# Phytosociological evaluation of terrestrial habitat types in Pyramiden area (Svalbard, Norway)

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## Abstract

Natural habitats in the area of Pyramiden town (Svalbard, Norway) were assessed as a part of landscape planning for purposes of tourism development. Habitat types evaluation was done by using phytosociological units and assessed by IUCN categories. Altogether, 15 main habitat types were united in following groups: 1. Arctic tundra, 2. Barrens, screes, young alluvia areas and glaciers, 4. Wetlands and marshes, 5. Meadows and grasslands, 6. Anthropogenic open plant communities.

***Key words and abbreviations*:** habitat types, Pyramiden, Svalbard**,** IUCN – International Union for Conservation of Nature

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## Introduction

Pyramiden is known as a far north 'ghost town' as it was abandoned in 1998. It is one of most popular tourist destinations in Svalbard, since there is an easy access by boat or snowscooter from Longyearbyen. In 2011 the Russian mining company, Trust Arktikugol, which also owns the other Russian town on Svalbard, Barentsburg, started to renovate and upgrade the town's infrastructure and facilities in order to increase tourist attractiveness of the area. A team from the Polar-Alpine Botanical Garden carried out an expedition to the area to investigate potential for landscape planning and knowledge-based tourism management issues with particular emphasis on vegetation assessment and identification of high value habitats. The resulting assessment of habitats and vegetation typology are presented in this paper.

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### *Topography, geology and climate*

Pyramiden town is situated on the western shore of Billefjorden, on Dickson land, at the foot of the southern slope of the Pyramiden Mountain (935 m a.s.l.) at 78°39' N, 16°17' – 16°24' E (Fig. 1). The climate is polar (Arctic), with mean annual temperature of –4°C, mean temperature of warmest month (July) reaches +7.7°C, of coldest month (March) –14.8°C (data from Pyramiden observation station established in 2012, source: www.yr.no). Typically, Billefjorden is ice-free from the end of May till the middle of October.

The area of Billefjorden has a great variety of tectonic and sedimentary rocks (Worsley et al. 1986) and is referred to as the most geologically diverse area of Svalbard. The Pyramiden Mountain is composed mainly of red Devonian sandstones. Lower Carboniferous strata in the innermost part of Billefjorden are formed by sandstones, limestone, and include coal-bearing layers, on which mining industry of town had been based up to 1998.

Inland part of the area is generally mountainous. On summits of the Pyramiden, hard rocks form steep cliffs. Mountain slopes are strongly eroded and covered with weathered unsorted stony material, with large talus deposits formed at the base of slope.

Landscapes of the Pyramiden area are various. Coastal landscape includes vast leveled seashore terraces as well as hilly glacier moraine deposits. Active cliffs are met only to the east from Pyramiden. Polygonal micro-relief formed by permafrost-related processes is very typical on marine terraces.

A large part of the area is occupied by the valley of river Mimerelva and its tributaries coming from Bertilbreen. The rivers have V-shaped valleys, and are supplied by the melting glaciers and snow: majority of meltwater floods take place in June and July. Rivers transport large amounts of sediments into Billefjorden and form an alluvial plain and extensive delta in the river mouth. Coarse stones and pebbles cover most of the river delta, meanwhile silt and fine sediment are deposited near the coastline and on the littoral zone in the river mouth area. Fluvial river activity is sometimes crucial for Pyramiden town. Flood protection structures have been built by Pyramiden inhabitants on the valley bank. After the town was closed in 1998, however, they were partly destroyed by snowmelt overflow in 2006, which carried mud and stones and flooded town streets, damaged roads, sport-ground and bridge.

### *Anthropogenic impact*

Early attempts at mineral explorations were carried out in Pyramiden in 1910. Trust Arktikugol has owned the territory since 1926, but serious mining started after 1940 with some interruptions during the Second World War. Between 1980 and 1990, there was a population of over 1000 inhabitants, most of whom were Ukrainian miners. Therefore, Pyramiden area has been affected by various aspects of industrial activity: *e.g.* coal mining and construction of mining facilities, houses, roads and pipelines.

Part of living area of the town constructed in 1970-ies consists of wooden detached buildings in lines with wide streets and yards. At this time, Pyramiden was supposed to be ‘the capital of Russian Svalbard’. There were not only living apartments in Pyramiden. Apart of them, Cultural Palace, swimming pool and an indoor sports complex, but also stalls for

cows and pigs and a chicken farm were built. Manure was used as a fertilizer in the greenhouse designed for production of vegetables and ornamental plants. In the living area of Pyramiden, turfs of grass were successfully planted to recover disturbed territories. After the USSR disintegration in 1991 and subsequent economical and political collapse, the funding to Russian towns in Svalbard has decreased. As a result of that, the mine and town Pyramiden were abandoned in 1998 (Fig. 2).

Modern land use of Pyramiden goes in accordance with the Svalbard Environmental Protection Act 2001, with amendments of 2012 (web source 1). Recently, an agreement was achieved between the Trust Arktikugol and the Governor of Svalbard about planning and maintenance of infrastructure for further development in Pyramiden area.

