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Botanica Pacifica
Botanical Garden-Institute FEB RAS
Makovskii Str. 142
Vladivostok 690024 RUSSIA

http://www.geobotanica.ru/bp

botanica.pacifica@icloud.com
krestov@biosoil.ru
v_bak@list.ru

RESEARCH PAPER

Mountains of Kilpisjärvi Host An Abundance of Threatened Plants in Finnish Lapland

Heikki O. Kauhanen

Heikki O. Kauhanen *
heikki.kauhanen@metla.fi

Finnish Forest Research Institute
Kolari Unit
Kolari FI-95900 Finland

* corresponding author

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ABSTRACT

Malla Strict Nature Reserve (Malla SNR), located by Lake Kilpisjärvi in the north-western corner of Finland, approximately 270 km north of the Arctic Circle, conserves 3050 ha of subarctic birch forest and alpine environment. Pikku-Malla Fell (734 m alt.) and the adjoining Saana Fell (1029 m alt.) are famous for their rich flora, including numerous rare species. Calcicolous alpine species, which are rare or absent in other parts of Finland, are the most characteristic element of the flora. In this paper I summarize the red-listed vascular plants and bryophytes recorded in Malla SNR and on Saana Fell. For Malla and Saana, 24 vascular plants and 68 bryophytes are currently classified as threatened, and 23 vascular plants and 47 bryophytes as near-threatened. Due to the high geomorphological diversity and base-rich bedrock, these mountains provide a wide variety of habitats for rare and threatened plant species.

Keywords

Caledonian orogeny, Finnish Lapland, Malla Strict Nature Reserve, lime-rich bedrock, species richness, threatened species, vascular plants, bryophytes, climate change

РЕЗЮМЕ

Кауханен Х.
На горах Килписьярви сосредоточено множество редких растений финской Лапландии

Природный заказник Малла, расположенный вблизи озера Килписьярви на северо-западной оконечности Финляндии, приблизительно в 270 км к северу от полярного круга, покрывает 3050 гектаров, занятых березовым криволесьем и горными тундрами. Небольшие горы Пикки-Малла (734 м над ур. м.) и Саана (1029 м над ур. м.) знамениты благодаря их богатой флоре, включающей большое количество редких видов. Кальцефильные альпийские таксоны, редкие или отсутствующие на остальной части Финляндии, являются наиболее характерным элементом флоры. В данной работе я обобщаю данные по «краснокнижным» видам сосудистых растений и мохообразных указывавшихся для заказника Малла и горы Саана. В настоящее время 24 вида сосудистых растений и 68 мохообразных, из указанных для этого района, классифицируются как нуждающиеся в охране и еще 23 вида сосудистых растений и 47 мохообразных как условно угрожаемые. Благодаря высокому разнообразию в геоморфологическом строении и широкому распространению основных пород, район исследования обладает большим разнообразием местообитаний для произрастания редких и угрожаемых видов растений. (Переведено редколлегией).

Ключевые слова

Каледонский тектогенез, финская Лапландия, заповедник Малла, известняковые скалы, видовое богатство, редкие виды, сосудистые растения, мохообразные, изменения климата

INTRODUCTION

The latitudinal gradient is one of the most obvious determinants of global diversity patterns, with species richness declining continuously towards the poles (Scheiner & Rey-Benayas 1994, Systra 2003, Willig & Bloch 2006). For example, a total of more than 1000 vascular plant species are documented for Lahemaa National Park (59°N) in North Estonia (Kukk & Kull 2005), 313 species for Kevo Strict Nature Reserve (69°45'N) in northern Finnish Lapland (Heikkinen & Kalliola 1990), and only 165 species for Svalbard (77–81°N) (Lydersen et al. 2010). However, there are significant regional and taxonomic exceptions, as demonstrated by the existence of biodiversity hotspots.

Bedrock, geology, topography and geography have proved to be effective explanatory variables of species richness (Birks 1991). Topographic heterogeneity is also mentioned as the primary determinant of species richness (Lenoir et al. 2010). Systra (2003, 2004, 2009, 2010, 2012) emphasizes the role of bedrock and ground water geochemistry in his studies in Estonia and eastern Fennoscandia. He states that the geochemistry of bedrock and Quarternary sediments strongly influences soil nutrient content and at the same time biodiversity. The Oulanka-Paanajärvi area, including Oulanka National Park in Finland and Paanajärvi National Park in Russia, is a well-known area

of high species richness and numerous rare plant species, due to its nutrient-rich soil and calcareous rocks.

The bedrock of Finland belongs to the Precambrian block of northern and eastern Europe. In Sweden and Norway, and in NW Finland, the current study area, the Fennoscandian shield is delimited by the Caledonian orogeny (Korsman & Koistinen 1998). Most of the Finnish bedrock (82 %) consists of acidic granites, gneisses, granulite, sandstone and quartzite (Sederholm 1925). These rocks contain 65–70 % of SiO_2 and insignificant amounts of the nutrients required by biota (Systra 2004). Intermediate mafic rocks, mica schist, diabase, gabbro, diorite and amphibolite comprise about 17 % of the bedrock (Sederholm 1925). The rock types favouring the most diverse vegetation and flora are calcitic marble and dolomite, which are very rare in Finland (0,1 %).

In addition to climate, acidic and poor bedrock and soils are very important factors determining vegetation and flora in Finland (Systra 2003, Husa & Kontula 2006). Due to the rarity of calcareous areas, species favouring high pH are rare and in many cases threatened in Finland. The variation in the chemical composition of bedrock is most clearly visible in the vegetation of the rock outcrops themselves and in calcareous seepage mires (Systra 2009). Acidic rocks have a completely different species composition from calcareous rocks, probably due to the difference in dissolved nutrients in the leachate (Ødegaard et al. 2010). The diversity of plants in general has a positive link with the lime content of the soil, and the proportion of herbaceous species, in particular, may be high in calcareous areas (Austrheim et al. 2010).

