20. *Шкляев В.А., Ермакова Л.Н., Шкляева Л.С.* Особенности долговременных изменений характеристик вегетационных периодов в Пермском крае// Географический вестник. 2012. № 2 (21). С. 68-73.

S.A. Kulakova

TRANSFORMATION OF ENVIRONMENT OF PERM REGION

Since biota primarily responds to external stimuli, so to evaluate the transformation of the natural environment in the Perm region analyzed data about the dynamics of the structure of the land fund, shares of forest and agricultural land, the natural and the age structure of forests, the structure of natural focal infections, the dynamics of development of road network as well as the recreational activities of the population.

K e y w o r d s: transformation, the natural environment, nature, dynamics, succession, restoration.

Svetlana A. Kulakova, Candidate of Geography, Associate Professor of Department of Biogeocenology and Nature Protection, Perm State University; 15 Bukireva, Perm, 614990 Russia; kulakovasa@mail.ru

УДК 574.45

E. Pirożnikow, E. Czwienczek, E. Moczydłowski

TERRESTRIAL ECOSYSTEMS ON SPITSBERGEN – FUNCTIONING

Consideration of ornitho – coprophilous effect and ecosystems regarding fiord Hornsund of Spitsbergen. Those ecosystems are poor in flora and fauna and are known from low productivity, because of two major factors, which are temperature and water sources. Western scientists think that in Arctic, ornitho – coprophilous effect decides about productivity of whole terrestrial ecosystems. Authors disagree with that hypothesis showing their own experience. Plants grow under the snow cover no matter of the ornitho – coprophilous effect.

K e y w o r d s: ecosystems, productivity, primary consumers, secondary consumers, detritivores.

The functioning of ecosystems in Spitsbergen has long been the subject of intense research because they are subjected to a very small anthropogenic influence and are considered to be the simplest. Descriptions of the functioning of terrestrial ecosystems on Spitsbergen are considered to be the most complete thanks to a good recognition of biodiversity, productivity and feed chains in comprehensively described habitat conditions, natural vegetation with low human pressure [13; 15].

The simplicity of these ecosystems is known due to the low biodiversity and long – term processes of decomposition of organic matter. Most environmentalists holds the view of [5], who recognized that ecosystems are open, that are maintained by constant supply of biogenic elements carried out by sea birds to the land. The authors of this paper believe that this view is not tenable because of the specificity of these ecosystems – there can be other factors deciding resulting from climate and geomorphology and soil properties.

Spitsbergen is the largest island of the Norwegian Svalbard archipelago lying in the Arctic (71°– 81° N and 10° – 35° E – 1100 km from the North Pole). The area of the archipelago is approximately 39 000 km². It is a mountainous (up to 1717 m above sea level), and 59.8% covered with glaciers. Spitsbergen climate is relatively warm for arctic conditions because the branch reaches the Gulf Stream, which carries warm water masses. They collide with the incoming of the north cold Arctic East – Spitsbergen Current. Average winter temperatures are 20 degrees higher than those recorded at similar latitudes, eg. in Canada. The lowest average temperature is in February and is – 20°C, the highest average temperature is +4.4°C and occurs in

Pirożnikow Ewa, PhD, Senior Lecturer, Faculty of Forestry in Hajnowka, Bialystok University of Technology; Pilsudskiego 8, 17-200 Hajnowka; e.piroznikow@pb.edu.pll
Czwienczek Ewelina, PhD, Assistant Professor, Faculty of Forestry in Hajnowka, Bialystok University of Technology; Pilsudskiego 8, 17-200 Hajnowka; e.czwienczek@pb.edu.pl
Moczydłowski Eugeniusz, PhD, Department of Antarctic Biology, Institute of Biochemistry and Biophysics, Polish Academy of Science; Ustrzycka 10/12, 02-141 Warsaw; gienekmoczydlowski@gmail.com

July. Winter temperatures range typically between – 25°C and up to a day to +5°C in summer between +2 ° and up to a day to +18 ° C.

The average annual temperature for the years 1978 – 2001 varied from – 7 to – 2°C, although for the past 50 years, winter temperatures in the Arctic have risen by 3 – 4°C. Precipitation is very low and varies each year from 200 to 300 mm per year, but the last century, they increased by approximately 8%. Svalbard is one of the arctic deserts, because rainfall occurs mainly in the form of snow. Air humidity, even close to the sea, is usually very small. Important for the climate of Spitsbergen is the fact that this region is a place of air clashing: coming from the north cold Arctic air masses flowing from the south with warm and moist air masses of the Atlantic. This results in a very active and frequent cyclonic circulation in the area lows (low pressure) and associated atmospheric fronts – large areas of cloud cover, rainfall and strong winds.

