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Variability of the structure and directions in the development of heaths and psammophilous grasslands within the artillery range near the city of Toruń

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Abstract. Phytosociological analysis of non-forest communities was carried out on one of the oldest and the biggest military training grounds in Europe, located near the city of Toruń, in central Poland. Heaths and psammophilous grasslands developed here as a result of deforestation of inland dunes in the valley of the Vistula River, as well as a result of destruction of soils and vegetation brought on by manoeuvres and artillery firings. They form a landscape mosaic with young self-seeding pines, mature pine forests and birch forests. Using the Braun-Blanquet method, 84 relevés were made in the areas dominated by dwarf shrubs and 32 relevés within psammophilous grasslands. Applying the classic phytosociological method, the following plant associations were distinguished in the first set of relevés: *Pohlio-Callunetum* and *Arctostaphylo-Callunetum*, as well as the community with *Cytisus scoparius.* Within the psammophilous grasslands, two associations were distinguished: *Spergulo vernalis-Corynephoretum* and *Calamagrostietum epigeji.* In this paper, the heterogeneity within associations and communities was presented together with descriptions of individual syntaxa, as well as dynamic and developmental relationships between the aforementioned were identified.

Key words: disturbances, heathlands, inland sand dunes**,** landscape mosaic, military training area, phytosociology, succession, syntaxonomy, Toruń Valley, Bydgoszcz Forest.

1. Introduction

Heathlands, similarly like frequently accompanying psammophilous grasslands, are anthropogenic communities, strictly dependent on human activity. Cessation of land use, consisting in grazing by farm animals, burning and mowing, trigger off succession processes, which quickly bring transformations of grasslands and heaths into fringe, thicket and forest communities. In the conditions of Poland, heaths generally develop on small areas in the landscape of pine forests, less frequently mixed forests. Those are forest glades, unsuccessful forest cultivations, division lines, roadsides, railway embankments etc. Nowadays, larger areas of the aforementioned occur only on military training grounds .

Effects of operations carried out by soldiers during their training courses on training grounds, such as explosions of shells and missiles, fires of forests, damaging the ground and vegetation by tanks, conveyors and artillery guns, building trenches, observation points and battle stations, as well as trampling down, act as inhibitors of the overgrowing process, suspending the succession processes of phyto- and zoocenoses, and ecosystems.

In the territory of Poland, there are seven large training areas of the total area over 90 thousand hectares. The artillery range located near Toruń (directly adjacent to the southern limits of the city), is one of the oldest and the

biggest objects of this type, both in Poland and in Europe. It was already created at the beginning of the 17th century and during the next centuries it was extended, reaching the area of more than 12 thousand hectares (Wasilewski 2004). Since the beginning of the 1990s, the area of the so-called working range, used for training of artillery armed forces, gradually has decreased. At present, besides the decrease of the training area, also the frequency and the intensity of military trainings decrease. Species of shrubs and trees, previously destroyed by military artillery, have begun to encroach on dunes covered with heaths and psammophilous grasslands. The same areas of dunes, which at the beginning of the 1990s were still covered with non-forest vegetation, nowadays constitute a mosaic of pine and birch forests, where only relatively frequent glades, covered with grassland and heath vegetation, remind about the previous exploitation of the training ground (Wasilewski 2004).

Flora and plant communities of the training ground, and especially heaths and psammophilous grasslands, developing here in the conditions of unique human influence, inspired the interest of botanists and ecologists already a long time ago. Botanical observations were conducted here by, inter alia, Wilkoń-Michalska (1964). Gawłowska (1964) and Werdyn (1964) informed that the training ground and the whole Toruń Valley are one of the main regions of abundant occurrence of kinnikinnick bearberry and bearberry heaths in Poland. However, difficult accessibility of the area does not create favourable conditions for nature observations on a larger scale. Nowadays, due to changes in the political situation, less frequently due to exploitation and implementation of the EU Programme Natura 2000 in Poland, the area of the training ground is easier to access by naturalists. This creates favourable conditions for understanding the structure and determining the directions of further transformations of ecological systems occurring here. In 1998–2001, the research on protected and rare plant species, as well as plant communities occurring over the whole area of the artillery range were carried out by W. Gugnacka-Fiedor and E. Adamska. The results of this research were presented in a separate paper included in the 12th Issue of Ecological Questions. The main objective of the present paper was to describe the species composition and the structural variability of heaths from the class *Nardo-Callunetea* occurring in the western part of the artillery range near Toruń. In the studied, so-called working part of the artillery range, there are located objects that constitute targets during the artillery firings.

The additional objectives of our research carried out on a smaller spatial scale were to determine the syntaxonomic affiliation of psammophilous grasslands and forest plant communities, which accompany the dwarf shrub heaths, as well as to determine the syndynamic relationships between all distinguished syntaxonomic units. The analyses were conducted with conviction that the research results will provide further information on chorology, as well as spatial and temporal variability of heaths, both in Poland and in Europe.

2. The study area

The artillery range stretches out from the city limits of Toruń in the north (Fig. 1) till the surroundings of Aleksandrów Kujawski in the south. From the east, it borders on the railway lines Toruń – Aleksandrów Kujawski, and from the west – on the road Toruń – Gniewkowo – Inowrocław. The southern boundary is constituted by the Tążyna rivulet, which runs at the longitude of the village of Otłoczyn, till the village of Grabie and further till the village of Suchatówka along the road leading to the town of Inowrocław. The training ground is in the shape of a pentagon, covers the area of more than 12 thousand hectares, its total length amounts to ca. 16 km, and the width – ca. 13 km (Wasilewski 2004). Administratively speaking, it is located within the commune of Wielka Nieszawka. Since the area is included in the Forest Division of Gniewkowo, which is under the management of the Regional Administration of State Forests in Toruń, it constitutes the property of the State Treasury. The Centre for Artillery and Weaponry Training in Toruń is the user of the training ground.

According to the regional, physical and geographical division of Poland, proposed by Kondracki (2000), the training ground is situated within the Province of the Central-European Lowland, the subprovince of Southern-Baltic Lake Districts, the mesoregion of the Toruń Valley (also called the Valley of Toruń and Bydgoszcz, which is a part of the macroregion of the Toruń-Eberswald ice-marginal valley) and the mesoregion of the Inowrocław Plain (the macroregion of the Wielkopolska Lake District). In accordance with the division of Poland into geobotanical regions done by J.M. Matuszkiewicz (1993), the training ground is located in the territory of the Mazovian-Polesie Divide, the Vistula District of Włocławek and Bydgoszcz and the subdistrict of Bydgoszcz Forest (code E1.6.d).

The 400-year history of the training ground is closely connected with the city of Toruń, which used to be under the rule of different countries during different periods. Toruń was a fortified town, a stronghold, and first of all, a borderland and commercial town, strategically important in campaigns, battles and operations, and the area to the south of the city, together with a bridge abutment protecting the access to the bridge and the city, was the place of fierce battles. Therefore, the city had to maintain relatively substantial defence forces. It was the place where major military forces concentrated, what imposed their training and preparing for wars, mostly with artillery firing. The area was needed to perform those tasks. Beyond the Vistula River, to the south of the city, the present-day central

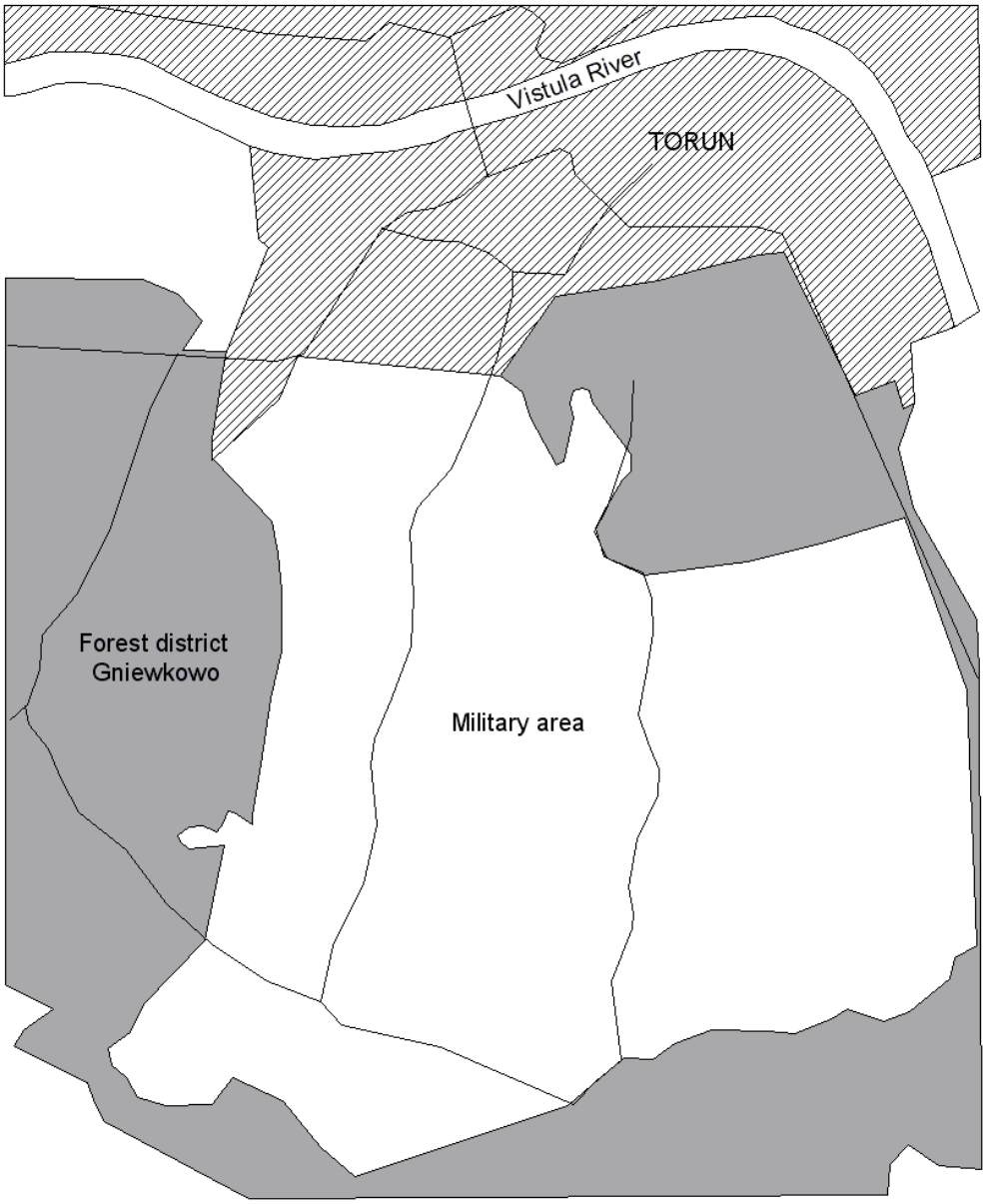

Figure 1. Location of the study area

part of the training ground was not populated due to poor soils. And thus, the area could be used for military trainings (Wasilewski 2004).

The most intensive development of the training ground occurred after 1815, when the area was under the dominion of the Prussian armed forces. After the Prussian-French war in 1871, the infrastructure of the training ground was further extended, using prisoners of war for all the works. At that time, among others, a railway siding was built for ammunition depots, a narrow-gauge railway running along the then boundaries of a working field of the training ground, which was used for distribution of supplies and ammunition. Many hectares of forests growing on those areas were cut down during that time. Until 1884 the area of about 900 ha was developed. During the next years, as a result of the Prussian act on repurchasing the lands, almost 4,900 ha were acquired for military purposes, out of which ca. 2/3 was allotted for the training ground. Already before the 1st world war, in the training ground located directly at the Prussian-Russian border, there was a training camp for about 20 thousand soldiers. During the 1st world war, the training ground covered 3,293.0 ha.

In January 1920, Toruń together with the adjacent training ground returned under the rule of Poland. In 1921, the

School of Artillery Firing was opened as a part of the Artillery Training Centre. At that time, the artillery range, taken over by the Polish Army, had the area of 3,890.7 ha.

The latest years before the 2nd World War were characterized by systematic intensification of trainings on the Toruń training ground. The encroachment of Wermacht troops in 1939 and the Nazi occupation lasting for the following years, completely changed the nature of this place. At the beginning of the occupation, construction of a training yard for anti-tank artillery commenced. For that reason, hundreds of hectares of forest were cut down exposing bare dunes, which since then were the place of trainings for German soldiers. A number of barracks for German armed forces were built. Also the area was transformed into prisoner-of-war camps and lands of martyrdom for soldiers of many different nationalities. The training ground and the city itself were fortified and incorporated into the zone of strongholds.