Large variations in species richness characterize northernmost Fennoscandia. This is especially pronounced for arctic–alpine plants and for plants favoured by lime-rich bedrock. The occurrence of lime-favouring arctic–alpine plants is strongly concentrated within a relatively small 'hotspot' area in the eastern and interior part of the mountain chain, stretching from the Abisko area in northernmost Swedish Lapland to Altafjord in Finnmark, Norway (Olofsson & Oksanen 2005). The taxon richness of vascular plants in the area of the present study is highest in the Caledonian mountain range of Scandinavia, based on the Atlas Florae Europaeae distribution grids (Väre et al. 2003). The aim of this paper is to present the species richness of this area in the northwestern corner of Finland, determine the red-listed vascular plant and bryophyte species of the area, and describe it as an environment for threatened species.

MATERIAL AND METHODS

Study area

The study area is located at Kilpisjärvi (69°03'N, 20°50'E) in the northwestern corner of Finland, 270 km north of the Arctic Circle, and only 50 km from the Arctic Ocean (Fig. 1). It is bordered by Norway and Sweden. This part of Finland is the only area where the Scandinavian Caledonian Range reaches Finland. Climatically, the area lies between the North

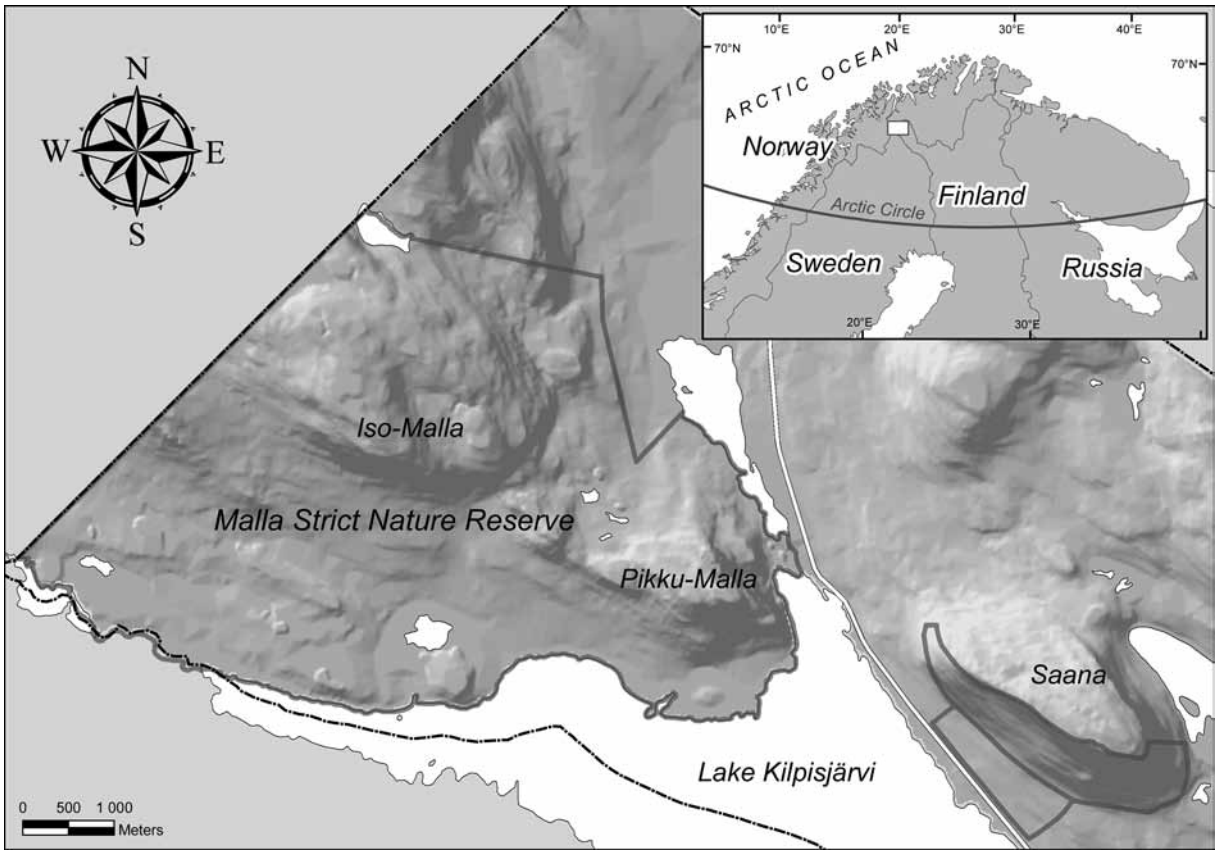

Figure 1 Location of the Kilpisjärvi area, Malla Strict Nature Reserve and the fells Iso-Malla, Pikku-Malla and Saana

Atlantic oceanic climate and the Eurasian continental climate. Mean annual, January and July temperatures are –2.0°C, –12.9ºC and 11.2ºC, respectively. The growing season lasts for 102 days. Lake Kilpisjärvi (473 m a.s.l.) lies in the rain-shadow of the Norwegian mountains; precipitation is therefore low in this region (annual mean 472 mm). A special feature of the study area is the large annual variation in solar radiation. In winter, the sun is below the horizon for 55 days, and in summer there is no sunset for 62 days between late May and late July.

Geologically the area belongs to the eastern thrust front of the Scandinavian Caledonide nappes.