In winter season, when the temperature contrasts are significant (there are changes of more than 20 degrees during the day), there are triggered huge amounts of energy, which causes frequent occurrence of storm winds. In the summer, winds are generally weaker, while fogs are frequent.

Generally, it can be said that the weather in the region of Spitsbergen is very variable and often during the growing season comes to breaks in photosynthesis due to low temperatures or lack of water in the soil.

In the Arctic growing season is very short (in the area of Hornsund it last 94 days), but photosynthetic efficiency is relatively high due to the fact that it is a polar day, which in the area of Hornsund lasts from 22 April to 21 August (121 calendar days).

In all Arctic, throughout the plants and animals life is severely limited in both time and space [15]. Most of the year the conditions are unfavorable for living organisms – environmental factors reach values exceeding tolerance of individual species, but in times of favorable life intensity factors change abruptly as "unpredictable", which reduces the number of species inhabiting these areas, so both flora and fauna are poor [1; 16].

Life focuses mainly on the border between sea and land; on land is limited to the narrow coastal zone and marine terraces of mountain slopes descending to the terraces and valleys of rivers flowing from glaciers. Only 6 – 7% of the island area is occupied by communities of plants and lichens. Other areas are covered with glaciers, which protrude rocky nunataks inhabited by a few lichens and bryophytes.

The vascular plant flora of Svalbard consists of 173 species [6]. Spitsbergen has an impressive mosaicism environments, ie the degree of contrast and fragmentation of environments. Individual species selectively inhabit a variety of habitats and can effectively colonize them through a minimum pressure of herbivores (until the end of the XX century). In plant associations/communities, where a large role is played by vascular plants, are abundant species like: purple saxifrages *Saxifraga oppositifolia*, drooping saxifrages *Saxifraga cernua*, polar willow *Salix plaris*, alpine bistort *Polygonum viviparum*. However, in the arctic vegetation the biggest importance belongs to lichens and bryophytes [4]. On Svalbard, there are 373 species of moss and 597 species of lichens [6]. The cause of poor flora regions of the Arctic is their "youth", that is a relatively recent period of glaciation resignation and remoteness of these areas of the continent because the sea separating the island from the mainland delay or prevent the migration of plants and animals.

Vegetation covers less than 10% of Svalbard. In places where snow cover long overdue and the growing season lasts 30 – 45 days to develop a polar desert communities with the participation of small rosette plants, mosses and lichens in which plants and lichens cover a maximum of 10%, while in places where snow cover disappears earlier, and better soil warms up, developing communities of northern arctic tundra of higher short circuit (approx. 50%) dominated by low – lying shrubs, bryophytes and lichens appears [6].

These plant associations are characterized by low productivity: on Spitsbergen it is 0,27-0.5 t/ha/year [15] while Brattbakk and Rønnig after [15] indicate 0,5 – 1,4 t/ha/year, in Hornsund area – 0,02 – 2,7 t/ha/year [13].

Mountain ecosystems in Europe have 6 – 450 times bigger productivity [15]

The utilization rate of primary production by consumers is very low – is approximately 1 – 2%, while the mountain meadows in Europe is 1,4 – 24% [15]. This is because a very small variety of Spitsbergen flora compared to other areas of tundra on the same latitude [15]; there are only some well represented systematic groups, in which individual species populations reach high numbers; Terrestrial vertebrate fauna is represented only by birds and mammals – what is very poor. 109 species of birds is recorded on Spitsbergen [16].

The most numerous birds are bi-environmental, or feeding at sea and on land-reproducing, for example: little auk (*Alle alle*), whose populations are counting several hundreds of thousands of individuals. On Spitsbergen there are 208 large colonies of seabirds [10]. Birds feeding on sea transport to land a huge amount of biogenic elements soil conditioners mainly at the foot of the colony.

Among primary consumers, the most important is the barnacle goose (*Branta leucopsis*) and reindeer (*Rangifer tarandus*) [12]. Until recently, the reindeer appeared in the area of Hornsund occasionally, but since 2000 the summer of permanently manned two herds with a total of approximately 30 pieces

(Kowalewska – Giżejewska personal information). The presence of such a large group of large herbivores has a significant impact on the vegetation and other elements of the ecosystem.

Secondary consumers are three species of birds and two mammals: glaucous gull (*Larus hyperboreus*) and black-backed gull (*L. marinus*) and to some extent skuas (*Stercorarius* sp.) That prey on other birds. Skuas most common prey forcing three – toed gulls to spit their food. Among the predators are mammals like arctic fox (*Vulpes lagopus*) or the polar bear (*Ursus maritimus*)[12].

