

CHANGES IN VEGETATION

Plant communities in 1982–1985

The making of phytosociological maps of Arctic areas is difficult because of incomplete knowledge about tundra plant communities. One of the problems is mosaic vegetation made up of many different communities occupying small areas. Available vegetation maps usually show the distribution of physiognomic types of tundra (CAVM Team 2003) or the distribution of plant communities on a large scale (Elvebakk 2005).

A detailed vegetation map catalogues plant communities in a given area and shows their extent and geographic location. The phytosociological map of northwest Sørkapp Land (Dubiel, Olech 1991), which was the basis for the current comparative study, was made on a 1 : 25 000 scale. Mapping was preceded by making a series of relevés according to the classic Braun-Blanquet method and creating phytosociological tables enabling the identification of plant communities. Detailed phytosociological research resulted in the selection of 28 plant communities, which were clearly distinguished phytosociologically and were visible in the field. The aim of the research was not to define the precise syntaxonomic position and names of the communities in question. The results included a vegetation map, which would be the basis for further comparative studies on vegetation changes in the area, and the characterization of the plant communities identified during the research.

A group of plant communities associated with dry habitats was identified based on relief and water conditions. This group includes vegetation types, for which high water content in the substratum is not crucial for existence and which are relatively resistant to the drying properties of wind. This type of vegetation is dominated by bryophytes and lichens, which usually obtain water directly from the atmosphere. On the Kulmstranda and Hornsundneset plains, large areas of boulders and pebbles can be found, which are made of siliceous sandstone. Most were covered by communities of epilithic lichens. The *Orphniospora moriopsis* community occurred in places exposed to strong winds. A lichen-bryophyte community, represented by *Sphaerophorus globosus*, developed between stones. The floristically poor *Racomitrium lanuginosum* community was also found in the region in places covered with small rocks.

This community was found quite often in depressions between old storm ridges. The spatial formation of the dominant moss species *Racomitrium lanuginosum* followed the direction of local foehn winds (Fig. 22). In places which are protected from the wind, *Umbilicaria arctica* and *Umbilicaria cylindrica* communities achieved their optimum. In areas where the wind coming from Hornsund is halted by the slopes of Hohenlohefjellet, a moss and lichen-dominated vegetation complex occurred, composed of *Orphniospora moriopsis* and *Racomitrium lanuginosum* communities.

Much closer to the shoreline, on marine terraces built mainly of sea pebbles, a mosaic of *Cetrariella delisei* and *Gymnomitrium coralloides* communities (Fig. 23), which usually exist together, could be found. The *Cetrariella delisei* community in this formation was dominant in the southern part of the research area, while the *Gymnomitrium coralloides* community was found further north. Patches of this vegetation complex had a characteristic brown-greyish color. In the central part of Hornsundneset, full of rocky ledges near lakes, another type of vegetation mosaic was identified, composed of *Cetrariella delisei*, *Gymnomitrium coralloides* and *Racomitrium lanuginosum* communities.



Fot. 22. *Racomitrium lanuginosum* community on the upper marine terrace of the Hornsundneset coastal plain: a typical shape formed by foehn winds. Photo: M. Węgrzyn, 2008



Fig. 23. A mosaic composed of the *Cetrariella delisei* community and the *Gymnomitrium coralloides* community on the Hornsundneset coastal plain (with the Sergeijevfjellet and Lidfjellet mountain massifs in the background). Fissures of frost polygons are visible. Photo: J. Dudek, 2008

Another mosaic dominated by the *Cetrariella delisei* community was one composed of *Cetrariella delisei*, *Gymnomitrium coralloides* and *Orphniospora moriopsis* communities. This type of formation, occupying mainly rocky ledges near the sea in an area of strong winds, was relatively rare.

The most spectacular vegetation type in the study area was most likely the *Flavocetraria nivalis* – *Cladonia rangiferina* community. The principal component of this community included numerous species of fruticose epigeic and epibryophytic lichens, along with bryophytes (Fig. 24). The *Flavocetraria nivalis* – *Cladonia rangiferina* community could be found on initial soils in areas protected from the wind by mountain slopes (Fig. 25). The best developed patches of this community were noted at the foot of Hohenlohefjellet, while a less developed form was found in the central part of the coastal plain near the sea and lakes. The *Flavocetraria nivalis* – *Cladonia rangiferina* community and the *Cetrariella delisei* community and the *Gymnomitrium coralloides* community form a complex found on rocky ledges between lakes.

