocophilous community rookeries are unique natural objects, where cause and effect relationships are difficult for understanding and modeling. Studies have shown that plant communities at the rookeries, where the reduced action of one of the limiting factors of the Arctic (poor soil horizon) give some idea of the “green Arctic”, where it is led by the climate change. In the Arc-

tic the nature carries out its unique experiments represented by the vegetation of rookeries, where life is determined by the organic matter, which is tranfered by birds from the sea and is only used by bird colonies.

Ecosystem functions are valuable for natural integrity in the Arctic region. Understanding how they work is related to knowledge of resistance mechanisms and plant plasticity, growing in these ecotops, their potential responses to climatic changes in the Arctic that remains a relevant ecological problem, an important step of wich is the development of reaction of individual species in the natural conditions. This is just one of the steps of research aimed at preservation of the fragile Arctic environment. Of course it requires scientific analysis and synthesis of many processes that go on not only in the plant world of the Arctic region, but also in the fauna and the waters of the northern seas and climate.

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