The Archaean basement mainly consists of gneissose granodioritic rocks with lesser mafic volcanics and mica gneisses (Lehtovaara 1995). This deformed and metamorphosed basement is overlain by sedimentary rocks and dolomitic limestones (Figs. 2, 3). Chemically, the rock is quite pure dolomite (Hausen 1942, Lehtovaara 1988). The lowest layer is clearly visible on the lower slopes of Malla and Saana as clayey slates (Fig. 3). The stratigraphy of the thrust front is best seen in the southeast-facing cliff of Saana. The upper part of the cliff nappe consists of hard arkose quartzite, which protects the lower layers from erosion. With respect to the diversity of vegetation, the dolomitic

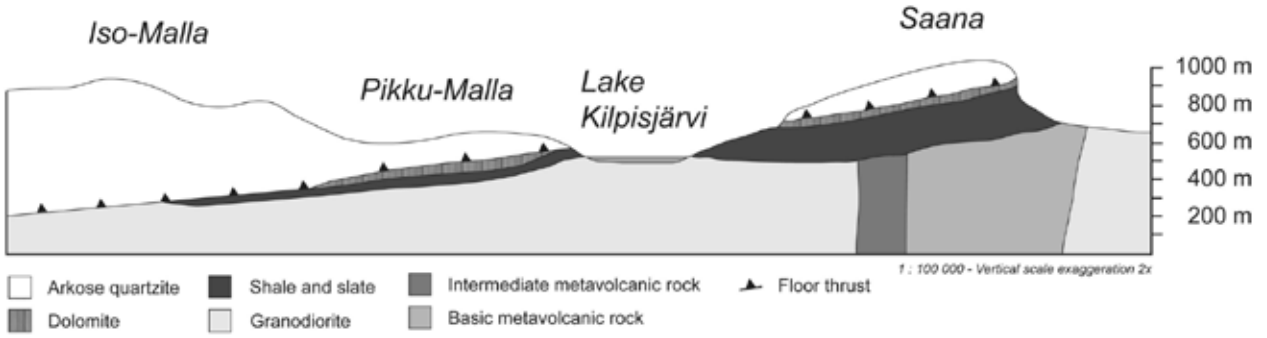

Figure 2 The profile of Iso-Malla–Saana

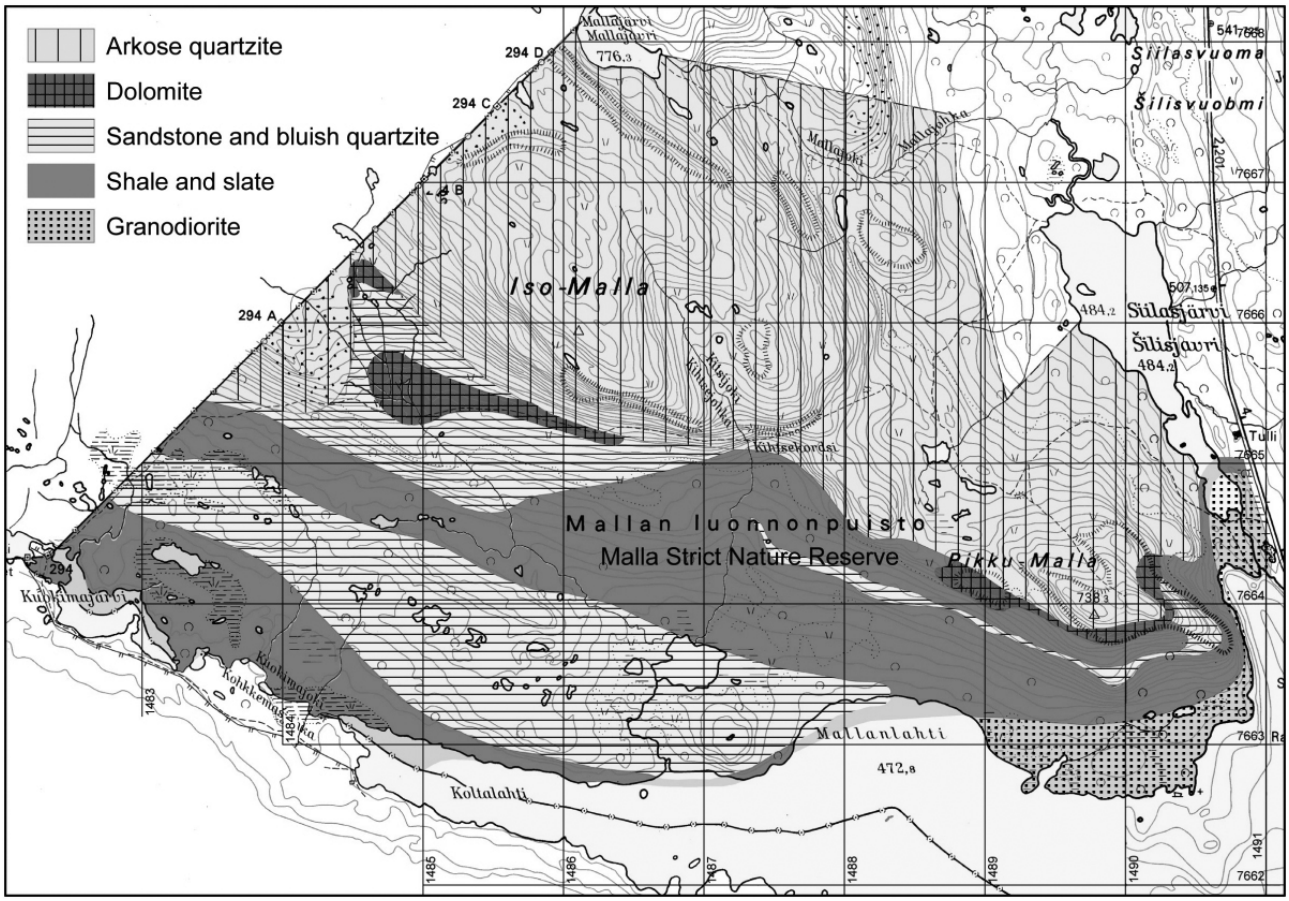

Figure 3 The bedrock of Malla Strict Nature Reserve. Compiled by Jorma Mattsson and Jari Hietanen according to Lehtovaara (1995). © Maanmittauslaitos, permission no. 250/MYY/04