All the vegetation types described above occupied the northern part of the research area. Farther south, a larger share of vascular plants was observed. Vascular plant-dominated communities were the most floristically rich in the study area. Their distribution was associated with areas of moderate soil humidity.



Fig. 24. General view of tundra vegetation in the central part of western Sørkapp Land (the Hornsundneset coastal plain and the Sergeijevfjellet mountain massif) in 1982. In the foreground: the *Carex subspathacea* community; in the background – the *Flavocetraria nivalis* – *Cladonia rangiferina* community with visible patches of yellow fruticose lichens. Photo: M. Olech



Fig. 25. *Flavocetraria nivalis* – *Cladonia rangiferina* community at the foot of Hohenlohefjellet. Photo: M. Olech, 1982

The *Saxifraga aizoides* community occupied large parts of the Breinesflya plain. It is a place which is annually flooded by water from melting snow. Therefore, a large amount of water is available only at the beginning of the vegetation season. Stony soil in this area includes a large amount of humus and a lot of calcium carbonate. The *Saxifraga aizoides* community was one of the most floristically rich communities in the study area.

Like the previous plant community, the *Bistorta vivipara* community also was floristically rich. It developed in the lower parts of the slopes of Sergeijevfjellet and Lidfjellet, as well as on elevated marine terraces, which are very favorable for plant development. The *Bistorta vivipara* community also formed a species-poor complex of vegetation with the *Cetrariella delisei* and the *Gymnomitrium coralloides* communities. This complex was found at numerous locations on marine terraces of Breinesflya and on the slopes of Kvarstttrabben.

The *Saxifraga nivalis* community was often found on moist, western mountain slopes. The substratum in these areas is fine-grained with signs of solifluction. This community was rich in species of both vascular plants and cryptogams – bryophytes and lichens.

The *Papaver dahlianum* community developed on scree slopes with western exposure, and on the gravelly sides of seasonal streams (Fig. 26). This community was floristically poor, mainly due to unstable ground.

The *Juncus biglumis* community was dominant in the southern part of the research area, i.e. on the Breinesflya plain, on the slopes of Lidfjellet and Wiederfjel-



Fig. 26. *Papaver dahlianum* with very expansive *Salix polaris* in the *Papaver dahlianum* community. Photo: M. Węgrzyn, 2008

let. Large patches of this community were found in places with long lasting snow cover and frequent solifluction episodes. The ground in these areas is moist during the entire vegetation season.

Rather infrequent in the study area, the *Saxifraga oppositifolia* community occupied seashore areas with poor gravelly-sandy soil.

Another group of plant communities was associated with wet areas such as land depressions, stream beds and lake shores. They were generally found in the central and southern parts of the research area.

A mosaic composed of the *Dupontia pelligera* community and the *Arctophila fulva* community appeared along streams and on moist lake shores. The first community preferred a very wet habitat, while the second grew in less moist places. This complex included numerous graminoids and resembled meadow formations.

The *Carex subspathacea* community developed in the wettest areas, often flooded during snowmelt season, and also by permanent and seasonal streams (Fig. 24). Under a layer of vascular plants and bryophytes, a 15 cm thick layer of peat was formed on gravelly or gravelly-sandy substratum. The largest areas of the *Carex subspathacea* community were found usually far from the sea, in land depressions at the foot of Lidfjellet and Sergeijevfjellet.

A typical peat-producing vegetation type in Sørkapp Land was the *Saxifraga hyperborea* – *Ranunculus spitsbergensis* community. This very floristically poor community formed in boggy areas on silt or sand with the addition of gravel. The layer of peat underneath the plants was 20–80 cm thick. Vascular plants typical of this community occurred infrequently within thick patches of mosses, mainly *Calliergon stramineum*.

Gravelly areas close to streams running across coastal plains were occupied by a very species-poor *Calliergon stramineum* community. The dominant species was a moss *Calliergon stramineum*. During the summer, areas occupied by these communities are often flooded by the changing water level of the streams. In the tundra landscape, one can easily spot those deep green patches among vegetation in dry habitats, which is grey or in various shades of brown (Fig. 24). In larger land depressions, a similar vegetation type can be found, i.e. the *Calliergon sarmentosum* community.