Again, after the 2nd World War the area was used as an artillery range for the Polish Armed Forces. During that time, access roads were extended, a working field was protected against fires of grasses and forest, edges of the training ground were marked, the equipment was modernized. The training ground became a base for education and training of artillerists, inter alia, at the Military Academy of Missile and Artillery Forces in Toruń. During the 1970s intensive artillery firings proceeded. At that time, several dozen thousand tonnes of ammunition were allocated and stored. During the 1980s and the 1990s the military trainings still took place, but due to financial reasons, they were performed on a smaller area as compared to the previous one (Dzięgielewski 1997).

At present, the training ground makes up 54% of the Gniewkowo Forest Division, comprising almost entirely its District of Otłoczyn. Forests of the training ground (5,138.51 ha) make up over 34% of the area of the Gniewkowo Forest Division. Training activity of the armed forces is limited in this area and any exploitation must be preceded by additional arrangements with administration of State Forests. In the land use structure, the largest part of the training ground is constituted by miscellaneous areas (6,934.26 ha), on which the Forest Division does not conducts any forest management, and which is earmarked for training sessions, classes and firings by armed forces. This part constitutes a working field of 7,850.90 ha, isolated from the total area of the training ground. In this area, there are training facilities, firing and bombarding zones, fire stations, observation points and technical facilities. After the 2nd World War, the area of the working field within the training ground has slowly decreased. From its northern side, intensive development of the area takes place, especially along the communication routes. During the last few years, at the northern end of the training ground, a clearway was built, which constitutes a southern ring road of Toruń.

In the District of Otłoczyn, within the boundaries of which the artillery range is located, two geological and soil formations cover most of the area: eolian formations, dunes and eolian sands, which altogether cover 51.7% of the total area, as well as fluvial sands of old Pleistocene river terraces covering altogether 36.1% of the District's area.

Dunes in the Toruń-Bydgoszcz Valley form one of the largest inland dune areas in Poland (Galon 1958). According to J. Kobendza and R. Kobendza (1958), the Toruń Valley, apart from the ice-marginal valley of the Rivers Warta and Noteć, as well as a junction of the ice-marginal valley of the Rivers Vistula, Bug and Narwia near Warsaw, is one of the most classic dune areas in Europe. Dune areas of the valley are covered by Bydgoszcz Forest. This extensive forest complex is situated within and under the influence of the recommended Bydgoszcz-Toruń Metropolitan Area.

More precisely, the area of our research is located within the dune field no. IV (the towns of Toruń, Aleksandrów and Gniewkowo), situated on the left shore of the ice-marginal valley between the Rivers Zielona and Tążyna. Eolian formations in this part of the Valley occur mainly on the upper, middle (V, VI) and the lower terrace, and in smaller assemblages one can find them also on the alluvial terrace – II (in the village of Nieszawka and the district of Rudak near the city of Toruń).

A characteristic feature of the artillery range near Toruń is a poverty of surface waters, which basically do not form any permanent watercourses, reservoirs of stagnant water or wetlands. Water stagnates only for a short period in small depressions between dunes or flows down very quickly infiltrating deep into the soil. However, the supply with rain waters is little. The neighbourhood of Toruń is one of the areas with the lowest precipitation in Poland. According to the data from the Base Station in Koniczynka obtained within the framework of Integrated Monitoring of Natural Environment in Poland in 1996–2008, the average annual precipitation was 541.4 mm and the average annual air temperature was 8.5˚C (Kejna 2009).

The area of the training ground is characterized by a relatively homogeneous soil cover. Within the training ground, the rusty soil is the dominant soil type covering 83.5% of the area, and within which the subtype of podzolized soils covers the area of 62.4%. Those are mainly soils developed in eolian sands and in sands of old river terraces. They cover the largest area of the remaining complexes of the Otłoczyn district. In the northern and the central part of the complex, where the research was also carried out, on the tops of dunes or flat surface areas of eolian sands, which are subject to secondary eolian processes, poorly developed soils from loose rocks occur. They cover 4.5% of the District's area.

The research on the structure, variability and dynamics of heaths and arenaceous grasslands was carried out in 19

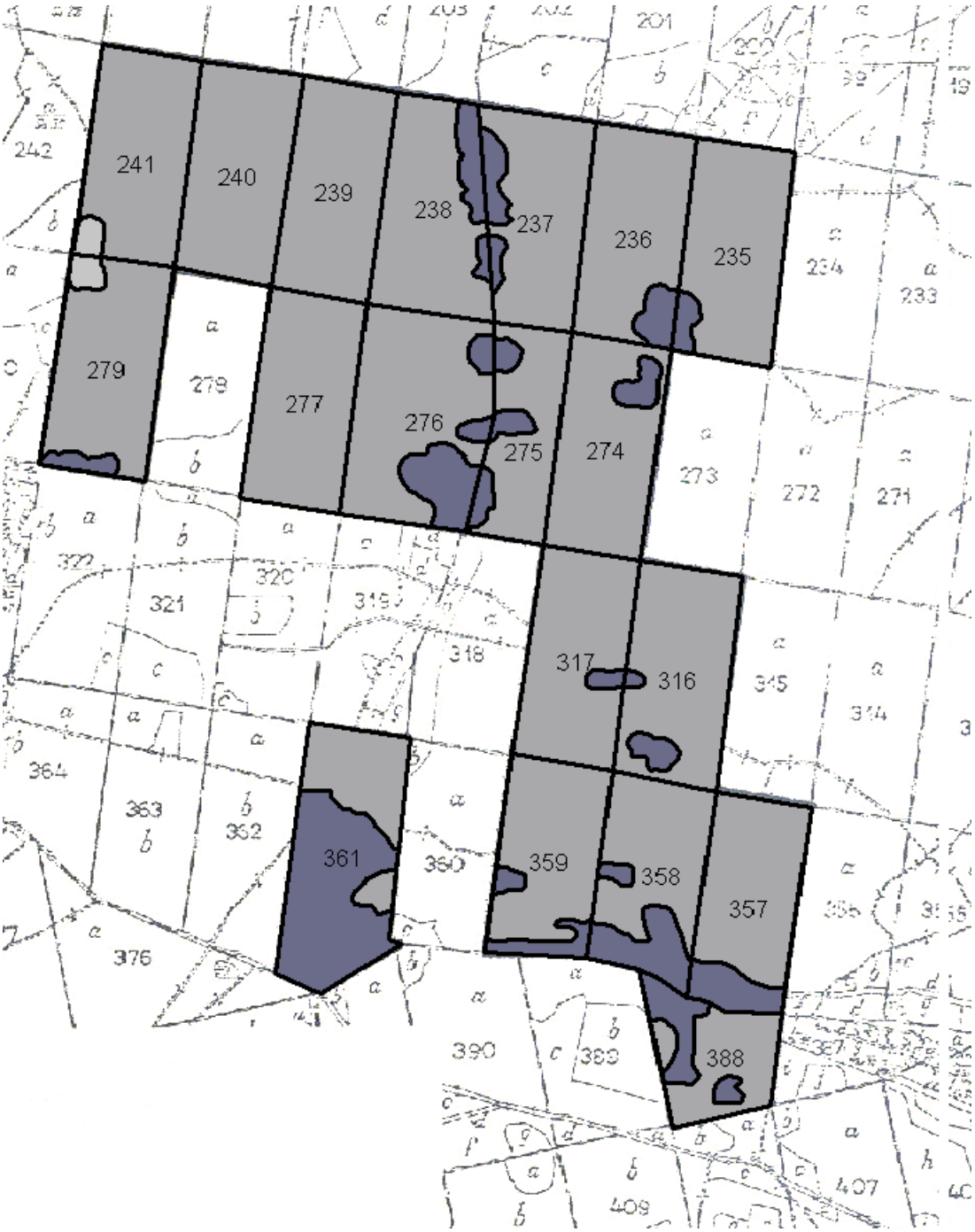

Figure 2. The map of forest sections, in which the research was carried out with the marked soil types (from the soil and habitat survey of the Forest Division of Gniewkowo, 2000)

unforested sections of the Otłoczyn District within the Forest Division of Gniewkowo. Those sections are included in the working training ground. The map of their distribution with the marked soil types according to the soil and habitat Survey of soils and habitats, the Forest Division of Gniewkowo (2000) is presented in Figure 2.

3. Research methods

Phytosociological and floristic studies on heathlands of the Toruń training ground were performed in 2008, from May till October. The analysis was focused on heath patches selected in the Natura 2000 Programme as a habitat 4030

(Kujawa-Pawlaczyk 2004), i.e. dry heaths comprising syntaxa *Calluno-Genistion, Pohlio-Callunion, Calluno-Arctostaphyllon.* Recommendation of natural habitats and objects, as well as field studies were carried out in 2006 and 2007 during a general inventorying of habitats in State Forests of the Gniewkowo Forest Division. During the same period, scientific studies were being conducted also in other non-forest communities of the training ground. The structure of phytocoenoses was described by the generally accepted method of Braun- Blanquet (1951). Altogether, 116 relevés were made, including 84 relevés on heaths and 32 relevés on psammophilous grasslands. The relevés were used for the initial identification of plant communities dominating in the artillery range, and then for their final classification into relevant syntaxonomic units.

Classification of relevés was based on the hierarchical system of plant communities of Poland developed by Matuszkiewicz (2007). Based on the species composition, contribution of differential species and characteristic combination of species, groups of objects were distinguished in the set of relevés, which belong to particular associations and plant communities. Subsets of relevés included in main phytosociological units were compiled into separate tables. Relevés in the tables were divided into units of a lower order, i.e. subassociations and variants. The information included in the tables and in their particular parts were used for further detailed description of all distinguished types of non-forest communities of the study area. A location of each relevé in the field, together with its number in the heading of a relevant table and its affiliation with a specific syntaxon, were presented on the map of the studied fragment of the training ground (Fig. 3).

Apart from the description of heaths and psammophilous grasslands, also a short general description of forest plant communities from the artillery range near Toruń was included in this paper. The detailed results of the phytosociological analysis, together with the phytosociological tables, will be presented in a separate report.

4. The research results

4.1. Types of plant communities and their affiliation with higher syntaxonomic units

The occurrence of two heath associations from the class *Nardo-Callunetea* was recorded in the studied area. This class also includes the community with *Cytisus scoparius* of not entirely determined systematic position. Psammophilous grasslands, occurring in the vicinity of heaths, were classified into the association of *Spergulo vernalis-Corynephoretum* from the class *Koelerio glaucae-Corynephoretea canescentis* and into the association of *Calamagrostietum epigeji* from the class *Epilobietea angustifolii*.

Affiliation of the distinguished communities and associations to higher syntaxonomic units is as follows:

Class: Nardo-Callunetea Prsg 1949
Order: *Calluno-Ulicetalia* (Quant. 1935) R.Tx. 1937

1. The community with *Cytisus scoparius*
   Alliance: *Pohlio-Callunion* Shimwell 1973 em. Brzeg 1981
2. *Pohlio-Callunetum* Shimwell 1973 em. Brzeg 1981
   Alliance: *Calluno-Arctostaphylion* R.Tx. et Prsg 1949
3. *Arctostaphylo-Callunetum* R.Tx. et Prsg 1940
   Class: Koelerio glaucae-Corynephoretea canecentis Klika in Klika et Novak 1941
   Order: *Corynephoretalia canescentis* R.Tx. 1937
   Alliance: *Corynephorion canescentis* Klika 1934
4. *Spergulo vernalis-Corynephoretum* (R. Tx. 1928) Libb. 1933
   Class: Epilobietea angustifolii R.Tx. et Prsg 1950
   Order: *Atropetalia* Vlieg. 1937
   Alliance: *Epilobion angustifolii* (Rubel 1933) Soo 1933
5. *Calamagrostietum epigeji* Juraszek 1928

4.2 Characteristics and diversity of heaths

Heath communities from the class *Nardo-Callunetea* occur in the whole studied area, in many places as a mosaic with psammophilous grasslands or pine forests and „birch groves". Most of the phytocoenoses dominated by *Calluna vulgaris* were classified as heaths with nodding thread-moss from the association *Pohlio-Callunetum.* Few and small clusters of bearberry heaths concentrate in the north-western part of the studied area, mainly in the section 279 of the Otłoczyn forest district. Whereas the community with *Cytisus scoparius* occurs most frequently in the southern part of the studied area.

The structure of phytocoenoses classified into particular syntaxa is presented in relevés included in Tables 1–3. The comparison of relative cover of species from different syngenetic groups of five distinguished syntaxa is presented in Figure 4.

4.2.1 Association *Pohlio-Callunetum*

Patches of heaths with nodding thread-moss *Pohlio-Callunetum* of different size are scattered all over the studied fragment of the artillery range near Toruń. Its patches occur both on slopes of dunes with different inclinations and in flat areas and in depressions. They neighbour on fragments of fresh coniferous forest *Peucedano-Pinetum*, grasslands with gray clubawn grass *Spergulo vernalis-Corynephoretum*, the community with chee reedgrass and common groom.