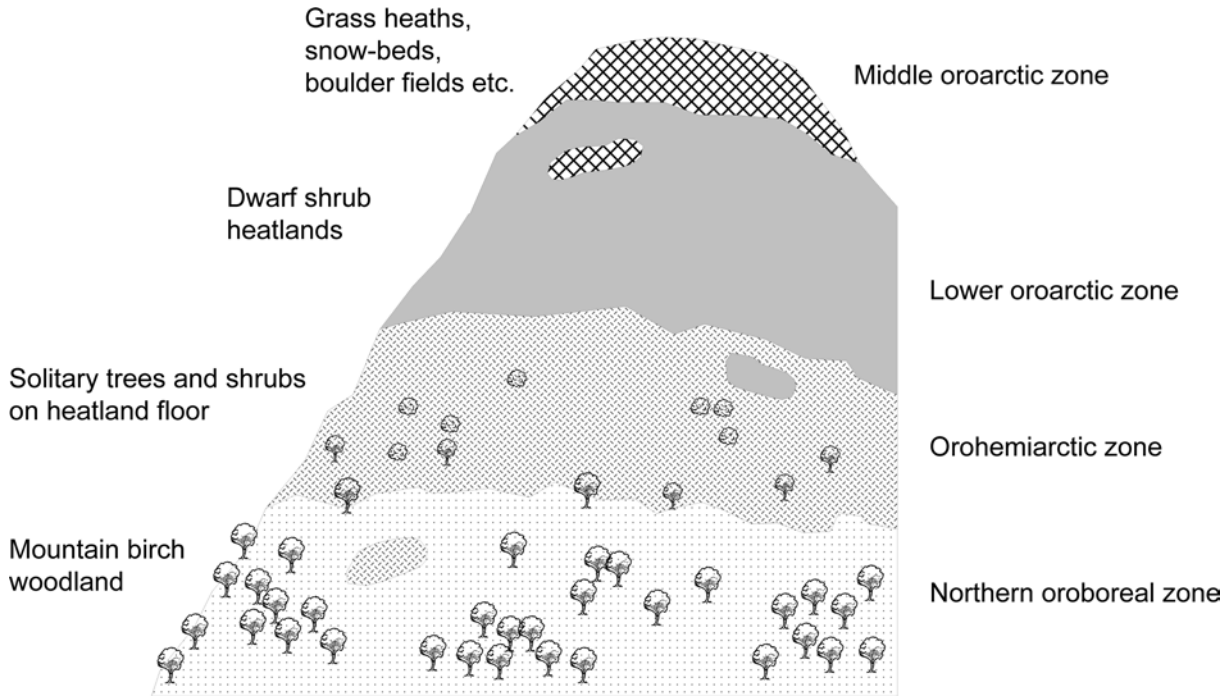

Figure 4 Altitudinal vegetation zones in Kilpisjärvi region

marble of the Jerta Nappe is the most interesting rock unit (Systra 2012). The dolomite layer is not horizontal but its altitude a.s.l. increases from Malla to Saana (Fig. 2). As a result, the lime-influenced area down the slope is larger in Saana than Malla. There are three botanically interesting fells in the study area: Iso-Malla (951 m), Pikku-Malla (734 m) and Saana (1029 m).

The Kilpisjärvi region lies about 100 km north of the continuous coniferous forest and belongs to the sub-alpine birch forest zone, with mountain birch (*Betula pubescens* ssp. *czerepanovii*) being the only forest-forming species. The composition and diversity of the flora of Kilpisjärvi area are primarily affected by the northern location, altitudinal variation, alkaline-rich bedrock, harsh winters, distribution of snow, vicinity of the Atlantic Ocean and the microclimate of sheltered valleys. The area is dominated by a wide range of ecosystems, from mountain birch forest at low altitude (480–600 m) to alpine (oroarctic) tundra above 600 m (Fig. 4). Biogeographically, the area belongs to Fjord Lapland, a sub-oceanic section of the northern boreal zone (Ahti et al. 1968, Eurola 1999). The frequency of luxuriant mountain birch forests of tall herb type is a typical feature of this section.

Between the forest and the treeless alpine tundra is the orohemiarctic zone, characterized by dwarf birch (*Betula nana*) and bush-like willows (*Salix* spp.). Above this transition zone is alpine (oroarctic) tundra dominated by dwarf shrubs, e.g. *Salix herbacea*, *Cassiope tetragona*, *Diapensia lapponica* and *Loiseleuria procumbens*. The alpine area is divided into three bioclimatic zones (Fig. 4): low alpine (lower oroarctic), middle alpine (middle oroarctic) and high alpine (upper oroarctic) (Austrheim et al. 2010). The lower limit of the middle alpine zone is 850–900 m a.s.l. and that of the high alpine zone 1100–1200 m a.s.l. The middle alpine vegetation occurs on the top plateau of Saana and in small patches on Iso-Malla, but high alpine vegetation is missing from the study area.

There are three nature reserves in the Kilpisjärvi area. Malla has been protected since 1916 and was declared a strict nature reserve (Malla SNR) in 1938. The area of the reserve is 30.5 km^2. The Saana Protected Area, encompassing 240 ha of the mountain slopes, was established in 1988. The Protected Herb-Rich Forest Area (76 ha) at the foot of Saana Fell was established in 1992.

METHODS

In order to evaluate and quantify the role of the study area as a refuge area for rare and threatened species, I selected vascular plants and bryophytes as indicator groups of species. Key tools in the data collection were the Environmental Information System (Hertta) of the Finnish environmental administration, the 2010 Red List of Finnish Species, which is based on IUCN criteria (Rassi et al. 2010), and the Handbook of Threatened Bryophytes in Finland (Laaka-Lindberg et al. 2009). Data on vascular plants are largely based on the Master's thesis of Federley (1969) and on my own observations during the inventories of 2002 and 2003 (Kauhanen 2005). An important source for bryophyte species was the survey report of the Metsähallitus Natural Heritage Services from Malla SNR (Juutinen 2011). The total number of bryophyte species is somewhat higher than that counted from the above-mentioned sources, since not all museum specimens are recorded in Hertta. Nomenclature for vascular plants, bryophytes and lichens follows Hämet-Ahti et al. (1998), Ulvinen et al. (2013) and Nordin et al. (2012), respectively.

I used the Red List categories in accordance with the most recent classification in Finland (Rassi et al. 2010). These categories describe the extinction risk, i.e. the probability of a species' disappearance over a certain period of time. All

species placed in the following three categories, Critically Endangered (CR), Endangered (EN) and Vulnerable (VU), are threatened. Together with threatened species, species assigned to the categories Regionally Extinct (RE), Near Threatened (NT) and Data Deficient (DD) form the Finnish Red List. Classifying a species as Regionally Extinct (RE) is usually based on information that its last known locality has disappeared or that no specimens have been found for a very long time. The category Near Threatened is applied to taxa that do not qualify as currently threatened, but may be close to qualifying as threatened. The category Data Deficient highlights taxa for which there is insufficient information to make a sound status assessment.