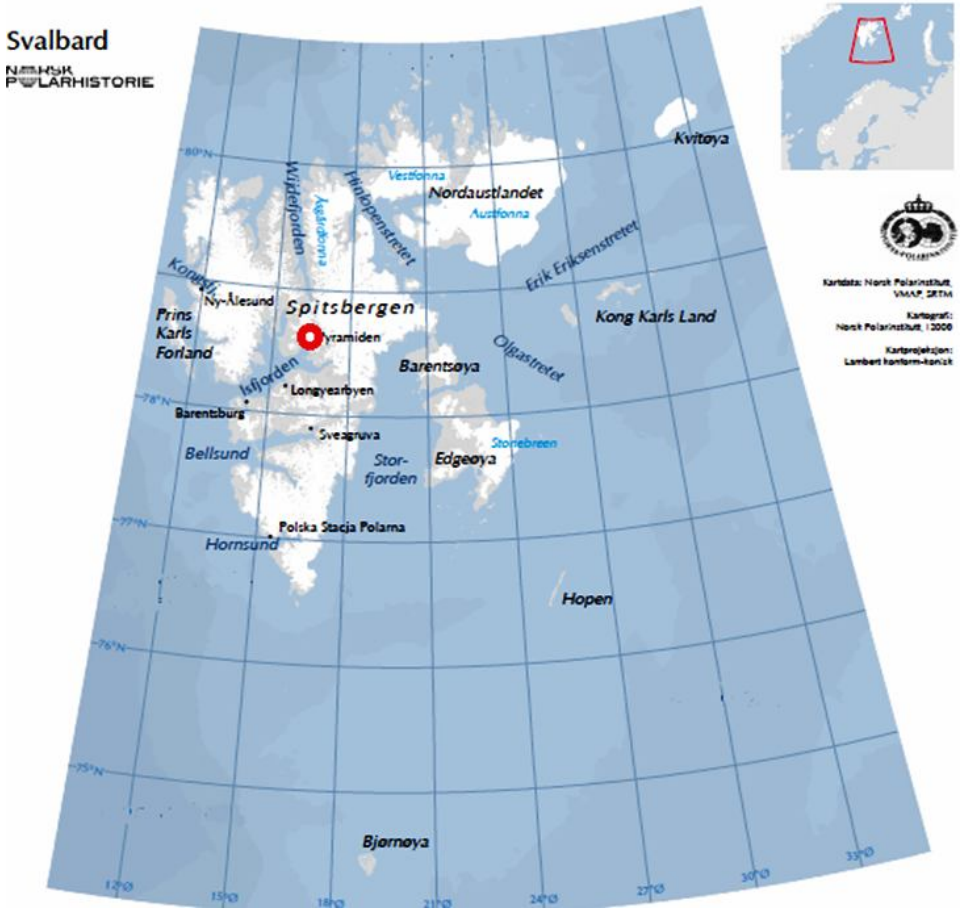


**Fig. 1.** Position of Pyramiden town. Received and modified from Norwegian Polar Institute (1999) and www.polarhistorie.no.

**Fig. 2.** Kittiwake nesting in the abandoned building.

### *Vegetation*

In accordance with division of the Arctic into bioclimatic zones (Elvebakk 1985, Möller 2000, CAVM Team 2003), the area of Pyramiden belongs to the Middle Arctic Tundra, or to the C bioclimatic zone of Arctic, with characteristic open *Dryas octopetala*- and *Cassiope tetragona* -dominated plant communities. Vegetation cover of the mountains is linked to the altitudinal gradient.

Svalbard represents one of the most thoroughly phytosociologically studied Arctic territories, where major vegetation units and their relationship to important basic environmental factors are known in detail (*e.g.* Thannheiser et Möller 1992, Elvebakk 1994, Möller 2000, Nilsen et Thannheiser 2013). Vegetation of Svalbard was classified in accordance with Braun-Blanquet approach and main vegetation units (associations) were established (Hadač 1946, 1989, Rønning 1965, Möller 2000). In the period of 1990-200, a pragmatic system of 'vegetation types' was developed in Norway as a base for vegetation mapping, but the territory of Svalbard was not covered (Fremstad 1997, Moen 1998).

The last three-leveled system of identification and classification of habitat types for Norwegian territory, including Svalbard, was presented in 2009 by Norwegian Biodiversity information Centre and named 'Nature types in Norway' (NiN) (http://artsdatabanken.no). These nature types cover not only vegetation variation in Norway, but also non-vegetated landscape elements (*i.e.* volcano fields and thermal springs). However major parts of them were connected with and determined by vegetation units. A comprehensive survey of habitat types of Svalbard and corre-

sponding vegetation associations after Braun-Blanquet classification was presented by Elvebakk (1994, 2005). He evaluated most of vegetation types of Svalbard as separate units, so called 'ecological system', with total number of 36 units (Elvebakk 2011). Some of habitats and vegetation types are considered as a united functional unit determined by some significant environmental factor. They are united into landscape-based assessment units called 'landscape element', such as *i.e.* complex of ornithophilous meadows and bird cliffs.

These nature types have served as mapped units in several regional and local vegetation and ecological maps of Svalbard issued since the 1960s. Both conventional methods and by the use of satellite images (Johansen et al. 2012) were used for production of such maps. The most recently produced vegetation maps of the entire Svalbard archipelago based on habitat types were published by Elvebakk (2005) and Johansen et al. (2012), and surveyed by Elvebakk (2011).

## Material and Methods

### *Sampling and describing of habitat types in the field*

For vegetation sampling and description, sample plots of 2x2 m were used for low herbaceous vegetation and dwarf-shrub tundra. For tall herbaceous vegetation and species-poor anthropogenic habitats or scattered vegetation, plots of 4x4 and 10x10 m, respectively, were used. In general, sample plots were square shaped, but often very irregular, as with sloping snow-beds or small Arctic mires stretched along springs. Sampling and description of the plots had to record all species present in the plant community, including bryophytes and macrolichens, and assess their cover-abundance values. Total number of relevés was 57.

Altitude, exposure, latitude and longitude were determined using GPS. Details of bedrock are given from Geological Survey maps. Landscape, microrelief, slope angle, exposure to wind, substrata character, zoogenic or anthropogenic impact, *etc*. – from field observation. Description and classification of vegetation were based on the Braun-Blanquet method (Westhoff et van der Maarel 1972). Most common and dominant bryophytes, lichens and algae mentioned in description of habitat types were identified by O. Belkina, E. Borovichev and L. Konoreva (data on general species composition of habitat types is not shown here). All herbarium specimens and descriptions taken during our study are available at the Polar-Alpine Botanical Garden-Institute, Kirovsk.