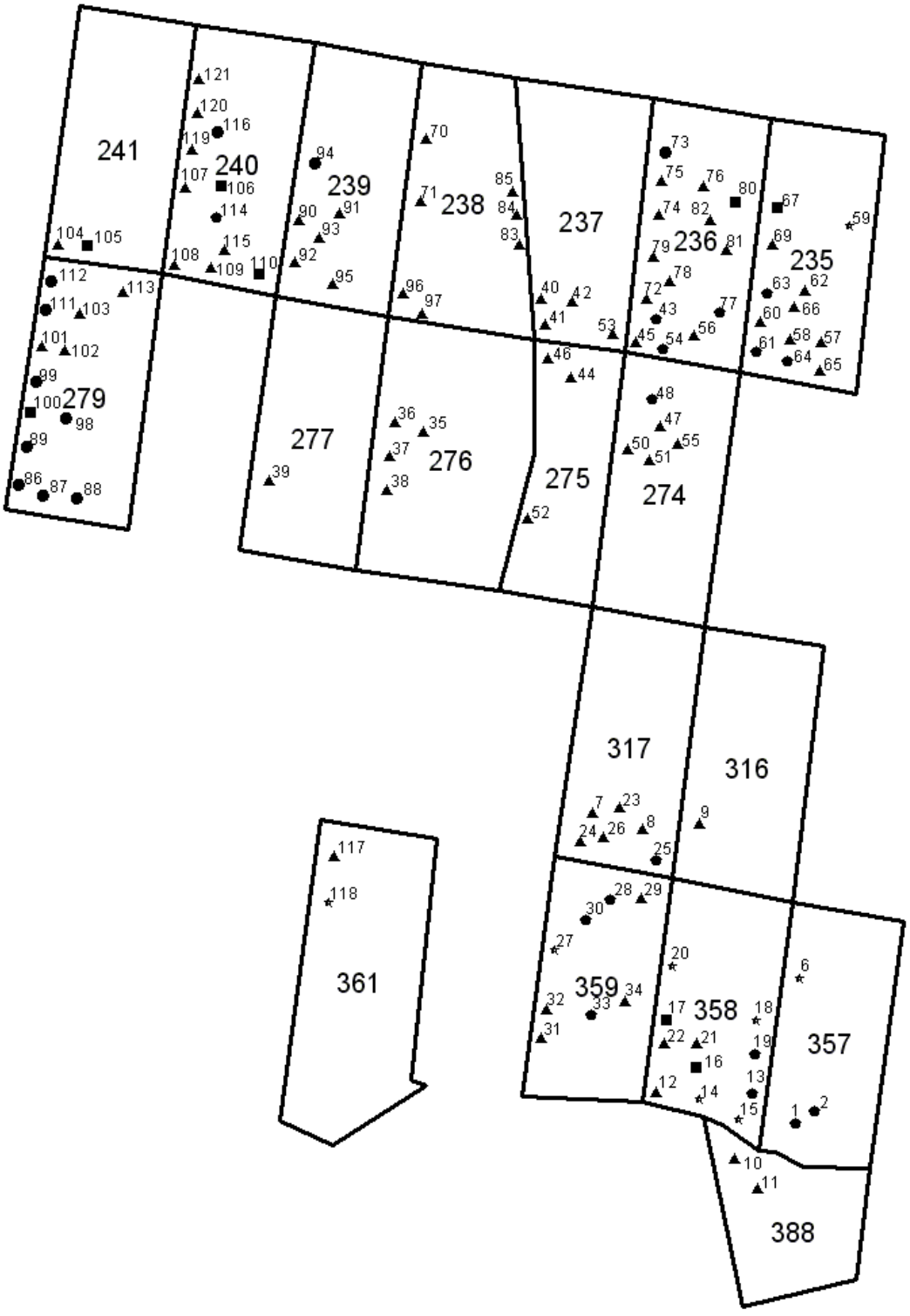

Figure 3. The map of forest sections with the marked sites of relevés

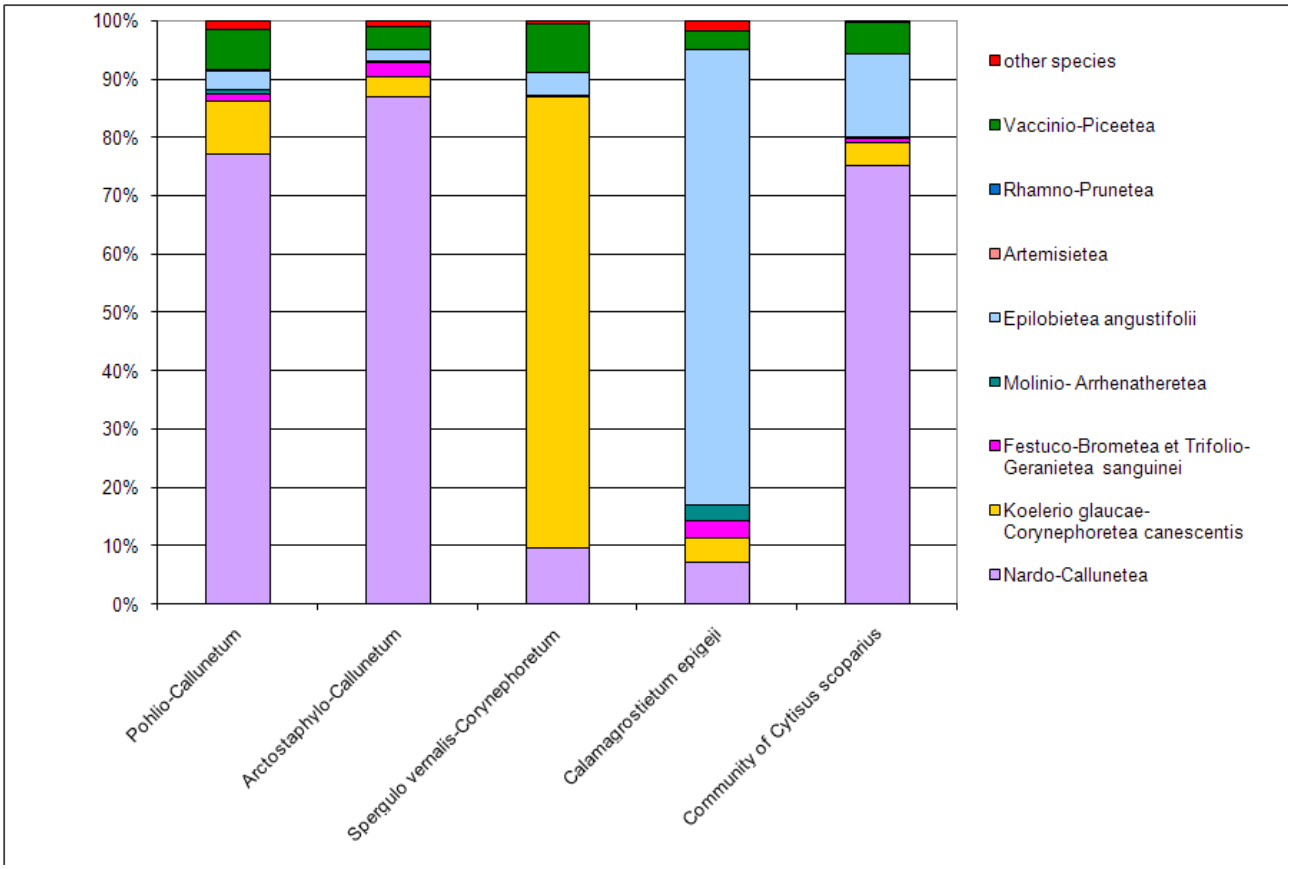

Figure 4. A relative cover degree of particular vegetation classes (syngenetic groups of species) in non-forest communities of the artillery range near the city of Toruń

Patches of *Pohlio-Callunetum* occur in the form of a community of dwarf shrubs, distinguished by the domination of Scots heather *Calluna vulgaris*, assuming most frequently a facial form. The structure of the association is two-layered. The higher layer is composed almost exclusively of *Calluna vulgaris*, whereas the lower one is dominated by much shorter plants, such as e.g.: yellow hawkweed *Hieracium pilosella,* wild thyme *Thymus serpyllum* or heath sedge *Carex ericetorum*. In some patches, forest succession proceeds, and this is expressed by the presence of seedlings and undergrowth trees, especially of Scots pine *Pinus sylvestris* and European white birch *Betula pendula*.

73 relevés were classified into the association *Pohlio-Callunetum* (Tab. 1). They are diversified into two variants: typical and with clusterhead pink *Dianthus carthusianorum*.

The typical variant is more species poor. It is mainly characterized by strong domination of *Calluna vulgaris*. Apart from the aforementioned species, the herb layer is mostly composed of: *Carex ericetorum, Hieracium pilosella, H. umbellatum* from the order *Calluno-Ulicetalia* and from the class *Nardo-Callunetea.* Among the species characteristic and differential of the association *Pohlio-Callunetum* and the alliance *Pohlio-Callunion*, certain species of mosses and lichens occur with small quantities: *Pohlia nutans, Dicranum scoparium, Cladonia chlorophaea* s. l., *C. coniocraea* and *C. deformis*. Also accompanying species from the class *Koelerio glaucae-Corynephoretea canescentis* are very significant in the typical variant, e.g. *Corynephorus canescens, Thymus serpyllum,* and from the class *Vaccinio-Piceetea,* mainly *Deschampsia flexuosa.*

In the patches classified into the typical variant, the form with *Pleurozium schreberi* was distinguished (relevés 67–73, Tab. 1). Its phytocoenoses cover shaded places of northern or north-eastern exposure, usually in the vicinity of coniferous forests. They are characterized by relatively high contribution of the aforementioned moss species and other species of vascular plants, mosses and lichens from the class *Vaccinio-Piceetea*, such as: *Deschampsia flexuosa, Dicranum undulatum, Cladonia squamosa*.

The variant with *Dianthus carthusianorum* is significantly richer in species than the typical variant. It is dis-

Table 1 (the first part). The association *Pohlio-Callunetum* (relevés 1–10, the variant with *Dianthus carthusianorum,* the subvariant with *Molinia caerulea*)

Relevé number in table	1	2	3	4	5	6	7	8	9	10	Constancy
Relevé number	60	66	82	56	93	35	81	103	58	65	
Date	16.07. 2008	16.07. 2008	17.07. 2008	16.07. 2008	17.07. 2008	25.06. 2008	17.07. 2008	18.08. 2008	16.07. 2008	16.07. 2008	
Forest section	235	235	236	236	239	276	236	279	235	235	
Relevé area (m)	20x20	10x10	20x20	20x20	20x20	20x20	10x10	20x20	20x20	10x10	
Slope (º)							10	20		10	
Exposure							E	N		E	
Density of layer a (%)	5		5	5	5				5	5	
Density of layer b (%)	5		5	5	5				5		
Cover of layer c (%)	90	90	90	90	90	90	90	90	90	90	
Cover of layer d (%)	20	10	10	10	10	10	20	20	10	10	
Number of species in relevé	25	24	22	23	23	20	20	25	21	24	
Ch. D. Pohlio-Callunetum et Pohlio-Callunion											
Pohlia nutans	+		+		1				+	1	**III**
Dicranum scoparium	+				+	+		+	+	+	II
Cladonia chlorophaea s. l		+	+		1		+	+		+	**IV**
Cladonia coniocraea							1				**II**
Cladonia deformis	+	+		+					+	+	**II**
Ch. D. Arctostaphylo-Callunetum et Calluno-Arctostaphylion:											
Carex ericetorum	1	1	+	+	1			+	2	+	V
Peucedanum oreoselinum	1	+	+	+	+	+	+	1	1	+	**V**
Solidago virgaurea	+	+	+	+		+	+	1	+	+	**V**
Polygonatum odoratum		+			+				+		**I**
Ch. D. Calluno-Ulicetalia et Nardo-Callunetea:											
Calluna vulgaris	4	2	3	5	3	4	4	4	4	3	V
Hieracium pilosella		1	+	+	1	1	1	3	1	+	**V**
Hieracium umbellatum			+	+	+		+		+		**II**
Viola canina		+		+							**I**
Veronica officinalis				1						+	I
Accompanying species:											
a) Cl. Koelerio glaucae-Corynephoretea canescentis											
Corynephorus canescens	+	1	1	1	1	+	2	+	1	1	**V**
Thymus serpyllum	1		+	1			1	3	1	+	**III**
Jasione montana	+	+			+		+		+	+	**II**
Scleranthus perennis		+				+					**I**