RESULTS

Vascular plants

The flora of the Kilpisjärvi area consists of northern boreal, alpine and arctic species. Species that thrive on high mountains and prefer or demand a calcium-rich substrate represent the most distinctive element of the region. A major part of this flora is rare or absent in other parts of Finland. A total of 326 vascular plant species and four subspecies have been found in the 30.5 km^2 area of the Malla SNR. Together with Saana Fell, the number of taxa is 369, including 16 subspecies. The number of species and subspecies in the 8 km^2 area of Saana Fell is respectively 325 and 15. The total number of calcicole species in these two areas is 87 (Table 1).

For Malla and Saana, 47 taxa are currently red-listed, 24 threatened and 23 near-threatened (Table 1). Two species are listed as CR, eight as EN, 14 as VU and 23 as NT. Except for two VU (*Epipogium aphyllum* and *Veronica alpina* ssp. *pumila*) and five NT (*Antennaria dioica*, *Campanula rotundifolia* ssp. *gieseckiana*, *Nardus stricta*, *Ranunculus glacialis* and *Sagina nivalis*) species, the other 40 are calcicoles. Most of the red-listed species occur on both mountains, except for *Carex microglochin*, *Erigeron uniflorus* ssp. *eriocephalus* and *Veronica alpina* ssp. *pumila*, which occur on Saana only, and *Antennaria porsildii*, *Lappula deflexa*, *Oxytropis lapponica* and *Platanthera obtusata* ssp. *oligantha*, which are known in Malla only. The arctic–alpine *Draba alpina* has presumably disappeared from the study area. It was collected from Saana in 1867 and recorded in Malla in the 1930s, but have not been re-discovered in recent surveys. The only population of this species in Finland is known on Toskalharji Fell, northeast of Kilpisjärvi (Väre et al. 2008).

Rarest among the threatened species are *Platanthera obtusata* ssp. *oligantha* and *Oxytropis lapponica*, the former being the rarest vascular plant in Finland. Only one individual was found in 2009 on Pikku-Malla (Mäkelä 2009). This species is very rare throughout its entire distribution area in northern Scandinavia and eastern Siberia (Høiland 1990). It is classified as CR in Finland (Rassi et al. 2010), in Sweden (Aronsson et al. 2010) and also in Norway (Høiland 1990, Alm 2012). The population of *Oxytropis lapponica* in Pikku-Malla is also the only locality where it is known to be found in Finland (Federley 1971, Kauhanen 2005, Väre 2012). These and other protected rare and threatened vascular plant species are mainly found in the presence of carbonate rocks. Although there are many other fjelds with the same elevation and slope aspect, most of the rare and protected species are absent where the bedrock is other than dolomite (Systra 2010).

Bryophytes and lichens

A total of 321 bryophyte species have been recorded for Malla SNR and 254 species for Saana. The combined number of the bryophyte flora of these two mountain areas comprises around 365 species. Since the bryophyte flora of these mountain areas has not been thoroughly inventoried, it is evident that numerous species are still waiting to be found. The threatened bryophyte species are considerably better known than is the total number of species. Based on IUCN criteria, 68 species are classified as threatened (CR, EN, VU) and 47 as NT (Table 2). Among the threatened species, 11 are considered as CR, 21 as EN and 36 as VU. Three rare species (*Arctoa hyperborea*, *Oedipodium griffithianum*, *Tortula systylia*) recorded in the area in the 1930s have not been rediscovered, and are classified as Regionally Extinct (RE). *Racomitrium macounii* subsp. *alpinum* is also officially classified as RE, but it was rediscovered in Malla after the last assessment of threatened species. As five species are classified as Data Deficient (DD), a total of 124 bryophyte species are included in the 2010 Red List of Finnish Species. Red-listed species represent approximately one third of the known bryophyte flora of the area. In addition to the national Red List, 22 species belonging to the category Least Concern (LC) are locally threatened in Fjeld Lapland, the northwestern section of the northern boreal vegetation zone.

At the national level, the rarest byophytes (CR) in the study area are *Blindia caespiticia*, *Cololejeunea calcarea*, *Encalypta longicolla*, *Gymnostomum boreale*, *Lophozia murmanica*, *Tortula systylia* and *Trematodon brevicollis*. These are each only known from one location in the whole country. The first three were found in Malla SNR as new species to Finland just a few years ago (Syrjänen 2010). *Lophozia murmanica* Kaal. (syn. *L. wenzelii* var. *groenlandica,* Konstantinova et al. 2009) was found as a new species to Finland at the foot of Saana Fell in 2009 (Kalinauskaite & von Cräutlein 2010). *Orthothecium lapponicum*, recorded both in Malla and Saana, is EN in Norway, VU in Sweden and rare everywhere throughout its distribution range (Ulvinen 2009). It is worth noting *Plagiobryum demissum*, which occurs in Finland only on Saana and on two fells (Annjalonji and Urtasvarri) outside the study area (Huttunen & Virtanen 2009).

The lichens of Malla and Saana have been less studied than the vascular plants and bryophytes. In 2007, Pykälä (2010) undertook lichen collections on Pikku-Malla and Saana. Despite the short visit, he collected numerous interesting species. Twenty species were noted as new to Finland and six (*Thelidium decussatum*, *Th. submethorium*, *Verrucaria cinereorufa*, *V. disjuncta*, *V. pinguicula* and *V. subjunctiva*) as new to Fennoscandia. Additionally, 24 species were new to the biogeographical province of Enontekiö Lapland (*Lapponia enontekiensis*, EnL). Most of the species new to Finland were found on calcareous rocks (dolomite), but two were collected on calcareous soils and three on schistose rocks.