Ornithocoprophilous vegetation, associated with seabird colonies, is completely different from the previous types. Soil constantly fertilized by guano rich in nutrients, i.e. compounds of phosphorus and nitrogen, is the key habitat-creating factor. In the study area, large nesting colonies of the Little Auk *Alle alle* found on the slopes of Hohenlohefjellet and Sergeijevfjellet fertilize the nearby area.

Ornithocoprophilous vegetation, which developed directly in bird colony areas included the *Candelariella arctica* community, composed of epilithic lichens with predominant yellow-colored *Candelariella arctica*. It developed on the surfaces of rocks and boulders of the Hohenlohefjellet and Sergeijevfjellet slopes.

The *Tetraplodon mnioides* community, on the other hand, developed below bird colonies. It benefits from compounds of phosphorus and nitrogen washed out from

bird colonies and carried by water into streams. This community, composed entirely of the ornithocrophilous bryophytes *Tetraplodon mnioides* and *Aplodon wormskjoldii*, was found at the base of the mountains, where the soil was sippy.

Apart from all the plant formations mentioned above, one could also find small areas almost entirely devoid of vegetation, where only initial communities of epilithic lichens have developed. These places were located in high mountain areas covered by snow most of the year.

Plant communities in 2008 – changes over the last 25 years

The analysis of vegetation in Sørkapp Land done in 1982 and 1985 (Dubiel, Olech 1990, 1991) was repeated in 2008. Historical phytosociological data and maps were compared with new results.

Phytosociological methodology is very effective for the monitoring of the state of vegetation and for observing changes in the composition and distribution of different vegetation types over time. Relevés made in the same area as during the previous study (Dubiel, Olech 1990, 1991) and a repeat of vegetation mapping allowed for an analysis of changes in vegetation in the area.

Vegetation dynamics in the research area and trends, in the context of factors operating during the last 25 years and currently, were analyzed.

On the basis of repeated vegetation mapping, significant changes in composition and extent of several plant communities were documented. The principal trend is a decrease in species diversity, leading to a more uniform vegetation. This process is most visible in dry habitats, while in wet areas, changes are less noticeable.

One of the most spectacular changes was the complete degradation of the *Flavocetraria nivalis* – *Cladonia rangiferina* community at the foot of Hohenlohefjellet and Sergeijevfjellet. This community, previously dominated by fruticose lichens from the genus *Cladonia* and *Cetraria*, has transformed completely. Currently, *Flavocetraria nivalis*, *Cladonia rangiferina*, and other species of *Cladonia* have practically disappeared. The moss *Racomitrium lanuginosum* and the lichen *Sphaerophorus globosus* became dominant instead. A larger number of vascular plants, especially *Luzula arcuata*, was also recorded. It seems that the *Flavocetraria nivalis* – *Cladonia rangiferina* community transformed into a moss-dominated one, with a predominance of *Racomitrium lanuginosum* (Fig. 27).

The main component of the *Flavocetraria nivalis* – *Cladonia rangiferina* community, fruticose lichens, was entirely consumed by reindeer. The remaining lichens gradually declined due to the fertilization of the substratum. Currently, these lichen species can only be found on very steep slopes of Hohenlohefjellet and in rock crevices on coastal plains, in places inaccessible to reindeer.

The patches of the *Flavocetraria nivalis* – *Cladonia rangiferina* community, which used to form a mosaic together with the *Cetrariella delisei* and the *Gym-*



Fig. 27. Degradated form of the *Flavocetraria nivalis* – *Cladonia rangiferina* community as a result of reindeer grazing, trampling and fertilizing over the last few decades, in the uppermost part of Hornsundneset at the foot of Hohenlohefjellet. Photo: M. Lisowska, 2008

nomitrium coralloides communities, were also destroyed. Currently, only *Cetrariella delisei* and *Gymnomitrium coralloides* are present in these areas.