Relevé number in table	1	2	3	4	5	6	7	8	9	10	Constancy
Festuca ovina					1	1					**II**
Helichrysum arenarium		+									**I**
Potentilla argentea		1									**I**
Rumex acetosella	+							+		+	**I**
Brachythecium albicans				+				+			**I**
Ceratodon purpureus	+	+		+			+	+			**III**
Polytrichum piliferum	+	+		+			+	+	+	1	**IV**
Cladonia macilenta	+		+	+		+	+				**III**
Cladonia cervicornis				+							**I**
Cladonia arbuscula subsp. mitis	+	+	+			+	+				**IV**
Cladonia uncialis			+		+		+				**I**
b) Cl. Festuco-Brometea et Trifolio-Geranietea:											
Galium verum						1	+				**I**
Dianthus carthusianorum	+	+	+		+		+	1			**II**
Euphorbia cyparissias						1		1			**II**
Potentilla arenaria								2			**I**
Geranium sanguineum				+							**II**
c) Cl. Molinio-Arrhenatheretea:											
Rumex acetosa								+			**I**
Molinia caerulea	1	1	+	1	+	+	+	+	1	1	**I**
d) Cl. Epilobietea angustifolii:											
Calamagrostis epigejos	+	2	+	+		+	1	1	1	+	**V**
Rubus idaeus						1					**I**
e) Cl. Artemisietea:											
Linaria vulgaris		+									**I**
Verbascum densiflorum						r					**I**
f) Species of Rhamno-Prunetea:											
Crataegus monogyna b								r			**I**
g) Cl. Vaccinio-Piceetea:											
Pinus sylvestris a	1		1		1					1	**I**
Pinus sylvestris b			+						+		**I**
Pinus sylvestris c					+						**II**
Deschampsia flexuosa			1		1	1		1	+		**III**
Pleurozium schreberi				+							**II**
Dicranum undulatum	+									+	**II**

Relevé number in table	1	2	3	4	5	6	7	8	9	10	Constancy
Cladonia rangiferina	+		+		+					+	**II**
Cladonia furcata	+		+				+	+			**II**
Cladonia arbuscula subsp. arbuscula											**I**
Cladonia gracilis				+	+				+		**II**
Cladonia fimbriata s. l.								+		+	**I**
Cladonia digitata		+						+			**I**
h) other species:											
Betula pendula a				1					1	1	**II**
Betula pendula b	r			+							**II**
Betula pendula c					+				+	+	**II**
Populus tremula c						+					**I**
Pyrus communis c					r	+					**I**
Hypericum perforatum	+	+			+			+			**II**
Sciuro-hypnum starkei			+								**I**
Polytrichum juniperinum	+	+				+				+	**III**
Cetraria ericetorum								+			**I**

Table 1 (the second part). The association *Pohlio-Callunetum* (relevés 11–22, the variant with *Dianthus carthusianorum,* the typical subvariant, the form with *Pleurozium schreberi*)

Relevé number in table	11	12	13	14	15	16	17	18	19	20	21	22
Relevé number	95	96	72	85	47	101	84	120	45	57	102	53
Date	17.07. 2008	17.07. 2008	17.07. 2008	17.07. 2008	7.07. 2008	18.08. 2008	17.07. 2008	10.10. 2008	7.07. 2008	16.07. 2008	18.08. 2008	16.07. 2008
Forest section	239	238	236	238	274	279	238	240	236	235	279	237
Relevé area (m) (m)	10/10	10/10	10/10	20/20	20/20	20/20	20/20	20/20	10/10	20/20	20/20	20/20
Slope (˚)				20		40					40	
Exposure				N		S					N	
Density of layer a (%)	5			10	5	10		5	5	5	5	5
Density of layer b (%)	5				5	5		30	5	5	5	5
Cover of layer c (%)	90	90	90	90	90	90	90	80	90	90	90	80
Cover of layer d (%)	10	20	10	10	10	30	20	10	20	10	10	10
Number of species in relevé	27	24	29	26	28	35	25	20	28	26	22	25
Ch. D. Pohlio-Callunetum et Pohlio-Callunion												
Pohlia nutans		1	+									
Dicranum scoparium	+	+		1	+	+	+			+	+	+
Cladonia chlorophaea s. l.							1		+	+		
Cladonia coniocraea	1								1			1
Cladonia deformis		+								+		+
Agrostis capillaris					+							
Ch. D. Arctostaphylo-Callunetum et Calluno-Arctostaphylion:												
Carex ericetorum	1	1	+	1	1	+	1			1		+
Peucedanum oreoselinum	+	+	+	+	1	2	+	1	1	+	1	1
Solidago virgaurea	+	+	+	+		+	1		1	+	+	+
Vincetoxicum hirundinaria	1				+	1						
Polygonatum odoratum											+	
Ch. D. Calluno-Ulicetalia et Nardo-Callunetea:												
Calluna vulgaris	3	4	3	4	3	2	4	4	2	4	3	4
Hieracium pilosella	1	+	+	+		2	+	1		2		+
Hieracium umbellatum		+	+	+								
Viola canina	+					+		+				
Veronica officinalis												
Relevé number in table	11	12	13	14	15	16	17	18	19	20	21	22
Potentilla erecta												
Cytisus scoparius					2							
Accompanying species:												

Relevé number in table	11	12	13	14	15	16	17	18	19	20	21	22
a) Cl. Koelerio glaucae-Corynephoretea canescentis												
Corynephorus canescens		1	1	+	1	2	1		+	2	+	1
Thymus serpyllum	1	1	1	+	+	1	1	+				+
Jasione montana	+			+				+	+	1		
Scleranthus perennis			+		+		+					
Festuca ovina	+		+	1					1			
Spergula vernalis												
Helichrysum arenarium					1			+				
Potentilla argentea			+					+	+			
Rumex acetosella										+		
Koeleria glauca												
Lotus corniculatus var. crassifolius					+							
Astragalus arenarius												+
Agrostis vinealis												
Carex arenaria												
Brachythecium albicans		+					+			+		
Ceratodon purpureus		+			+	+		+	+	+		
Polytrichum piliferum			+			+	+		+			+
Cladonia macilenta		+			+	+	+				+	
Cladonia cervicornis								+				
Cladonia arbuscula subsp. mitis			+	+	+	+	+		+		+	+
Cladonia uncialis		+	+		+							
Cladonia phyllophora					+							
b) Cl. Festuco-Brometea et Trifolio-Geranietea:												
Galium verum		+	1	1			+		+			
Dianthus carthusianorum	+		+	+	+	1	+					
Euphorbia cyparissias	+		1	1	+	+		+			+	
Anthericum ramosum	+	+	+	+	+							+
Potentilla arenaria?	+					1		+				
Achillea pannonica	+		+									
Silene nutans												
Lathyrus sylvestris												
Potentilla neumanniana												
Geranium sanguineum	+											

Relevé number in table	11	12	13	14	15	16	17	18	19	20	21	22
Carlina vulgaris							+					
c) Cl. Molinio-Arrhenatheretea:												
Rumex acetosa						2					1	
Achillea millefolium			1						+			
Molinia caerulea												
Knautia arvensis						+				+		
Sanguisorba officinalis												
Dianthus superbus												
d) Cl. Epilobietea angustifolii:												
Calamagrostis epigejos	2		1	+	1	1		1		1	1	
Rubus idaeus												
Epilobium angustifolium												
e) Cl. Artemisietea:												
Artemisia vulgaris			+									
Linaria vulgaris												
Verbascum densiflorum												
f) Cl. Rhamno-Prunetea:												
Crataegus monogyna b												
Berberis vulgaris b						r						
g) Cl. Vaccinio-Piceetea:												
Pinus sylvestris a						1			1	1	1	
Pinus sylvestris b						+			+			+
Pinus sylvestris c	+		+			+	+			r		
Convallaria majalis									+		1	
Deschampsia flexuosa		1	1	1	1	2	+		2	1	2	1
Vaccinium vitis-idaea				1					2		1	
Vaccinium myrtillus				+								
Calamagrostis arundinacea												
Pleurozium schreberi	1	2	1	2	1	2	1	1	1	1	1	1
Dicranum undulatum			+	+	+	+	1	+	+	+	+	+
Cladonia rangiferina						+		+	+			
Cladonia furcata										+	+	
Cladonia arbuscula subsp. arbuscula			+			+			+	+	+	
Cladonia gracilis		+	+		+		+	+	+	+		+
Cladonia fimbriata s. l.												

Relevé number in table	11	12	13	14	15	16	17	18	19	20	21	22
Cladonia squamosa	+	+		+		+	+		+			+
Cladonia digitata												
h) other species:												
Betula pendula a	1				1	1						1
Betula pendula b	+							+			+	r
Betula pendula c		+				+					+	
Populus tremula b								+		r		
Populus tremula c										1		
Prunus padus b												
Pyrus communis c												
Hypericum perforatum	+		+		+					+		+
Hypochoeris radicata												
Trifolium medium												
Senecio vulgaris												
Sorbus aucuparia c												r
Carlina acaulis						r						
Polypodium vulgare											+	
Trifolium lupinaster						+						
Quercus petreae c									+			r
Sciuro-hypnum starkei				+					+			
Sciuro-hypnum oedipodium	+			+		+	+		+			
Oxyrrhynchium hians				+				+				
Polytrichum juniperinum	+											
Peltigera rufescens		+					+					
Cetraria ericetorum		+			+							

Table 1 (the third part). The association *Pohlio-Callunetum* (relevés 23–43, the variant with *Dianthus carthusianorum,* the typical subvariant)

Relevé number in table	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**
Relevé number	92	97	83	22	32	79	8	10	50	108	104	117	11	78	109	36	37	24	26	29	51
Date	17.07. 2008	17.07. 2008	17.07. 2008	18.06. 2008	22.06. 2008	17.07. 2008	9.06. 2008	9.06. 2008	7.07. 2008	18.08. 2008	18.08. 2008	10.10. 2008	9.06 2008	17.07. 2008	18.08. 2008	25.06. 2008	25.06. 2008	22.06. 2008	22.06. 2008	22.06. 2008	7.07. 2008
Forest section	239	238	238	358	359	236	317	388	274	240	241	361	388	236	240	276	276	317	317	359	274
Relevé area (m)	20x20	20x20	20x20	10x10	10x10	20x20	20x20	20x20	20x20	20x20	20x20	10x10	10x10	10x10	20x20	20x20	20x20	20x20	10x10	20x20	20x20
Slope (°)					20	10	30				10	10	10			30	20	30	20		
Exposure					N	N	N				N	W	E			NW	E	E	W		
Density of layer a (%)	5							5				10									
Density of layer b (%)		5	5	5	5	5	5	5				5	5	5			5				5
Cover of layer c (%)	90	90	90	80	80	90	90	70	90	90	90	90	60	90	90	80	90	90	80	90	90
Density of layer d (%)	10	20	10	10	10	10	30	20	10	30	20	10	20	10	30	10	10	10	20	10	20
Number of species in relevé	27	34	28	21	25	28	22	20	24	25	19	23	20	23	22	21	15	16	14	17	21
Ch. D. Pohlio-Callunetum et Pohlio-Callunion																					
Pohlia nutans			+				+		+	+	+	+	+	+	+				+		+
Dicranum scoparium											+				+						
Cladonia chlorophaea s. l.	+	+	+		+	+	+	+	+	+			+	+	+	+	+	+			+
Cladonia coniocraea		1		+				+		+			1		+	+					
Cladonia deformis		+																			
Agrostis capillaris					+				+							1	1			1	
Ch. D. Arctostaphylo-Callunetum et Calluno-Arctostaphylion:																					
Carex ericetorum	+	1	1	1	1	2	2	1	+	2	+	1	+	2	+	+	+	1		2	1

Relevé number in table	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Peucedanum oreoselinum	+	+	+	1	1	+	1	2	1	1	1	+	1	+	1	+	1	1	+	1	1
Solidago virgaurea	+	+	+		1	+	1	1	+	1	+		1	+		1	1	1	1	1	+
Vincetoxicum hirundinaria	+									1				+	+						
Polygonatum odoratum		+	+		1																+
Ch. D. Calluno-Ulicetalia et Nardo-Callunetea:																					
Calluna vulgaris	4	3	4	4	4	4	4	4	5	3	4	3	3	4	4	4	4	5	5	5	3
Hieracium pilosella	1	1	1		1	2	1		+	2	2	2	+	2	2	1	1	+		2	
Hieracium umbellatum	+	+			+				+												
Viola canina														+							
Veronica officinalis						+						+									
Potentilla erecta		+	+																		
Cytisus scoparius					+	+		1				+	1	+							
Accompanying species:																					
a) Cl. Koelerio glaucae-Corynephoretea canescentis																					
Corynephorus canescens		2	1		1	+	+	+		1	1	2	1	2	+	+	1	+	1	2	2
Thymus serpyllum	1	1	1	+		2			1	1	+		1	1	+	+		+	+	1	1
Jasione montana	+	+	+		+	+		+						+				+	+		
Scleranthus perennis							+														+
Festuca ovina	1	1	1		1		1						+			1					
Spergula vernalis				+	+											+			1	1	
Helichrysum arenarium	+	+		+			+			1		1									
Potentilla argentea																					