The species nomenclature of vascular plants followed Lid et Lid (1994), nomenclature of mosses, liverworts, and lichens was according to Ignatov et al. (2006), Konstantinova et al. (2009), and Santesson et al. (2004), respectively. The names of places followed the official nomenclature of Svalbard presented by Orheim et Hoel (2003).

### *Habitat types characteristics*

Major habitat types of the Pyramiden area are equivalent to the associations of the Braun-Blanquet school and generally to the 'ecological system' in system of Nature types in Norway (NiN), and the type of habitat reported by Fremstad (1997).

The habitat type characteristics were organized in a modular method with the following characteristics 1) the name of the vegetation type; 2) its existing synonyms; 3) total number of vascular plants, mosses and lichens separately and lists of dominants; 4) the pattern of frequency and abundance of groups of plants, structure, variation in dominance and the growth form; 5) ecological relationships; 6) occurrence and distribution of vegetation type on Svalbard and elsewhere in Arctic.

## Results

**Habitat types in the Arctic tundra** (24 relevés). — Arctic tundra occupies lower mountain slopes, terrains at the bottom of mountain, in valleys of rivers and on the seashore and is represented by following habitat types.

Habitat type '*Cassiope tetragona*-dominated Arctic tundra' ('Arctic Bell-heather tundra'). Synonyms: ass. ***Dryado–Cassiopetum tetragonae*** (Fries 1913) Hadač (1946) 1989, ***Tetragono- Dryadetum*** Rønning 1965.

Total number of dwarf shrubs and herbs was 12–14 per plot, 15–20 mosses and 15–25 lichens were found. Dominant vascular plants were *Cassiope tetragona*, *Dryas octopetala,* mosses – *Sanionia uncinata, Tomentypnum nitens, Ditrichum flexicaule*, *Distichium capillaceum*, *Abietinella abietina, Scorpidium cossonii*, lichens – *Cetrariella delisei*, *Cladonia pyxidata, Flavocetraria nivalis, Ochrolechia frigida, Peltigera rufescens*.

Closed plant communities with characteristic dark-green appearance due to dominance of *Cassiope tetragona* in combination with *Cetrariella delisei* and patches of mosses *Sanionia uncinata* and *Tomentypnum nitens* were found frequently. The communities occupied gentle slopes and areas protected by snow in winter and can be characterized as weakly calciphytic, mesotraphent, meso- to hygrophytic and chionophytic, with rather moist soil conditions in the growing season.

The habitat type is common in Pyramiden area and in most parts of Svalbard, with the exception of the northern- and easternmost regions. The habitat is common and characteristic of calcium-rich substrata in inner fjords areas. Its zonal distribution is supposedly confined to the southern and middle arctic dwarf shrub- and shrub zone of circumpolar Arctic (Daniëls et al. 2000).

Habitat type '*Dryas octopetala*-dominated Arctic tundra' ('Mountain Avens tundra', Fig. 3). Synonyms: ass. ***Salici polaris–Dryadetum octopetalae*** (Rønning 1965) Koroleva 2012, ***Dryadetum minoris*** Hadač (1946) 1989, ***Polari-Dryadetum*** Rønning 1965.

Total number of dwarf shrubs and herbs was 7–13 per plot. Some 8–15 moss and 10–23 lichen species were found, respectively. Dominant vascular plants were *Dryas octopetala*, *Salix polaris*; mosses *Bryum* spp., *Distichium* spp., *Sanionia uncinata*, *Orthothecium chryseon, Tomentypnum nitens, Syntrichia ruralis*, *Drepanocladus polygamus, Ditrichum flexicaule*, *Stereodon revolutus, Leptobryum pyriforme*, lichens *Cetrariella delisei*, *Cladonia pocillum*, *Fulgensia bracteata*, *Lecidea alpestris*, *Thamnolia vermicularis*.

Dwarf shrubs and green pleurocarpic mosses prevailed in plant cover. Dominance of *Dryas octopetala* may indicate warmer, drier and more wind-exposed conditions compared to the sites of the *Cassiope tetragona*-dominated communities. Polygonal cryogenic microrelief is well-expressed on flat land. Thanks to cryoturbation and sloping

processes, plant cover is patterned, *i.e.* scattered cushions of dwarf shrubs are divided by stony and fine ground polygons and patches.

Habitat type occurred everywhere in valleys and in the mountains in the Pyramiden area, and is widely distributed on Svalbard, as well as everywhere in the northern Euro-Asiatic Arctic regions.

**Fig. 3.** Open *Dryas octopetala*-dominated arctic tundra on the seashore terrace in the Mimerelva river valley.

Habitat type '*Dryas octopetala – Carex rupestris*-dominated Arctic tundra' ('Mountain Avens – Rock Sedge tundra'). Synonyms: ass. ***Dryado–Caricetum rupestris*** (Rønning 1965) Hadač 1989, ***Rupestri-Dryadetum*** Rønning 1965.

Total number of dwarf shrubs and herbs was 8–14 per plot. Some 10–15 moss and 23–38 lichen species were found as well. Dominant vascular plants were *Carex rupestris*, *C. nardina*, *C. misandra*, *Dryas octopetala*, mosses *Sanionia uncinata*, *Tomentypnum nitens*. *Encalypta spp.* (*E. alpina, E. procera, E. rhaptocarpa*), *Ditrichum flexicaule, Stereodon revolutus*, lichens *Brodoa oroarctica*, *Cetrariella delisei*, *Cladonia pyxidata*, *Gowardia nigricans*, *Lecanora epibryon*, *Ochrolechia frigida*, *Physconia muscigena*.