Table 1 Threatened (CR, EN, VU) and Near Threatened (NT) vascular plants, by Red List Category (Cat), and calcicolous (Ca+) species of Malla Strict Nature Reserve (Ma) and Saana Fell (Sa) – ●. Very old record – (●). Sign '–' means not recorded/not calcicole.

Species	Cat	Ma	Sa	Ca+
Antennaria dioica	NT	●	●	–
Antennaria porsildii	VU	●	–	●
Arabis alpina		●	–	●
Arenaria norvegica	VU	●	●	●
Arnica angustifolia	EN	●	●	●
Asplenium viride		●	●	●
Astragalus frigidus		●	●	●
Bartsia alpina		●	●	●
Botrychium boreale	VU	●	●	●
Botrychium lunaria	NT	●	●	●
Campanula rotundifolia ssp. *gieseckiana*	NT	●	●	–
Campanula uniflora	VU	●	●	●
Carex atrata	NT	●	●	●
Carex atrofusca	NT	●	●	●
Carex capillaris		●	●	●
Carex capitata		–	●	●
Carex flava		●	●	●
Carex juliginosa ssp. *misandra*	NT	●	●	●
Carex glacialis		●	●	●
Carex microglochin	EN	●	●	●
Carex norvegica ssp. *norvegica*		●	●	●
Carex panicea		●	●	●
Carex parallela		●	●	●
Carex rupestris	NT	●	●	●
Carex saxatilis		●	●	●
Cassiope tetragona		●	●	●
Cerastium alpinum ssp. *glabratum*		●	●	●
Cerastium alpinum ssp. *lanatum*		●	●	●
Chamorchis alpina	EN	●	●	●
Cystopteris fragilis ssp. *dickieana*		–	●	●
Cystopteris montana		●	●	●
Dactylorhiza fuchsii		●	●	●
Draba alpina	EN	(●)	(●)	●
Draba daurica	VU	●	●	●
Draba fladnizensis	VU	●	●	●
Draba lactaea	VU	●	●	●
Draba nivalis	NT	●	●	●
Dryas octopetala		●	●	●
Epilobium davuricum		●	●	●
Epilobium lactiflorum		●	●	●
Epipogium aphyllum	VU	●	●	–
Equisetum scirpoides		●	●	●
Equisetum variegatum		●	●	●
Erigeron borealis	VU	●	●	●
Erigeron humilis	NT	●	●	●
Erigeron uniflorus ssp. *eriocephalus*	NT	–	●	●
Eriophorum brachyantherum		●	●	●
Erysimum strictum		–	●	●
Euphrasia frigida var. *palustris*		●	●	●
Euphrasia salisburgensis	EN	●	●	●
Gentianella tenella	EN	●	●	●
Gymnadenia conopsea		●	●	●
Hierochloe odorata ssp. *odorata*	NT	●	●	●
Juncus arcticus		–	●	●
Juncus triglumis		●	●	●
Lappula deflexa	VU	●	–	●
Minuartia biflora		●	●	●
Minuartia rubella	VU	●	●	●
Minuartia stricta	VU	●	●	●
Nardus stricta	NT	●	●	–
Oxytropis lapponica	CR	●	–	●
Parnassia palustris		●	●	●
Pedicularis hirsuta	NT	●	●	●
Pinguicula alpina		●	●	●
Platanthera obtusata ssp. *oligantha*	CR	●	–	●
Polystichum lonchitis	NT	●	●	●
Potetilla chamissonis	NT	●	●	●
Potentilla nivea	NT	●	●	●
Pseudorchis albida ssp. *straminea*	NT	●	●	●
Pyrola rotundifolia ssp. *norvegica*		●	●	●
Ranunculus glacialis	NT	●	●	–
Rhododendron lapponicum	NT	●	●	●
Sagina nivalis	NT	●	●	–
Salix arbuscula	EN	●	●	●
Salix lanata ssp. *lanata*		●	●	●
Salix myrsinites		●	●	●
Salix polaris		●	●	●
Salix reticulata		●	●	●
Saxifraga aizoides		●	●	●
Saxifraga cespitosa		●	●	●
Saxifraga nivalis		●	●	●
Saxifraga oppositifolia		●	●	●
Saxifraga rivularis		●	●	●
Sedum villosum	VU	–	●	●
Selaginella selaginoides		●	●	●
Silene acaulis		●	●	●
Silene wahlbergella	NT	●	●	●
Thalictrum alpinum		●	●	●
Trichophorum alpinum		●	●	●
Triglochin palustris		●	●	●
Veronica alpina ssp. *pumila*	VU	–	●	–
Veronica fruticans	NT	●	●	●
Viola rupestris ssp. *relicta*	EN	●	●	●
Woodsia alpina		●	●	●
Woodsia glabella	NT	●	●	●

DISCUSSION

Factors explaining species richness

Malla SNR hosts a diverse range of vascular plants, bryophytes and lichens in its 30.5 km^2 of mountain birch forests, mires and springs, brook-sides, alpine heaths and meadows, rock walls, boulder fields, talus slopes and snowbeds. The high numbers of red-listed vascular plants (44 species) and bryophytes (90 species) known in the area highlight the importance of this reserve. Compared with Malla SNR, as high a number of red-listed vascular plants (45 species) and bryophytes (91 species) are known in the smaller area of Saana Fell (around 8 km^2). Together, these two mountain areas host 47 red-listed vascular plant species and 123 bryophyte species. The high proportion (one third) of red-listed bryophytes is presumably an overestimate, since bryologists have concentrated on threatened species in their inventories. Similar to Malla and Saana, Toskalharji Fell (33 km northeast of Kilpisjärvi) is known for its rich flora and calcicole species. This mountain is also located at the eastern thrust front of the Scandinavian Caledonides but above the treeline. A total of 19 red-listed vascular plant species and 44 bryophyte species have been found on Toskalharji, which is around 20 km^2 in area (Väre et al. 2008). Of the vascular plants of Toskalharji, 53 species are calcicoles. Usually the size of an area is the most important single variable explaining species richness (e.g. Shmida & Wilson 1985, Wohlgemuth 1998). As Malla and Saana are small in area, some other factors than size must explain their high diversity of plant species.