Relevé number in table	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Rumex acetosella						1				+				+							
Koeleria glauca																					
Lotus corniculatus var. crassifolius									1											+	
Astragalus arenarius																			+		+
Agrostis vinealis					+				+							+	+			+	
Carex arenaria																					
Brachythecium albicans				+						+			+								
Ceratodon purpureus	+		+	+		+	+	+	+	1		+				+	+		+	+	
Polytrichum piliferum	+	1	+			1	+	+	1	1	+	+	+	1	1		+	+	1		+
Cladonia macilenta	+		+	+		+	+		+	1	+			+							+
Cladonia cervicornis		+		+			+	+				+			+						
Cladonia arbuscula subsp. mitis		+	+		+			+	+	+	+		+		+	+		+		+	+
Cladonia uncialis	+					+			+					+							+
Cladonia phyllophora									+												+
b) Cl. Festuco-Brometea et Trifolio-Geranietea:																					
Galium verum	1	+	+	1	+	+			+												
Dianthus carthusianorum	+	+	+	+	+	+				+	+	+						+	+	+	+
Euphorbia cyparissias	2	1	+		+	+	1		+				1	+		+	+				
Anthericum ramosum	+	+								1					1						
Potentilla arenaria?	+	+	+	1																	
Achillea pannonica		+	+	+				+													
Silene nutans				r			+														
Lathyrus sylvestris	+																				

Relevé number in table	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Potentilla neumanniana								1													
c) Cl. Molinio-Arrhenatheretea:																					
Sanguisorba officinalis					1																
d) Cl. Epilobietea angustifolii:																					
Calamagrostis epigejos	1	1		1	1	1	1	1	+	2		+	1	1	+	1	2			1	+
Rubus idaeus																				+	
Epilobium angustifolium						+															
e) Cl. Artemisietea:																					
Artemisia vulgaris			+																		
Artemisia vulgaris			+																		
g) Cl. Vaccinio-Piceetea:																					
Pinus sylvestris a												1									
Pinus sylvestris b		+	+		+																
Pinus sylvestris c	+	+	+			+					+	+		+	+						
Convallaria majalis					1										1						
Deschampsia flexuosa		1				1	2			+			+	1	+	1	1	+			
Calamagrostis arundinacea												+									
Dicranum undulatum					+			+					+						+		
Cladonia rangiferina			+			1	+	+							1			+			
Cladonia furcata		+			+	+	+											+			
Cladonia gracilis	+											+				+	+		+		
Cladonia fimbriata s. l			+				+			+	+										

Relevé number in table	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
h) other species:																					
Betula pendula a	1											1									
Betula pendula b						+								+							
Betula pendula c				+		+			+												1
Populus tremula c				1																	
Hypericum perforatum	+	+		+		+			+	1	+	+		+	+						
Trifolium medium								r													
Sciuro-hypnum starkei		+										+									
Sciuro-hypnum oedipodium		+									+										
Oxyrrhynchium hians													+								
Polytrichum juniperinum		+	+	+		+				+	+				+	+		+		+	+
Peltigera rufescens												+									
Cetraria ericetorum									+							+					+

Table 1 (the fourth part). The association *Pohlio-Callunetum* (relevés 44–66, the typical variant)

Relevé number in table	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**
Relevé number	7	9	12	31	34	39	41	46	52	62	69	71	74	75	76	90	91	107	113	115	119	21	23
Date	9.06	9.06	18. 06	22. 06	22. 06	25. 06	7.07	7.07	16. 07	16. 07	16. 07	16. 07	17. 07	17. 07	17. 07	17. 07	17. 07	18. 08	18. 08	18. 08	10. 10	18. 06	22. 06
Forest section	317	316	358	359	359	277	237	275	275	235	235	238	236	236	236	239	239	240	279	240	240	358	317
Relevé area (m)	20x 20	10x 10	20x 20	20x 20	10x 10	20x 20	20x 20	20x 20	20x 20	20x 20	10x 10	10x 10	20x 20	20x 20	10x 10	20x 20	20x 20	20x 20	20x 20	20x 20	20x 20	10x 10	10x 10
Slope (°)	20			10	20	10				30	20		20	30	20			20	10	10			
Exposure	N			N	S	NW				NW	N		N	N	W			SW	N	E			
Density of layer a (%)								5	5	5	5	5		5	5				5				
Density of layer b (%)				10	20	10		5		5	5			5			10		5				
Cover of layer c (%)	90	80	80	80	80	80	90	90	80	90	90	90	90	90	90	90	80	90	80	90	90	90	90
Cover of layer d (%) d	50	30	20	10	20	10	20	10	20	10	10	10	10	10	10	20	10	20	20	10	20	10	10
Number of species in relevé	24	18	18	24	21	21	21	19	16	20	18	23	18	17	14	21	22	23	29	15	15	19	17
Ch. D. Pohlio-Callunetum et Pohlio-Callunion																							
Pohlia nutans	+	+			+		1			+			1			+	+	+			+	+	
Dicranum scoparium											+	+	+		+								
Cladonia chlorophaea s. l.	+	+		+	+		+	+	+	+	+	+		+	+	+	+	+		+	+	+	+
Cladonia coniocraea	+						+			+						+	+	+			+	+	
Cladonia deformis									+	+	+	+	1				1				1		
Agrostis capillaris				1		1																	
Ch. D. Arctostaphylo-Callunetum et Calluno-Arctostaphylion:																							
Carex ericetorum	1	1	1	2	1	1		+	+	+	1	+	1	1		1		+	+	1	1	1	1
Peucedanum oreoselinum		1	1	1	1	1	+	1	1	+	+	+	+	+	+	+	+	1	+	1	+	+	1

Relevé number in table	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Solidago virgaurea	3	1	2	1		1	1	+	+	+	+	+	+	+	+	+	+	1	1	1	1	+	1
Vincetoxicum hirundinaria																		+	+				
Polygonatum odoratum												+							+				
Ch. D. Calluno-Ulicetalia et Nardo-Callunetea:																							
Calluna vulgaris	4	4	4	4	2	4	4	4	3	4	3	3	4	4	4	4	3	4	3	5	4	4	5
Hieracium pilosella	2	2	+	2	2	1	3	1			+	+	1	+	+	1	1	2	1	1	2		1
Hieracium umbellatum	+		1	1	+						+		+			+							
Viola canina																			+				
Cytisus scoparius	1	1		1																		+	
Accompanying species::																							
a) Cl. Koelerio glaucae-Corynephoretea canescentis																							
Corynephorus canescens	2	2	+	2	2	2	2	1	2	+	1	1	1	2	1	1	1	3	1				2
Thymus serpyllum			+		+					+						1		+	+	+		+	
Jasione montana	+		1	1	+		+						+				+				+		
Scleranthus perennis			+									+				+							
Festuca ovina				1			1						1										
Spergula vernalis	1				+	+																+	
Helichrysum arenarium							+																
Potentilla argentea																							
Rumex acetosella		+				1					+										+		
Koeleria glauca				1																		+	
Lotus corniculatus var. crassifolius								+															
Agrostis vinealis				+		+		+															

Relevé number in table	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Brachythecium albicans	+			+														+					
Ceratodon purpureus	1	+	+		+	+	+	+	+	+	+		+	+		+	+	+			+	+	
Polytrichum piliferum	1		1	+		+	+	+	+	+	+		+			1	+	1	1	+	1	+	+
Cladonia macilenta	+				+	+	+	+		+	+	+				+	+	1					
Cladonia cervicornis			+															+					
Cladonia arbuscula subsp. mitis	1	+			+		+	+	+	+		+	+	+	+	+	+	1	+				+
Cladonia uncialis																+	+					+	
b) Cl. Festuco-Brometea et Trifolio-Geranietea:																							
Potentilla arenaria																						+	+
c) Cl. Molinio-Arrhenatheretea:																							
Rumex acetosa												+											
Achillea millefolium				+																			
Knautia arvensis																							+
Dianthus superbus																		+					
d) Cl. Epilobietea angustifolii:																							
Calamagrostis epigejos	2	2	2	1	2	2	1	+	+			+	2	1	1	1	+		1	+	1	1	1
f) Cl. Rhamno-Prunetea:																							
Crataegus monogyna b																							r
g) Cl. Vaccinio-Piceetea:																							
Pinus sylvestris a										1		1			1				1				
Pinus sylvestris b				+		r		+									+						
Pinus sylvestris c				+	+							r		+	+		+		+	+	+		r
Convallaria majalis				+										+					1				
Deschampsia flexuosa			3			1	+	1	1			1	2	1	1	+	1	+	2	+			

Relevé number in table	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Vaccinium vitis-idaea																			1				
Calamagrostis arundinacea														+									
Dicranum undulatum		+		+															+				
Cladonia rangiferina			+			+	+					+			+		+			+			+
Cladonia furcata									+	+						+			+	+			
Cladonia arbuscula subsp. arbuscula							+												+				
Cladonia gracilis			+			+			+		+	+	+			+		+	+	+		+	+
Cladonia fimbriata s. l.					+													+				+	
Cladonia digitata																						+	
h) other species:																							
Betula pendula a								1	1		1	+		+									
Betula pendula b					r	+		+		+	+			+					+				
Betula pendula c		r					+			+				+	1		2		+				
Populus tremula c				+																			
Prunus padus b					+																		
Pyrus communis c					1												r						
Hypericum perforatum										+								+					
Hypochoeris radicata	+																						
Quercus petreae c						r						+											
Sciuro-hypnum starkei	+	+																	+				
Sciuro-hypnum oedipodium	+	+																	+				
Oxyrrhynchium hians	+																		+				
Polytrichum juniperinum	+	+		+	+	+	+	+	+	+	+	+						+	+	+			+
Peltigera rufescens	+		+																+				

Table 1 (the fifth part). Association *Pohlio-Callunetum* (relevé 44–73 the typical variant, relevé 67–73 the form with *Pleurozium schreberi*)

Relevé number in table	**67**	**68**	**69**	**70**	**71**	**72**	**73**
Relevé number	38	40	42	44	55	70	121
Date	25.06. 2008	7.07. 2008	7.07. 2008	7.07. 2008	16.07. 2008	16.07. 2008	10.10. 2008
Forest section	276	237	237	275	274	238	240
Relevé area (m)	20x20	10x10	20x20	10x10	20x20	20x20	20x20
Slope (°)	10		10				
Exposure	N		NE				
Density of layer a (%)		5		5			5
Density of layer b (%)	5			5			
Cover of layer c (%)	90	90	90	80	90	90	90
Cover of layer d (%)	10	20	20	20	10	20	20
Number of species in relevé	18	22	18	18	25	17	21
Ch. D. Pohlio-Callunetum et Pohlio-Callunion							
Pohlia nutans			+	+			1
Dicranum scoparium	+	+	+	+		+	+
Cladonia chlorophaea	+	+		+		+	+
Cladonia coniocraea D							+
Cladonia deformis					+	+	
Agrostis capillaris	+						
Ch. D. Arctostaphylo-Callunetum et Calluno-Arctostaphylion:							
Carex ericetorum	+				1	+	+
Peucedanum oreoselinum	+		+	1	1	+	1
Solidago virgaurea		1	1		+	1	+
Vincetoxicum hirundinaria D							
Polygonatum odoratum							
Ch. D. Calluno-Ulicetalia et Nardo-Callunetea:							
Calluna vulgaris	4	4	5	3	5	4	4
Hieracium pilosella		+	+		+	1	
Hieracium umbellatum		+			+		
Viola canina					+		
Veronica officinalis							
Potentilla erecta							
Cytisus scoparius							
Accompanying species:							
a) Cl. Koelerio glaucae-Corynephoretea canescentis							
Corynephorus canescens	1	+	+			+	
Thymus serpyllum					1	+	
Jasione montana		+					

Relevé number in table	67	68	69	70	71	72	73
Scleranthus perennis		1					
Festuca ovina		1					
Spergula vernalis							
Helichrysum arenarium							
Potentilla argentea							
Rumex acetosella							+
Koeleria glauca					+		
Lotus corniculatus var. crassifolius							
Astragalus arenarius							
Agrostis vinealis							
Carex arenaria							2
Brachythecium albicans		+				+	+
Ceratodon purpureus	+		+			+	
Polytrichum piliferum			+				+
Cladonia macilenta			+	+	+	+	
Cladonia cervicornis							
Cladina mitis	+	+			+	+	
Cladonia uncialis					+		
Cladonia phyllophora					+		
b) Cl. Festuco-Brometea et Trifolio-Geranietea:							
Galium verum							
Dianthus carthusianorum							
Euphorbia cyparissias							
Anthericum ramosum							
Potentilla arenaria							
Achillea pannonica							
Silene nutans							
Lathyrus sylvestris							
Potentilla neumanniana							
Geranium sanguineum							
Carlina vulgaris							
c) Cl. Molinio-Arrhenatheretea:							
Rumex acetosa							+
Achillea millefolium							
Molinia caerulea							
Knautia arvensis							
Sanguisorba officinalis							
Dianthus superbus							
d) Cl. Epilobietea angustifolii:							
Calamagrostis epigejos	1	1			+		