Plant cover had a distinctly xeromorphic appearance due to dominance of Rock Sedge and other xeric sedges. The type was similar with *Dryas octopetala*-dominated Arctic tundra in species composition and habitat conditions. Both they were characterized as xerophytic, calciphytic and achionophytic.

'Mountain Avens – Rock Sedge tundra' habitat type occupied shallow well drained soils on from strongly to moderately wind-exposed mountain slopes and morainic hilltops.

The habitat type is widely distributed in Pyramiden area as well as in calcium-rich substrata everywhere on Svalbard. Vicariant plant communities with dominance of *Carex rupestris* and *Dryas octopetala* are widespread in calcium-rich habitats in mountains of northern Scandinavia.

Habitat type '*Salix polaris* – mosses dominated Arctic tundra' ('Polar Willow tundra'). Synonyms: ass. ***Luzulo confusae-Salicetum polaris*** Hadač (1946) 1989.

Total number of dwarf shrubs and herbs was 15 per plot. Altogether, 24 moss and 13 lichen species were found. Dominant vascular plants were *Salix polaris*, *Bistorta vivipara*, *Luzula confusa*, mosses *Catoscopium nigritum*, *Tomentypnum nitens*, *Orthothecium chryseon, Scorpidium cossonii,* lichens *Cetraria islandica*, *Cetrariella delisei*, *Lecidea ramulosa*, *Ochrolechia frigida*.

Habitat type occurred on slightly sloping sites in small wind-sheltered depressions and at bottoms of slopes, often near rivulets, where the vegetation was strongly supplied with melt water. The vegetation stands showed a small-scale pattern of microhabitats: low hummocks due to tussocks and cushions of graminoids (*Deschampsia alpina, Luzula confusa*), and moister shallow hollows. Thus the habitat type was more hygrophytic, than all above-specified arctic tundra communities and is characterized as chionophytic and weakly acido- to neutrophytic.

In Pyramiden, habitat type 'Polar Willow tundra' in less developed than *e.g.* in Barentsburg area. It is generally found as small band shaped communities of a few tenths of square meters in Pyramiden. This habitat type is, however, common everywhere in Svalbard, as well as in Euro-Asiatic Arctic tundra.

Habitat type '*Oxyria digyna*-mosses dominated Arctic tundra' ('Mountain Sorrel – mosses tundra'). Synonyms: ass. ***Oxyrio–Trisetetum spicati*** Hadač (1946) 1989.

Total number of dwarf shrubs and herbs species was 12–16 per plot. Also some 10–11 moss and 13–15 lichen species were found. Dominant vascular plants were *Oxyria digyna*, *Trisetum spicatum*, *Cerastium regelii*, mosses *Bryum pseudotriquetrum*, *Dicranum spadiceum, Sanionia uncinata*, *Scorpidium cossonii*, lichens *Cetraria islandica*, *Cetrariella delisei*, *Flavocetraria nivalis*, *Lecidea ramulosa*, *Ochrolechia frigida*, *Peltigera rufescens*, *Stereocaulon alpinum*.

Vascular plants were scattered on a dense moss carpet, with dominance of mesophytic herbs, and species of wet eroded habitats (*Sagina intermedia, Saxifraga cernua*). Tundra plants (*Salix polaris, Silene acaulis*) were common.

Habitat type occurred on the moist, clayey soil and was characterized by rather long snow protection and good water supply during growing season.

The habitat type is widely presented in Svalbard, with the exception of the northern- and easternmost regions, and rarely covers extensive areas, though it was reported on large areas in the lower parts of sea-exposed slopes of Grønfjordfjellet and in Barentsburg town (Hadač 1989, Koroleva et al. 2008).

**Habitat types in the barrens, screes, young alluvia and glaciers** (5 relevés). **—** These habitat types were characterized by open plant cover (~ 5–25 %) and abundance of stones and bare earth or ice. They were situated mainly higher up the slope than Arctic tundra habitat types.

Habitat type '*Dryas octopetala*-dominated open barrens and screes' ('Mountain Avens barrens and screes'). Synonyms: ass. ***Salici polaris–Dryadetum octopetalae*** (Rønning 1965) Koroleva 2012, ***Dryadetum minoris*** Hadač (1946) 1989, ***Polari-Dryadetum*** Rønning 1965.

Total number of dwarf shrubs and herbs was 4–10 per plot. Within a single plot, 4–16 moss and 3–30 lichen species were found. Dominant vascular plants were *Dryas octopetala*, *Salix polaris*, mosses *Dicranum spadiceum*, *D. acutifolium*, *Didymodon asperifolius, Ditrichum flexicaule*, *Stereodon revolutus,* species of genus *Encalypta, Niphotrichum canescens, Syntrichia ruralis*; lichens *Cetraria islandica*, *Cladonia pyxidata*, *Flavocetraria nivalis*, *Gowardia nigricans*, *Physconia muscigena*, *Xanthoria elegans*.

Floristically, the habitat type was very similar to the type 'Mountain Avens Arctic tundra', but the structure of plant cover was quite different as a result of strong weathering, erosion and disturbance of substrata caused by cryoturbation, snow and aluvium movements. Plant cover formed a mosaic with open patches of stones covered by epilythic lichens. Thus these habitat types could be regarded as a landscape element divided into two major types: open plant communities of *Dryas octopetala*-dominated barrens and screes and epylithic lichen communities on bare stones and boulders.

This habitat type is widely distributed in the Pyramiden area, as well as on Svalbard, and can be regarded as typical for calcium-rich substrata on slopes and terrains higher up the closed tundra. It is the most common habitat type on carbonate rocks in the Euro-Asiatic circumpolar Arctic.