In the first year of destruction the dead plant material lost 30 – 45% of its initial value, after 10 years only ca 25% of the initial amount of organic matter was left. In tundra ecosystem the majority of primary production (99%) enters the decomposition chain, whereas herbivores, especially invertebrates, play no important role in the energy flow and matter cycling [15].

Among detritivores, there are the most important protozoan animals (*Protozoa*), rotifers (*Rotifera*), nematodes (*Nematoda*), earthworms (*Oligocheta*), tardigrade (*Tardigrada*), crustaceans (*Crustacea*), mites (*Acari*), spiders (*Aranea*), springtails (*Collembola*), flies (*Diptera*) [16]. Because the plant food at low temperatures is very poorly absorbed by the cold – blooded animals, practically all invertebrate animals and animal protozoa are detritivores or predators. Necromass makes functioning most of food chains [16].

The theory is generally accepted that sea birds nesting in the Arctic in huge groups during several months of the breeding colonies, transport large amounts of nutrients from sea to land, which determines the size of the primary production of terrestrial ecosystems. This phenomenon is considered to be the main factor responsible for enriching the land part of the Arctic ecosystem in marine organic matter (mainly nitrogen ions). This is a result of deposition and subsequent decomposition of guano, but also leaving leftovers, egg shells, feathers and dead birds nearby colony.

Breeding colony of little auk *Alle Alle*, which has in the region of Hornsund 100 000 pairs of supplies chicks to 70 tons/month of food while food gained biomass in the sea of warm – blooded vertebrates is 2500 tons/year [16].

Huge amounts of excrements (*Plautus alle*) constantly washed by the water, run down the slope and cause soil fertilization. This fact was decisive for the emergence ornitho – coprophilous plant associations whose variation depends on the substrate, configuration of the terrain and the concentration of faeces [2; 3].

The concentration of nutrients in the colonies of seabirds on Spitsbergen is from 3 to 6 times higher than in their neighborhood [5]. Primary production of tundra on Spitsbergen in the area that is under the influence of bird colonies is at least three times greater for mosses and about seven times greater for vascular plants on places away from the bird colonies. Ornitho – coprophilous effect is strong only in the immediate vicinity of the colony (expires dozen meters from the border colonies) [16]. For this reason, the authors believe that the ornitho – coprophilous effect could not be considered as a major factor in defining the size of the primary production of terrestrial ecosystems on Spitsbergen.

The volume of primary production depends mainly on the temperature of the ground, which depends on the exposure and share part of the backbone and stones. Studies of Aleksndrova (1983) showed that the difference between the soil with fine fractions (eg. gravel, sand) and stones can be 30°C. Vascular plants of rocky habitats achieve significantly bigger sizes and have more production because the physiological processes occur much more intense here than in habitats without stones [14]. Plants have the right conditions for growth and development only in the air layer close to ground surface [11]. Furthermore, the development of vegetation is limited by the shortage of moisture in the soil, especially in the second half of the growing season when plants are not able to use water from melting snow [8].

Research conducted by one of the authors (E. Moczydłowski) in April 2008 showed that under the 300 cm layer of snow cover there were green growth parts on moss gametophyte. The study continued after the snow cover melts in July 2008. Pirożnikow and Moczydłowski showed complete inhibition of growth of moss. Since the permeation PAR (photosynthetically active radiation) by a layer of snow having a thickness of 300 cm was found to be unlikely, as it is doubtful presence of liquid water in the frozen ground after winter – likely hypothesis was: that mosses intensively increase at the end of the polar day of the previous year, under the thin layer of first snow fall and last on standby for photosynthesis during the winter, until the spring, when the snow layer is again thin, PAR penetrates the surface of the tundra, and the temperature rise causes melting of ice.

The results indicate the need for a redefinition of the vegetation season of bryophytes, understood so far as the period following the descent of snow and lasting until the first snowfall and temperature drop below zero in the fall.

It is likely that bryophytes grow in fall and/or early spring – always under the cover of snow. The increase or duration is maintained throughout the melt period. The life activity of those plants is completed after the melt waters are gone.

We hope that the continuation of our research using the equipment for the electronic monitoring of multiple environmental factors will contribute to a new look at the functioning of terrestrial ecosystems on Spitsbergen.

References

1. *Aleksandrova V.D.* 1983. Rastitielnost polarnych pustyń. Nauka, Leningrad, 142 pp.

2. *Dubiel E., Olech M.* 1992. Ornithocoprophilous plant communities on the southern slope of Ariecammen (Hornsund region, Spitsbergen). In: Landscape, life word and man in High Arctic. Institute of Ecology, Polish Academy of Sciences, Warsaw: 167 – 175.