Relevé number in table	67	68	69	70	71	72	73
Rubus idaeus							
Epilobium angustifolium							
e) Cl. Artemisietea:							
Artemisia vulgaris							
Linaria vulgaris							
Verbascum densiflorum							
f) Cl. Rhamno-Prunetea:							
Crataegus monogyna b							
Berberis vulgaris b							
g) Cl. Vaccinio-Piceetea:							
Pinus sylvestris a							1
Pinus sylvestris b	+			+			
Pinus sylvestris c					+		
Convallaria majalis				+			
Deschampsia flexuosa	2	2	+	2			+
Vaccinium vitis-idaea				2			
Vaccinium myrtillus							
Calamagrostis arundinacea							
Pleurozium schreberi	1	2	1	2	2	1	2
Dicranum polysetum	+	+	+	+	+	+	+
Cladonia rangiferina				+	+		+
Cladonia furcata							+
Cladonia arbuscula	+	+					
Cladonia gracilis			+	+			
Cladonia fimbriata			+				
Cladonia squamosa	+	+	+	+	+		+
Cladonia digitata					+		
h) other species:							
Betula pendula a		1		1			
Betula pendula b	+						
Betula pendula c				2		+	
Populus tremula b							
Populus tremula c					1		
Hypericum perforatum					+		
Senecio vulgaris		+					
Sciuro-hypnum oedipodium	+		+				+
Oxyrrhynchium hians							
Polytrichum juniperinum							
Peltigera rufescens		+	+	+	+		
Cetraria ericetorum					+		

tinguished by the presence of species from the classes *Festuco-Brometea* and *Trifolio-Geranietea,* such as *Galium verum, Dianthus carthusianorum, Euphorbia cyparissias, Anthericum ramosum*. One can distinguish two subvariants within this variant: typical and the one with purple moor grass *Molinia caerulea.* The latter develops mainly in depressions between dunes, where soil moisture is periodically higher. Therefore, it is characterized by higher species richness. Apart from characteristic and differential species of the association *Pohlio-Callunetum*, numerous species of mosses and lichens are present in its patches, forming a relatively well developed layer of mosses and lichens, covering on average 20% of the relevé's area. In the layer of herbaceous vegetation, apart from purple moor grass *Molinia caerulea*, usually also chee reedgrass *Calamagrostis epigejos* occurs. Whereas, among the most frequent mosses and lichens of the described community, the following are included: *Pohlia nutans, Dicranum scoparium, Polytrichum piliferum, Ceratodon purpureus*.

Additionally, in patches of the typical subvariant, one can distinguish a form with *Pleurozium schreberi,* which develops in places adjacent to pine forests. Its species composition is characterized by the presence of many species from the class *Vaccinio-Piceetea,* such as: the grass *Deschampsia flexuosa*, the moss *Dicranum undulatum* and lichens *Cladonia gracilis* and *C. arbuscula* subsp. arbuscula.

4.2.2 Association *Arctostaphylo-Callunetum*

Phytocoenoses of the bearberry heath *Arctostaphylo-Callunetum* cover a much smaller area in the studied area. They develop in the form of two variants: typical and the one with wild thyme *Thymus serpyllum* (Tab. 2).

The typical variant usually covers insolated sites on the tops of dunes and hills, less frequently on slopes of small inclination and southern exposure. *Arctostaphylos uva-ursi* definitely dominates in its patches. Clusters of heather are small and very sparse. Therefore on the exposed soil beneath the heather, heliophilous species of lichens may settle, mainly *Cladonia arbuscula* subsp. *mitis, C. furcata, C. cervicornis* and *C. chlorophaea* s. l. Also, the high abundance of kinnikinnick bearberry is related to the type of habitat, which is open and exposed to strong insolation. In the patches of the described community, besides bryophytes and lichens, often other short plants grow, e.g. *Hieracium pilosella*. Also seedlings of trees and shrubs appear individually and dispersed, mainly Scots pine *Pinus sylvestris* and European white birch *Betula pendula*. Depending on the light conditions, the cover of the herbaceous layer reaches 80–90%, whereas the moss layer covers from 5 to 20% (Tab. 2).

The variant with *Thymus serpyllum* occurs most frequently on sunny and warm exposures, but not on the tops of hills and other elevations. More frequently one can also find it on flat areas or on slopes with small inclination. Its patches are characterized by the domination of *Calluna vulgaris,* which often forms facies, reaching the maximum cover. The heather, through limiting the access of light to the substrate, causes that the bearberry, as well as mosses and lichens from the class *Koelerio glaucae-Corynephoretea canescentis* occur in smaller quantities.

As compared with the typical variant, the variant with *Thymus serpyllum* is characterized by a higher contribution of species differential for the association *Arctostaphylo-Callunetum* and the alliance *Calluno-Arctostaphylion,* such as: *Carex ericetorum*, *Peucedanum oreoselinum* and *Solidago virgaurea. Thymus serpyllum* occurs in all patches of the variant. Moreover, those patches are characterized by a higher number of species, ranging from 23 to 36. At the same time, their floristic composition comprises lots of species of sandy grasslands from the class *Koelerio glaucae-Corynephoretea canescentis*, such as the aforementioned *Thymus serpyllum*, or *Corynephorus canescens* and *Potentilla argentea*. Whereas from among heath plants, *Hieracium pilosella* occurs, as well as occasionally *Viola canina*, *Veronica officinalis* and *Potentilla erecta*. Moreover, the variant with *Thymus serpyllum* is characterized by higher contribution of species from the class *Vaccinio-Piceetea* such as: *Deschampsia flexuosa* and *Pinus sylvestris*, and also lichens and mosses: *Cladonia arbuscula* subsp. *arbuscula, C. fimbriata* s. l., *C. rangiferina, Dicranum undulatum, Pleurozium schreberi*. In the patches of this variant, also species from the class *Festuco-Brometea* and *Trifolio-Geranietea* grow: *Potentilla arenaria*, *Hypericum perforatum*, *Galium verum*, *Dianthus carthusianorum*, *Euphorbia cyparissias, Anthericum ramosum*, *Achillea pannonica* and *Filipendula vulgaris* (reaching the degree of constancy II or I, Tab. 2).

4.2.3 The community with *Cytisus scoparius*

The community dominated by common groom- *Cytisus scoparius* covers the areas adjacent to heathlands *Pohlio-Callunetum* and *Arctostaphylo-Callunetum*, as well as with grasslands of the gray clubawn grass *Spergulo vernalis-Corynephoretum.* Based on the analysis of 8 relevés from the training ground, two forms of the described community were distinguished: the typical one and the form with *Dianthus carthusianorum* (Tab. 3).

The typical form covers gentle slopes of northern or southern exposure. Apart from the domination of common broom, it is characterized by the significant contribution of heathland species from the class *Nardo-Callunetea*, such as: *Calluna vulgaris* and to a lesser extent *Carex ericetorum*. However, it is necessary to emphasize that due to considerable shadiness in the middle of patches brought on by common groom, the aforementioned species, similarly

Table 2. The association *Arctostaphylo-Callunetum* (relevés 1–6, the variant with *Thymus serpyllum,* relevés 7–11, the typical variant)

Relevé number in table	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Constancy**
Relevé number	116	94	112	73	111	99	86	87	88	89	98	
Date	10.09. 2008	17.07. 2008	18.08. 2008	17.07. 2008	18.08. 2008	18.08. 2008	11.10. 2008	11.10. 2008	11.10. 2008	11.10. 2008	18.08. 2008	
Forest section	240	239	279	236	279	279	279	279	279	279	279	
Relevé area (m)	20x20	20x20	10x10	10x10	10x10	10x10	10x10	10x10	10x10	10x10	10x10	
Slope (º)		10			10	10		10		10		
Exposure		N			S	E		S		S		
Density of layer a (%)	10	20	10	10	5	5	10	10	5	10	10	
Density of layer b (%)		5	5	10	5	5	5	10	10	5	5	
Cover of layer c (%)	90	90	70	90	70	80	80	80	80	90	80	
Cover of layer d (%)	20	10	20	10	20	10	10	20	10	10	5	
Number of species in relevé	38	26	24	27	23	24	18	19	16	16	12	
Ch. D Arctostaphylo-Callunetum et Calluno-Arctostaphylion:												
Arctostaphylos uva-ursi	+	+	2	1	2	1	4	4	5	5	4	V
Solidago virgaurea	1	+	1	+	+	+	+	+	+		1	V
Peucedanum oreoselinum	1	+	+	+	+	1	+	+	+	+	+	V
Carex ericetorum	2		+	+			+	+	+	+	+	IV
Vincetoxicum hirundinaria	+	+	1		+							II
Polygonatum odoratum				+								I
Ch. D. Calluno-Ulicetalia et Nardo-Callunetea:												
Calluna vulgaris	4	4	3	3	3	4	1	+	+	1	1	V
Hieracium pilosella	2	+	2		1	1	1	+		+		IV
Viola canina	1					+						I
Veronica officinalis	+		+									I
Potentilla erecta	+	+										I
Hieracium umbellatum			+									I
Pohlia nutans	+				+	+	+					II
Dicranum scoparium	+		+			+						II
Cladonia chlorophaea s. l.			+	+	+		+	+			+	III
Cladonia coniocraea	+			1						+		II
Accompanying species:												
a) Cl. Koelerio glaucae-Corynephoretea canescentis												
Corynephorus canescens	+	1	+	1	+		1	1	+	+		V
Thymus serpyllum	+	+	1	+	1	+		+				IV
Jasione montana	+											I
Scleranthus perennis				+								I
Potentilla argentea	+			+								I
Rumex acetosella	+											I
Koeleria glauca						+						I

Relevé number in table	1	2	3	4	5	6	7	8	9	10	11	Constancy
Carex arenaria	1											I
Ceratodon purpureus	+				+			+			+	II
Polytrichum piliferum		+			+	1	1	1	+	+	+	IV
Cladonia macilenta	+		+		+	+	+	+	+		+	IV
Cladonia cervicornis		+		+			+		+	+		III
Cladonia arbuscula subsp. mitis	+	+		+		1		+		+		III
Cladonia furcata			+		+		+			+	+	III
b) Cl. Festuco-Brometea i Trifolio-Geranietea:												
Potentilla arenaria	+	+	+	+								II
Hypericum perforatum	1	+	+									II
Galium verum	+	+										I
Dianthus carthusianorum	+		+									I
Euphorbia cyparissias	+	+										I
Anthericum ramosum		+										I
Achillea pannonica	1											I
Filipendula vulgaris	2											I
c) Cl. Molinio-Arrhenatheretea:												
Rumex acetosa						+						I
Achillea millefolium	1			+								I
Molinia caerulea				+								I
d) Cl. Epilobietea angustifolii:												
Calamagrostis epigejos	2	1	+	+	+	+		+		+		IV
e) Cl. Vaccinio-Piceetea:												
Pinus sylvestris a	2	3	1	2	2	3	1	1	1	1	1	V
Pinus sylvestris b	+		+	1	+	+	+	1	+	+	+	IV
Pinus sylvestris c	+	+		1		+	+	+	+			III
Deschampsia flexuosa			+	1	1	+						II
Vaccinium vitis-idaea				1								I
Vaccinium myrtillus		+		+								I
Pleurozium schreberi		+		+								I
Dicranum undulatum	+	+		+	+							II
Cladonia rangiferina	+		+		+	+	+					III
Cladonia fimbriata s. l.		+	+		+	+			+			III
Cladonia arbuscula subsp. arbuscula	+			+		+						II
f) other species:												
Betula pendula a					1	1			1	1		III
Betula pendula b								+				I
Betula pendula c		+			+				+	+		III
Polytrichum juniperinum	+	+				+	+		+			III

like lichens and mosses usually cover the sites on the edge of the community.

The form with *Dianthus carthusianorum* differs from the typical form mainly in the higher abundance of species in the patches. Most commonly it develops in flat places. Its patches are distinguished by the presence of *Dianthus carthusianorum*, as well as by great constancy of *Hypericum perforatum* and species from the class *Koelerio glaucae-Corynephoretea canescentis,* such as: *Jasione montana, Scleranthus perennis, Hypohoeris radicata, Helichrysum arenarium* and *Rumex acetosella*. The layer of mosses and lichens is more properly developed here as compared to the typical form. Among others, it is composed by: *Pohlia nutans, Dicranum scoparium, Cladonia coniocraea, C. deformis* from the class *Nardo-Callunetea,* as well as *Polytrichum piliferum, Cladonia uncialis, C. macilenta*, from the class *Koelerio glaucae-Corynephoretea canescentis*. Also species from the class *Vaccinio-Piceetea* are present, mainly: *Solidago virgaurea* and *Deschampsia flexuosa*, as well as single specimens of *Pinus sylvestris* and *Betula pendula.*

4.3 Communities accompanying the heaths

The above mentioned and described heath communities occur in the analysed territory as a mosaic with arenaceous grasslands and spontaneously developed pine and birch forests from the class *Vaccinio-Piceeta.* Among heathlands, also the association *Calamagrostietum epigeji* is relatively frequently encountered.