Habitat type 'dwarf shrubs-and herbs-patches on barrens and screes'. Synonyms: ass. ***Papaveretum dahliani*** Hofm. 1968 (Fig. 4).

**Fig. 4.** *Papaver dahlianum* is one of the most common species in barren and screes.

Total number of dwarf shrubs and herbs was 6–10 per plot. Number of moss and lichen species reached the ranges of 10–16, and 0–38, respectively.

Dominant vascular plants were *Cerastium arcticum*, *Salix polaris*, *Saxifraga oppositifolia*, *Papaver dahlianum*, mosses *Catoscopium nigritum, Ditrichum flexicaule*, *Distichium* spp. (*D. capillacium, D. inclinatum, D. hagenii)*, lichens *Cetraria aculeata*, *C. islandica*, *Cladonia pyxidata*, *Flavocetraria cucullata*, *F. nivalis*, *Gowardia nigricans*, *Peltigera didactyla*, *Physconia muscigena*, *Stereocaulon botryosum*, *Xanthoria sorediata*.

Open plant communities (plants cover 1–5%), were composed of scattered individual plants often found in crevices between stones or small cryoturbation polygons in upper mountain slopes and bedrock outcrops. These habitat types, however, can also be regarded as landscape element, like open *Dryas octopetala*-dominated barrens. Cryptogamic crusts with high species diversity often occurred in fissures and somewhat snow-protected microhabitats on stony fields. They represented a mosaic of lichens and cushions of vascular plants.

The strongly xerophytic, achionophytic habitat type covered extensive areas on mountain slopes near Pyramiden. They prevail on extensive barrens of desert-like landscapes of mountains in Svalbard, as well as everywhere in circumpolar High Arctic.

Habitat type '*Saxifraga aizoides*-dominated open stony alluvial system' ('Yellow Mountain Saxifrage open stony alluvial system', Fig. 5).

**Fig. 5.** Tufts of *Saxifraga aizoides* on alluvia in the Mimerelva river valley.

Total number of dwarf shrubs and herbs was 10. The number of moss and lichen species was 6 and 23, respectively. Dominant vascular plants were *Saxifraga aizoides*, *S. oppositifolia*, *Cerastium arcticum*, mosses *Campylium* sp. *Ceratodon purpures*, *Leptobryum pyriforme*; lichens *Cladonia pocillum*, *Stereocaulon alpinum*, *Thamnolia vermicularis*.

Scattered cushions of *Saxifraga aizoides* occurred in the Mimer river delta on the frontier of the islets-terrain and in stony alluvial fields. Clayey and earthy alluvia hummocks of 0.2–0.3 m in diameter and high 0.1–0.15 m were often formed under cushions of *Saxifraga* (of 0.2–0.5 m in diameter). Patches of *Saxifraga oppositifolia* occurred on fine ground and between stones and pebble. *Cerastium arcticum* and some other herbs and dwarf shrubs (*Salix polaris*) grew within the *Saxifraga* cushions.
Almost closed plant cover on more fine-earthy part of the river valley included some species common on adjacent terrain tundra (*Silene acaulis, Dryas octopetala*) and species of alluvial wetlands (*Deschampsia alpina*).

The habitats occurred in open alluvia under extremely unstable conditions of substrata erosion and movement during the seasonal flood and represent a short-lived dynamic stage. Similar open communities occur in moist eroded habitats on calcium-rich rocks, *i.e.* along rivulets and brooks in middle and southern arctic zone, as well as in Scandinavian mountains.

Habitat type 'moss laccolites on glaciers'. The habitat type represented small (0.5–1.5 cm in diameter), ball-shaped moss tufts on glaciers (*see* Fig. 6). A few moss species form these tufts on glaciers of Svalbard: *Paludella squarrosa*, *Ceratodon purpureus*, *Warnstorfia sarmentosa*, *Sanionia uncinata*, *Hygrohypnella polare* (Belkina et Mavlyudov 2011).

**Fig. 6.** Ball-shaped tuft of mosses on the Bertilbreen glacier.

**Habitat types wetlands and marshes** (6 relevés). — Wetlands and marshes occurred on the seashore plain of Billefjorden, and were affected by long inundation, often by haline effect of the sea water and high organic deposition.

Habitat type '*Puccinellia phryganodis*-dominated marshes ('Creeping Saltmarsh Grassmarshes'). Synonyms: ass. ***Puccinellietum phryganodis*** Hadač 1946.

Total number of dwarf shrubs and herbs was 7–9 per plot. We found 5–20 moss and 1–19 lichen species per plot. Dominant vascular plants were *Puccinellia phryganodes*, *Stellaria humifusa*, *Ranunculus hyperboreus*, mosses *Bryum* spp., *Sanionia uncinata*, *Drepanocladus aduncus, D. polygamus Bryum calophyllum, Distichium hagenii, Orthothecium chryseon*; lichens *Collema tenax*, *Lecidea alpestris*, *Peltigera didactyla*, *P. lyngei*, *Xanthoria candelaria*, *X. elegans*.

Dense closed plant cover was formed by prostrate halophytic herbs *Puccinellia phryganodes, Stellaria humifusa* and *Ranunculus hyperboreus* growing in shallow moist depressions on fine-textured sediments (mud, clay) in the Mimerelva river mouth and on the Billfjorden shore, as well as on moist eroded areas in the Pyramiden town, where communities are influenced by mineralized coal mining wastewater. The stands were subjected to irregular flooding and stayed moist during the growing season. *Poa alpigena* and *Deschampsia alpina* were common herbs on hummocks. This habitat type could be characterized as distinctly minerotraphent and strongly hydro-, hygrophytic.