3. *Dubiel E., Olech M.,* 1992. Ornitocoprophilous plant communities on the southern slope of Ariekamen (Hornsund region, Spitsbergen), in: Ladscape, life word and man in High Arctic , Opaliński K. W. Klekowski R. Z. (reds.). Institute of Ecology, Polish Academy of Sciences, Warsaw, 1992, s. 167 – 175.

4. *Elvebakk A.*1985. Higher phytosocjological syntaxa on Svalbard and their use on subdivision of the Arctic. Nord J. Bot. 5:273 – 284.

5. *Eurola S., Hakala U. K.* 1977. The bird cliff vegetation of Svalbard.— Aquilo Ser. Bot., 15:1-18.

6. *Jónsdóttir I.S.* 2005. Terrestrical ecosystems on Svalbard: heterogeneity, complexity and fragility from an arctic island perspective. Biology and Environment: Proceedings of the Royal Irish Academy 105B (3):155 – 165.

7. *Klekowski R. Z., Opaliński K.* 1884. Przepływ materii i energii w tundrze Spitsbergenu. Wiadomości Ekologiczne 30:143 – 166.

8. *Korotkievič E.S.* 1972. Poljaryne pustyni. Gigrometeoizdat., Leningrad: 1 – 420.

9. *Kuc M., Dubiel E.* 1995. The vascular plants of the Hornsund area (SW Spitsbergen). Fragmenta Floristica et Geobotanica 40(2):797 – 824.

10. *Mehlum F., Fljeld P.E.* 1987. Catalogue of seabird colonies in Svalbard. Rapportserie Norsk Polarinstitutt 35, Oslo, 222pp.

11. *Moczydłowski E., Pirożnikow E.* 1993. The temperatures in the plant communities of Ariecammen – Fugleberget catchement area (West Spitsbergen). W: J. Repalewska-Pękalowa, K. Pękala (red.) Man impact on polar environment. Wydawnictwo Uniwersytetu Marii Curie –Skłodowskiej, Lublin:229 – 232.

12. *Moskal W.* 1990. Southern Spitsbergen mammals (Mammalia). In: Romuald Z. Klekowski, Węsławski J.M. (red.). Atlas of the marine fauna of southern Spitsbergen. V.1. Vertebrates. Ossolineum, Wrocław, Warszawa, Kraków (…):89 – 97 .

13. *Opaliński K.W.* 1991. Primary production and organic matter destruction in Spitsbergen tundra. Polish Polar Research 12/3:419 – 434.

14. *Pirożnikow E.* 1996. Strategie adaptacyjne roślin w warunkach pustyń arktycznych. Dział Wydawnictw Filii Uniwersytetu Warszawskiego w Białymstoku, Białystok:1 – 121.

15. *Remmert H.* 1980. Arctic animal ecology. Springer Verlag, Berlin, Heidelberg, New York, 250 pp.

16. *Stempniewicz L., Zwolicki A., Iliszko L., Zmudczyńska K., Wojtuń B., Matuła J.* 2006.Impact of plankton – and fish – eating seabird colonies on the Arctic tundra ecosystem- a comparison. Journal of Ornithology 147, suppl.: 257 – 258.

E. Pirożnikow, E. Czwienczek, E. Moczydłowski

ФУНКЦИОНИРОВАНИЕ НАЗЕМНЫХ ЭКОСИСТЕМ ШПИЦБЕРГЕНА

Рассмотрена продуктивность в экосистемах архипелага Шпицберген. Видовой состав растительного покрова и животного населения отличается малым разнообразием. Экосистема обладает низкой продуктивностью из-за действия температуры и недостатка водных ресурсов. По мнению многих ученых, причиной продуктивности наземных экосистем в Арктике является орнитокопрофильный эффект. Авторы, не согласные с данной гипотезой, описывают свой собственный опыт. Растения могут расти под снежным покровом, где орнитокопрофильный эффект не имеет значения.

К л ю ч е в ы е с л о в а: экосистемы, продуктивность, первичные консументы, вторичные консументы, детритофаги.

Евгения Пирожникова, PhD, Факультет лесного в Хайнувке, Белостокский технический университет; Polska ul. Piłsudskiego 8 17-200 Hajnówka; e.piroznikow@pb.edu.pl

Эвелина Тшвэнтшэк, PhD, Факультет лесного хозяйства в Хайнувке, Белостокский технический университет; Polska ul. Piłsudskiego 8 17-200 Hajnówka; e.czwienczek@pb.edu.pl

Евгений Мотшидловский, PhD, Кафедра антарктической биологии, Института биохимии и биофизики, Польской академии наук, Ustrzycka 10/12, 02-141 Warsaw; gienekmoczydlowski@gmail.com