A similar trend of unification is visible in places, where a mosaic of the *Racomitrium lanuginosum* and the *Orphniospora moriopsis* communities used to exist. Presently, boundaries between these two communities have become unclear as a result of the expansion of *Racomitrium lanuginosum*. This species used to occupy depressions between storm ridges, where fine-grained rock material would accumulate. Now its extent has moved onto the top parts of the ridges.

Within vegetation complexes with a predominance of the *Cetrariella delisei* community, no clear boundaries between the complex components currently exist. *Cetrariella delisei* has expanded greatly along the shore, just like *Racomitrium lanuginosum* has done inland.

The *Cetrariella delisei* community creates a well-defined complex with the *Gymnomitrium coralloides* community. Within this mosaic, the expansion of the *Cetrariella delisei* community is also visible.

In the central part of Hornsundneset, an earlier map showed a complex of the *Cetrariella delisei*, the *Gymnomitrium coralloides*, and *Racomitrium lanuginosum* communities, however currently the *Cetrariella delisei* has expanded. Boundaries

between the components have vanished, which reflects the general trend in the area, and the same situation is visible in the complex of the *Cetrariella delisei* and the *Orphniospora moriopsis* communities. In the latter complex, stony ledges occupied previously by *Orphniospora moriopsis* and other epilithic lichens, are comparatively small patches in an area becoming more and more dominated by fruticose lichens.

Changes in the structure of plant communities in wet areas are not as substantial as in communities associated with dry habitats.

The structure of the *Saxifraga aizoides* community, which covers large areas of the Breinesflya plain, has not changed since the 1980s.

In the *Bistorta vivipara* community, which is also floristically rich, an increase of abundance of *Salix polaris* was recorded. It is clear that *Salix polaris* is an expansive species in this community.

On the shore, in the *Cetrariella delisei* and the *Gymnomitrium coralloides* communities, expansion of *Salix polaris* was not observed. Consequently, the expansion of this species may be directed from the shore inland, towards mountain slopes.

The dynamics of the *Saxifraga nivalis* community is stable, and no changes in the structure of the community were observed. However, within the *Papaver dahlianum* community, which occupies the western slopes of the mountains, an expansion of *Salix polaris* is evident (Fig. 26). In the 1980s, *Salix polaris* used to be found in this community only occasionally. However, now it grows in dense patches.

The occurrence of *Luzula arcuata* was noted in this community for the first time.

Within the *Juncus biglumis* community, which dominates in the southern parts of the research area, on the Breinesflya plain and at the foot of Lidfjellet and Wiederfjellet, the structure remains unchanged. Both the boundaries of the formation and the species structure seem to be stable.

The *Saxifraga oppositifolia* community was very diverse in the 1980s. Presently, major changes can be observed within this pioneer community. The previously dominant *Saxifraga oppositifolia* is in decline, while other expansive species, which used to be scarce, appear in larger quantities. *Salix polaris* is found in large quantities, as is *Cetrariella delisei*, which migrates from neighboring communities. *Gymnomitrium coralloides* can be observed to a smaller extent as well. On the updated vegetation map, the *Saxifraga oppositifolia* community includes a mosaic composed of the *Cetrariella delisei* and the *Gymnomitrium coralloides* communities.

In permanently wet areas, the extent of the following communities did not change: the *Dupontia pelligera* and the *Arctophila fulva* communities, the *Carex subspathacea* community, the *Saxifraga hyperborea* – *Ranunculus spitsbergensis* community (Fig. 28), the *Calliergon stramineum* community and other moss bog variants. Species composition also does not fundamentally deviate from the one noted in the 1980s. Only the general condition of plants and the state of preservation have visibly changed due to reindeer grazing.

Within ornithocoprophilous vegetation, species composition remained the same and changes in their extent were not observed. This is associated with the specific character of these communities, one composed of epilithic lichens, with leading spe-



Fig. 28. *Saxifraga hyperborea* – *Ranunculus spitsbergensis* community on the Hornsundneset plain just below Hehenloheskardet. Photo: M. Węgrzyn, 2008

cies *Candelariella arctica*, and the other typically bryophytic, created mainly by *Tetraplodon mnioides*. The size of the colonies of *Alle alle* seems to be unchanged, therefore ornithocoprophilous vegetation constantly receives enough nutrients to prevail.