It is unevenly distributed on Svalbard seashores, being linked with fine-textured alluvia in big river mouths and shore of sheltered sea gulfs and bays, with favorable conditions for sedimentation of fine-textured material, *e.g.*, mud. The type has mainly arctic circumpolar distribution, though southwards it reaches even into the northern boreal zone and occurs on the White Sea shore of Kola Peninsula and Norwegian seashore (Koroleva et al. 2011).

Habitat type '*Deschampsia alpina*-dominated wetlands' ('Alpine Tufted Hair-Grass Wetlands'). Synonyms: ass. ***Deschampsietum alpinae*** (Samuellson 1913) Nordh. 1943.

Total number of dwarf shrubs and herbs was in the range of 15–16 per plot. Some 14–17 moss and 0–4 lichen species were found as well per a single plot. Dominant vascular plants were *Deschampsia alpina*, *Poa alpigena*, *Equisetum arvense* ssp. *boreale*; mosses *Bryum* sp., *Ceratodon purpureus*, *Philonotis tomentella, Sanionia uncinata, Scorpidium cossonii;* lichens *Peltigera rufescens*, *Rinodina roscida*.

High tufts of Alpine Hair Grass *Deschampsia alpina* marked the stands with a peculiar pale-green color. *Poa alpigena* maked up an important part of the plant cover as well. Both these species were found together in wetlands and anthropogenic grasslands in centre of Pyramiden. They had, however, different ecological niches: hygrophytic *Deschampsia alpina* was a common species colonizing moist newly formed habitats on pebbles, sandy and clayey alluvia, whereas *Poa alpigena* was a more mesophytic species and has its optimum in moderately dry tundra and often in eroded habitats.

This habitat type occurred in Pyramiden area on mudflats along the seashore, on hummocks and hillocks, comparing with *Puccinellia phryganodis*-dominated marshes, but both habitat types were floristically similar and included common halophytic species (*Puccinellia phryganodes,* and *Stellaria humifusa*). The habitat type 'Alpine Tufted Hair-Grass-wetlands' is widely distributed in middle and high European Arctic.

Habitat type '*Dupontia psilosantha*-dominated wetlands' ('Tundragrass wetlands'). Synonyms: ass. ***Bryo-Dupontietum pelligerae*** (Hadač 1946) 1989.

Total number of dwarf shrubs and herbs was 4–5 per plot. We found about 15 mosses and 0–23 lichens as well. Dominant vascular plants were *Dupontia psilosantha*, mosses *Bryum* spp., *Campylium stellatum*, *Scorpidium cossonii, Pseudocalliergon turgescens, Pohlia wahlenbergii*, *Leptobryum pyriforme,* lichens *Fulgensia bracteata*, *Lecidea alpestris*, *Lepraria neglecta*, *Solorina bispora*.

Extensively sprouting grass *Dupontia psilosantha* occupied wide areas on the fine ground and clayey alluvia of the shore. This habitat type was characteristic for the river mouth, along seashore, mainly at slightly higher elevations than true marshes and could be characterized as distinctly hydro-, hygrophytic and weakly minerotraphent. Closed mono-dominant communities often form a mosaic with stands of other alluvial types, as 'Yellow Mountain Saxifrage open communities' and 'Alpine Tufted Hair-Grass-wetlands'.

The habitat type does not occupy wide areas near Pyramiden, but is rather common on Svalbard as well as in seashores everywhere in circumpolar Arctic.

**Habitat types in the meadows and grasslands** (13 relevés). **—** Meadows and grasslands occupy rather small area in Svalbard, but they support high biodiversity and multi-layered structure of plant cover. They are typically visited and influenced by birds and mammals.

Habitat type 'nitrophytic *Cochlearia groenlandica*-dominated meadows' ('nitrophytic Common Scurvy Grass meadows', Fig. 7). Synonyms: ass. ***Phippsio–Cochlearietum groenlandicae*** Hadač 1989.

Total number of dwarf shrubs and herbs was 4–15 per plot. The average of 5–10 moss (in moist places its diversity increased to a 15–20 species) and 9–19 lichen species were found. Dominant vascular plants were *Cochlearia groenlandica*, *Trisetum spicatum*, *Poa alpigena*, *Puccinellia angustata*, mosses: *Ceratodon purpureus*, *Bryum* species (*B. pallescens, B. pseudotriquetrum, B. amblyodon, B. nitidulum*), *Sanionia uncinata, Pohlia wahlenbergii, Philonotis tomentella, Scorpidium cossonii*, *Orthothecium chryseon, Tomentypnum nitens*; lichens *Collema flaccidum*, *Lecidea alpestris*, *Peltigera didactyla*, *Physconia muscigena*, *Xanthoria sorediata*.

Plant cover distinctly consisted of different ecological units, which depended on manure and nitrogen supply from the nesting birds or grazing animals. This habitat type was defined as a 'landscape element' in the system of 'Nature types in Norway' (NiN). Just under the nesting area only single vascular plants are scattered on the dense cover of algae (*Prasiola* spp., *Phormidium autumnale*). At the distance about 0.5–1 m from the algal zone, species-poor productive meadows were situated. The larger the distance from manure zone, the higher number of species. Species composition in wet places (near brooks and rivulets) was similar to Creeping Saltmarsh Grass-marshes.

These plant communities were described near abandoned houses and industrial constructions, where kittiwake (*Rissa tridactyla*) breeding colonies were established after Pyramiden abandonment. Meadows occured as 2–5 m wide strip around the breeding colony. Another locality of nitrophytic *Cochlearia groenlandica*-dominated meadows were found near abandoned pigsties and chicken farm on former manure piles and in the center part of Pyramiden visited and manured by seabirds and reindeer. This habitat type can be characterized as strongly minerotraphent and chionophytic. It is

common on Svalbard and along the entire coasts of Norway and included in the Norwegian Red List for Ecosystems and Habitat Types (2011).