One of the most important factors explaining the high species richness is undoubtedly the bedrock. Schistose rocks, such as slates, are predominant in Malla and Saana (Lehtovaara 1995), but both mountains have dolomite rock outcrops on their steep slopes, being mainly situated above the treeline. Rainwater acts to extend the influence of calcium downslope far from the dolomite outcrops on the

Table 2 Threatened (CR, EN, VU) and Near Threatened (NT) bryophytes of Malla Strict Nature Reserve (Ma) and Saana Fell (Sa), by Red List Category (Cat)

Species	Cat	Ma	Sa
Amblyodon dealbatus	VU		●
Anastrophyllum cavifolium	EN		●
Andreaea blyttii	NT	●	
Anoectangium aestivum	NT	●	●
Anomobryum concinnatum	VU		●
Aongstroemia longipes	EN		●
Arctoa hyperborea	RE		●
Arnellia fennica	VU		●
Asterella lindenbergiana	CR	●	●
Athalamia hyalina	VU	●	●
Blindia caespiticia	CR	●	
Brachytheciastrum collinum	VU	●	●
Brachytheciastrum trachypodium	NT		●
Brachythecium coruscum	VU	●	●
Bryum knowltonii	NT	●	●
Bryum pseudotriquetrum var. *neodamense*	VU	●	●
Bryum wrightii	EN	●	●
Campylium laxifolium	EN		●
Campylophyllum halleri	NT	●	●
Cololejeunea calcarea	CR	●	
Coscinodon cribrosus	EN	●	●
Cyrtomnium hymenophylloides	NT	●	●
Cyrtomnium hymenophyllum	VU	●	●
Dicranum acutifolium	NT	●	●
Dicranum spadiceum	NT		●
Distichium inclinatum	NT	●	●
Ditrichum gracile	EN	●	●
Encalypta affinis subsp. *macounii*	EN		●
Encalypta alpina	NT	●	●
Encalypta brevipes	CR		●
Encalypta longicolla	CR	●	
Encalypta mutica	EN	●	●
Encalypta procera	NT	●	●
Encalypta rhaptocarpa var. *leptodon*	DD	●	
Eremonotus myriocarpus	EN	●	●
Grimmia anodon	EN		●
Grimmia donniana	VU		●
Grimmia fuscolutea	EN		●
Grimmia mollis	EN	●	
Grimmia montana	NT	●	
Grimmia sessitana	VU		●
Gymnomitrion apiculatum	NT	●	
Gymnostomum aeruginosum	NT	●	●
Gymnostomum boreale	CR	●	●
Hygrobiella laxifolia	NT	●	●
Hygrohypnum alpinum	VU	●	
Hymenostylium recurvirostrum	NT	●	●
Hypnum bambergeri	NT	●	●
Hypnum callichroum	VU	●	
Hypnum hamulosum	VU	●	●
Jungermannia polaris	NT		●
Leiocolea badensis	VU	●	
Leiocolea bantriensis	NT	●	●
Leiocolea collaris	NT	●	
Lophozia elongata	DD		●
Lophozia grandiretis	EN	●	●
Lophozia murmanica	DD		●
Mannia pilosa	VU	●	●
Marsupella emarginata subsp. *aquatica*	NT	●	
Marsupella sphacelata	VU	●	
Marsupella sprucei	EN		●
Mielichhoferia elongata	CR	●	
Mnium blyttii	NT	●	●
Mnium spinosum	NT	●	●
Moerckia blyttii	VU	●	
Moerckia hibernica	VU	●	●
Mylia taylorii	NT	●	●
Myurella tenerrima	NT	●	●
Nardia breidleri	NT	●	
Odontoschisma macounii	NT	●	●
Oedipodium griffithianum	RE		●
Oncophorus elongatus	DD	●	
Orthothecium intricatum	NT	●	●
Orthothecium lapponicum	CR	●	●
Orthothecium rufescens	EN	●	●
Orthothecium strictum	NT	●	●
Orthotrichum pellucidum	CR	●	●
Palustriella commutata	VU	●	●
Palustriella decipiens	NT	●	●
Palustriella falcata	NT	●	●
Plagiobryum demissum	EN		●
Plagiobryum zieri	NT	●	●
Plagiomnium curvatulum	NT	●	
Pohlia andrewsii	VU		●
Pohlia atropurpurea	EN		●
Pohlia crudoides	NT	●	●
Pohlia erecta	EN	●	
Pohlia ludwigii	NT		●
Porella cordaeana	VU	●	
Preissia quadrata subs. *quadrata*	DD	●	●
Prasanthus suecicus	NT	●	
Pseudocalliergon angustifolium	VU		●
Pseudoleskea incurvata	NT	●	●
Pseudoleskeella papillosa	NT		●
Pseudoleskeella rupestris	NT	●	●
Psilopilum laevigatum	CR		●
Racomitrium macounii subsp. *alpinum*	RE	●	
Sanionia georgicouncinata	NT	●	
Scapania aequiloba	EN	●	
Scapania calcicola	VU	●	●
Scapania crassiretis	EN		●
Scapania cuspiduligera	VU		●
Scapania gymnostomophila	NT	●	●
Scapania kaurinii	VU	●	
Scapania paludosa	NT	●	
Scapania praetervisa	NT	●	●
Scapania uliginosa	NT	●	●
Schistidium poeltii	VU		●
Schistidium sordidum	VU	●	●
Schistidium tenerum	VU	●	●
Schistidium trichodon	NT	●	
Schistidium umbrosum	VU	●	
Schistidium venetum	VU		●
Sciuro-hypnum glaciale	VU	●	
Sciuro-hypnum latifolium	NT	●	
Sciuro-hypnum tromsoeense	NT	●	
Seligeria campylopoda	VU	●	●
Stegonia latifolia	VU	●	●
Tayloria froelichiana	VU	●	●
Timmia bavarica	VU	●	●
Timmia comata	VU		●
Timmia norvegica	EN	●	●
Tortula systylia	RE		●
Trematodon brevicollis	CR		●