Communities of epilithic lichens, with the *Umbilicaria arctica* and the *Umbilicaria cylindrica* communities, are rather stable and have not transformed much over the last 25 years. Patches of these communities are found in the northern part of the study area, where extensive rock surfaces, boulders and storm ridges made of sea pebbles occur frequently.

Causes of changes

Vegetation maps are a valuable source of information for estimating changes in vegetation in a given area. They are also very useful for assessing the speed and direction of changes, which is particularly important because vegetation is dynamic, influenced by numerous factors such as climate changes, animal and human impact.

These factors and the changes caused by them have been thoroughly analyzed throughout the Arctic. The research results provide insight into the speed of the changes and their direction, and allow to make predictions concerning future trends.

Svalbard ecosystems are described in the literature as adapted to extreme fluctuations in climate conditions on different temporal scales and slowly reacting to climate changes (Jónsdóttir 2005). Research confirms this, revealing that the impact of climate change on vegetation can not be detected in whole Svalbard. Vegetation mapping in Adolfbukta (Billefjorden, middle Spitsbergen) repeated in 2008 after 70 years did not show any changes in vegetation (Prach et al. 2010). The authors suggest that the reason for such a state of affairs, apart from the Arctic ecosystems' slow reaction to climate changes, could be the pressure of herbivores, masking the possible development of vegetation in that area.

In the case of Sørkapp Land, research results show a different situation. Major changes in vegetation have taken place since the 1980s, especially in dry or slightly moist areas. On the contrary, minute changes were recorded in very wet areas. The results of experimental research in Central Spitsbergen (Speed et al. 2010) were in line with observations from Sørkapp Land. A herbivore simulation (goose pressure) showed that different vegetation types have different levels of resistance to herbivore disturbance. Wetlands and mires proved to be the most resistant.

The main cause of vegetation changes in Sørkapp Land is the rapidly growing population of reindeer in the area. In addition to environmental changes favoring reindeer expansion, the legal protection of these animals in the area was also of great importance thanks to the creation of South Spitsbergen National Park in 1973. A rapid expansion of the reindeer population was observed, from 1 or 2 animals in the 1980s to ca. 100 in the year 2000 (Ziaja 2002), and even later to about 170 animals in 2008. The growing number of reindeer has a strong effect on the structure and distribution of plant communities. The impact of herbivores has included grazing on lichens and over-ground parts of vascular plants, as well as the trampling of bogs (Fig. 29) and the fertilization of the ground.

Svalbard reindeer, unlike other reindeer subspecies, hardly migrate (Tyler, Øritsland 1989). It can thus be assumed, that in the future the population of reindeer in western Sørkapp Land will not decrease, provided there is enough forage.

For comparison, the reintroduction of reindeer in the area of Ny Ålesund, Northwest Spitsbergen, caused a major transformation of the tundra over a short period of time, and the effects are similar to those observed in Sørkapp Land. In 1978 twelve reindeer were brought to Brøggerhalvøya, near Ny Ålesund. Until 1986–1987, the number of animals increased to 110 (Øritsland 1987). In 1991 there were already 300 reindeer (Wegener et al. 1992, after: Elvebakk 1997). Only one year after the introduction of reindeer, the destruction of the *Flavocetraria nivalis* population in Brøggerhalvøya was observed, and one year after that, *Cladonia arbuscula ssp. mitis* disappeared as well (Elvebakk 1997). After some time, it was observed that a part of the *Cetrariella delisei* population, previously not grazed on by reindeer, was also destroyed (Elvebakk 1997). Negative changes in the population of epigeic fruticose li-

1983



2008



chens can be also observed in other regions of the Arctic, for instance in Alaska (Joly et al. 2009), where a decrease in cover and biomass of ground lichens was recorded in recent years. This tendency is associated with several factors such as reindeer and caribou activity as well as competition with vascular plants spreading as a result of climate change. An experiment simulating the influence of global warming on tundra resulted in a decrease in lichen cover (Hudson, Henry 2010).



Fig. 29. Wet moss tundra in the outlet of Hohenlohenskardet valley at a time without any reindeer in the upper photograph, and the same tundra with a visible effect of reindeer grazing and trampling since the 1990s in the bottom photo. Top photo: W. Ziaja. Bottom photo: M. Węgrzyn