4.3.1 Psammophilous grasslands

Psammophilous grasslands on the artillery range near Toruń are represented by the association *Spergulo vernalis-Corynephoretum* (Tab. 4). They cover a very large area here. They develop most completely on insolated slopes

Table 3. The community with *Cytisus scoparius* (relevés 1–4, the typical form; relevés 5–8, the form with *Dianthus carthusianorum*)

Relevé number in table	1	2	3	4	5	6	7	8	Constancy
Relevé number	14	15	6	20	27	59	118	18	
Date	18.06. 2008	18.06. 2008	29.05. 2008	18.06. 2008	22.06. 2008	16.07. 2008	10.10. 2008	18.06. 1008	
Forest section	358	358	357	358	359	235	361	358	
Relevé area (m)	10x10	20x20	50x50	10x10	20x20	10x10	10x10	20x20	
Slope (º)	20	10	10	10			30		
Exposure	N	S	N	S			S		
Density of layer a (%)	5						5		
Density of layer b (%)	70	90	10	60	80	60	60	80	
Cover of layer c (%)	20	5	80	20	10	40	40	20	
Cover of layer d (%)	10	5	10	5	10	5	10	5	
Number of species in relevé	10	9	15	14	18	18	22	17	
D. of community									
Cytisus scoparius	4	5	4	5	5	3	4	4	V
Accompanying species:									
a) Cl. Calluno-Ulicetalia et Nardo-Callunetea:									
Calluna vulgaris	3	+	2	+		2	+		IV
Carex ericetorum			1	+	1	1	+		IV
Hieracium pilosella	1	1	2	+	2	1	2		V
Viola canina			+						I
Pohlia nutans						+	+		II
Dicranum scoparium								+	I
Cladonia coniocraea				+	+	+			II
Cladonia deformis						+			I

Relevé number in table	1	2	3	4	5	6	7	8	Constancy
b) Cl. Epilobietea angustifolii:									
Calamagrostis epigejos	1	1	3	2	2	1	2	3	V
c) Cl. Koelerio glaucae-Corynephoretea canescentis:									
Corynephorus canescens	+	+	2	1	1	1	+	+	V
Spergula morisonii			+		1				II
Helichrysum arenarium				+		+		+	II
Potentilla arenaria								+	I
Thymus serpyllum					1			+	II
Rumex acetosella						+	+		II
Jasione montana					+	+	1		II
Lotus corniculatus var. crassifolius					1				I
Scleranthus perennis						+			I
Hypohoeris radicata							+		I
Brachythecium albicans	+		+						II
Ceratodon purpureus	+		+						II
Polytrichum piliferum	+	+		+	+		+	+	IV
Cladonia uncialis					+			+	II
Cladonia macilenta					+	+			II
d) Cl. Festuco-Brometea et Trifolio-Geranietea:									
Galium verum								1	I
Dianthus carthusianorum					1	+	1	+	III
e) Cl. Vaccinio-Piceetea:									
Pinus sylvestris b			1	+					II
Peucedanum oreoselinum	1		+	+	+		+	2	IV
Solidago virgaurea	2	+	+	+	1	1	+	+	V
Deschampsia flexuosa			1				1		II
Cladonia fimbriata s. l.		+		+			+	+	III
Cladonia gracilis				+			+	+	II
Calamagrostis arundinacea							1		I
f) Cl. Molinio-Arrhenatheretea:									
Rumex acetosa							+		I
Molinia caerulea						1			I
Knautia arvensis					+				I
g) other species:									
Betula pendula a							1		I
Betula pendula c			+						I
Quercus petreae c							+		I
Hypericum perforatum						+	+	+	II
Polytrichum juniperinum		+			+			+	II

of southern, less frequently western exposure. The association is characterized by the domination of the tussock grass *Corynephorus canescens*, which is accompanied by *Spergula vernalis*. It is a pioneer community, very scattered, floristically poor, which initiates the process of secondary overgrowing of sandy dunes (Namura-Ochalska 2004). Between tussocks of gray clubawn grass, bare sand occurs, on which annual species appear in spring, including previously mentioned *Spergula vernalis*, which vanishes just after seeding. In the more advanced developmental phases, when the substratum is more and more stable, there begin to appear smaller or bigger clusters of lichens, mostly from the genus *Cladonia* and mosses, mainly *Polytrichum piliferum*. The frequent presence of heath plants, such as: *Hieracium pilosella* and *Calluna vulgaris*, in the composition of the described community is its significant characteristic. As compared to typical dry heaths in the described association, the latter species occurs less abundantly and usually on the outskirts. Also species differential for coniferous forests from the class *Vaccinio-Piceetea*, constitute a component of *Corynephorus* grasslands in the studied area (Fig. 4). The occurrence of trees – Scots pine *Pinus sylvestris* and European white birch *Betula pendula* is a frequent phenomenon.

The association *Calamagrostietum epigeji*, classified within clearing communities from the class *Epilobietea angustifolii*, border on grasslands of gray clubawn grass or heathlands. However, it is a relatively rare community in the training ground. It forms small patches in flat areas, less frequently on slopes of very small inclination. Most frequently its phytocoenoses border on grasslands of gray clubawn grass or heathlands. In this association from the studied area, two forms were distinguished: typical and with *Vincetoxicum hirundinaria* (Tab. 5).

4.3.2 Pine forests and groves of birch and aspen trees

At present, in the studied part of the artillery range near Toruń, heaths and psammophilous grasslands dominate, however, in many places the landscape is diversified by different size fragments of developing forests, which are at several different developmental phases. Among them, communities dominated by pine predominate. Also a large area is covered by groves of birch and aspen trees, as well as birch and pine forests. Their age is diversified and ranges from 5 to 65 years. The majority of tree stands are at the age of 21–30 years. Moreover, a small area is covered by forests with some contribution of oak and hazel thickets. In phytosociological respect, pine forests from the class *Vaccinio-Piceetea* predominate in the studied area. Small areas are covered by acidophilous oak forest from the class *Quercetea robori-petraea* and thickets of mixed lime-oak-hornbeam forests from the class *Querco-Fagetea.*

Melkowska (2009) stated that pine forests of the studied area belong to the subcontinental association *Peucedano-Pinetum,* which differentiates here into three variants: the variant with *Geranium sanguineum*, the typical and the poor variant. A different number of species occur in them. The variant with *Geranium sanguineum* is the richest in species. On average, 29 species of vascular plants, bryophytes and lichens occur in a relevé of 400 m^2. In the typical and the poor variant, the average number of species amounts to 22 and 16 respectively.

Out of three variants, the variant with *Geranium sanguineum* is the most diverse one in respect of species composition. Within it, one can distinguish two subvariants: with *Molinia caerulea* and the typical one.

Melkowska (2009) distinguishes the following syntaxa among deciduous forests: the community with *Corylus avellana* in the habitat of mixed lime-oak-hornbeam forest *Tilio-Carpinetum* from the class *Querco-Fagetea,* the association *Calamagrostio arundinaceae-Quercetum petraeae* from the class *Quercetea robori-petraeae*, as well as the community with *Populus tremula* and the community with *Betula pendula* in the habitat of pine forest *Peucedano-Pinetum.*

5. Syndynamic tendencies of vegetation from the training ground and discussion of the results

In the analysed set of relevés and among the distinguished communities of psammophilous grasslands and dry heaths occurring on the training ground near Toruń, one can observe phytocoenotic structures proving the extinction of certain types of communities and their transformation into other communities, which are the subsequent stage of secondary succession. This succession is manifested by the presence of early phases of encroachment of species from psammophilous grasslands or kinnikinnick bearberry *Arctostaphylos uva-ursi* on dune quicksand. Together with „maturation" of psammophilous grasslands and bearberry heaths, on their patches there encroach species initiating the further development of a phytocoenosis towards heaths of nodding thread-moss *Pohlio-Callunetum,* the association of chee reedgrass *Calamagrostietum epigeji,* or the community with common groom *Cytisus scoparius*. The last stage of secondary succession consists in the encroachment of tree species and transformation of non-forest communities into birch forests, as well as pine and mixed forests.

In the studied area, the association *Spergulo vernalis-Corynephoretum* occurs both in the early stages of succession, as well as in the subsequent developmental phases. In the pioneer *Corynephorus* grasslands, the layer of mosses and lichens is poorly developed, which can be observed in relevés 4, 13, 14, 15 in the Table 4. The average number

of species per relevé amounts to 11. As the contribution of gray clubawn grass increases and the substratum stabilizes, the number of species and, at the same time, the diversity of a community increases. It is the subsequent phase of succession, in which mosses begin to occur in more humid places, whereas dry and insolated sites are taken over by lichens. Then, heather and pine seedlings encroach. In the still more advanced stages of the development, young specimens of trees and shrubs are highly significant, the layer of mosses and lichens is already very well developed and the number of species per relevé reaches 22 (relevés 2, 5, 6, Tab. 4). Ultimately, the community assumes the features of the association *Pohlio-Callunetum*.

Based on the analysis of floristic composition and comparisons of developmental phases of the association *Spergulo vernalis-Corynephoretum,* one can state that it is an impermanent community, susceptible to processes of secondary succession. It develops in insolated areas and therefore it is rich in photophilous species. Artificial planting of pine, as well as spontaneous encroachment of shrubby and arborescent species from neighbouring pine forests, trigger off the processes of secondary succession leading to transformations of *Corynephorus* grasslands into the communities of dwarf shrubs and thickets, followed by forest communities. In other regions of Poland, succession transformations of the association *Spergulo vernalis-Corynephoretum* may lead towards communities from the class *Festuco-Brometea* and *Molinio-Arrhenatheretea*, whereas in the case of *Corynephorus* grasslands from the artillery range near Toruń, the succession leads towards reconstruction of pine forests.

In the studied area, heath patches of *Arctostaphylo-Callunetum*, similarly like those of the association *Spergulo vernalis-Corynephoretum,* are not durable phytocoenoses. They are subject to perceivable transformations of the structure, despite their occurrence in extreme habitat and thermal conditions, with the disturbance resulting from military operations, which restrains or delays the succession processes.

Patches of the association *Arctostaphylo-Callunetum*, where kinnikinnick bearberry *Arctostaphylos uva-ursi* dominates, are pioneer succession stages. Those patches cover highly insolated areas on the tops of dunes, where thermal and soil conditions are favourable for photophilous species. Patches of this association, recorded in the studied area, with slightly different structure, are characterized by significantly lower contribution of *Arctostaphylos uva-ursi* and the domination of *Calluna vulgaris,* as well as high contribution of coniferous-forest species, such as *Pinus sylvestris* or *Deschampsia flexuosa*. Low contribution of bearberry proves its retreat from areas dominated by heather. This process causes transformations of the association *Arctostaphylo-Callunetum* into heaths of *Pohlio-Callunetum.*

When describing the biology and dynamics of bearberry and bearberry heaths, Ciosek (2000) paid attention to the results of the research by Hobbs (1984), who studied the influence of extracts of some plant species occurring in heaths on other species, as well as quantitative relationships between those species. The results revealed harmful influence of bearberry on the germination and the growth of *Calluna vulgaris*. Based on his own research carried out on heathlands from eastern Poland, Ciosek (2000) stated that in most cases the range lines of *Arctostaphylos uva-ursi* and *Calluna vulgaris* do not overlap. From this it appears that in the tussocks of bearberry heaths *Arctostaphylo-Callunetum*, bearberry and heather generally exclude each other.

A similar relationship becomes apparent from the research carried out on the artillery range near Toruń. When the cover of *Calluna vulgaris* exceeds 25%, the occurrence of *Arctostaphylos uva-ursi* is low. Whereas, in the patches where percentage cover of the heather is below 25%, the density of bearberry is evidently higher and the species dominates in these areas. Additionally, in places dominated by bearberry, heather persists only on the edges of bearberry patches and it does not encroach into their interior parts.