The habitat type occurs everywhere in circumpolar Arctic, in localities of breeding colonies of seabirds and near manure stocks.

**Fig. 7.** Nitrophytic meadow under the kittiwakes nesting area on the abandoned facility for coal transport.

Habitat type 'anthropogenic *Poa alpigena*-dominated grasslands' ('anthropogenic Meadowgrass grasslands', Fig. 8).

Total number of dwarf shrubs and herbs was 5–8 (11) per plot. We found 5–10 mosse and 1–19 lichen species, respectively. Dominant vascular plants were *Poa alpigena*, *Poa alpina*, *Cerastium arcticum*, *Deschampsia alpina*, mosses *Bryum* spp., *Leptobryum pyriforme, Sanionia uncinata, Distichium spp., Bryum calophyllum, Hennediella heimii* var. *arctica*; lichens *Cetraria islandica*, *Cladonia pyxidata*, *Collema tenax*, *Lecidea alpestris*, *Peltigera didactyla*, *P. lyngei*, *P. rufescens*, *Xanthoria elegans*, *X. sorediata.*

Plant communities occured on streets and yards and in Pyramiden town, where the turf was planted in order to establish lawn as an element of the urban plan, and where vegetation recovered after destruction. Viviparous grasses *Poa alpigena*, *Poa alpina, Deschampsia alpina* formed an almost closed carpet and readily colonize open patches with propagules. Some alien species (*Achillea millefolium, Barbarea vulgaris*) are rarely met there.

These seminatural grasslands are grazed by reindeers and are visited by seabirds, and similarity with nitrophytic meadows is very high. Since the conservation of Pyramiden, *Poa alpigena*-dominated grasslands in town have been partly destroyed by melt water runoff and trampling.

Anthropogenic grasslands are reported as more characteristic and very common for southern arctic tundra and forest-tundra, where they are linked with destroyed habitats and contain portion of boreal grasses. They are also considered 'the corridor' for boreal species movement to the Arctic. But such plant communities are rare in high Arctic, where process of plant cover recovery takes a long time. Long-existent anthropogenic *Poa alpigena*-dominated grasslands in Pyramiden are an example of successful re-vegetation of destroyed Arctic ecosystem.

**Fig. 8.** Anthropogenic grasslands in center of Pyramien town.

**Anthropogenic open habitat types** (9 relevés). — Anthropogenic vegetation is typical for towns in Svalbard and everywhere in Arctic territories, where plant cover and soils were destroyed – on the roadsides, near building and houses, on the waste earth and coal mines.

Habitat type '*Poa alpigena* plant communities on dry destroyed areas'.

Total number of dwarf shrubs and herbs was 8–13 per plot. The ranges of 5–10 moss and 1–17 lichen species were found. Dominant vascular plants were *Poa alpigena*, *Poa alpina*, *Trisetum spicatum*, *Deschampsia alpina*, *Taraxacum* spp. et al., mosses *Ceratodon purpureus*, *Leptobryum pyriforme*, *Bryum* spp., *Sanionia uncinata, Ditrichum flexicaule, Polytrichum hyperboreum, Psilopilum cavifolium*, *Distichium spp.,* lichens *Cladonia pocillum*, *Peltigera didactyla*, *P. rufescens*.

Plant cover consisted of scattered individuals and patches of grasses, pioneer apocarpic mosses and lichens. Cover and number of pioneering vascular plants, mosses

and lichens differed in particular habitats, but in general the composition and structure of plant communities were quite similar. Floristic similarity with mountain barren and screes was rather high, but anthropogenic open plant communities differ by higher portion of grasses and herbs.

**High value habitat types in the Pyramiden area**. — Habitat protection is aimed, primarily, at the conservation of biodiversity and protection of important cultural heritage and special physical features. Many protected areas are important for recreation and education as well as for research and long-term monitoring.

Norway is one of a few countries having published an official Norwegian Red List for Ecosystems and Habitat Types (2011). The assessment of threatened habitat types is based on the International Union for Conservation of Nature (IUCN) criteria estimation of change in quantity and quality – whether a given habitats reduced their occurrences or declined their qualitative development for the last 50 years (Rodríguez et al. 2011).

In the Norwegian Red List for Ecosystems and Habitat Types (2011), the following IUCN categories are accepted: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), and Near Threatened (NT). Habitats placed into threatened categories suffer from substantial reduction in their surface area or in their state; they have few or very few localities. Assigning a habitat type to the category Not Evaluated (NE) and Data Deficient (DD) indicates that its risk of extinction has not been assessed, mainly it concerns artificial habitats. Habitat type is qualified as LC (Least Concerned), when substantial part of this habitat is in good ecological state and occupies large total surface area, and there is not supposed significant change in its occurrence and character.

Habitats types in Svalbard were evaluated separately from Norwegian mainland (Elvebakk 2011). In threatened categories on Svalbard are placed following habitat types: bird cliffs (NT), thermal springs (VU), lime poor mire (NT), arctic permafrost wetland (NT), polar desert (NT), wind-exposed arctic steppe (VU). Habitat types in these threatened categories were not found in the Pyramiden area.