steep slopes of Pikku-Malla and Saana. Additionally, only the northwesternmost corner of Finnish Lapland, including Malla and Saana, contains mountains reaching over 1000 m in altitude, thus favouring arctic–alpine species. This also explains the number of rarities in the area. Northernmost Fennoscandia is characterized by large variations in species richness, which is especially pronounced for arctic–alpine plants and for plants favoured by lime-rich bedrock. To illustrate the general pattern of this variation, Olofsson & Oksanen (2005) compiled a map of the occurrence of lime-favouring arctic–alpine vascular plant species in different northern grids of the Atlas Florae Europaeae (Jalas et al. 1972–1999). The highest species richness is found on the grid encompassing the surroundings of Lake Kilpisjärvi, but values obtained for the surroundings of Torneträsk in Sweden and Reisadalen in Norway are only marginally lower. In Sweden, an area of similar species richness is Peltsa Fell and, in Norway, Paras Fell. All these together

create this unique diversity in the northern Scandinavian mountain range. According to Olofsson & Oksanen (2003), the underlying reason for the floristic richness of the area is the rich occurrence of dolomite in the lowermost and oldest overthrust plate of the Scandinavian mountain chain, as well as the relatively continental climate, which counteracts leaching. Carlsson et al. (1999), Odland & Munkejord (2008), Austrheim et al. (2010) and Systra (2010, 2012) also emphasize the role of base-rich rocks as an explanation for a distinct and species-rich, calcicolous vegetation.

Another factor explaining the high biodiversity of the study area is the high geomorphological diversity (steep slopes, considerable altitudinal range). A strongly variable local topography may often be the most important factor determining vegetation structure in the alpine belt (Carlsson et al. 1999). Topography, for example, determines where water is readily available for plants, or where it is scarce, thus governing the overall distribution of dry, mesic and wet communities. Screes and rock outcrops are known as distinctive habitats with a large biological diversity because of the numerous complex microhabitats they contain (Ødegaard et al. 2010). Steep rocky knolls and rock ledges often have a species-rich vascular plant vegetation when they face the sun and where calcareous seepage water periodically trickles over the rock. Special environments such as overhangs, caves and crevices, issuing springs and surfaces with trickling water also create large variations. In addition, the varying exposures of cliff faces and the sides of boulders produce a great variation in species composition (Ødegaard et al. 2010).

Considering the bryoflora of Pikku-Malla, the most important areas are the northeastern slope and the dolomite cliff lying west of the mountain top (Juutinen 2011). The former is characterized by trickling water and high rock walls and the latter by dryness, torridity and low rock walls. On the whole, the strong influence of dolomite, trickling water and the abundance of precipices explain the high diversity and the concentration of demanding and threatened species on Pikku-Malla. According to Juutinen (2011), this mountain is unique for bryophytes at the national scale: it is a real 'bryophyte hotspot'. Together with Mt. Saana it is an important area for rare and threatened plants in Finland.

However, it must be kept in mind that this unique area in Finland is a continuum of a much wider area of the Scandinavian mountains. Most species in Finnish territory are more widely distributed in northern Norway and Sweden. Even so, Malla and Saana are of highest importance for the conservation of floral diversity on the national scale.

Conservation and threats

Threatened species are usually related with several threat factors. Climate change is projected to be a threat to plant diversity in arctic and alpine areas (Thuiller et al. 2005, Björk & Molau 2007). A warming climate causes a decrease in the distribution and duration of snowbeds, which in turn leads to a decrease in the amount of meltwater during the summer, and hence to drier habitats (Björk & Molau 2007, Eide & Aronsson 2010). A rise in temperature is detrimental to species that are weak competitors and physiologically adapted to a cold climate. As the tree limit is advancing towards higher altitudes and shrubs are spreading into the mountain heaths, the living space of many species dependent on open alpine heaths is shrinking.

Theurillat & Guisan (2001) calculated that an increase of 3.3 K in mean air temperature, corresponding to an altitudinal shift of 600 m in the European Alps, would on average reduce the area of alpine vegetation by 63 %. For Scandinavia one should expect even higher reductions of these zones due to the low mountain height (Odland 2010). The areas that currently lie above the upper limit for vascular plants have a very small extent in Scandinavia, and consequently the available space for plant growth in the case of future temperature increase is very limited. Climate change is recognized as the most significant threat to bryophytes. Since bryophytes are often habitat specialists, and the populations of red-listed species are usually small, they are threatened by stochastic effects (Syrjänen et al. 2010). It is estimated that random factors are a cause of threat for 67 % of mosses and 38 % of liverworts in Finland.

The majority of the threatened vascular plants of Malla and Saana have been conserved due to the three nature reserves. However, small population size makes some species (e.g. *Platanthera obtusata* ssp. *oligantha*) sensitive to random factors. Disturbance by reindeer grazing is a threat to tall herbs dependent on sexual reproduction. For instance, *Arnica angustifolia* occurs primarily on the shelves of rocky walls on Saana, which belongs to the local reindeer pastures (Kauhanen 2005). In Malla SNR, where reindeer grazing has been restricted since the 1950s and totally prohibited since 1981, *Arnica* also survives among the heath vegetation. Outside the study area *Arnica* occurs on the grazed mountain heaths of Toskalharji Fell. During the last 20 years, the reindeer range has illegally been extended to Malla SNR. This will gradually alter the nature of that area, prohibiting comparative studies between grazed and ungrazed alpine ecosystems. Unlike tall herbs, small plants, which are weak competitors and require disturbed ground for successful reproduction, benefit from reindeer grazing (Austrheim & Eriksson 2001, Olofsson & Oksanen 2003) and find suitable microhabitats on the disturbed slopes of Saana, e.g. the population of *Viola rupestris* ssp. *relicta*, is much larger on Saana than in Malla SNR. Besides grazing disturbance, this species benefits from the weathered slate that covers large areas on the slopes of Saana. The unstable slate substrate favours *Viola rupestris* ssp. *relicta* which is small in stature and a weak competitor. In the context of the conservation of rare and threatened species, Malla and Saana compensate for each other.

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