The association of *Pohlio-Callunetum* is also subject to succession processes, which is manifested by high diversity of its types and the number of species. Numerous variants, subvariants and forms of this association prove that other communities occurring in its neighbourhood have significant influence on its structure. And thus, it takes on features of both pioneer communities, i.e. *Corynephorus* grasslands and bearberry heaths, as well as features of the community with *Cytisus scoparius*, the association *Calamagrostietum epigeji* and pine forests *Peucedano-Pinetum* occurring within the training ground. The form of the association with *Pleurozium schreberi*, both in the variant and in the typical subvariant, proves the encroachment of coniferous-forest species on the heathlands, including tree species, particularly *Pinus sylvestris* and *Betula pendula*. Relevés from the form with *Pleurozium schreberi* were made on the heathlands developing near pine forests *Peucedano-Pinetum.* The sites with this kind of location are characterized by habitat conditions different from those prevailing in heath patches situated at a further distance from the forest, and where the remaining relevés of the association were made. During the field studies, one could observe that the soil moisture, its acidity and the shading of vegetation in the *Pohlia nutans* heathlands increased along the gradient from the outskirts of pine forest towards its interior, which was expressed through different species composition, in the form of numerous forest species of mosses and lichens, e.g. *Dicranum undulatum, Pleurozium schreberi, Cladonia gracilis, C. rangiferina, C. arbuscula* subsp. *arbuscula.* At the same time, the quantity of *Cal-*

luna vulgaris often decreased giving way to species from the class *Vaccinio-Piceetea*.

Apart from psammophilous grasslands and heaths, also two other communities occur in the studied area of the artillery range, covering much smaller areas, i.e. the association *Calamagrostietum epigeji* and the community with common groom *Cytisus scoparius*. The former syntaxon occurs near the grasslands *Spergulo vernalis-Corynephoretum* and heaths *Pohlio-Callunetum*. According to Matuszkiewicz (2007), *Calamagrostis epigejos* is not a very demanding species concerning the habitat conditions. It grows on loose and acid soils, and its strongly expanding stolons choke up other plant species. Probably, when this association encroach on favourable dune areas, covered with grasslands, it contributes to their overgrowing and disappearance. In the studied area of the training ground, only few patches of this association were recorded and due to a small number of documentary materials, comprising only 8 relevés, it is difficult to draw any tangible conclusions concerning the changes and transformations occurring within thereof.

The community with *Cytisus scoparius*, similarly like the association *Calamagrostietum epigeji,* covers only small areas in the studied sections of the forest district of Otłoczyn. However, within the whole area of the artillery range, there can be observed fast spreading of *Cytisus scoparius*, which is related to good habitat conditions of this species. No species from the class *Rhamno-Prunetea* have been observed in the patches of this community occurring here (Fig. 4).

The presence of species characteristic of *Corynephorus* grasslands in the phytocoenoses dominated by common broom and in the patches of chee reedgrass, allows to assume that the community with *Cytisus scoparius*, as well as the association *Calamagrostietum epigeji* constitute the transitional form of the association *Spergulo vernalis-Corynephoretum* on the artillery range near the city of Toruń.

6. Conclusions

1. Plant communities occurring in the studied part of the artillery range constitutes a succession sequence, starting from pioneer *Corynephorus* grasslands *Spergulo vernalis-Corynephoretum* and bearberry heaths *Arctostaphylo-Callunetum*, through a transitional stage of heaths with nodding thread-moss *Pohlio-Callunetum*, or communities with common groom *Cytisus scoparius*, or the association with chee reedgrass *Calamagrostietum epigeji*, ending with the final stage of pine forests *Peucedano-Pinetum.*

2. Communities occurring in the direct, close contact of grasslands and heaths have a strong influence on the direction of succession transformations in the training ground near Toruń. Depending on neighbouring plant communities, species composition and directions of succession transformations change.

3. Psammophilous grasslands and heaths occurring within the artillery range near Toruń are anthropogenic and are strictly dependent on the intensity of human activities.

4. Encroachment of shrub and arborescent species reflects less common and less intense exploitation of the training ground in recent years for military trainings. Because operations comprising artillery firing, hand grenade throwing and using heavy technical equipment, especially military vehicles, have a significant influence on the preservation of non-forest communities in the training ground. Periodic fires, brought on by explosions of grenades, shells and missiles, contribute to the destruction of self-seeding shrubs and trees, and at the same time contribute to exposing the soil cover, which is favourable to the development of heliophilous dune vegetation, psammophilous grasslands and patches of *Arctostaphylos uva-ursi* initiating the development of pioneer bearberry heaths.

5. Cessation of military activities in certain parts of the training ground, as well as the fact that the anthropogenic factor is not really heavily destructive, contributes to disappearance of grassland and heath communities on the training ground through encroachment of forest species and formation of birch, aspen and pine thickets, and then pine forest, which constitutes a subsequent stage of secondary succession.

6. The conducted research contributed to better appreciation of nature values of this area and induced some actions aiming at its protection. The research validated the efforts to create the Special Area of Conservation of Natura 2000 Habitats within the training ground, called „Dunes of the Toruń Valley".

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Table 4. The association *Spergulo vernalis-Corynephoretum*

Relevé number in table	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Constancy**
Relevé number	1	2	13	19	25	28	30	33	43	48	54	61	63	68	77	114	
Date	29.05. 2008	29.05. 2008	18.06. 2008	18.06. 2008	22.06. 2008	22.06. 2008	22.06. 2008	22.06. 2008	7.07. 2008	7.07. 2008	16.07. 2008	16.07. 2008	16.07. 2008	16.07. 2008	17.07. 2008	18.08. 2008	
Forest section	357	357	358	358	317	359	359	359	236	274	236	235	235	235	236	240	
Relevé area (m)	10x10	20x20	20x20	20x20	20x20	20x20	20x20	20x20	10x10	20x20	10x10	10x10	20x20	20x20	20x20	20x20	
Slope (°)	20	30	10	30	20	10	40	40		30	10		40	20	10	20	
Exposure	S	S	S	S	S	S	W	W		SE	N		E	W	S	S	
Density of layer a (%)									1		5	1			5		
Density of layer b (%)		5			1	10		10	1			5			1		
Cover of layer c (%)	70	80	60	40	70	50	60	80	80	90	70	70	90	90	80	90	
Cover of layer d (%)	40	50	20	30	30	30	20	20	10	30	20	20	20	20	20	10	
Number of species in relevé	16	20	15	12	22	20	16	17	18	19	19	18	14	13	11	19	
Ch., D. Spergulo-Corynephoretum, Corynephorion canescentis:																	
Corynephorus canescens	4	3	4	3	3	4	4	5	4	4	3	3	3	4	4	4	V
Spergula morisonii	3	2		1	1		2	2		2							III
Cladonia macilenta	+		+	+	+	+		1		+	+		+		1	+	III
Cladonia cervicornis	+	+			+				+	+		+		+		+	III
Cladonia arbuscula subsp. mitis	1	+		+	+		1	1	+	1	+	1		1		+	V
Cladonia uncialis			1	2	1			+	+	+	+		+				III
Cladonia furcata					+		+	+			1	+	+	+	1	+	III
Cladonia phyllophora			+		+					+	+						II
Ch. D. Corynephoretalia canescentis et Koelerio-Corynephoretea:																	
Agrostis capillaris					1	1											I
Festuca ovina						+	+	1									I

Relevé number in table	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Constancy
Jasione montana						1						+					I
Rumex acetosella		1			1	+						+	1				II
Scleranthus perennis										1		+					I
Thymus serpyllum	+		+		1							+					II
Astragalus arenarius					+												I
Brachythecium albicans		+					+						+				I
Ceratodon purpureus	+	+					+										I
Polytrichum piliferum	1	3	+	+	+	+	1	+	+	2	1	1	2	1		1	V
Polytrichum piliferum	1	3	+	+	+	+	1	+	+	2	1	1	2	1		1	V
Accompanying species:																	
a) Cl. Calluno-Ulicetalia et .Nardo-Callunetea:																	
Calluna vulgaris			+	+		1	1		1	+	1	1				+	III
Carex ericetorum				+	+	1	1		1	+	+	1	1	+		+	IV
Hieracium pilosella	2	2	1	1	1	1	1	1	1		1	2	2	+	2	2	V
Viola canina									+								I
Hieracium umbellatum									+	+							I
Vincetoxicum hirundinaria																+	I
Genista germanica						+						+					I
Pohlia nutans			+								+	+					I
Cladonia chlorophaea s. l.	+		+		+						+	+		+		+	III
Cladonia coniocraea	+		+		+					+			+	+			II
b) Cl. Festuco-Brometea et Trifolio-Geranietea:																	
Dianthus carthusianorum							+	+								+	I
Euphorbia cyparissias																+	I
Potentilla arenaria						+											I

Relevé number in table	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Constancy
c) Cl. Epilobietea angustifolii:																	
Calamagrostis epigejos	2	1	+	+			2	1	+	1			1		2		IV
d) Cl. Vaccinio-Piceetea:																	
Pinus sylvestris a											1						I
Pinus sylvestris b		+			+	+											I
Pinus sylvestris c									+			3					I
Peucedanum oreoselinum	1	+		+	1	1	1	1		+	1	1	+	+	+	+	V
Solidago virgaurea	1	+	+	+	+	+	1				+			+		+	IV
Deschampsia flexuosa						+		+	3		2				+	+	II
Convallaria majalis		1															I
Cladonia rangiferina		+				+						+			+	+	II
Cladonia fimbriata s. l.		+			+				+		+			+			II
Cladonia arbuscula subsp. arbuscula		+								+							I
Cladonia gracilis		+			+			+		+	+						II
f) other species:																	
Betula pendula a									1		1				1		I
Betula pendula b						+			+						+		I
Betula pendula c									+						+	+	I
Anthoxanthum odoratum	+							+									I
Pyrus pyraster c		+				+		+		+							II
Polytrichum juniperinum	+	+	+			+	+			+			+	+		+	III
Cetraria ericetorum			+					+	+				+				II

Table 5. The association *Calamagrostietum epigeji* (relevés 1–5, the typical form; relevés 6–8, the form with *Vincentoxicum hirundinaria*)

Relevé number in table	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Constancy**
Relevé number	16	17	106	100	67	80	110	105	
Date	18.06. 2008	18.06. 2008	18.08. 2008	18.08. 2008	16.07. 2008	17.07. 2008	18.08. 2008	18.08. 2008	
Forest section	358	358	240	279	235	236	240	241	
Relevé area (m)	10x10m	10x10	10x10	20x20	10x10	10x10	10x10	10x10	
Slope (º)	10								
Exposure	S								
Density of layer a (%)					1				
Density of layer b (%)									
Cover of layer c (%)	90	70	90	90	90	90	90	90	
Cover of layer d (%)	5	10	10		5	5	10	10	
Number of species in relevé	12	15	14	11	13	16	22	23	
Ch. Calamagrostietum epigeji									
Calamagrostis epigejos	5	4	5	5	3	4	4	5	V
Ch. D. Epilobion angustifolii et Epilobietea angustifolii:									
Cytisus scoparius	+							+	II
Rubus idaeus				2					I
Fragaria vesca								+	I
Rumex acetosella						+	+		II
Accompanying species:									
a) Cl. Calluno-Ulicetalia et.Nardo-Callunetea:									
Calluna vulgaris	2	+	+	+	+		1	+	V
Carex ericetorum		1	+		1	+		+	IV
Hieracium pilosella	+	1	1		1	2	1	1	V
Viola canina							+	+	II
Vincetoxicum hirundinaria						+	1	1	II
Hieracium umbellatum						+			I
Genista tinctoria	1								I
Dicranum scoparium							+		I
Cladonia coniocraea		+						+	II
Cladonia chlorophaea s. l.	+	+	+			+	+		IV
Cladonia deformis					+				I
b) Cl. Koelerio glaucae-Corynephoretea canescentis:									
Corynephorus canescens		1	+		1	1	2	+	IV
Thymus serpyllum	+	+	+				1	1	IV

Relevé number in table	1	2	3	4	5	6	7	8	Constancy
Helichrysum arenarium						+	+	+	II
Potentilla arenaria								1	I
Festuca ovina		+							I
Jasione montana		+							I
Lathyrus sylvestris				+					I
Polytrichum piliferum							+	+	II
Cladonia furcata					+				I
c) Cl. Festuco-Brometea et Trifolio-Geranietea:									
Dianthus carthusianorum	+		+			1	+	+	IV
Euphorbia cyparissias							+	2	II
Achillea pannonica							+	1	II
Galium verum					+				I
Anthericum ramosum					+				I
d) Cl. Molinio-Arrhenatheretea:									
Molinia caerulea		1			+	+	1		III
Rumex acetosa				2					I
Achillea millefolium								+	I
e) Cl. Vaccinio-Piceetea:									
Solidago virgaurea	+	1	1	+	+	+	1	+	V
Peucedanum oreoselinum		+	+				+	+	III
Deschampsia flexuosa	+			2			+		II
Pinus sylvestris c					+		+		II
Cladonia arbuscula subsp. arbuscula					+	+	+		II
Cladonia fimbriata s. l.			+			+		+	II
f) other species:									
Betula pendula a					1				I
Betula pendula c				1					I
Hypericum perforatum		+	+			1	+	+	IV
Linaria vulgaris				1			+	1	II
Anthoxanthum odoratum	+								I
Pyrus communis c		+							I
Carduus crispus				+					I
Campanula rotundifolia								+	I

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