Seven habitat types from the European list of high value habitat types NATURA 2000, on Svalbard were allocated to NE category: gully, cave, waterfall-sprayed rocks and meadows, open alluvial system, seepage spring and spring-fed fen, lowland spring. Habitat type 'Yellow Mountain Saxifrage open stony alluvial system' described in the Pyramiden area on the open alluvial system of the delta of Mimerelva represents a high value habitat at the European level, but is not included in the Norwegian Red List for Ecosystems and Habitat Types (2011). Of the 15 units (habitat types) described in the Pyramiden area 3 ('nitrophytic *Cochlearia groenlandica*-dominated meadows', 'Anthropogenic *Poa alpigena*-dominated grasslands', '*Poa alpigena* plant communities on dry destroyed areas') were placed in the NE ('not evaluated') category, and other 12 habitat types in LC ('least concerned' category).

All natural and commonly occurring habitat types on Svalbard can be considered to be under ecologically satisfactory conditions since they have not decreased their area a downgraded their state on Svalbard for last 50 years. Thus, they can be referred to belong to LC category. Change in area and occurrence of 'Barrens, screes, young alluvia and glaciers' habitat types can be linked with succession. Habitat types linked with and arisen as a result of anthropogenic impact were not evaluated accordingly IUCN criteria (NE category).

It should be mentioned that IUCN criteria for threatened habitat types and ecosystems were rather formally transferred from the Red Data Books species of plants and animals. Therefore, they can not always be correctly applied to plant communities, especially in

the Arctic, where plant cover was not studied sufficiently, comparing with more southern European territories, with long history of development and investigations. Reduction in area of Arctic ecosystems and functions can be assessed only provisionally. Data on climate change impact on Arctic terrestrial ecosystems, especially on plant communities, are incomplete.Thus, the assessments of climatic change effect on Arctic plant communities might be mainly speculative. New and more detailed data as well as co-ordinated investigations are needed to put on the criteria of threatened ecosystems and habitat types in the Arctic and on Svalbard.

**Zones of environmental management in Pyramiden town surroundings**. **—** Having in mind natural and historical value of the habitat types and in accordance with evaluation of Svalbard habitat types, we suppose the following environmental management zones in the Pyramiden town area.

1. Zone of natural arctic tundra. Zone includes following habitat types: *Cassiope tetragona*-dominated arctic tundra; *Dryas octopetala*-dominated (moss-lichens) tundra, '*Dryas octopetala – Carex rupestris*-dominated arctic tundra', '*Salix polaris* – mosses dominated arctic tundra', '*Oxyria* digyna – mosses dominated arctic tundra'; *Dryas octopetala*-dominated open barrens and screes; '*Saxifraga oppositifolia*-dominated open barrens and screes'; '*Saxifraga aizoides*-dominated open stony alluvial system'; *Puccinellia phryganodis*-dominated marshes'; '*Deschampsia alpina*-dominated wetlands'; '*Dupontia psilosantha*-dominated wetlands'; nitrophytic *Cochlearia groenlandica*-dominated meadows'. Such zone does not include rare habitat types of the Norwegian Red List for Ecosystems and Habitat Types (2011) and is influenced by human activity (roads, trails, *etc*.). However, it includes natural arctic tundra plant communities with typical species diversity and structure of plant cover. In this zone, we propose to prohibit the construction of roads and houses and adjust it for winter sports and tourism (to construct the snowmobile trails, to arrange of parking areas, *etc*.).

2. Zone of naturally disturbed habitats. Zone includes large almost vegetation-free areas in the Mimerelva River and its tributaries delta. Those areas are periodically influenced by snowmelt runoff, slump masses of snow, glacier debris, and mud flows. Engineering structures should be constructed for protection of the southeastern periphery of the town.

3. Zone of anthropogenic disturbed landscapes**.** The zone includes 'anthropogenic *Poa alpigena* dominated grasslands', *Poa alpigena* plant communities on dry destroyed areas, 'nitrophytic *Cochlearia groenlandica*-dominated meadows'. In this zone, there are no rare habitat types, and plant cover gradually recovers. However, some of these habitats types have great historical and recreational value. The *Poa alpigena* dominated grasslands (the lawn) were planted on disturbed areas in Pyramiden streets and yards as part of the living environment in the Arctic and are an example of the successful restoration of destroyed Arctic ecosystem. In the area of lawns, construction of new roads and houses should be prohibited. The lawns are to be managed and protected from destruction.

The area with a colony of kittiwakes and complex of nitrophytic meadows near abandoned industrial building and construction is an example of a natural breeding colony ecosystem on an artificial construction and can be included into a tourist route in the Pyramiden town as a place to observe the behavior of birds and their nesting activity (bird-watching).

## Conclusion

In the area of Pyramiden town, 15 main habitat types were distinguished and classified into the following groups: Arctic tundra; Barrens, screes, young alluvia and glaciers; Wetlands and marshes; Meadows and grasslands; Anthropogenic open plant communities. Three of them were assessed as NE ('not evaluated') and 12 as LC ('least concerned') accordingly IUCN criteria. As far as the criteria of natural habitats value is still under consideration, new data and investigations are needed to assess threatened ecosystems and habitat types in the Arctic and on Svalbard.

On the base of IUCN evaluation of habitat types, we distinguished the following environmental zones in area of Pyramiden town: 1) Zone of natural Arctic tundra, which contains a complex of typical habitat types of Arctic tundra with its species diversity and structure of plant cover. In this zone we propose to prohibit the construction of roads and houses and make necessary adjustments for winter sports and tourism. 2) Zone of naturally disturbed habitats, which experience devastating effects of running water from glacier melt. In the zone, the construction of roads and houses should be also prohibited, with the exception for engineering structures for the protection of the town. 3) Zone of anthropogenically disturbed landscapes with no rare habitat types, but gradually recovering vegetation cover. In this zone it is possible to construct the roads and buildings for tourism and sport activity. We propose to protect some habitats here, *i.e.* anthropogenic *Poa alpigena*-dominated grasslands of historical and recreational value, and the complex colony and ornithogenic meadows on the border of the town, as prospective area for bird-watching.

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